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# AN ENGINEERING MODEL OF QUANTUM GRAVITY

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**Abstract**
It is proposed that gravitational fields may be interpreted as a variation in the relative available driving power (Watts) of the Electromagnetic, Zero-Point Field (ZPF). It is shown that variations in the relative available power are covariant with variations in the coordinate speed of light as measured by a distant observer in unaltered space-time. Gravitational time dilation and length contraction may then be interpreted as a loss of driving power from the ZPF. It is hypothesized that the loss of power is due to increased radiative damping of matter, resulting from an increase in the local relative energy density which promotes this process. The relative radiative damping factor affects the relative ground state energy of the quantum mechanical harmonic oscillator such that, the mean-square fluctuations in matter reproduce the behavior attributed to, and resulting from variations in the space-time metric of General Relativity (GR). From this principle, all of the variations observed by a distant observer that occur due to gravity, or space-time curvature under GR may be reproduced from the variable relative damping function acting on the harmonic oscillator. What is presented herein, is an engineering model for quantum gravity that puts gravity in the hands of engineers, who will understand this process and will potentially advance artificial gravity and anti-gravity technology from pure speculation, to achievable endeavors in our lifetime.

**Keywords:** Polarizable vacuum, electromagnetic zero-point field, quantum gravity, quantum physics, general relativity.

**Nomenclature**

| | | |
|---|---|---|
| $g_{\mu\nu}$ | = | metric tensor where, $\mu$ and $\nu$ are indices in this context |
| $\chi$ | = | the relative dielectric susceptibility, to be used as the engineering control parameter |
| $K=\sqrt{g_{11}/-g_{00}}$<br>$K=1+\chi$ | = | the relative refractive index of the vacuum as measured from a distant reference frame |
| $c_0$ | = | the speed of light in vacuum as measured in a local, inertial reference frame (m/s) |
| $c_K=c_0/K$ | = | the relative coordinate speed of light, as measured from a distant reference frame (m/s) |
| $\Delta x_0$ | = | an interval along the x axis as measured in a local, inertial reference frame (m) |
| $\Delta x=\Delta x_0/\left\|\sqrt{K}\right\|$ | = | an interval along the x axis as measured from a distant reference frame (m) |
| $\Delta t_0$ | = | an interval of time as measured in a local, inertial reference frame (s) |
| $\Delta t=\Delta t_0\left\|\sqrt{K}\right\|$ | = | an interval of time as measured from a distant reference frame (s) |
| $q^2$ | = | squared magnitude of the electrical charge quantum e (C) |
| $\hbar$ | = | the reduced Planck's constant, $h/2\pi$ (J-s/rad) |
| $\varepsilon_0$ | = | the dielectric permittivity of vacuum as measured in a local, inertial reference frame (F/m) |
| $\mu_0$ | = | the dielectric permeability of vacuum as measured in a local, inertial reference frame (H/m) |
| $G$ | = | the gravitational constant (N-m$^2$/kg$^2$) |

## 1. INTRODUCTION

Practically speaking, time is what is measured with a clock and space is what is measured with a ruler. Each is a device used to compare with other identical devices at different sets of coordinates. The distant observer uses his own devices to establish a coordinate system with which to compare his observations to identical devices at distant coordinates. He chooses for example, to observe the light emitted by distant supernova and then compare them to the light of other similar events. From this data the distance to these events, and their motion relative to the observer is determined. [1]

Of course there are other ways to achieve this. This was just one example to illustrate the point, that measurements are made using physical tools of our choosing which are composed of some form of matter, and all matter must react to the physical effects of gravity in the same way. There are no absolute rulers or absolute clocks that are impervious to the physical effects of gravity.

In the reference frame of the distant observer, *space* and *time* appear to be variables, or *curved* when the local devices and the remote devices disagree. It is interpreted such that the remote devices are variables which undergo gravitational length contraction and time dilation in the presence of gravitational fields. This is not an illusion. Time dilation and length contraction are real, physical effects whose action can be described using elementary quantum mechanics, *and* the correct procedure to do so, which shall be shown here.

The Engineering Model of Quantum Gravity presented here-in uses the reference frame of the distant observer because it allows all observations to be consistently scaled without the need of complicated tensor coordinate transformations when working with gravitational fields. In this presentation, gravity is treated as a scalar field. However, due to the quantum mechanical basis of the model itself, the quantum to classical correspondence principle will apply. Whereby, individual quantum oscillators behave in such a way that, in large numbers their averages should reproduce the behavior of classical test particles in a curved space-time.

