Quantum Electric Gravity

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Abstract

This paper proposes a new theory of gravity called quantum electric gravity (QEG) based entirely on electromagnetic and quantum electrodynamics principles. Neutral atoms contain equal amount of positive and negative charge that enable them to interact by both attractive and repulsive forces. The absolute magnitudes of these forces should be exactly and symmetrically identical. However, from a quantum mechanical perspective the picture is subtly different. In quantum electrodynamics the response of intermolecular bonds to external bipolar (attractive and repulsive) force fields is not exactly and symmetrically identical. In particular, the van der Waals interactions exhibit a well known asymmetrical characteristic that tends to enhance attractive over repulsive energies and forces on a microscopic level. This leads the symmetry between the forces to breakdown and leaves a clear non-zero net force synonymous with and indistinguishable from the force of gravity. Quantum electric gravity is in line with Newton's, can substantially account for many of the phenomena attributed to general relativity and successfully reconciles these theories with that of quantum mechanics. Remarkably, quantum electric gravity theoretically derives the underlying formula for the gravitational "constant" *G* and predicts its nonlinear behaviour at high field intensities.

Keywords: quantum electric gravity, quantum gravity, new theory of gravity, corrections to gravitational constant, quantum electrodynamics, quantum mechanics, van der Waals, Lennard-Jones potential, 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.

As it turned out, the opposing attractive and repulsive forces between atoms are not symmetrically identical due to the well known asymmetrical characteristic exhibited by the van der Waals interactions, which tend to enhance attractive over repulsive energies and forces on a microscopic scale. This gives rise to asymmetric behaviour which leaves a clear non-zero net force synonymous with and indistinguishable from the force of gravity. QEG in line with Newton's and can substantially account for many of the phenomena attributed 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, QED and interatomic/intermolecular bonding:

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

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 and electric force mediation via virtual particles. We then analyse inter-atomic and inter-molecular van der Waals bonding forces using the Lennard-Jones potential, which exhibit a fundamental asymmetric behaviour. We then use this fundamental asymmetric property of inter-molecular bonding to form the basis of a proposed new experimentally-determined quantum electric coupling mechanism and associated parameters that microscopically enhances attractive over repulsive forces. We then determine electromagnetic forces first between atoms using Dipole Atomic model and then extend that to larger objects. 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 discuss some of QEG 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 ~1×10^{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 and the dipole atomic model.

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 $\mathbf{F}_{\text{EM}}$ can be written as follows:

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

where T_{D} is a generic motion-dependent dynamic factor or term. For example, for a system comprising a source charge q_1 moving with constant velocity $\mathbf{v}_1$ and a test charge q_2 moving with constant velocity $\mathbf{v}_2$, the tangential term T_{Dt} can be determined using Lorentz Transformations [5] with factor γ, as follows:

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

where $\mathbf{v}_1$ and $\mathbf{v}_2$ are along the normal to r (distance between charges) 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.

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 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 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.

4. Quantum Electric Coupling

The total energy U of a system comprising two objects distance r apart comprises potential energy ($\mathrm{U_r}$), kinetic energy ($\mathrm{U_k}$) and internal energy ($\mathrm{U_d}$) between the atoms or molecules within each object. The reason for including $\mathrm{U_d}$ is that each object exerts a "differential" force on the other which modifies its internal energy $\mathrm{U_d}$ due to the fact that the nearside always experiences larger forces than the far side. Differential forces may alternatively be called tidal forces and the two terms may be used interchangeably. Depending on polarity, attractive tidal forces tend to extend objects and increase $\mathrm{U_d}$ while repulsive tidal forces tend to contract objects and decrease $\mathrm{U_d}$. In large objects the tidal forces may be quite large and may, for example, cause object deformations, heat generation and volcanoes. The total energy of the system can be written as:

$$\mathrm{U} = \mathrm{U}_r + \mathrm{U}_d + \mathrm{U}_k \tag{5}$$

Energy U_d is inversely proportional to *r*, i.e. it increases at shorter *r* values. When objects move the distance between them changes and the energy is traded off between the various components in (5). Since they directly act on atoms and molecules, tidal forces will be superposed on interatomic forces within the object. The total energy of the system (5) is conserved so one can write:

$$U_{r1} + U_{d1} + U_{k1} = U_{r2} + U_{d2} + U_{k2} \tag{6}$$

Or alternatively:

$$\Delta U_r + \Delta U_d + \Delta U_k = 0 \tag{7}$$

We shall analyse below the effect of variations in U_d and how this can affect potential energy U_r between two objects which is relevant to the force of gravity.

