On Gravity and Electricity's Indelible Scientific Link

Rad H Dabbaj
United Kingdom
rdabbaj@btinternet.com
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Abstract

This paper describes a new scientific link between gravity and electromagnetic forces (GE-Link) in the hope of finding the origin and secret of gravity. In the GE-Link one can use pure EM/QED principles to derive a clear residual electric force synonymous with and indistinguishable from the force of gravity. Atoms and molecules have equal amount of positive and negative charge and, as a result, interact by attractive and repulsive electric forces that almost completely cancel each other out. However, these interactions are not symmetrically identical because the experimentally-verified intermolecular van der Waals interactions exhibit a well known asymmetrical characteristic property that tends to enhance attractive over repulsive energies on a microscopic level. When applied to large objects, this breakdown of symmetry provides the basis for the GE-Link and produces a force in line with Einstein's General Relativity and, in the limit, Newton's Law of Gravitation. In addition to Newton's, the force has an orbital velocity-dependent term and a term proportional to gravitational field strength or intensity, both of these "electrical" terms support similar ones in Einstein's General Relativity. Among the surprise findings is that *radial* (not orbital) object velocity actually decreases the force of gravity due to EM/Special Relativity considerations. This feature is expected to have some potential implications for the expansion and dynamics of the universe. As an upshot, the GE-Link enables one to theoretically derive the underlying formula for the Newtonian gravitational constant *G*.

Keywords: gravity and electricity link, GE-Link, electric gravity, electric gravitation, gravity, gravitation, quantum electrodynamics, van der Waals, gravitational constant, cosmology

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1. Introduction

This paper establishes a new scientific link between gravity and electromagnetic forces (GE-Link) and eventually between gravity and the quantum world via quantum electrodynamics (QED). 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]. Scientists give Einstein's GR the upper hand despite its short comings because it is difficult to fault GR as most of the phenomena it proposed have already been backed up by solid experimental proofs.

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]. What makes matter even worse is the fact that, hitherto, the nature and origin of gravity continue to be highly elusive and stubbornly incompatible with the other fundamental forces of nature like electromagnetic (EM) and atomic forces. 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. The general consensus among scientist is this: it is quite acceptable for the world to be governed by two apparently independent theories; GR and QM even though these theories do not see eye-to-eye at present. It may be time for scientists to stop trying to reconcile GR with quantum mechanics – the two are simply irreconcilable. There is no GR in QM just as much as there is no QM in GR!

It's time to look at alternative approaches to gravity preferably ones that are inherently compatible with and based entirely on QM - not at odds with it. According to this paper, the only 100% QM-compatible up to the job alternative is the venerable mighty electromagnetic force (EM). As I will demonstrate in this paper, the EM force and its modern Quantum Electrodynamics (QED) formulation will by and large support Einstein's GR and backs up most of its findings one-by-one and beyond.

As it turned out, the opposing attractive and repulsive forces between neutral atoms and molecules 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 leads the symmetry between the forces to breakdown and leaves a clear non-zero net force between objects synonymous with and indistinguishable from the force of gravity in line with Einstein's and Newton's. The GE-Link enables one to derive the underlying formula for the Newtonian gravitational constant *G*. As described below in more details, the following equation is derived from basic EM theory:

$$\mathbf{F}_{\text{QEG}} = -G\frac{m_1 m_2}{r^2}\,T_{\text{v}}\left(1+\frac{T_{\text{micro}}}{T_{\text{macro}}}\right)\hat{\mathbf{r}} \tag{1}$$

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 by virtual particles. We then analyse intermolecular van der Waals bonding forces using the Lennard-Jones potential, which exhibit a fundamental asymmetric energy and force behaviour. We then use this fundamental asymmetry to establish a link between gravity and electromagnetic forces. We develop a new general purpose electric model, the Tripole Atomic Model (TAM), to determine electromagnetic forces between atoms and molecules first at small distances, and then extend that to larger distances at which gravity operates. Using charge-mass relations we can then show how to determine object charge from its mass and eventually arrive at a force equation encompassing Newton's (NLG) and Einstein's GR and beyond. We shed some light on the gravitational parameter *G* and derive its formula from EM/QED. Finally we discuss some of the implications of the GE-Link.

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 gravity with EM one must first overcome some major issues, among them:

a) Magnitude – there is an enormous magnitude-difference with EM/gravity force ratio $\sim 1\text{x}10^{40}$!

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.

d) Nearly half of matter in the universe is made of "neutral" neutrons

e) Shielding issues

As we will see in more details below, one can resolve all these issues and successfully combine gravity with electromagnetism via the GE-Link. As neutral charge-dual entities, atoms interact with other atoms via two types of EM forces of almost identical magnitudes; attractive and repulsive. Although these opposite direction forces largely cancel each other out, they leave a clear residue that resolves issues (a) and (b) above. The issue of mass and charge (c) can be resolved because both are quite closely related in the standard model of particle physics, as defined by the Faraday Constant (9.6485e7). The neutrons (d) though are neutral charge-dual, they in fact contain equal amount of positive and negative charge that make them capable of electric interactions. As we will see below, shielding issues (e) do not arise because we are dealing with self-cancelling bipolar forces. The long-range aspect of both gravity and EM forces is very fundamental and represents the crucial common attribute to the successful combination of the two forces, which would not otherwise be possible.

3. Electric and Magnetic Forces

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, 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:

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

where T_{v} 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_{vt} can be determined using Lorentz Transformations [5] with factor γ, as follows:

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

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,

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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 (N_{vp}) 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]. Note that Coulomb's Law represents a statistical average of large number of QED particle interactions.

Coulomb's law and its modern QED interpretation is a fundamental law of nature and is one of the pillars of the standard model of particle physics. Each and every atoms in the universe is built from electric charge; positive and negative. For this reason, electrical forces between atoms/molecules are ubiquitous. We don't make the rules: all atoms and molecules interact like so, and you and I cannot remove these forces nor strike it out nor vanish it – it's omnipresent.

How do these attractive and repulsive forces simultaneously exist? According to QED, these forces are communicated by virtual photons (vp) that are superposed together and interact independently of each other. Unlike classical electrostatics, the interactions in QED are highly dynamic and are driven by "digital-like" on/off virtual particles or photons. The big difference crucial to the GE-Link is that while classical electrostatic (DC) forces can totally cancel each other, under QED the two superposed forces act independently because each is communicated by statistically averaged randomly occurring virtual particles. So, each polarity can "complete" its interaction which may subsequently be partially or completely counteracted (or reversed) by the other polarity. Put another way, if an attractive and repulsive force fields of identical absolute magnitudes interact with a given charge entity, the two types of interactions can proceed independently of each other, which may cancel when overlapping and not cancel when not. What matters in the end is the QM statistical averaging. One cannot do the same under classical electrostatics where total force cancellation can (theoretically) occur. QED can therefore explain electrical interactions that may otherwise be unfeasible under classical EM.

3.3 Empirical Intermolecular Energy and Force

Adjacent molecules, including single neutral atoms, interact by instantaneous dipole-induced dipole forces which are part of van der Waals (vdW) forces (London Dispersion forces). These interactions may be caused by quantum-induced instantaneous polarization. In molecules these forces are induced by instantaneous polarization multipoles 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 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 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 and determine intermolecular interactions. The empirical method was specifically developed to describe the short-range intermolecular interactions. One of the most popular forms of L-J potential is the 6-12 potential (or 12-6), which describes how the potential U_d varies with distance *d*, as follows [10]:

$$\mathrm{U_d} = \mathrm{U_0}\left[\left(\frac{d_0}{d}\right)^{12} - 2\left(\frac{d_0}{d}\right)^{6}\right] \tag{5}$$

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. In (5) the first term is repulsive varying with $1/d^{12}$ while the second term is attractive varying with $1/d^{6}$. The distance *d* at which the potential equals to zero is called σ and can be found from $\sigma = (2^{-1/6})\, d_0$. Equation (5) 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.