That being said, it is necessary to drop any notion of doing quantum field theory on a curved space-time manifold. In this model, space-time is considered to be perfectly flat. As such, the typical equations of QED in flat space-time will be applied. (See Milonni for example.) [2]

Engineers are smart people, but aside from the calibration of the Global Positioning Satellite network, we really don't know what to do with space-time curvature as a means to manipulate gravity. The *Gravitic Caliper* is not a tool in our toolbox. Likewise, referring to gravitational fields as a variable refractive index, as is done in the Polarizable Vacuum (PV) Model of GR [3, 4, 5] adds some pedagogical value to gravitational fields, but does not address the pressing issue of; *"What to do to create or mimic gravity?"* What engineers require is a more practical set of tools to work with when dealing with the effects of gravitational fields, so that they can acquire a deeper understanding of the "Nuts and Bolts" regarding, how gravity and matter interact.

Space-time curvature is a useful, mathematical description of the available data regarding gravity, but it is not the only useful interpretation of the data. The interpretation presented herein, describes gravitational time dilation and length contraction in the proximity of increased mass-energy densities, as a physical effect acting on clocks and rulers at the quantum scale. This physical effect begins with a typical harmonic oscillator. Something most engineers should be familiar with. For the practical purposes of discussion, matter may be usefully approximated as being comprised of such oscillators. [2]

If there is dissipation occurring within the oscillator, eventually the oscillation will decay to its lowest energy state. In a passive electronic oscillator circuit for example, there may be a sinusoidal power supply (a.c. source) driving a resonant $LC$ circuit. [6] In the circuit there may be a resistance, $R$ which dissipates power and damps the oscillation. Eventually, the source of power and the dissipation reach an equilibrium condition.

In the case of matter, when it decays to its lowest energy state, it is in the ground-state where, the minimum energy is not zero. [2, 7] The minimum energy is the equilibrium between a constant, *uniform* ZPF which drives the oscillators, and a variable damping function which damps them. The damping function is dependent on the local mass-energy density, which increases the radiative damping, resulting in the observed behavior of oscillators in a gravitational field. Where, they have a lower ground state energy than they would in an unperturbed ZPF. In other words, the damping function lowers the relative ground state energy below that which the ZPF establishes as the natural ground state. In GR, this is interpreted as the gravitational field possessing *negative energy density*.

In section 2, the physical effects of gravitation are derived from the space-time metric of GR and associated with the variable refractive index of the PV Model for illustration. In section 3, the quantum vacuum processes that determine the ground state equilibrium condition between matter and vacuum are discussed, in addition to the co-variant relationship between relative power and the relative coordinate velocity of light.

In section 4, the *relative radiative damping factor* is derived and the connection to gravity is established. It is shown that the variable metric coefficients result from variations in the radiative damping factor that reduces the relative available power of the ZPF, making it vary in a way which may be interpreted as *curved space-time*. In section 5, the expected relationship is established between the relative damping factor and the *local energy density*, in accordance with GR.

## 2. THE PHYSICAL EFFECTS OF GRAVITATION

It has been shown that a gravitational field may be interpreted as a variable refractive index that alters space-time and determines the relative scale of rulers and clocks in the altered region, as measured by a distant observer in an unaltered region of space-time. [3, 4, 5] A brief introduction to the *physical effects* that engineers will encounter when working with modified space-time and matter, in the context of GR and the PV Model, will be presented in this section.

One obvious disadvantage of working with GR from the perspective of a local observer is that the speed of light remains constant in the local inertial reference frame. Observers in the local frame cannot measure light moving faster than $c_0$, the speed of light in vacuum. Nor can they measure light moving slower than $c_0$, in the local vacuum using rulers and clocks immersed in the same local vacuum. Therefore, it is advantageous for engineers to understand what to expect, what to look for and why there is a need to make observations from the perspective of a distant observer in an unaltered reference frame, outside of the effects to be measured.

In GR, the four-dimensional line element is given by the expression,

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu \tag{1}$$

where summation is assumed for repeated indices. In a flat space-time, the line element reduces to the more familiar expression,

$$ds^2 = -c_0^2 dt^2 + dx^2 + dy^2 + dz^2 \tag{2}$$

The reader does not need to be well versed in GR to follow most of what is presented here. Think of this as calculating the length of the hypotenuse of a right-triangle in two dimensions.