4.1 Inter-Atomic Potential

Adjacent neutral atoms and molecules interact by van der Waals forces (and London Dispersion forces) that combine two types of forces, long range attractive and short range repulsive [10,11,12]. The attractive force pulls atoms and molecules closer together while the repulsive force pushes them apart, both forces progressively increase at shorter distances. At sufficiently short distances the outer shells of atoms (electron cloud regions) become too close and experience higher repulsive forces due to the Pauli's exclusion principle. Van der Waals energies and forces can be determined using the Lennard-Jones (L-J) potential, which is a simple approximate pair potential between two atoms or molecules [10,11,12]. One form of L-J potential was first proposed by John Lennard-Jones back in 1924 [13]. The empirical L-J potential matches actual experimental data and is widely used in the field of Molecular Dynamics (MD) to simulate interatomic and intermolecular interactions. One of the most popular forms of L-J potential is the 6-12 potential (or 12-6), which shows how the potential U_d varies with distance *d*, as follows [10]:

$$U_d = U_0\left[\left(\frac{d_0}{d}\right)^{12} - 2\left(\frac{d_0}{d}\right)^{6}\right] \tag{8}$$

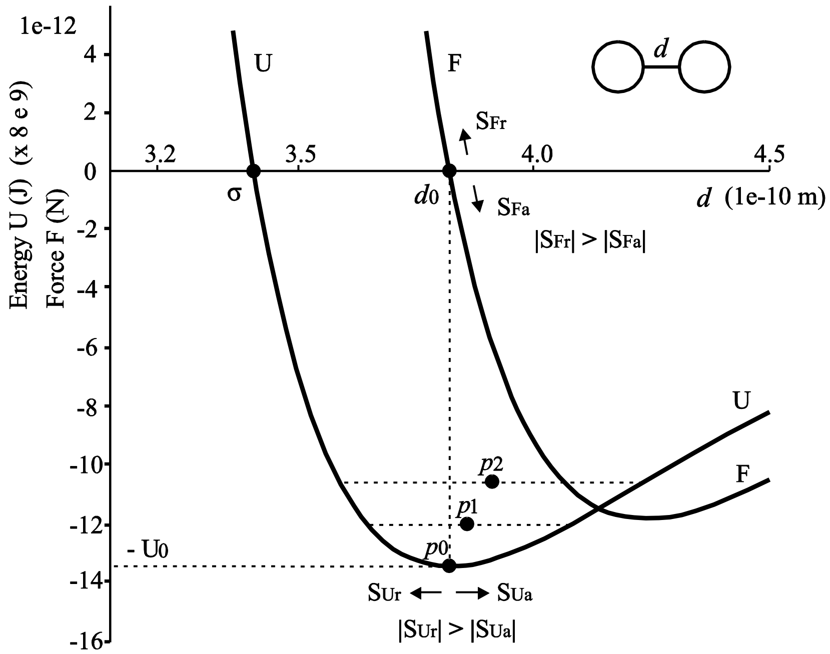

Figure 1 – Lennard-Jones Energy & Force – Argon

where energy U_0 is the depth of the potential well, *d* is the distance between the particles and d_0 is the distance when the potential reaches its minimum $-U_0$ as shown in Figure 1. Equation (8) is plotted in Figure 1 using data for Argon, $U_0 = 1.68 \times 10^{-21}$ J, $d_0 = 3.82 \times 10^{-10}$ m. In (8) the first term is repulsive varying with $1/d^{12}$ while the second term is attractive varying with $1/d^{6}$. In Molecular

Dynamics, the parameters in (8) are normally fitted to reproduce experimental data and/or data from accurate quantum chemistry analysis. The force $\mathbf{F}_d$ can be determined by differentiating the potential in (8), as follows:

$$\mathbf{F}_d = -\frac{d}{d\,d}\left(U_d\right)\hat{\mathbf{r}} = \frac{12U_0}{d_0}\left[\left(\frac{d_0}{d}\right)^{13} - \left(\frac{d_0}{d}\right)^{7}\right]\hat{\mathbf{r}} \tag{9}$$

Equation (9) is also plotted in Figure 1 using data for Argon. As distance d decreases the attractive and repulsive forces increase, but the rate of increase in the repulsive force exceeds that of the attractive force and, at a certain minimum distance (d_0), these two forces become equal with a zero net force and a minimum total energy $-U_0$ (or $-\varepsilon$), where the system reaches a balanced equilibrium state. The distance d at which the potential equals to zero is called σ and can be found from $\sigma = (2^{-1/6})\, d_0$. Due to its computational simplicity, the Lennard-Jones potential is used extensively in Molecular Dynamics's computer simulations even though other more accurate but complex potentials do exist.