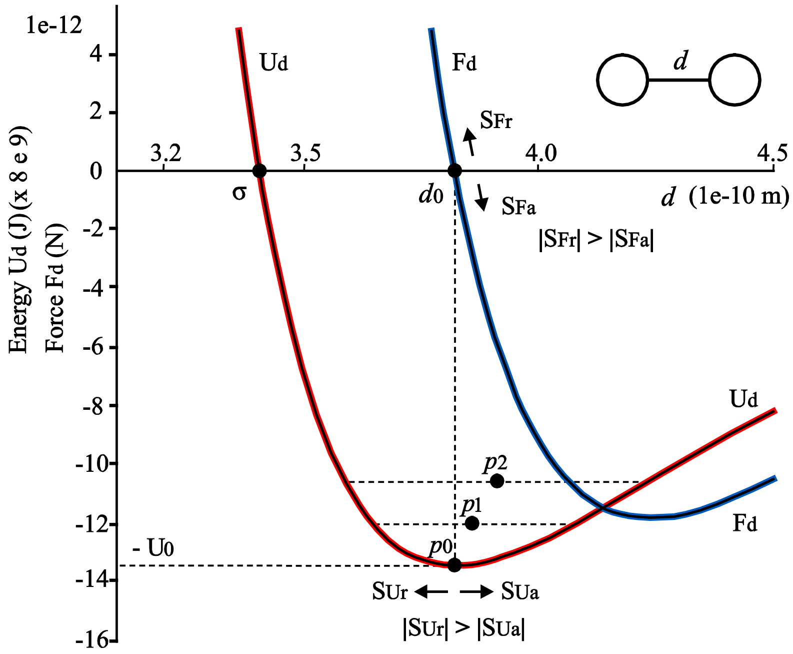

Figure 1 – Lennard-Jones Energy $U_{L\text{-}J}$ & Force $F_{L\text{-}J}$ versus Distance – Argon

The force $\mathbf{F}_d$ can be determined by differentiating the potential in (5), as follows:

$$\mathbf{F}_d = -\frac{d}{dd}\left(U_d\right) = \frac{12U_0}{d_0}\left[\left(\frac{d_0}{d}\right)^{13} - \left(\frac{d_0}{d}\right)^{7}\right] \tag{6}$$

Equation (6) is also plotted in Figure 1 using data for Argon. As distance d decreases both 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 $\mathbf{F}_d = 0$ and a minimum total energy $-U_0$ (or $-\varepsilon$), where the system reaches a balanced equilibrium state at position p_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. 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. The parameters in (5) are normally used to reproduce experimental data and/or data from accurate quantum chemistry analysis.

Note that the auto-balancing mechanism above will always automatically *drive* the system towards the equilibrium condition $\mathbf{F}_d = 0$ for all external forces no matter how strong or weak. This is a universal and ever-present blanket effect in which the system will always try to self-adjust in order to "equalize" the net effective internal attractive and repulsive forces, and leaves atoms "hovering" around at $\mathbf{F}_d = 0$. This important mechanism may be referred to as Automatic Force Balance "AFB". In essence, what AFB does is to always automatically set up or "bias" the system at an effective $\mathbf{F}_d = 0$.

4. Asymmetric Electric Coupling

The total energy U of a system of two interacting objects distance *r* apart comprises potential energy (U_r), kinetic energy (U_k) and internal energy (U_d) between the atoms and molecules within each object (SS-3.3). EM and gravitational energies are conservative and the total energy of the system remains locked up in the system irrespective of whether the relative magnitudes of the various components vary with distance. A change in energy of one component will cause one or more of the remaining ones to change in the opposite direction.

Each object exerts a "differential" or "tidal" force $\mathbf{F}_t$ on the other due to the fact that the nearside always experiences larger forces than the far side. Differential or tidal forces may be used interchangeably. Tidal force $\mathbf{F}_t$ gives rise to a tidal energy U_t which is superposed on and modifies the object's internal energy between atoms and molecules (U_d). Depending on polarity, attractive tidal forces extend objects while repulsive tidal forces contract objects, both these forces increase energy 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:

$$\mathrm{U} = \mathrm{U_r} + \mathrm{U_t} + \mathrm{U_k} \tag{7}$$

Tidal energy U_t increases at shorter *r* values. When objects move, the distance between them changes and the energy is traded off between the various components in (7). Since they directly act on atoms and molecules, tidal forces will be superposed on intermolecular forces ($\mathbf{F}_d$) within the object. Assuming there are no non-conservative forces acting on the system, the total energy of the system (7) is conserved so one can write:

$$\mathrm{U_{r1}} + \mathrm{U_{t1}} + \mathrm{U_{k1}} = \mathrm{U_{r2}} + \mathrm{U_{t2}} + \mathrm{U_{k2}} \tag{8}$$

$$\Delta\mathrm{U_r} + \Delta\mathrm{U_t} + \Delta\mathrm{U_k} = 0 \tag{9}$$

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

4.1 Asymmetric Properties of Intermolecular Bonding

It is important to observe that the energy and force in L-J curve (Figure 1) exhibit asymmetrical characteristic property on either side of the AFB equilibrium position p_0. At this position the energy and force required to decrease distance *d* (compression) are greater than that required to increase distance *d* (extension). As explained above, since attractive tidal forces increase *d* and cause extension while repulsive tidal forces decrease *d* and cause compression, we shall use subscript "a" for the former and "r" for the latter. The slopes of energy and force can be expressed as:

$$\left|\mathrm{S_{Ur}}\right| > \left|\mathrm{S_{Ua}}\right| \qquad \left|\mathrm{S_{Fr}}\right| > \left|\mathrm{S_{Fa}}\right| \tag{10}$$

where S_{Ua}, S_{Ur} are the energy slopes for extension and compression, respectively, and S_{Fa}, S_{Fr} are the force slopes for extension and compression, respectively. What (10) is saying is that it is harder to ***compress*** a material than it is to ***extend*** it by the same amount.

One can analyse the system of Figure 1 using a spring analogy [10] by considering the attractive and repulsive tidal forces ($\mathbf{F}_t$) 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 (Δd) can be calculated from (6) 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 ($\mathbf{F} = -k\,\Delta d$) we can write:

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

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$$\Delta \mathrm{U}_{\mathrm{ta}} = \frac{1}{2} k_{\mathrm{a}} \, \Delta d_{\mathrm{a}}^{2} \qquad \Delta \mathrm{U}_{\mathrm{tr}} = \frac{1}{2} k_{\mathrm{r}} \, \Delta d_{\mathrm{r}}^{2} \tag{12}$$

where $\mathbf{F}_{ta}$, ΔU_{ta}, k_a are the attractive force, energy-change and spring constant, and $\mathbf{F}_{tr}$, ΔU_{tr}, 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:

$$|k_{\mathrm{r}}| > |k_{\mathrm{a}}| \qquad \left|\frac{k_{\mathrm{r}}}{k_{\mathrm{a}}}\right| > 1 \tag{13}$$

The asymmetry in (10,13) 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 expand 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.

4.2 Response to External Forces

Let us see how a system of molecules bound by van der Waals bonding and AFB (Figure 1) will respond to two external electric fields ($\mathbf{E}_r$), one attractive ($\mathbf{E}_{ra}$) and one repulsive ($\mathbf{E}_{rr}$), of identical absolute magnitudes, i.e. $|\mathbf{E}_{ra}| = |\mathbf{E}_{rr}|$. As explained in S-5 below, neutral atoms interact with these types of bipolar (bi-directional) electrical fields and give rise to attractive and repulsive forces. Recall that in QED both of these forces are communicated by virtual particles that are superposed together and act independently of each other. The QED force concept is quite important because it allows the attractive and repulsive forces to do their "actions" on matter and facilitates QM random processes and statistical averaging.