In two dimensions, $ds^2 = -c_0^2 dt^2 + dx^2$. The metric coefficients from equation (1) are, $g_{00} = -1$, $g_{11} = 1$, and $g_{\mu\nu} = 0$ for $\mu \neq \nu$. Where, $dx^0 = dt$ and, $dx^1 = dx$ in Cartesian coordinates.

For any light ray, $ds^2 = 0$ and may be solved to discover $c_0^2 = c_K^2$. Where, $c_K = \frac{dx}{dt}$ is the relative *coordinate velocity* of light. The refractive index of this metric is then simply defined by, $K \equiv |c_0 / c_K|$.

Similarly, Eq. (2) may be written in terms of variable metric coefficients $g_{00}$ and $g_{11}$, in a curved space-time. In two dimensions for simplicity, the resulting line element becomes,

$$ds^2 = g_{00} c_0^2 dt^2 + g_{11} dx^2 \tag{3}$$

The refractive index can now be read off as,

$$K = \left|\sqrt{g_{11} / -g_{00}}\right| \tag{4}$$

The refractive index is accompanied by physical effects in the gravitationally altered region of space-time. The metric coefficients alter the scale of rulers and clocks in their region of influence, as compared to those of the observer in a distant unaltered region. For example; when $\left|\sqrt{-g_{00}}\right| < 1$ and $\left|\sqrt{g_{11}}\right| > 1$, then $\left|\sqrt{-g_{00}}\right| dt < dt$ and, $\left|\sqrt{g_{11}}\right| dx > dx$. Clocks in the altered region, as well as atomic oscillations there, appear to have slowed down; $\Delta t = \Delta t_0 / \left|\sqrt{-g_{00}}\right|$ and rulers in the altered region, as well as atomic spacing, appear to have contracted; $\Delta x = \Delta x_0 / \left|\sqrt{g_{11}}\right|$, as compared to those rulers and clocks used by the distant observer. [3] This is simply gravitational time dilation and length contraction as described in GR.

In the special case where $-1 / g_{00} = g_{11} = K$, the physical effects of altering the refractive index can be simplified and tabulated for engineering purposes in terms of $K$, as shown in TABLE 1.

Power is measured in Watts. It is the change in energy per unit of time. Power, $P_K$ varies inversely with the refractive index and is therefore covariant with the relative coordinate velocity of light, $c_K$. Referring to TABLE 1, it can be shown that,

$$\begin{aligned} P_K &= \Delta E / \Delta t = P_0 / K \\ c_K &= c_0 / K \end{aligned} \tag{5}$$

Why this is true will become evident in section 4 where the effect on power will be derived from first principles.

From the perspective of the distant observer in an unaltered region of space-time. It is observed that in an altered region of space-time near a massive star for example. C locks are running slower, rulers are contracted and the speed of light has become slower. The conclusion drawn would be that, matter in the region is running low on power. There is not enough power to *inflate* matter to its "proper" size, as was presented in [8].

Alternatively, from the same perspective, in a region of space-time where matter is moving faster than light (FTL). Matter is *inflated*, clocks are running faster, rulers are expanded and the speed of light has increased. The conclusion would then be drawn that the *scale* of matter and the speed of light, is regulated by the relative power of the ZPF available to do work to drive these physical processes, as will be shown in the following sections.

**TABLE 1**: *Physical effects of space-time acting on matter in a gravitationally altered region, as measured by a distant observer in an unaltered region of space-time.*

| **Variable Refractive Index** $K = \left|\sqrt{g_{11} / -g_{00}}\right|$ | **Gravity of a Massive Star** $K > 1$ | **Anti-Gravity or FTL Effects** $K < 1$ |
|---|---|---|
| $c_K = c_0 / K$ | speed of light is slowed | speed of light is faster |
| $\Delta x = \Delta x_0 / \left|\sqrt{K}\right|$ | rulers contract | rulers expand |
| $\Delta t = \Delta t_0 \left|\sqrt{K}\right|$ | clocks run slower | clocks run faster |
| $v = \Delta x / \Delta t = v_0 / K$ | velocity is slower | velocity is faster |
| $a = a_0 / \left|K^{3/2}\right|$ | acceleration is decreased | acceleration is increased |
| $m = F / a = m_0 \left|K^{3/2}\right|$ | force is invariant mass is increased | force is invariant mass is decreased |
| $\omega = 2\pi / \Delta t = \omega_0 / \left|\sqrt{K}\right|$ | frequency is decreased | frequency is increased |
| $\Delta E = \hbar\omega = \Delta E_0 / \left|\sqrt{K}\right|$ | ground state energy decreases | ground state energy increases |