4.2 Asymmetrical Properties of Interatomic Potential

The system in Figure 1 settles at a stable null-balance equilibrium point p_0 (d_0). If disturbed by some force, the system will automatically readjust to achieve a new stable and balanced position at a new d-value where the net force $\mathbf{F}_d$ is zero and the energy is at a minimum. It is important to observe that the energy and force in L-J curve exhibit asymmetrical characteristic property about the equilibrium position p_0. At this position the energy slopes required to decrease distance d and that required to increase distance d are not identical, and the same applies to force slopes. This asymmetry can be expressed as:

$$|S_{Ur}| > |S_{Ua}|, \qquad |S_{Fr}| > |S_{Fa}| \tag{10}$$

where S_{Ua}, S_{Ur} are the slopes of attractive and repulsive energies, respectively, and S_{Fa}, S_{Fr} are the slopes of attractive and repulsive forces, respectively. One can infer from (10) that the energy required to ***compress*** the object (decrease d) is always slightly greater than that required to ***extend*** it (increase d), and the same applies to forces.

One can analyse the system of Figure 1 using a spring analogy [10] by treating the attractive and repulsive forces as though each is acting on its own respective mechanical spring of spring constants k_a, k_r, respectively. The effective spring constant (k) for small changes in d (Δd) can be calculated from (9) by substituting $d = d_0 + \Delta d_a$ in the attractive case (k_a) and $d = d_0 - \Delta d_r$ in the repulsive case (k_r). Using Hooke's Law ($\mathbf{F} = -k\, x$) we can write:

$$\mathbf{F}_{da} = -k_a\,\Delta d_a \qquad \mathbf{F}_{dr} = -k_r\,\Delta d_r \tag{11}$$

$$\Delta U_{da} = \frac{1}{2}k_a\,\Delta d_a^2 \qquad \Delta U_{dr} = \frac{1}{2}k_r\,\Delta d_r^2 \tag{12}$$

where $\mathbf{F}_{da}$, ΔU_{da}, k_a are the attractive force, energy change and spring constant, and $\mathbf{F}_{dr}$, ΔU_{dr}, k_r are the repulsive force, energy change and spring constant. Since the spring constant k is itself the actual slope (force/distance) in N/m, one can write the force slopes in (10) in terms of k as follows:

$$|k_r| > |k_a| \qquad \frac{k_r}{k_a} > 1 \tag{13}$$

4.3 Response to External Fields

In this paper we are primarily interested in how a system of atoms bound by van der Waals interactions will respond to external forces. According to QED, the electromagnetic field is constantly changing and fluctuating about average values, and is communicated via the exchange of virtual photons. There are two types of external force fields that act independently and separately, attractive between unlike charges and repulsive between like charges. In neutral atoms the absolute magnitudes of positive and negative charge are exactly identical, which should normally gives identical force fields. The external effect of bipolar electromagnetic fields will be superposed on and interact with the internal atoms in the object (with characteristics as in Figure 1) and will try to slightly move or nudge the atoms about their balanced condition at d_0 (see Figure 1). It is here where the slopes in (10) will make a difference and play an important role as explained next.

Let us see how the system will respond to two external forces, one attractive ($\mathbf{F}_{\text{att}}$) and one repulsive ($\mathbf{F}_{\text{rep}}$). These forces will be superposed on the atoms in the object such that the attractive force will try to pull the atoms apart by a force $\mathbf{F}_{\text{da}} = \mathbf{F}_{\text{att}}$ and the repulsive force will try to push the atoms closer together by a force $\mathbf{F}_{\text{dr}} = \mathbf{F}_{\text{rep}}$. Since the atoms are electrically neutral, we have $|\mathbf{F}_{\text{att}}| = |\mathbf{F}_{\text{rep}}|$ and $|\mathbf{F}_{\text{da}}| = |\mathbf{F}_{\text{dr}}|$, which when substituted in (11) yields:

$$\Delta d_{\text{r}} = \frac{k_{\text{a}}}{k_{\text{r}}} \Delta d_{\text{a}} \tag{14}$$

By substituting (14) in (12) and using (13) one obtains the followings:

$$\frac{\Delta \text{U}_{\text{da}}}{\Delta \text{U}_{\text{dr}}} = \frac{k_{\text{r}}}{k_{\text{a}}} > 1 \qquad \left(\mathbf{F}_{\text{da}} = \mathbf{F}_{\text{dr}}\right) \tag{15}$$