The external fields $\mathbf{E}_{ra}$**,** $\mathbf{E}_{rr}$ will be superposed on the atoms of Figure 1 and give rise to attractive tidal force $\mathbf{F}_{ta}$ and repulsive tidal force $\mathbf{F}_{tr}$, respectively, both will try to slightly move or nudge the atoms about their balanced position at d_0 (Figure 1). Force $\mathbf{F}_{ta}$ will try to pull the atoms apart while force $\mathbf{F}_{tr}$ will try to push the atoms closer together. It is here where the slopes in (10,13) will now make a difference and play an important and crucial role. Since $|\mathbf{E}_{ra}| = |\mathbf{E}_{rr}|$, the internal tidal forces should also be equal, i.e. $|\mathbf{F}_{ta}| = |\mathbf{F}_{tr}|$, which when substituted in (11) should lead to:

$$\Delta d_{\mathrm{r}} = \left|\frac{k_{\mathrm{a}}}{k_{\mathrm{r}}}\right| \Delta d_{\mathrm{a}} \tag{14}$$

By substituting (14) in (12) and making use of (13) one obtains the following:

$$\left|\frac{\Delta \mathrm{U}_{\mathrm{da}}}{\Delta \mathrm{U}_{\mathrm{dr}}}\right| = \left|\frac{k_{\mathrm{r}}}{k_{\mathrm{a}}}\right| > 1 \tag{15}$$

Equation (15) is quite important because it states that if one applies external attractive and repulsive fields of exactly identical absolute magnitudes, the asymmetric characteristics property of intermolecular bonding will cause slightly greater internal attractive energy change/exchange (ΔU_{ta}) in the object than repulsive energy change/exchange (ΔU_{tr}), i.e. ($|\Delta U_{ta} / \Delta U_{tr}|$) > 1. But since energy is conserved (7-9), this should in turn produce slightly greater change in external attractive potential energy (ΔU_{ra}) than in repulsive potential energy (ΔU_{rr}), from which one can obtain the ratio of external potential energy change via (12,15), as follows:

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$$\boxed{\left|\frac{\Delta U_{ra}}{\Delta U_{rr}}\right| = \left|\frac{k_r}{k_a}\right| > 1} \tag{16}$$

Since force $\mathbf{F} = -dU/dr$, one can conclude from (16) that the following should also be true:

$$\boxed{\left|\frac{\mathbf{F}_{ra}}{\mathbf{F}_{rr}}\right| = \left|\frac{k_r}{k_a}\right| > 1} \tag{17}$$

Note that if the material was symmetric ($k_r = k_a$), then the externally applied fields will give rise to equal forces $|\mathbf{F}_{ra}| = |\mathbf{F}_{rr}|$. But it is the asymmetric property of van der Waals bonding (AFB) that causes $|\mathbf{F}_{ra}| > |\mathbf{F}_{rr}|$, as in (17).

4.3 Asymmetric Quantum Electric Coupling Mechanism - AEX

Based on (16,17) one can propose a mechanism responsible for the breakdown of symmetry between the otherwise symmetrically identical external fields. Such a mechanism may be referred to as Asymmetric Energy eXchange "AEX". Mechanism AEX operates at the equilibrium position biasing point $\mathbf{F}_d = 0$ brought about by the AFB, as follows: an external attractive field causes greater energy change/exchange in/with the material than does a repulsive field. In other word, matter extracts more attractive energy from external fields than repulsive energy at the equilibrium position. The AEX mechanism will tip the balance in favour of enhancing attractive over repulsive forces and leads to the following proposed non-identical dimensionless attractive and repulsive force and energy multipliers P_a and P_r, respectively:

- **Matter slightly *enhances* external attractive energy & force → attractive multiplier P_a**
- **Matter slightly *resists* external repulsive energy & force → repulsive multiplier P_r**
- **Multipliers ratio should be in line with (16,17) → $P_a/P_r > 1$ or $P_a - P_r > 0$**

Since AEX applies to all matter held together by vdW bonds that are perfectly biased by AFB at $\mathbf{F}_d = 0$, one needs to reflect this fundamental "blanket" effect in the force equation (3). One practical way to implement this phenomenon is by multiplying the force in (3) by multipliers P_a and P_r, as follows:

$$\boxed{\mathbf{F}_{att} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_v P_a \,\hat{\mathbf{r}}} \qquad \boxed{\mathbf{F}_{rep} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_v P_r \,\hat{\mathbf{r}}} \tag{18}$$

The QED force between charges is communicated by virtual particles (SS-3.2) and, therefore, multipliers P_a and P_r may each be viewed as the interaction with a single virtual particle or virtual particle's "quanta", each is expected to have a fixed/constant contribution or effect. The number or density of these virtual particles N_{vp} is proportional to charge q and follows inverse square law. Note that multipliers P_a and P_r may be viewed as the probability amplitudes of QED interactions for the attractive and repulsive forces, respectively, occurring at the AFB equilibrium bias position. P_a and P_r may be derived from theory using QM/QED, however in this paper we shall determine their values from experiments – see S-7.

Had the characteristic property of van der Waals forces been symmetrical, then one would get $P_a = P_r = 1$ and $\mathbf{F}_{att} = \mathbf{F}_{rep}$ in (18). Additionally, without this asymmetry, thermal expansion too will cease to exist [15]. Note that 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 auto-balancing equilibrium mechanism.

5. Analyses of Intermolecular Forces

The empirical method in S-3 is an approximate ad hoc formula valid for and specifically developed to reproduce experimental data at intermolecular distances ($r \sim d$) as is extensively used in the field of Molecular Dynamics calculations. It is not, however, suitable for much larger distances where $r >> d$ and, therefore, one cannot use it to probe the GE-Link because gravity operates at much larger distances. In this section we propose a new electric atomic model (Tripole) meeting the following stringent requirements:

- Robust general purpose electric atomic model
- Totally derived from electromagnetic theory
- Operating at all distances large and small ($d < r <$ infinity)
- As a pre-condition it must reproduce the tried and tested empirical formula for intermolecular energy and force at $r \sim d$, i.e. reproducing the characteristic property of vdW/L-J shown in Figure 1
- Only then would one feel confident enough to extend this model to large distances and scales in order to enable the assessment of the GE-Link between gravity and electricity.

5.1 Tripole Atomic Model - TAM

By and large matter exists in the form of neutral charge-dual entities having equal absolute magnitudes of positive and negative charge as in molecules, including single neutral atoms or monatomic molecules. The terms atoms and molecules may be used interchangeably to refer to neutral charge-dual entities. The properties of neutral charge-dual entities are described in Appendix-B. For electric force calculations, the atom can be represented by a simple effective electric model, comprising positive and negative charge such as any of the atoms 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. For electron cloud one needs a more accurate representation of the distributed nature of charge. One good and simple method is to split the negative charge $-q$ into two parts one on either side of nucleus as shown in each atom of Figure 2. This approximates the atom into three point charges, hence the name "Tripole" Atomic Model (TAM). Although models with more charge points may be more accurate, the TAM greatly reduces calculations and simplifies the overall analysis. As we shall see below, the Tripole will prove to be quite powerful in that it will quite accurately trace and reproduce the characteristics property of van der Waals and L-J energy and force similar to that of Figure 1.

5.2 Electric Forces between Two Molecules – Tripoles

We shall consider electrical interactions between two neutral atoms or molecules as neutral charge-dual entities. In order to simplify the analysis we shall consider interactions between two simple or monatomic molecules like Argon, although the same analysis should also apply to more complex molecules. Figure 2 shows two neutral atoms 1 and 2 separated by distance r. Atom 1 comprises positive charge $+q_1$ and negative charge $-q_{1a}$, $-q_{1b}$ situated at distances a_1, b_1 from nucleus, respectively. Atom 2 comprises positive charge $+q_2$ and negative charge $-q_{2a}$, $-q_{2b}$ situated at distances a_2, b_2 from nucleus, respectively. In order to account for magnetic forces too (T_v), we 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 average distance between the atoms. We assume that each atom is locally bound by interatomic forces with its neighbouring atoms/molecules (not shown) and exhibiting the AFB equilibrium condition $\mathbf{F}_d = 0$ at which the AEX is facilitated, as described in S-3 and S-4 above.

It is instructive to express the total EM force between the atoms as the sum of two separate and independent main components, namely that of the attractive component ($\mathbf{F}_{att}$) and that of the repulsive component ($\mathbf{F}_{rep}$). This will pave the way for the GE-Link and, as we will see later, will enable one to account for the force of gravity by describing it 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.