## 3. ZERO-POINT EQUILIBRIUM IN A GRAVITATIONAL FIELD

Although a charged particle is constantly undergoing accelerated motion due to interactions with the electromagnetic ZPF, it does not appear to radiate. [2, 7] The reason for this apparent lack of radiation is that the ground state of the particle is at steady-state equilibrium with the electromagnetic ZPF of the quantum vacuum.

In section 3.3 of *The Quantum Vacuum*, Milonni [2] writes,

*"The fact that an accelerating charge loses energy by radiating implies, according to classical ideas, that an electron should spiral into the nucleus and that atoms should not be stable. The balancing of the effects of radiation reaction and the vacuum field..., however, suggest that the stability of atoms might be attributable to the influence on the atom of the vacuum field.... We now know that the vacuum field is in fact formally necessary for the stability of atoms in quantum theory. As we saw..., radiation reaction will cause canonical commutators* $[x, p_x]$ *to decay to zero unless the fluctuating vacuum field is included, in which case commutators are consistently preserved."*

In an inertial reference frame where a charged particle is in bounded, steady-state motion, such as in a harmonic oscillator, an atom or matter in general. There is a non-zero ground state that is in equilibrium with the local ZPF. All fields, including the Dirac field (fermions) that makes up matter, and force carriers, (photons and gluons) have a ZPF where the ground state energy is, $E_{gs} = \hbar\omega / 2$, per frequency mode.

An intuitive way for engineers to look at this is that in the ground state, the mean power absorbed by the particle from the ZPF is equal in magnitude to the power radiated from the particle, due to acceleration.

$$\left\langle P_a^{rad} \right\rangle = \left\langle P_{zp}^{abs} \right\rangle \tag{6}$$

The works of Milonni [2, 9, 10] and also Puthoff [7] illustrate this clearly. Power absorbed from the ZPF by a charged particle in bounded, steady-state motion is given by,

$$\left\langle P_{zp}^{abs} \right\rangle = \frac{q^2 \hbar \omega_0^3}{12\pi\varepsilon_0 m_0 c_0^3} \tag{7}$$

Power radiated from an accelerated charge to the vacuum is given by,

$$\left\langle P_a^{rad} \right\rangle = \frac{q^2 \left\langle a^2 \right\rangle}{6\pi\varepsilon_0 c_0^3} \tag{8}$$

Where, $\left\langle a^2 \right\rangle$ is the mean-square acceleration fluctuation given in Eq. (16). It may be inferred that when the symmetry of this equilibrium state is broken, the system accelerates.

Puthoff uses the Stochastic Electrodynamics (SED) Fourier composition of the ZPF as the proposed driving function. [3] The electric field is given by,

$$\mathbf{E}_{ZP} = \mathrm{Re}\sum_{\sigma=1}^{2}\int d^3k\hat{\boldsymbol{\varepsilon}}\left(\hbar\omega / 8\pi^3\varepsilon_0\right)^{1/2} e^{i\mathbf{k}\cdot\mathbf{r}-i\omega t+i\theta(\mathbf{k},\sigma)} \tag{9}$$

The exponential term is the wave part of the equation. A similar equation can be expressed for the magnetic field by replacing $\mathbf{E}_{ZP}$ with $\mathbf{H}_{ZP}$, the unit vector $\hat{\boldsymbol{\varepsilon}}$ with $\left(\hat{\mathbf{k}}\times\hat{\boldsymbol{\varepsilon}}\right)$ and $\varepsilon_0$ with $\mu_0$. However, this example is sufficient to describe the concepts to be conveyed.

The indefinite integral over the field modes, $k$ in Eq. (9) may be *tuned* by utilizing matter in ways that alter the limits of the integration, as is done in the Casimir effect. [2, 11] These limits are referred to as the cut-off modes of the field. The frequency limits of the ZPF are formally infinite, but can be modified or limited by the presence of matter.