Equation (15) is quite important because it states that if one applies external attractive and repulsive forces of exactly identical absolute magnitudes, the asymmetric characteristics of interatomic bonding will cause greater internal attractive energy change ($\Delta \text{U}_{\text{da}}$) in the object than repulsive energy change ($\Delta \text{U}_{\text{dr}}$), i.e. ($\Delta \text{U}_{\text{da}} / \Delta \text{U}_{\text{dr}}$) > 1. By combining equation (15) and (7) one would expect that attractive tidal forces would produce slightly greater change in potential energy ($\Delta \text{U}_{\text{r-att}}$) than that produced by repulsive tidal forces ($\Delta \text{U}_{\text{r-rep}}$). Put another way, this should effectively ***enhance*** external attractive over repulsive interactions between objects, i.e.:

$$\boxed{\frac{\Delta \text{U}_{\text{att}}}{\Delta \text{U}_{\text{rep}}} = \frac{\Delta \text{U}_{\text{r-att}}}{\Delta \text{U}_{\text{r-rep}}} = \frac{k_{\text{r}}}{k_{\text{a}}} > 1} \tag{16}$$

The asymmetry in the potential curve is the main cause of a number of other fundamental physical phenomena including the ubiquitous phenomenon of thermal expansion. In thermal expansion, thermal energy causes the molecules to vibrate in all directions, but since it is easier for objects to extend than contract (Figure 1), the average distance (d_0) will increase (e.g. move from p_0 to p_1 and d_0 to d_1 in Figure 1) and cause expansion [14,15]. In another phenomenon, most materials can withstand higher compressive than tensile strengths such as the case with air, for example, in which it is much harder to compress air molecules than to separate them as evident in the application of pneumatic tyres.

4.4 Quantum Electric Coupling Mechanism

The asymmetrical characteristic property of van der Waals interactions will directly lead to an interesting phenomenon namely; attractive external force will cause greater energy trade off between U_d and U_r (5-7) than does repulsive force – see (15,16). This will enhance attractive type of electrical interactions between objects over that of the repulsive field. Although we applied initially equal forces $|\mathbf{F}_{\text{att}}| = |\mathbf{F}_{\text{rep}}|$, the asymmetric property of van der Waals will modify that as follows:

$$\frac{\mathbf{F}_{\text{att}}}{\mathbf{F}_{\text{rep}}} > 1 \tag{17}$$

Therefore, one may use (17) to propose a new mechanism responsible for breaking down the symmetry between the otherwise symmetrically identical forces ($\mathbf{F}_{\text{att}}$, $\mathbf{F}_{\text{rep}}$), which give rise to non-identical dimensionless attractive and repulsive force multipliers P_a and P_r, as follows:

- **Matter slightly *enhances* attractive energy & force → attractive multiplier P_a**
- **Matter slightly *resists* repulsive energy & force → repulsive multiplier P_r**
- **Multiplier magnitudes is such that → $P_\text{a} / P_\text{r} > 1$**

One way to impellent this asymmetrical phenomenon is by multiplying the forces (3) by multipliers P_a and P_r, as follows:

$$\boxed{\mathbf{F}_{\text{att}} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_{\text{D}} P_{\text{a}} \ \hat{\mathbf{r}}} \qquad \boxed{\mathbf{F}_{\text{rep}} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_{\text{D}} P_{\text{r}} \ \hat{\mathbf{r}}} \tag{18}$$

Multipliers P_a and P_r may possibly be derived from theory using quantum chemistry, however in this paper we shall determine their values from experiments – see S-7. Had the characteristics of van der Waals forces been symmetrical, then one will get $P_a = P_r = 1$ and $\mathbf{F}_{att} = \mathbf{F}_{rep}$ in (18) (and thermal expansion will cease too [15]). Note that the auto null-balance mechanism ($\mathbf{F}_d = 0$) will always ensure and guarantee that the condition $P_a / P_r > 1$ remains valid all the times. Similar mechanisms may also be presents with other types of bonding such as ionic, covalent and others as long as they exhibit similar asymmetric characteristics with automatic null-balance equilibrium mechanism.

5. Force between Objects

In this section we shall determine the total electric and magnetic forces between two objects by first considering the forces between two atoms, one in each object. We assume that each atom is locally bound by asymmetric interatomic forces with its neighbouring atoms, which may be part of molecules as described in S-4 above. We can then extend this to determine the total force between two objects.