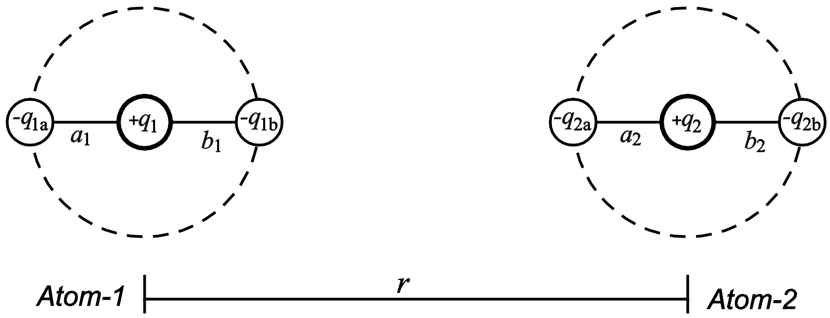

Figure 2 – Electrical Interaction between two Neutral Atoms using Tripole Atomic Model

The total Coulomb's attractive and repulsive EM forces between atoms 1 and 2 can be determined using (18) by adding all corresponding attractive and repulsive components. Since there are six charge entities in Figure 2 ($+q_1$, $-q_{1a}$, $-q_{1b}$, $+q_2$, $-q_{2a}$, $-q_{2b}$), there is a total of nine interatomic force components, five repulsive and four attractive, as follows:

$$\mathbf{F}_{rep} = \frac{T_v P_r}{4\pi\varepsilon_0}\left(\frac{(+q_1)(+q_2)}{r^2} + \frac{(-q_{1a})(-q_{2a})}{(r+a_1-a_2)^2} + \frac{(-q_{1a})(-q_{2b})}{(r+a_1+b_2)^2} + \frac{(-q_{1b})(-q_{2a})}{(r-b_1-a_2)^2} + \frac{(-q_{1b})(-q_{2b})}{(r-b_1+b_2)^2}\right)\hat{\mathbf{r}} \quad (19)$$

$$\mathbf{F}_{att} = \frac{T_v P_a}{4\pi\varepsilon_0}\left(\frac{(+q_1)(-q_{2a})}{(r-a_2)^2} + \frac{(+q_1)(-q_{2b})}{(r+b_2)^2} + \frac{(+q_2)(-q_{1a})}{(r+a_1)^2} + \frac{(+q_2)(-q_{1b})}{(r-b_1)^2}\right)\hat{\mathbf{r}} \quad (20)$$

Since the negative charge is split into parts a and b, one on either side of nucleus and that the atomic charge is fixed, one would expect the following to hold true for the TAM:

$$-q_{1a} = -q_1 x_{1a}, \quad -q_{1b} = -q_1 x_{1b}, \quad x_{1a} + x_{1b} = 1, \quad -(q_{1a} + q_{1b}) = -q_1 \quad (21)$$

$$-q_{2a} = -q_2 x_{2a}, \quad -q_{2b} = -q_2 x_{2b}, \quad x_{2a} + x_{2b} = 1, \quad -(q_{2a} + q_{2b}) = -q_2 \quad (22)$$

where parameter x denotes the charge multiplier fraction. Substituting (21,22) in (19,20) and taking common multiplier ($q_1 q_2 / r^2$) outside yields:

$$\mathbf{F}_{rep} = +\frac{q_1 q_2}{4\pi\varepsilon_0} T_v P_r \left(\frac{1}{r^2}\left(1 + \frac{x_{1a}x_{2a}}{\left(1+\frac{a_1-a_2}{r}\right)^2} + \frac{x_{1a}x_{2b}}{\left(1+\frac{a_1+b_2}{r}\right)^2} + \frac{x_{1b}x_{2a}}{\left(1-\frac{b_1+a_2}{r}\right)^2} + \frac{x_{1b}x_{2b}}{\left(1-\frac{b_1-b_2}{r}\right)^2}\right)\right)\hat{\mathbf{r}} \quad (23)$$

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$$\mathbf{F}_{\text{att}} = -\frac{q_1 q_2}{4\pi\varepsilon_0} T_{\text{v}}\, P_{\text{a}} \left(\frac{1}{r^2} \left(\frac{x_{2\text{a}}}{\left(1-\frac{a_2}{r}\right)^2} + \frac{x_{2\text{b}}}{\left(1+\frac{b_2}{r}\right)^2} + \frac{x_{1\text{a}}}{\left(1+\frac{a_1}{r}\right)^2} + \frac{x_{1\text{b}}}{\left(1-\frac{b_1}{r}\right)^2} \right) \right) \hat{\mathbf{r}} \tag{24}$$

If we denote the bracketed repulsive and attractive terms by T_{Trep}, T_{Tatt} in (23,24), respectively, we can simplify these terms using Binomial Expansions as detailed in Appendix-C to yield:

$$T_{\text{Trep}} = 2\left(\frac{1}{r^2} + \frac{Y_{\text{r3}}}{r^3} + \frac{3}{2}\frac{Y_{\text{r4}}}{r^4} + \cdots \right) \tag{25}$$

$$T_{\text{Tatt}} = 2\left(\frac{1}{r^2} + \frac{Y_{\text{a3}}}{r^3} + \frac{3}{2}\frac{Y_{\text{a4}}}{r^4} + \cdots \right) \tag{26}$$

where the terms Y_{rn} and Y_{an} are as defined in Appendix-C for n=3,4,5......... By substituting (25,26) in (23,24) we can re-write (23,24) in a simpler manner as follows:

$$\mathbf{F}_{\text{rep}} = +\frac{q_1 q_2}{2\pi\varepsilon_0} T_{\text{v}}\, P_{\text{r}} \left(\frac{1}{r^2} + \frac{Y_{\text{r3}}}{r^3} + \frac{3}{2}\frac{Y_{\text{r4}}}{r^4} + \cdots \right) \hat{\mathbf{r}} \tag{27}$$

$$\mathbf{F}_{\text{att}} = -\frac{q_1 q_2}{2\pi\varepsilon_0} T_{\text{v}}\, P_{\text{a}} \left(\frac{1}{r^2} + \frac{Y_{\text{a3}}}{r^3} + \frac{3}{2}\frac{Y_{\text{a4}}}{r^4} + \cdots \right) \hat{\mathbf{r}} \tag{28}$$

5.3 Net Force between Two Molecules – Tripoles

The repulsive and attractive forces (27,28) can now be added together to determine the total net force $\mathbf{F}_{\text{net}}$ which, after a little sign manipulation, yields the following:

$$\mathbf{F}_{\text{net}} = \mathbf{F}_{\text{rep}} + \mathbf{F}_{\text{att}} \tag{29}$$

$$\boxed{\mathbf{F}_{\text{net}} = \frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{v}} \left(-\left(P_{\text{a}} - P_{\text{r}}\right) - \left(\frac{1}{r}\left(P_{\text{a}}Y_{\text{a3}} - P_{\text{r}}Y_{\text{r3}}\right) + \frac{1}{r^2}\frac{3}{2}\left(P_{\text{a}}Y_{\text{a4}} - P_{\text{r}}Y_{\text{r4}}\right) + \cdots \right) \right) \hat{\mathbf{r}}} \tag{30}$$

After re-arranging, equations (30) can be simplified and re-written as:

$$\boxed{\mathbf{F}_{\text{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{v}} \left(T_{\text{macro}} + T_{\text{micro}} \right) \hat{\mathbf{r}}} \tag{31}$$

where we have defined two new dimensionless terms T_{macro} and T_{micro}, as follows:

$$T_{\text{macro}} = \left(P_{\text{a}} - P_{\text{r}} \right) \tag{32}$$

$$T_{\text{micro}} = \frac{1}{r}\left(P_{\text{a}}Y_{\text{a3}} - P_{\text{r}}Y_{\text{r3}}\right) + \frac{1}{r^2}\frac{3}{2}\left(P_{\text{a}}Y_{\text{a4}} - P_{\text{r}}Y_{\text{r4}}\right) + \cdots \tag{33}$$

Equations (30,31) 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_{v} (T_{macro} +T_{micro}) and divided by the square of distance and permittivity of free space. The term T_{macro} describes an inverse square law force while the term T_{micro} describes a force dependent on higher $1/r^{\text{n}}$ terms, where n=3, 4 .... The force equation (30) may alternatively be expressed as:

$$\mathbf{F}_{\text{net}} \equiv -\left(\mathbf{F}_{\text{r2}} \propto \frac{1}{r^2}\right) - \left(\mathbf{F}_{\text{r n}} \propto \sum_{n=3}^{n=\infty} \frac{Y_{\text{n}}}{r^n}\right) \tag{34}$$

From the above analysis one can make the following interesting observations about the characteristic properties of the force (30,31,34):

a) The force has an inverse square term (T_{macro}) dominating at large distances ($r >> d$) where it is acting between the total absolute charge q_1, q_2 irrespective of how the charge is locally distributed
b) The force has a multipole term (T_{micro}) with higher dependency on $1/r^{\text{n}}$, where n=3, 4 .... and thus departs away from inverse square law at small distances ($r \sim d$), which makes the force more dependent on how the charge is locally distributed (*ecc* – see below)
c) Although the total force depends on both T_{macro} and T_{micro} terms, each dominates the force equation at its respective scale.
d) Therefore, the force equation (30,31,34) depends on infinite $1/r^{\text{n}}$ terms, from n=2,3,4.... What determines whether the force follows inverse square law or anything else is nothing other than a **Scale Factor** determined by distance *r* relative to intermolecular distances, as follows:
   i) The force follows Inverse Square Law for $r >> d$, which defines a "macro-scale"
   ii) The force depends on higher $1/r^{\text{n}}$ terms over and above inverse square for $r \sim d$, which defines a "micro-scale"
   iii) The force follows a combination of (i) and (ii) for $d < r <$ *infinity*