The electromagnetic ZPF is used to calculate the mean-square fluctuations in position, velocity and acceleration of a particle in bounded, steady-state motion. Utilizing the standard procedures from quantum mechanics, these fluctuations are determined by integrating over the modes and summing the various polarizations of $\mathbf{E}_{ZP}$. The derived equations of motion for a particle with charge to mass ratio, $q/m$ are as follows, [2, 7]

$$\begin{aligned}
x &= \frac{q}{m}\mathrm{Re}\sum_{\sigma=1}^{2}\int d^3k\left(\hat{\boldsymbol{\varepsilon}}\cdot\hat{\mathbf{x}}\right)\left(\frac{\hbar\omega}{8\pi^3\varepsilon_o}\right)^{1/2}\left(\frac{1}{D}\right)e^{i\mathbf{k}\cdot\mathbf{r}-i\omega t+i\theta(\mathbf{k},\sigma)},\\
v = \dot{x} &= \frac{q}{m}\mathrm{Re}\sum_{\sigma=1}^{2}\int d^3k\left(\hat{\boldsymbol{\varepsilon}}\cdot\hat{\mathbf{x}}\right)\left(\frac{\hbar\omega}{8\pi^3\varepsilon_o}\right)^{1/2}\left(-i\frac{\omega}{D}\right)e^{i\mathbf{k}\cdot\mathbf{r}-i\omega t+i\theta(\mathbf{k},\sigma)},\\
a = \ddot{x} &= \frac{q}{m}\mathrm{Re}\sum_{\sigma=1}^{2}\int d^3k\left(\hat{\boldsymbol{\varepsilon}}\cdot\hat{\mathbf{x}}\right)\left(\frac{\hbar\omega}{8\pi^3\varepsilon_o}\right)^{1/2}\left(-\frac{\omega^2}{D}\right)e^{i\mathbf{k}\cdot\mathbf{r}-i\omega t+i\theta(\mathbf{k},\sigma)},
\end{aligned} \tag{10}$$

where the denominator, $D$ expresses a resonance condition at the natural frequency, $\omega_0$.

$$D = -\omega^2 + \omega_0^2 - i\Gamma\omega^3 \tag{11}$$

The natural radiative damping function, $\Gamma$ is expressed as,

$$\Gamma = \frac{q^2}{6\pi\varepsilon_0 m c_0^3} = \left(\frac{2\alpha}{3}\right)\frac{\hbar}{mc_0^2} \tag{12}$$

Equations (8) and (12), come from the Larmor radiation power formula. [7, 12] For an electron in the reference frame local to the distant observer, $\Gamma = 6.336\times10^{-24}$ s. Which is small in comparison to the natural frequency of the electron, such that, $\Gamma\omega_0 = .005$. If the natural frequency is taken to be, $\omega_0 = \frac{mc^2}{\hbar}$. Then the natural damping function is just a proportionally scaled re-expression of the period of the natural frequency.

$$\Gamma_0 = \frac{2\alpha}{3\omega_0} \tag{13}$$

## 4. PARTICLE FLUCTUATIONS AND GRAVITY

From the equations of motion above, the mean-square fluctuations in the particle's motion are derived. For example, from equation (10), the mean-square position fluctuation is,

$$\left\langle x^2 \right\rangle = \frac{q^2\hbar}{6\pi^2\varepsilon_0 m^2 c^3}\int_0^\infty \frac{\omega^3 d\omega}{\left(\left(\omega_0^2-\omega^2\right)^2 + \Gamma^2\omega^6\right)} \tag{14}$$

The derived integrand is almost precisely a Lorentzian line-shape, because, $\Gamma_0\omega_0 \ll 1$ is small and the integrand in equation (14) is sharply peaked. Therefore, the standard resonance approximation for a harmonic oscillator may be used to high precision. Making the appropriate substitutions, simplifying and noting that the Lorentzian line-shape integral is unity, the resulting mean-square position fluctuation is,

$$\left\langle x^2 \right\rangle = \frac{\hbar}{2m\omega_0}\int_{-\infty}^{\infty}\frac{1}{\pi}\frac{\left(\Gamma\omega_0^2/2\right)}{\left(\omega_0-\omega\right)^2 + \left(\Gamma\omega_0^2/2\right)^2}d\omega = \frac{\hbar}{2m\omega_0} \tag{15}$$

An easy to follow derivation of the mean-square fluctuations is found in [7]. These results are the standard quantum mechanical values for the mean-square fluctuations in *position, velocity* and *acceleration*, that will be referred to in what follows.