5.1. 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 [16], the positive $+q$ and negative $-q$ atomic charges can be treated as point charges located at the centre of their respective entity.

5.2. Forces between Two Atoms

Figure 2 shows two 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 $-q_2$. For completeness, we also assume that atom 1, 2 are moving at constant velocities $\mathbf{v}_1$ and $\mathbf{v}_2$, respectively in direction normal to r. The distance r between nuclei is taken as the effective distance between the atoms.

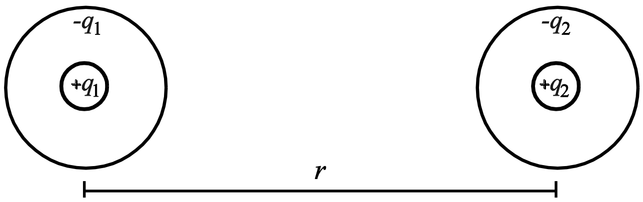

Figure 2 – Electrical Interaction between Two Atoms

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 ($\mathbf{F}_{att}$) and that of the repulsive component ($\mathbf{F}_{rep}$). 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 (18) by adding all corresponding attractive and repulsive components. Since there are four charge entities in Figure 2 ($+q_1$, $-q_1$, $+q_2$, $-q_2$), there is a total of four interatomic force components, two attractive and two repulsive, as follows:

$$\mathbf{F}_{\text{att}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{(-q_1)(+q_2)}{r^2} T_{\text{D}} P_{\text{a}} + \frac{(+q_1)(-q_2)}{r^2} T_{\text{D}} P_{\text{a}}\right)\hat{\mathbf{r}} \tag{19}$$

$$\mathbf{F}_{\text{rep}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{(+q_1)(+q_2)}{r^2} T_{\text{D}} P_{\text{r}} + \frac{(-q_1)(-q_2)}{r^2} T_{\text{D}} P_{\text{r}}\right)\hat{\mathbf{r}} \tag{20}$$

After re-arranging, equations (19,20) can be simplified and re-written as follows:

$$\mathbf{F}_{\text{att}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}} P_{\text{a}}\ \hat{\mathbf{r}} \tag{21}$$

$$\mathbf{F}_{\text{rep}} = +\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}} P_{\text{r}}\ \hat{\mathbf{r}} \tag{22}$$

Thus, in the system of Figure 2 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 as explained next.

5.3. Total Force between Two Atoms

The two forces in (21,22) can now be added together to obtain the total net force F_{net}, as follows:

$$\mathbf{F}_{\text{net}} = \mathbf{F}_{\text{att}} + \mathbf{F}_{\text{rep}} \tag{23}$$

$$\boxed{\mathbf{F}_{\text{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}}\left(P_{\text{a}} - P_{\text{r}}\right)\hat{\mathbf{r}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}} T_{\text{P}}\ \hat{\mathbf{r}}} \tag{24}$$

where $T_{\text{P}} = (P_{\text{a}} - P_{\text{r}})$. Recall that the basis of $(P_{\text{a}} - P_{\text{r}})$ was the asymmetrical behaviour in interatomic bonding as derived using the L-J potential function. In S-7 below we shall determine $(P_{\text{a}} - P_{\text{r}})$ from experiments. Equation (24) shows that the total EM force $\mathbf{F}_{\text{net}}$ between the two atoms (Figure 2) is proportional to the product q_1q_2 multiplied by a dimensionless factor $T_{\text{D}}\ (P_{\text{a}} - P_{\text{r}})$ and divided by the square of distance and permittivity of free space. The concept behind equation (24) is quite interesting because it attributes the force to the asymmetry in the characteristics of interatomic bonding. As we will see below, equation (24) can be successfully applied to the force of gravity between large objects with results largely in line with Newton's.

5.4. Force between Two Objects

For objects made up of large number of neutral atoms, one needs to determine the total charge 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 [16]. For example, in SS-5.1 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:

$$Q = Q_{\text{sh1}} + Q_{\text{sh2}} + Q_{\text{sh3}} \cdots + Q_{\text{sh}n} = \sum_{i=1}^{n} Q_{\text{sh}i} \tag{25}$$

Note that Newton used a similar method (shell theorem) for treating mass of spherically symmetric bodies [17]. 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 (24) with object charge Q_1, Q_2, respectively, as follows:

$$\boxed{\mathbf{F}_{\text{net}} = -\frac{1}{2\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2} T_{\text{D}} T_{\text{P}}\ \hat{\mathbf{r}}} \tag{26}$$

Since T_{D} and T_{P} are both dimensionless, the unit of force in (26) is Newton as in Coulomb's Law.