Thus, in the system of Figure 2 each charge is acted upon by almost identical attractive and repulsive forces that are superposed together, so much so they do largely but incompletely cancel each other out. In S-6 we shall see how equations (30,31,34) can be applied to large astronomical objects that leads us to the GE-Link and electric gravity in line with Newton's, Einstein's and beyond. Equation (31) may alternatively be written as:

$$\mathbf{F}_{\text{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{v}}\, T_{\text{macro}} \left(1 + \frac{T_{\text{micro}}}{T_{\text{macro}}}\right) \hat{\mathbf{r}} \tag{35}$$

5.4 Short–Range Electric Force - Tripole

The force equation (30,31) is actually quite powerful as it can reproduce the energy and force versus distance characteristics of vdW and L-J at $r \sim d$ shown in Figure 1. The way we do that is by making the following reasonably simple assumptions. The electron cloud charge polarization or "shift" may be modelled by a dimensionless parameter like charge eccentricities ecc_1, ecc_2 for atoms 1, 2, respectively, as follows:

$$x_{1\text{a}} = \frac{1}{2}(1 + ecc_1), \quad x_{1\text{b}} = \frac{1}{2}(1 - ecc_1) \tag{36}$$

$$x_{2\text{a}} = \frac{1}{2}(1 + ecc_2), \quad x_{2\text{b}} = \frac{1}{2}(1 - ecc_2) \tag{37}$$

As mentioned in SS-3.3, charge polarization is caused by instantaneous dipole-induced dipole between neighbouring atoms and molecules. At these distances ($r \sim d$) the eccentricity *ecc* can be quite large by virtue of proximity of atoms where a strong "correlated" coupling occurs as in (36,37). However, as *r* increases this correlated coupling decreases. Deriving a formula for correlated coupling from theory should be possible using quantum mechanical/EM means, but this is outside the scope of this paper. We shall use approximate values here in order to show characteristic trends.

In addition, the instantaneous polarization is a temporary and transient phenomenon lasting a short period of time, which must be assigned an appropriate duty cycle ratio. It was found that a duty cycle of ~ 1/250 was needed in order to match experimental data in line with that of vdW/L-J. The charge shift may also change the effective distances from nuclei in a similar manner to (36,37), as follows:

$$a_1 = a_{01}\left(1 + ecc_1\right) \qquad b_1 = a_{01}\left(1 - ecc_1\right) \tag{38}$$

$$a_2 = a_{02}\left(1 + ecc_2\right) \qquad b_2 = a_{02}\left(1 - ecc_2\right) \tag{39}$$

where we used a_{01} and a_{02} as the nominal atomic radii of atoms 1 and 2, respectively. Although variable, the eccentricities may be assigned some practically reasonable values such as for example:

$$ecc_1 = ecc_2 = 0.6 \tag{40}$$

In order to plot force versus distance, one needs to evaluate (30,31) to calculate total net force. Similarly one can integrate (30,31) in order to plot energy versus distance. Note that for $r \sim d$, T_{micro} dominates the force equation because $T_{micro} >> T_{macro}$. The atomic radii were assumed to be approximately a_{01}=a_{02} =1.60e-10 m and the velocity term T_v = 1. The plots for the TAM model are shown in Figure 3; the force $\mathbf{F}_{TAM}$ vs r and the energy U_{TAM} vs r. For comparison, the vdW/L-J force $\mathbf{F}_{L\text{-}J}$ and energy $U_{L\text{-}J}$ from Figure 1 are also shown in the Figure (broken lines).

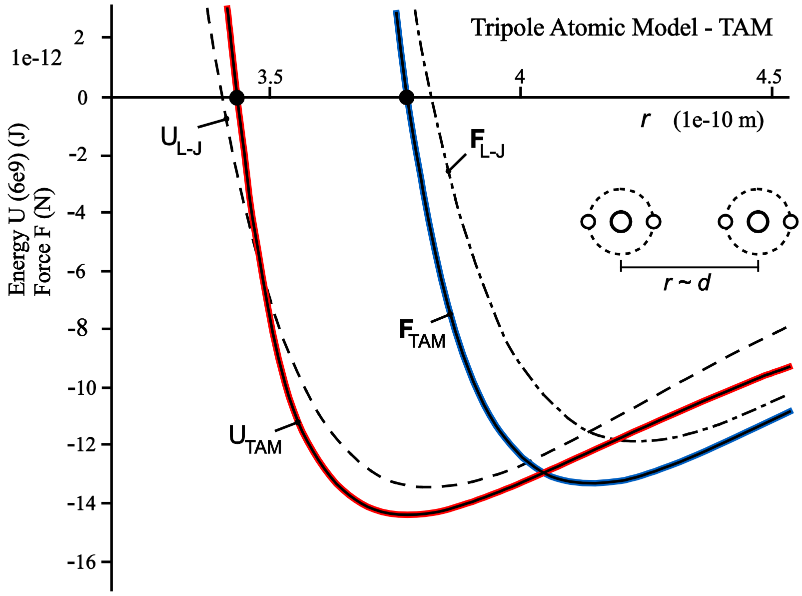

Figure 3 – Tripole Energy U_{TAM} & Force F_{TAM} vs distance ($r \sim d$) – Argon

Also shown are $U_{L\text{-}J}$ & $F_{L\text{-}J}$ vs distance (broken lines)

The TAM curves in Figure 3 come quite close to the energy and force of van der Waals and L-J of Figure 1, which is a remarkable vindication of TAM and its validity at the short-range or "micro-scale" world $r \sim d$. The vindication of the TAM model provides the backing and confidence to extend the force (30,31) to the long-range force of gravity, which is at the other end of the distance scale, the "macro-scale" world $r >> d$, as explained below.

Note that part of the repulsive r-terms inside the bracket of (30) with n >= 4 (i.e. those multiplied by 6 in Appendix-C)) have no corresponding attractive counterparts r-terms, as detailed in Appendix-C. In fact this goes a long way to explain why L-J repulsive force component (depending on r^-13) is much higher than the attractive force component (depending on r^-7) – see (6).

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5.5 Long–Range Force – Inverse Square Law

Note that only the inverse square term T_{macro} depends on ($P_{\mathrm{a}} - P_{\mathrm{r}}$), which can explain why the force (and gravity) is so comparatively weak. Recall that the basis for ($P_{\mathrm{a}} - P_{\mathrm{r}}$) > 0 was the asymmetrical behaviour of interatomic bonding as derived using the L-J potential function in S-4. In S-7 below we shall determine the value of ($P_{\mathrm{a}} - P_{\mathrm{r}}$) from experiment.

At larger distances where $r >> d$, the term T_{micro} diminishes such that $T_{\mathrm{micro}}/T_{\mathrm{macro}} << 1$ (35), in which case one can re-write (30,31) as:

$$\mathbf{F}_{\mathrm{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\mathrm{v}}\, T_{\mathrm{macro}}\ \hat{\mathbf{r}} \tag{41}$$

The force (41) is an inverse square law force, which can be applied to the force of gravity if one can derive object charge from its mass as will be explained in more details in S-6. Note that although the "local" *ecc*-values may be large (see 40) due to the proximity of local adjacent atoms in each object, these are by and large random and uncorrelated in relation to that of the other object. The effect of un-correlated random *ecc*-values should statistically average to zero. However, it is expected that there should be a small inter-object correlated *ecc*-component that is superposed on the local *ecc*, which can contribute to the T_{micro} term (33) depending on r.