$$\begin{aligned}
\left\langle x_0^2 \right\rangle &= \frac{\hbar}{2m\omega_0},\\
\left\langle v_0^2 \right\rangle &= \frac{\hbar\omega_0}{2m},\\
\left\langle a_0^2 \right\rangle &= \frac{\hbar\omega_0^3}{2m}
\end{aligned} \tag{16}$$

The mean-square fluctuations in Eq. (16), provide the coupling to the oscillator *and* the gravitational effects. The mean-square power fluctuation of the oscillator is given by,

$$\left\langle P_M^2 \right\rangle = m^2\left\langle a^2 \right\rangle\left\langle v^2 \right\rangle = \left(\hbar\omega^2/2\right)^2 \tag{17}$$

The smallness of $\Gamma_0\omega_0 \ll 1$ implies that the oscillator is extremely *underdamped*. [6] Meaning, once stimulated it will continue to oscillate for a long time. This fact greatly simplifies what follows.

In an underdamped oscillator, the *relative damping factor,* $\zeta$ may be defined in terms of the power lost from the mean power fluctuations at the natural frequency.

$$\frac{\hbar\omega_\zeta^2}{2} = \frac{\hbar\omega_0^2}{2} - \frac{\hbar(\omega_0 \cdot \zeta)^2}{2} \tag{18}$$

Where the power term on the left is the difference between the initial mean power of the oscillator and the power lost to the local environment. The value of $\zeta$ is a variable in the coordinate system of the distant observer. It may be thought of as a *deficit* in the equilibrium condition of equation (6). These are photons that were radiated and not reabsorbed, i.e., lost to the environment.

In agreement with the *underdamped* oscillator, a naturally variable frequency (energy) arises that is dependent on the relative damping factor. [6]

$$\omega_\zeta = \omega_0 \left|\sqrt{1-\zeta^2}\right| \tag{19}$$

Increased damping, such that $\zeta > 0$ will result in $\omega_\zeta < \omega_0$ and thereby, reduce the ground state energy of the oscillator below its natural value.

Similarly, substituting the new resonant frequency, $\omega_\zeta$ into equation (17) yields a reduced power fluctuation.

$$\begin{aligned} P_0 &= \frac{\hbar\omega_0^2}{2}, \\ P_\zeta &= P_0 \cdot \left(1-\zeta^2\right) \end{aligned} \tag{20}$$

The key new idea that permits this phenomenon to be interpreted as space-time curvature is as follows. Given equation (5) and the understanding that in the coordinates of the distant observer, the relative coordinate velocity of light varies with the relative available power. The coordinate velocity of light, $c_K$ may be expressed anew as,

$$c_\zeta = c_0 \cdot \left(1-\zeta^2\right) \tag{21}$$

From this, wavelength and mass may be determined from the dispersion relationship in the usual way,

$$\lambda = 2\pi \frac{c_\zeta}{\omega_\zeta} = 2\pi \frac{c_0}{\omega_0} \left|\sqrt{1-\zeta^2}\right| \tag{22}$$

$$m = \frac{\hbar\omega_\zeta}{c_\zeta^2} = \frac{\hbar\omega_0}{c_0^2} \frac{1}{\left|\left(1-\zeta^2\right)^{\frac{3}{2}}\right|} \tag{23}$$

In total, all of the references in TABLE 1 that apply to GR and the PV Model, can be reproduced by substituting the metric components with the local relative damping factor, as shown in TABLE 2.

$$\frac{1}{\left(1-\zeta^2\right)} = \left|\sqrt{g_{11}/-g_{00}}\right| \tag{24}$$

It may be inferred by inspection that for a spherical mass, such as the planet Earth with mass, $M_E = 5.972 \times 10^{24}$ kg and radius, $R_E = 6.371 \times 10^6$ m, the relative damping factor is,

$$\zeta = \sqrt{\frac{2GM_E}{c_0^2 R_E}} \tag{25}$$

The ratio, $\frac{2GM}{c_0^2 R}$ is the familiar gravitational potential found in the Schwarzschild solution of GR, [13] and in the PV Model. [14, 15] Where,

$$K = \frac{1}{\left(1-\zeta^2\right)} \equiv \frac{1}{1-\frac{2GM}{c_0^2 R}} \tag{26}$$

The normalized frequency shift at the surface of the Earth may then be expressed as,

$$\frac{\omega-\omega_0}{\omega_0} = \left|\sqrt{1-\zeta^2}\right| - 1 = 6.961 \times 10^{-10} \tag{27}$$

The normalized value for the frequency shift of the oscillator appears to be very small, but it results in a gravitational acceleration of $g = 9.8 \ \frac{\text{m}}{\text{s}^2}$. Notice that it does not take much of a frequency shift to generate significant results. However, determining this shift in energy for each particle, multiplied by the number of particles to be shifted, such as levitating a car for example, requires a significant amount of power. This is one of many engineering problems to be tackled.