6. Force from Object Mass

In general, charges Q_1, Q_2 in equation (26) 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.

6.1. 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:

$$q = A_{\text{q}}\, e \tag{27}$$

As shown in Appendix-C, the atomic charge factor A_{q} can be calculated as follows:

$$A_{\text{q}} = \frac{2}{3}\left(A+Z\right) \tag{28}$$

For example, the charge in a Carbon atom with Z=6 and A=12 can be calculated from (28) as:

$$q_{\text{Carbon12}} = \frac{2}{3}\left(A+Z\right) e = \frac{2}{3}\left(12+6\right) e = 12e \tag{29}$$

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-6.2), 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:

$$N = N_{\text{A}}\,\frac{m}{A_{\text{q}}} \tag{30}$$

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 $N = m/(\text{u}A_{\text{q}})$. The charge Q contained in mass m can now be determined from equations (27,30), as:

$$Q = q\,N = A_{\text{q}}\, e\, N_{\text{A}}\,\frac{m}{A_{\text{q}}} = e\,N_{\text{A}}\,m \tag{31}$$

Note that the atomic charge factor A_{q} appears in both numerator and denominator of (31) and so cancels out, which simplifies charge calculation directly from mass irrespective of object composition. It is clear from (31) 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 (31) 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 $F = eN_{\text{A}}$= e/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 (31) as:

$$Q_{\text{sh}} = e\,N_{\text{A}}\,m_{\text{sh}} \tag{32}$$

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 (32) in (25) to determine total object charge Q from object mass m, as follows:

$$Q = \sum_{i=1}^{n} Q_{shi} = e N_A \left(m_{sh1} + m_{sh2} + m_{sh3} \cdots + m_{shn} \right) = e N_A \sum_{i=1}^{n} m_{shi} = e N_A m \qquad (33)$$

In a sense equation (33) combines the shell theorems of Gauss [16] and Newton [17] 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 (33) as follows:

$$Q_1 = e N_A m_1 \qquad Q_2 = e N_A m_2 \qquad (34)$$

6.2. Quantum Electric Gravity Force between Objects

We can now express the force in terms of mass by substituting Q_1 & Q_2 from equations (34) in equation (26) to obtain the total net force F_{net}, as follows:

$$\mathbf{F}_{net} = -\frac{e^2 N_A^2}{2\pi\varepsilon_0} \frac{m_1 m_2}{r^2} T_D T_P \hat{\mathbf{r}} \qquad (35)$$

Equation (35) 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 ($\mathbf{F}_{QEG}$) and re-write (35) as:

$$\mathbf{F}_{QEG} = \mathbf{F}_{net} = -\frac{e^2 N_A^2}{2\pi\varepsilon_0} T_D T_P \frac{m_1 m_2}{r^2} \hat{\mathbf{r}} \qquad (36)$$

The force in (36) may be rewritten in an alternative and more familiar form, i.e. similar to that of Newton's Law of Gravitation, as follows:

$$\boxed{\mathbf{F}_{QEG} = -G_{QE} \frac{m_1 m_2}{r^2} \hat{\mathbf{r}}} \qquad (37)$$

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

$$G_{QE} = \frac{e^2 N_A^2}{2\pi\varepsilon_0} T_D T_P \rightarrow (\equiv G) \qquad (38)$$

The force in (36,37) is proportional to a motion-dependent term T_D and a van der Waals term T_P (24) that can be determined experimentally (S-7). Since parameters T_D and T_P are all dimensionless, the units of G_{QE} should match that of Newton's gravitational constant G:

$$\frac{\mathrm{N\,m^2}}{\mathrm{C^2}} \frac{\mathrm{C^2}}{\mathrm{kg^2}} = \frac{\mathrm{N\,m^2}}{\mathrm{kg^2}} \equiv G \qquad (39)$$

It is interesting to observe that equations (36-38) combine the hitherto irreconcilable theories of Newton's and quantum mechanics/physics. QEG achieves all that despite the heretofore prevailing notion that Newton's gravity is different and otherwise seemingly unrelated paradigm to the disciplines of QM/EM on which QEG is founded. Equation (36) can be alternatively written as:

$$\mathbf{F}_{QEG} = -\frac{1}{2\pi\varepsilon_0} \left(\frac{e}{\mathrm{u}} \right)^2 T_D T_P \frac{m_1 m_2}{r^2} \hat{\mathbf{r}} \qquad (40)$$

Although we have derived the terms T_P and T_D, 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.