6. Electric Force between Two Objects

6.1 Force from Object Charge

For objects made up of large number of neutral atoms or molecules, 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:

$$Q \ = \ Q_{\mathrm{sh1}} + Q_{\mathrm{sh2}} + Q_{\mathrm{sh3}} \cdots + Q_{\mathrm{sh}n} \ = \ \sum_{i=1}^{n} Q_{\mathrm{sh}i} \tag{42}$$

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 $\mathbf{F}_{\mathrm{net}}$ between the two objects can be determined by replacing charges q_1, q_2 in (31) with object charge Q_1, Q_2, respectively, as follows:

$$\mathbf{F}_{\mathrm{net}} = -\frac{Q_1 Q_2}{2\pi\varepsilon_0 r^2} T_{\mathrm{v}} \left(T_{\mathrm{macro}} + T_{\mathrm{micro}} \right) \hat{\mathbf{r}} \tag{43}$$

Since T_{v}, T_{macro} and T_{micro} are all dimensionless, the unit of force in (43) is Newton as in Coulomb's Law.

6.2 Charge–Mass Relation

In general, charges Q_1, Q_2 in equation (43) cannot be easily determined, particularly when each of objects 1, 2 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.

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:

$$q = A_\mathrm{q}\, e \tag{44}$$

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

$$A_\mathrm{q} = \frac{2}{3}\left(A + Z\right) \tag{45}$$

For example, the charge in a Carbon atom with Z=6 and A=12 can be calculated from (45) as:

$$q_{\mathrm{Carbon12}} = \frac{2}{3}\left(A + Z\right) e = \frac{2}{3}\left(12 + 6\right) e = 12e \tag{46}$$

In order to determine the number of atoms N in mass m, one should recall that what matters here 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. From the GE-Link perspective, 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 electrical perspective (see SS-6.3), 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:

$$N = N_\mathrm{A}\,\frac{m}{A_\mathrm{q}} \tag{47}$$

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 $N = m/(\mathrm{u}A_\mathrm{q})$. The charge Q contained in mass m can now be determined from equations (44,47), as:

$$Q = q\,N = A_\mathrm{q}\, e\, N_\mathrm{A}\,\frac{m}{A_\mathrm{q}} = e\, N_\mathrm{A}\, m \tag{48}$$

Note that the atomic charge factor A_q appears in both numerator and denominator of (48) and so cancels out, which simplifies charge calculation directly from mass irrespective of object composition. It is clear from (48) 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 (48) 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 $F = eN_\mathrm{A} = e/\mathrm{u}$ = 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 (48) as:

$$Q_{\mathrm{sh}} = e\, N_\mathrm{A}\, m_{\mathrm{sh}} \tag{49}$$

For a spherically symmetric object comprising a number of uniform concentric shells n of masses m_{sh1}, m_{sh2}, m_{sh3}....$m_{\text{sh}n}$, one can apply the principle of superposition and substitute (49) in (42) to determine total object charge Q from object mass m, as follows:

$$Q = \sum_{i=1}^{n} Q_{\text{sh}i} = e\,N_{\text{A}}\left(m_{\text{sh1}} + m_{\text{sh2}} + m_{\text{sh3}} \cdots + m_{\text{sh}n}\right) = e\,N_{\text{A}} \sum_{i=1}^{n} m_{\text{sh}i} = e\,N_{\text{A}} m \tag{50}$$

In a sense equation (50) combines the shell theorems of Gauss [16] and Newton [17] together. The total effective 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 (50) as follows:

$$Q_1 = e\,N_{\text{A}}\,m_1 \qquad\qquad Q_2 = e\,N_{\text{A}}\,m_2 \tag{51}$$

6.3 Electric Force from Object Mass

We can now express the force in terms of mass by substituting Q_1 & Q_2 from equations (51) in equation (43) to obtain the total net force between the objects, as follows:

$$\mathbf{F}_{\text{net}} = -\frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0}\,\frac{m_1 m_2}{r^2}\,T_{\text{v}}\left(T_{\text{macro}} + T_{\text{micro}}\right)\hat{\mathbf{r}} \tag{52}$$

The force (52) may be rewritten in an alternative way, as follows:

$$\mathbf{F}_{\text{net}} = -\frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0}\,T_{\text{macro}}\,\frac{m_1 m_2}{r^2}\,T_{\text{v}}\left(1 + \frac{T_{\text{micro}}}{T_{\text{macro}}}\right)\hat{\mathbf{r}} \tag{53}$$

Equation (53) 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. Thus (53) provides a credible scientific link between gravity and electricity – the GE-Link. Note that the forces we dealt with so far are; a) all Electric (EM), b) all Quantum because EM/QED is a quantum phenomenon and c) Intermolecular forces which are also Quantum Electric phenomena. Based on that, one may appropriately refer to the force in (53) as that due to Quantum Electric Gravity "QEG", and rename the force to $\mathbf{F}_{\text{QEG}}$ as follows:

$$\boxed{\mathbf{F}_{\text{QEG}} = -G\,\frac{m_1 m_2}{r^2}\,T_{\text{v}}\left(1 + \frac{T_{\text{micro}}}{T_{\text{macro}}}\right)\hat{\mathbf{r}}} \tag{54}$$

where G represents the true and actual gravitational constant, expressed as:

$$G = \frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0}\,T_{\text{macro}} = \frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0}\left(P_{\text{a}} - P_{\text{r}}\right) = \frac{1}{2\pi\varepsilon_0}\left(\frac{e}{\text{u}}\right)^2\left(P_{\text{a}} - P_{\text{r}}\right) \tag{55}$$

One can observe from (54) that the force is proportional to $G\,m_1 m_2 / r^2$, T_{macro}, T_{micro} and T_{v}. The T_{v} term does not depend on r (SS-3.1). The T_{macro} term (32) is proportionate to a fixed/constant difference ($P_{\text{a}} - P_{\text{r}}$) and makes the force dependent on the inverse square of distance. The T_{micro} term (33) comprises an infinite number of terms, and depends on $1/r^{\text{n}}$ and also on quantum parameters P_{a} and P_{r}. Term T_{micro} 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 parameters T_{v}, T_{macro} and T_{micro} are all dimensionless, the units of force should be in Newton.

It is interesting to observe that equation (54) can combine the hitherto irreconcilable theories of Einstein's/Newton's and quantum mechanics. QEG achieves that despite the heretofore prevailing

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notion that Einstein's GR and Newton's gravity are both different and otherwise seemingly unrelated paradigms to the disciplines of QM/EM on which QEG is founded.

Although derived from pure EM/QED principles, which is a totally different paradigm to that of GR, equation (54) actually has a lot in common with Einstein's GR, in particular the following important terms over and above that of Newton's:

i) Velocity-dependent term - T_v

ii) Gravitational field intensity-dependent term **-** T_{micro}, which depends on shift or *ecc* and both are dependent in turn on electric field strength (**E)**

While GR added up similar parameters to Newton's in order to "patch" it up, in QEG these two parameters are intrinsically fundamental in EM and pop up naturally in the equations. Although we have derived the terms T_{macro}, T_{micro} and T_v 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.

6.4 Electric Force from Charge & Mass

Equations (43,51,54) 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:

$$\mathbf{F}_{QEG} = -\frac{G}{e\,N_A}\frac{Q_1\,m_2}{r^2}\,T_v\left(1+\frac{T_{micro}}{T_{macro}}\right)\hat{\mathbf{r}} \tag{56}$$

Equations (56) may be quite useful in determining $\mathbf{F}_{QEG}$ on any form of charge, potentially including a postulated effective charge or that of virtual particle pairs associated with EM radiation. In equation (56) one can also express the acceleration of gravity $\mathbf{g}$ in terms of charge by letting $\mathbf{g} = \mathbf{F}_{QEG} / m_2$.