**TABLE 2**: *Comparison of Relative Damping Factor vs the PV Refractive Index.*

| **Variable Refractive Index** $K = \left\|\sqrt{g_{11}/-g_{00}}\right\|$ | **Variable Relative Damping** $\frac{1}{\left(1-\zeta^2\right)} = \left\|\sqrt{g_{11}/-g_{00}}\right\|$ | **Description** |
|---|---|---|
| $c_K = c_0 / K$ | $c_\zeta = c_0 \cdot \left(1-\zeta^2\right)$ | Speed of light |
| $\Delta x = \Delta x_0 / \left\|\sqrt{K}\right\|$ | $\Delta x_\zeta = \Delta x_0 \cdot \left\|\sqrt{1-\zeta^2}\right\|$ | Length |
| $\Delta t = \Delta t_0 \left\|\sqrt{K}\right\|$ | $\Delta t_\zeta = \Delta t_0 \cdot \frac{1}{\left\|\sqrt{1-\zeta^2}\right\|}$ | Time |
| $v = v_0 / K$ | $v_\zeta = v_0 \cdot \left(1-\zeta^2\right)$ | Velocity |
| $a = a_0 / \left\|K^{3/2}\right\|$ | $a_\zeta = a_0 \cdot \left\|\left(1-\zeta^2\right)^{3/2}\right\|$ | Acceleration |
| $m = m_0 \left\|K^{3/2}\right\|$ | $m_\zeta = m_0 \cdot \frac{1}{\left\|\left(1-\zeta^2\right)^{3/2}\right\|}$ | Mass |
| $\omega = \omega_0 / \left\|\sqrt{K}\right\|$ | $\omega_\zeta = \omega_0 \cdot \left\|\sqrt{1-\zeta^2}\right\|$ | Frequency |
| $\Delta E = \Delta E_0 / \left\|\sqrt{K}\right\|$ | $\Delta E_\zeta = \Delta E_0 \cdot \left\|\sqrt{1-\zeta^2}\right\|$ | Energy |

The mean-square fluctuations from equation (16) may be restated in terms of the relative damping factor,

$$\left\langle x_\zeta^2 \right\rangle = \frac{\hbar}{2m\omega_0} \cdot \left(1-\zeta^2\right),$$
$$\left\langle v_\zeta^2 \right\rangle = \frac{\hbar\omega_0}{2m} \cdot \left(1-\zeta^2\right)^2, \tag{28}$$
$$\left\langle a_\zeta^2 \right\rangle = \frac{\hbar\omega_0^3}{2m} \cdot \left(1-\zeta^2\right)^3$$

This illustrates how the mean-square particle fluctuations transform according to the relative damping factor. Note that this is *identical* to how such variables behave in a gravitational field, under GR.

*As a result of increased relative damping, a particle's frequency (clock) is slowed and its mean-square position fluctuation (length) contracts. There is less available power to inflate matter to its proper scale, as observed by a distant observer in an unaltered space-time.*

There is less available power, because the power provided by the ZPF source is radiated away by the damping of the oscillation. This explains why gravity has negative energy density, i.e., an energy density less than the ZPF. Matter in a gravitational field is oscillating at energies *less than* the normal ground state energy in a region without a gravitational field. It is less than its ground state energy in a ZPF because the ZPF sets the baseline driving power (the a.c. source), and the radiative damping (loss) reduces the energy and the available power to a value below that baseline. *This energy deficit is why it is required to do work to climb a hill.*

## 5. ENERGY DENSITY

Equation (29) expresses the Electrostatic force between two identical charges, $q$ separated by a distance, $r_0$ .

$$8\pi r_0^2 \rho_E = \alpha\hbar \frac{c_0}{r_0^2} = \frac{q^2}{4\pi\varepsilon_0 r_0^2} \quad \text{N} \tag{29}$$