6.3. Quantum Electric Gravity from Charge & Mass

Equations (31-38) can be combined to derive some interesting and versatile ways to calculate $\mathbf{F}_{QEG}$, namely from the mass of one object and the charge of the other or vice versa, as follows:

$$\mathbf{F}_{\mathrm{QEG}} = -\frac{eN_{\mathrm{A}}}{2\pi\varepsilon_0} T_{\mathrm{D}} T_{\mathrm{P}} \frac{Q_1 m_2}{r^2}\ \hat{\mathbf{r}} = -\frac{G_{\mathrm{QE}}}{e N_{\mathrm{A}}} \frac{Q_1 m_2}{r^2}\ \hat{\mathbf{r}} \tag{41}$$

Equations (41) 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 (41) one can also express the acceleration of gravity $\mathbf{g}$ in terms of charge by letting $\mathbf{g} = \mathbf{F}_{\mathrm{QEG}} / m_2$.

7. Experimental Determination of T_{P} and 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 x 10^{-11}. QEG can qualify this and replaces G with the quantum electric gravitational parameter G_{QE} (38) as follows:

$$G_{\mathrm{QE}} = \frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0} T_{\mathrm{D}} T_{\mathrm{P}} = G \tag{42}$$

Since there was no velocity involved in Cavendish's experiment, we can assume T_{D} = 1 to obtain:

$$\frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0} T_{\mathrm{P}} = G \tag{43}$$

$$T_{\mathrm{P}} = \frac{2\pi\varepsilon_0}{e^2 N_{\mathrm{A}}^2} G \tag{44}$$

$$T_{\mathrm{P}} = 3.9875 \times 10^{-37} = 4 \times 10^{-37} \tag{45}$$

Equation (45) can be substituted in (38) to write the quantum electric parameter G_{QE} (as determined from Cavendish's experiment) in general, as follows:

$$G_{\mathrm{QE}} = \frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0} 4 \times 10^{-37} T_{\mathrm{D}} = 6.67259 \times 10^{-11} T_{\mathrm{D}} \tag{46}$$

It remains to be seen whether or not T_{P} may have some other dependencies which may, if any, reflect on the quantum gravitational parameter G_{QE}. Note that it should be possible to derive parameters P_{a}, P_{r}, T_{P} from EM and QM/QED principles.

8. Polarization and Non-Linear Effects

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 $\mathbf{E}$, e.g. field arising from other atoms. Field $\mathbf{E}$ causes electric polarization where the centre of the electron cloud moves in one direction while the nucleus moves in the opposite, such that the total shift $\boldsymbol{\delta}$ between centres lies substantially along the field [18,19]. 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 $\mathbf{p}$ is given by:

$$\mathbf{p} = q\boldsymbol{\delta} = \alpha \mathbf{E} \tag{47}$$

where q is the atomic charge and α is a property of atoms known as (deformation) polarizability ($\alpha = 4\pi\varepsilon_0 a^3$) [18,19]. The values of α for various elements can be found in published data [20], e.g. $\alpha_{\mathrm{(Hydrogen)}} \sim 7.419 \times 10^{-41}$ $\mathrm{Cm^2/V}$. Shift $\boldsymbol{\delta}$ depends on ratio α/q and can be determined from (47) as:

$$\boldsymbol{\delta} = \frac{\alpha}{q} \mathbf{E} \tag{48}$$

It is expected that the overall effects of atomic charge shift $\boldsymbol{\delta}$ would be to introduce additional force dependencies on higher $1/r^n$ terms, where n=3, 4 .... etc. which can all be embodied in a new dimensionless term T_δ. For example, for shift $\boldsymbol{\delta}_1$ and $\boldsymbol{\delta}_2$ in atoms 1 and 2 in Figure 2, respectively, the T_δ term can be written as [21]:

$$T_\delta = \frac{1}{r}\left(\boldsymbol{\delta}_1 - \boldsymbol{\delta}_2\right) + \frac{3}{2r^2}\left(\boldsymbol{\delta}_1^2 + \boldsymbol{\delta}_2^2\right) + \frac{3}{r^2}\left(\frac{P_\mathrm{r}}{\left(P_\mathrm{a} - P_\mathrm{r}\right)}\right)\boldsymbol{\delta}_1\boldsymbol{\delta}_2 \cdots \tag{49}$$