7. Experimental Determination of *G* and T_{macro}

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 changes 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. The apparatus in Henry Cavendish's or like experiments actually measures the true force $\mathbf{F}_{Cav}$ between objects from which the value of *G* was subsequently calculated from the Newton's to be $G = 6.67259 \times 10^{-11}$. However, we can derive a more accurate formula for *G* from (54) by equating $\mathbf{F}_{QEG}$ to $\mathbf{F}_{Cav}$ as follows:

$$\mathbf{F}_{QEG} = \mathbf{F}_{Cav} = -G\frac{m_1\,m_2}{r^2}\,T_v\left(1+\frac{T_{micro}}{T_{macro}}\right) \tag{57}$$

From which one can determine the true value of *G* according to QEG as follows:

$$G = \frac{r^2}{m_1\,m_2}\,\mathbf{F}_{Cav}\,\frac{1}{T_v\left(1+\frac{T_{micro}}{T_{macro}}\right)} \tag{58}$$

One can now determined *G* by substituting known data from Cavendish experiment; m_1, m_2, *r* and $\mathbf{F}_{Cav}$ in (58) and also letting $T_v = 1$ (**v**=0) to obtain the true and actual value of *G* as follows:

$$G = 6.67259 \times 10^{-11} \left(1 + \frac{T_{\text{micro}}}{T_{\text{macro}}} \right)^{-1} \tag{59}$$

Remember that in Cavendish's and like experiments distance r is made necessarily small (0.11 m) in order to maximise sensitivity, but this may not necessarily justify ($T_{\text{micro}}/T_{\text{macro}}$) << 1 in (54,59). This is because the smaller the distance the higher the value of T_{micro} and the less true is ($T_{\text{micro}}/T_{\text{macro}}$) << 1.Without knowing the true value of T_{micro} in the experiment some possible inaccuracy in the value of G may arise, which may have some important astronomical implications. According to the force equation (54), the value of G calculated from Cavendish experiment (G_{Cav}) is an "approximation" valid only if one assumes T_{micro}= 0 and T_{v} = 1 (**v**=0). This may help explain why G is one on the least accurately-determined constant of nature.

Unless ($T_{\text{micro}}/T_{\text{macro}}$) << 1 holds true in Cavendish experiment, one may need to multiply the standard gravitational constant by the correction factor shown in (59) for a revised more accurate value. This is not a trivial point because the value of G as determined from Cavendish experiment was then used "as is" to calculate the masses of all astronomical objects like Earth, Moon, Sun, Galaxies and all others. One may have to revise the masses of all these objects downward and in line with (59) if T_{micro} is found not to be negligibly small in the experiment.

Using (55,59) one can determine T_{macro} as follows:

$$\begin{gathered} T_{\text{macro}} = \left(P_{\text{a}} - P_{\text{r}} \right) = G\, \frac{2\pi\varepsilon_0}{e^2 N_{\text{A}}^2} \\ T_{\text{macro}} = 3.9875 \times 10^{-37} \approx 4 \times 10^{-37} \quad \rightarrow \quad \left(if\; T_{\text{micro}} / T_{\text{macro}} << 1 \right) \end{gathered} \tag{60}$$

We saw in S-4 that multipliers P_{a} and P_{r} may be viewed as the probability amplitudes of QED interactions for the attractive and repulsive forces, respectively, occurring at the AFB where AEX takes place. Multipliers P_{a} and P_{r} may each be viewed as the interaction with a single QED virtual particle or virtual particle's "quanta", each of which is expected to have a fixed/constant contribution or effect. This goes a long way to explain how and why the value of T_{macro} and G should largely remain constant.

8. Discussion

1) The force equations (31,54) are quite versatile in that they are applicable to a wide range of r-values, from intermolecular to astronomical distances. At large distances where $r >> d$ equation (54) can account for gravity at the macro-scale. At small distances where $r \sim d$ equations (30,31) can account for intermolecular forces at the micro-scale. In between these scales at $d < r <$ *infinity* each term contributes to the total force by varying amounts depending on distance.

2) The neutrons are already included in the QEG force equation as charge constituent of mass – see SS-6.2. 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 [18,19]. 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 neutral charge-dual entities capable of interacting with other neutrons (or other charges) in a manner similar to neutral atoms (Appendix-B). Accordingly, it is expected that the neutron-neutron interactions may exhibit an auto-balanced equilibrium condition like molecules albeit at much smaller scale.

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 neutral charge-dual particles. In one experiment [20] 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 [20]. The latter may be considered as experimental evidence in support of the GE-Link and QEG, which are based entirely on EM/QED.

4) Perihelion Advance of Mercury. Inner planets experience slightly larger forces than do outer planets, such as in the case of the perihelion advance of Mercury. The GE-Link and QEG provide two main reasons to explain that:

a) At reduced Planet-Sun distances the contribution of the T_{micro} term to the force equation (54) should increase accordingly. When taken into account, this should increase the force of gravity over and above that of inverse square law. Note that the force modification arising from T_{micro} could potentially explain some of the other phenomena associated with Einstein's General Theory of Relativity, the so called Post-Newtonian Corrections.

b) Inner planets travel at higher velocities than do outer planets, which alter T_{vt} in (4) and increase the force. 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_{v}. For other objects such as fast rotating stars, neutron stars, quasars and magnetars, one may follow the same methodology above to derive appropriate T_{v} formula, taking into account the different velocities of the various parts within each object.

5) 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 [21].

We saw in S-4 that EM and gravitational energies are conservative. That means that a change in energy of one component will cause the remaining ones to change in the opposite direction. Thus using energy conservation one can interpret the phenomenon of gravitational red/blue shifts. When light moves into a region of lower gravitational field its potential energy increases and, from (7-9), its internal energy should decrease by increasing its wavelength and decreasing its frequency, i.e. red-shifted. The reverse is true resulting in blue-shift when moving into a region of higher gravitational field.

6) Universe Expansion - Radial Velocity

For objects moving at radial velocities (along r) such as in the example shown in Figure 4, a source charge q_1 is moving along r at velocity v_1 relative to a stationary test charge q_2. One can derive the appropriate radial velocity term T_{vr} using Lorentz Transformations. The term T_{vr} can be written as [5]:

$$T_{vr} = \frac{1}{\gamma^2} = \left(1 - \frac{\mathbf{v}_1^2}{c^2}\right) \tag{61}$$

By substituting (61) in (54) and letting $T_v = T_{vr}$ one can write the force as follows:

$$\mathbf{F}_{QEG} = -G\,\frac{m_1\,m_2}{r^2}\left(1 - \frac{\mathbf{v}_1^2}{c^2}\right)\left(1 + \frac{T_{micro}}{T_{macro}}\right)\hat{\mathbf{r}} \tag{62}$$

This indicates that gravity in QEG can be influenced by object's radial velocity in an interesting way, namely that the force decreases as v_1 increases and continues to decrease all the way down to zero (no gravity?) at $v_1 = c$. If $v_1 > c$, the first bracketed term in (62) becomes negative which makes the electric force changes sign and becomes "repulsive". This appears to imply that gravity too can become repulsive, but $v_1 > c$ is not allowed in Special Relativity. The force in (62) is in good agreement with observations confirming the expansion of the universe and that the strength of gravity appears to decrease with recession velocity. With this understanding (62), it appears that the need to postulate the existence of Dark Energy may not arise, which is expected to have potential implications for the expansion, dynamics and evolution of the universe.

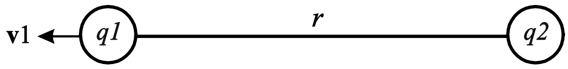

Figure 4 - EM Forces between two Charges – Radial Velocity

7) The force in QEG may possibly have another quite interesting behaviour, namely that of temperature sensitivity and effect. The temperature may alter the "bias" or operating point (p_0, p_1, p_2 .....) on the curve shown in Figure 1, which effect may produce some nonlinear behaviour that can impact energy trade-off of the system.

8) It is interesting to observe that the "*asymmetrical*" behaviour (AEX) of the vdW/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 (vdW), 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 (via AEX) in order to extract some unidirectional (likened to rectified direct current DC) energy and force, again, in a manner reminiscent of electrical circuits.