Equation (49) may be added to the quantum electric gravitational parameter G_QE (38) to obtain the following more accurate formula:

$$G_\mathrm{QE} = \frac{e^2 N_\mathrm{A}^2}{2\pi\varepsilon_0}\, T_\mathrm{D}\, T_\mathrm{P}\left(1 + T_\delta\right) \;\rightarrow\; \left(\equiv G\right) \tag{50}$$

One can observe from (50) that G_QE would now be 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 (24) depends on the difference in force parameters (P_a – P_r) and makes the force dependent on the inverse square of distance. The T_δ term (49) comprises an infinite number of terms, and depends on shifts $\boldsymbol{\delta}_1$ and $\boldsymbol{\delta}_2$, on $1/r^n$ 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. Since the external electric field **E** (arising from external atoms/dipoles) varies with distance as $1/r^3$ [22], the shift is expected to vary in a similar manner, i.e. $1/r^3$, thus making the T_δ term proportional to $1/r^4$ and higher. When multiplied by $1/r^2$ outside the brackets in (36,37), T_δ would make the forces vary with $1/r^n$, where n =6 and higher.

It is expected that when the effect of the T_δ term is taken into account, this should increase the force of gravity over and above that of inverse square law at shorter distances and/or high field intensities. This could potentially explain the perihelion advance of planet Mercury and may also explain some of the other phenomena associated with Einstein's General Theory of Relativity – see S-9 point (3).

9. Discussion

1) The neutrons are already included in the QEG force equation as charge constituent of mass – see SS-6.1. 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 [23,24]. 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).

2) 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 [25] 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 [25]. The latter may be considered as experimental evidence in support of QEG.

3) 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} (49) due to the reduced Planet-Sun distance, and/or some nonlinear effects. The tangential velocity term (4) 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.

4) 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 [26]. 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.

5) For objects moving at radial velocities (along r) such as in the example shown in Figure 3, 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]:

$$T_{Dr} = \frac{1}{\gamma^2} = \left(1 - \frac{\mathbf{v}_1^2}{c^2}\right) \tag{51}$$

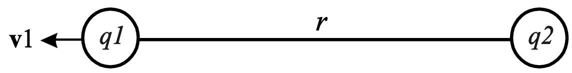

Figure 3 - EM forces between two charges – radial velocity

By substituting (51) in (38) and letting $T_D = T_{Dr}$ one can write the G_{QE} equation as follows:

$$G_{QE} = \frac{e^2 N_A^2}{2\pi\varepsilon_0}\left(1 - \frac{\mathbf{v}_1^2}{c^2}\right) T_P \tag{52}$$

which indicates that gravity in QEG can be influenced by object's radial velocity. Substituting (52) in (37) 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 (52) becomes negative which will make gravity change sign and become "repulsive". Equation (52) is expected to have potential implications for the expansion, dynamics and evolution of the universe [27].

6) It is interesting to observe that the "*asymmetrical*" behaviour of the L-J potential (see Figure 1) is akin to that of a *leaky* Diode Rectifier commonly used in electrical circuits, which enhances one

polarity over another. It appears that, by virtue of its property, matter itself is able to dictate how it can *exploit* the bi-directional EM field (likened to alternating current AC) by rectifying part of its energy in order to extract some unidirectional (likened to rectified direct current DC) energy and force, again, in a manner reminiscent of electrical circuits.

7) We can use Figure 1 to visualize what happens during object's free fall in gravitational field. The gravitational field will try to extend the object by moving the auto-balanced equilibrium point from p_0 to p_1 and d_0 to d_1. In turn this will shorten distance r from r_0 to r_1. The object is now effectively moved closer to a higher gravitational field. The process will now repeat itself leading to shorter and shorter r values until the two objects come into contact. Thus the free fall is driven by a positive feedback chain reaction that thrives to bring the system into the lowest energy state possible. Here is a summary of the free fall sequences, moving from left to right:

$$\begin{aligned} &r_0 > r_1 > r_2 \cdots\cdots > r_\mathrm{n} \\ &d_0 < d_1 < d_2 \cdots\cdots < d_\mathrm{n} \\ &p_0 \to p_1 \to p_2 \cdots\cdots \to p_\mathrm{n} \end{aligned} \tag{53}$$

8) The simple Dipole Atomic model (SS-5.1) 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 making 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 instead get progressively higher in line with the standard van der Waals and the Lennard-Jones potential (8) and force functions (9). 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 [28]. 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.

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 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.

10. 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. 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 [29].

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: Atomic Charge Factor A_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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