9) We can use Figure 1 to visualize what happens during object's free fall in gravitational field. The gravitational field will produce tidal forces trying to extend the object by moving the auto-balanced equilibrium point from p_0 to p_1 and d_0 to d_1, and increase U_t. Energy conservation (7-9) will cause U_r to decrease and at the same time shorten distance r from r_0 to r_1. The object is now effectively moved slightly closer to a higher gravitational field. The process will now repeat itself leading to progressively shorter and shorter r values until the two objects come into contact. This is not surprising at all since the lowest energy between atoms and molecules is that attained by van der Waals' intermolecular bonds (close to U_0). Thus the free fall is driven by a positive feedback chain-reaction that thrives to bring the system into the lowest energy state possible (vdW minimum). Here is a summary of the free fall sequences, moving from left to right:

$$\begin{aligned} &r_0 \;>\; r_1 \;>\; r_2 \cdots\cdots \;>\; r_n \\ &d_0 \;<\; d_1 \;<\; d_2 \cdots\cdots \;<\; d_n \\ &p_0 \rightarrow p_1 \rightarrow p_2 \cdots\cdots \rightarrow p_n \end{aligned} \tag{63}$$

10) From the QEG equations presented in this paper, one would expect the QEG force to be valid as

long as the structure of neutral 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. The analysis and investigation of the Tripole Atomic Model (S-5) appears to suggest that, providing the structure and form of these 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 neutral 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 structure of these 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

This paper demonstrated the existence of an indelible scientific link (GE-Link) between gravity and electromagnetism. The GE-Link is real because it is based on some of the most fundamental pillars of physics, namely EM/QED, from which it was possible to derive a clear residual electric force synonymous with and indistinguishable from the force of gravity. The force equation supports Einstein's General Relativity and, in the limit, Newton's Law of Gravitation. This compels one to suggest a new electric theory of gravity referred to as Quantum Electric Gravity (QEG). QEG shows that in addition to Newton's, the force has a velocity-dependent term and a term proportional to gravitational field-strength or intensity, both of these "electrical" terms support similar ones in Einstein's General Relativity. Among the surprise findings is that *radial* (not orbital) object velocity actually decreases the force of gravity due to EM/Special Relativity considerations. This feature is expected to have some potential implications for the expansion and dynamics of the universe. By combining the hitherto irreconcilable theories of Newton's/Einstein's and quantum mechanics, it is expected that the new understandings brought about by the GE-Link and 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 this 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 the GE-Link 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 [22].

Appendix–B: Atoms as Neutral Charge-Dual Entities

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

- 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 charge or charge-dual entities.
- The absolute magnitudes of positive and negative charge are identical.
- The opposite direction fields and forces above will almost completely cancel each other out and, on average, portray atoms as electrically neutral.
- They also include neutrons, which do have internal charge structure capable of interacting with fields and forces.
- They are the fabric of the universe.

Appendix–C - Binomial Expansions – (Multipole Expansion)

$$\frac{1}{(1\mp x)^2}=(1\mp x)^{-2}=1\pm 2\frac{x}{r}+3\left(\frac{x}{r}\right)^2\cdots \qquad |x|<1$$

A) Repulsive Components (23)

$$T_{\text{rep1}}=\frac{1}{r^2}$$

$$T_{\text{rep2}}=\frac{x_{1\text{a}}x_{2\text{a}}}{r^2}\left(1+\frac{a_1-a_2}{r}\right)^{-2}=\frac{x_{1\text{a}}x_{2\text{a}}}{r^2}\left(1-2\frac{a_1}{r}+2\frac{a_2}{r}+3\frac{a_1^2}{r^2}+3\frac{a_2^2}{r^2}-6\frac{a_1a_2}{r^2}\cdots\right)$$

$$T_{\text{rep3}}=\frac{x_{1\text{a}}x_{2\text{b}}}{r^2}\left(1+\frac{a_1+b_2}{r}\right)^{-2}=\frac{x_{1\text{a}}x_{2\text{b}}}{r^2}\left(1-2\frac{a_1}{r}-2\frac{b_2}{r}+3\frac{a_1^2}{r^2}+3\frac{b_2^2}{r^2}+6\frac{a_1b_2}{r^2}\cdots\right)$$

$$T_{\text{rep4}}=\frac{x_{1\text{b}}x_{2\text{a}}}{r^2}\left(1-\frac{b_1+a_2}{r}\right)^{-2}=\frac{x_{1\text{b}}x_{2\text{a}}}{r^2}\left(1+2\frac{b_1}{r}+2\frac{a_2}{r}+3\frac{b_1^2}{r^2}+3\frac{a_2^2}{r^2}+6\frac{b_1a_2}{r^2}\cdots\right)$$

$$T_{\text{rep5}}=\frac{x_{1\text{b}}x_{2\text{b}}}{r^2}\left(1-\frac{b_1-b_2}{r}\right)^{-2}=\frac{x_{1\text{b}}x_{2\text{b}}}{r^2}\left(1+2\frac{b_1}{r}-2\frac{b_2}{r}+3\frac{b_1^2}{r^2}+3\frac{b_2^2}{r^2}-6\frac{b_1b_2}{r^2}\cdots\right)$$

Summing up similar power (n) repulsive r-terms and using $x_{1\text{a}}+x_{1\text{b}}=1$ and $x_{2\text{a}}+x_{2\text{b}}=1$ (21-22) yield:

$$T_{\text{rep-r2}}=\frac{1}{r^2}\left(1+x_{1\text{a}}x_{2\text{a}}+x_{1\text{a}}x_{2\text{b}}+x_{1\text{b}}x_{2\text{a}}+x_{1\text{b}}x_{2\text{b}}\right)=\frac{2}{r^2}$$

$$T_{\text{rep-r3}}=\frac{2}{r^3}\left[x_{1\text{a}}x_{2\text{a}}\left(-a_1+a_2\right)+x_{1\text{a}}x_{2\text{b}}\left(-a_1-b_2\right)+x_{1\text{b}}x_{2\text{a}}\left(+b_1+a_2\right)+x_{1\text{b}}x_{2\text{b}}\left(+b_1-b_2\right)\right]$$

$$= \frac{2}{r^3}\left[-a_1\left(x_{1a}x_{2a} + x_{1a}x_{2b}\right) + a_2\left(x_{1a}x_{2a} + x_{1b}x_{2a}\right) + b_1\left(x_{1b}x_{2a} + x_{1b}x_{2b}\right) - b_2\left(x_{1a}x_{2b} + x_{1b}x_{2b}\right)\right]$$

$$= \frac{2}{r^3}\left(-a_1x_{1a} + a_2x_{2a} + b_1x_{1b} - b_2x_{2b}\right) = \frac{2}{r^3}Y_{r3}$$

$$T_{\text{rep-r4}} = \frac{3}{r^4}(\cdots\cdots) = \frac{3}{r^4}Y_{r4}$$

$$\boxed{T_{\text{Trep}} = +\left(T_{\text{rep-r2}} + T_{\text{rep-r3}} + T_{\text{rep-r4}} + \cdots\right) = 2\left(\frac{1}{r^2} + \frac{Y_{r3}}{r^3} + \frac{3}{2}\frac{Y_{r4}}{r^4} + \cdots\right)}$$

B) Attractive Components (24)

$$T_{\text{att1}} = \frac{x_{2a}}{r^2}\left(1 - \frac{a_2}{r}\right)^{-2} = \frac{x_{2a}}{r^2}\left(1 + 2\frac{a_2}{r} + 3\frac{a_2^2}{r^2}\cdots\right)$$

$$T_{\text{att2}} = \frac{x_{2b}}{r^2}\left(1 + \frac{b_2}{r}\right)^{-2} = \frac{x_{2b}}{r^2}\left(1 - 2\frac{b_2}{r} + 3\frac{b_2^2}{r^2}\cdots\right)$$

$$T_{\text{att3}} = \frac{x_{1a}}{r^2}\left(1 + \frac{a_1}{r}\right)^{-2} = \frac{x_{1a}}{r^2}\left(1 - 2\frac{a_1}{r} + 3\frac{a_1^2}{r^2}\cdots\right)$$

$$T_{\text{att4}} = \frac{x_{1b}}{r^2}\left(1 - \frac{b_1}{r}\right)^{-2} = \frac{x_{1b}}{r^2}\left(1 + 2\frac{b_1}{r} + 3\frac{b_1^2}{r^2}\cdots\right)$$

Summing up similar power (n) attractive r-terms and using $x_{1a} + x_{1b} = 1$ and $x_{2a} + x_{2b} = 1$ (21-22) yield:

$$T_{\text{att-r2}} = \frac{1}{r^2}\left(x_{2a} + x_{2b} + x_{1a} + x_{1b}\right) = \frac{2}{r^2}$$

$$T_{\text{att-r3}} = \frac{2}{r^3}\left(x_{2a}a_2 - x_{2b}b_2 - x_{1a}a_1 + x_{1b}b_1\right) = \frac{2}{r^3}Y_{a3}$$

$$T_{\text{att-r4}} = \frac{3}{r^4}Y_{a4}$$

$$\boxed{T_{\text{Tatt}} = \left(T_{\text{att-r2}} + T_{\text{att-r3}} + T_{\text{att-r4}} + \cdots\cdots\right) = 2\left(\frac{1}{r^2} + \frac{Y_{a3}}{r^3} + \frac{3}{2}\frac{Y_{a4}}{r^4} + \cdots\right)}$$

Appendix–D: Atomic Charge Factor A_q – Neutral Atoms

$$\text{Electrons} \quad \to Z$$

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

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

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

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

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