Where, $\alpha = \dfrac{q^2}{4\pi\varepsilon_0 \hbar c_0}$ is the Fine Structure Constant and, $\rho_E$ is the *local energy density* of the electric field surrounding the charges.

$$\rho_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{\varepsilon_0}{2}\left(\frac{q}{4\pi\varepsilon_0 r_0^2}\right)^2 \quad \frac{\text{J}}{\text{m}^3} \tag{30}$$

Equation (29) can be expressed as a function of the relative damping dependent variables presented in TABLE 2.

$$8\pi r_\zeta^2 \rho_\zeta = \alpha\hbar \frac{c_\zeta}{r_\zeta^2} \quad \text{N} \tag{31}$$

The right hand side of this equality is invariant with respect to changes in the relative damping factor, therefore the left hand side must also be invariant to these changes. The individual variables however, are not invariants. $c_\zeta$ is covariant with $r_\zeta^2$ , such that their ratio remains constant.

On the left hand side of the equation, the only two dependent variables are the area, $r_\zeta^2$ and the energy density, $\rho_\zeta$ which must be contravariant variables. Meaning, when $r_\zeta^2$ contracts due to increased damping, $\rho_\zeta$ must *increase* by the same proportion such that their product remains invariant. Therefore, the energy density and the relative damping factor must have the following relationship.

$$\rho_\zeta = \rho_E \cdot \frac{1}{1-\zeta^2} \tag{32}$$

This result is perfectly consistent with GR and the PV Model.

To put this another way. In GR one would say that gravity, resulting from the increased local energy density, *caused* the gravitational length contraction. In which case, the relative refractive index and the relative damping factor, may be defined in terms of the relative energy densities.

$$K = \frac{1}{1-\zeta^2} \equiv \frac{\rho}{\rho_0} \tag{33}$$

Where, $\rho_0$ would be the value of the vacuum energy density (any source, electrostatic or otherwise), in the reference frame *local* to the distant observer, and $\rho$ is the energy density of the identical system being observed from a distance. In this context, Quantum Gravity may be summarized as follows;

*The increased energy density in the region local to the oscillator, leads to increased radiative damping and a loss of power. Resulting in length contraction of the mean-square position fluctuations, along with a reduction in frequency which is observable as relativistic time dilation effects. Length contraction does not occur independently from time dilation effects, because both result from the same root cause, i.e., a change in the relative damping factor,* $\zeta$ .

Sensibly, one can surmise that it is the very same process that results in time dilation and Lorentz contraction in Special Relativity (SR). The gravitational potential in equation (25) is the ratio of velocities squared. It is identical to the way the velocity potential arises in SR as $v^2 / c_0^2$ . Therefore, it may be deduced that in SR, the relative damping factor is,

$$\zeta^2 = \beta^2 \equiv \frac{v^2}{c^2} \tag{34}$$

Obviously, this does not change any of the physics associated with SR or Lorentz invariance. It is simply a reinterpretation of the physics in terms which are more appropriate for engineering purposes.

This equality between GR and SR provides a clue as to how the damping factor should be interpreted. The damping factor may be expressed as a *damping ratio*, relative to the natural frequency. [6]

$$\zeta \equiv \frac{\sigma}{\omega_0} \tag{35}$$

Where, $\sigma$ is a *scattering* parameter. It is also referred to as the *Neper frequency*. It may be interpreted as the rate at which collisions cause a *stimulated emission* from the oscillator, resulting in a loss of power.

Up until now, only cases where $\zeta \ll 1$ have been considered. In the case where $\zeta = 1$ , the oscillator is said to be critically damped. From equation (26), this is understood to be the event horizon of a black hole in the Schwarzschild space-time. In cases where $\zeta > 1$ , the oscillator is overdamped and will not oscillate, but rather decay exponentially. This gives engineers an intuitive understanding for what it means when it is said that; "time stops", at the event horizon or when the speed of light is reached. *Literally, it means that damping has increased to the point where the natural oscillation can no longer exist.*

Given the Compton frequency of an electron as its natural frequency,

$$\frac{\omega_0}{2\pi} = \frac{m_e c_0^2}{h} = 1.222 \times 10^{20} \text{ Hz} \tag{36}$$

The change in energy at the surface of the Earth, relative to the distant observer is given by equation (27).

$$\Delta E = \hbar\omega_0 \left( \left| \sqrt{1-\zeta^2} \right| - 1 \right) = -5.637 \times 10^{-23} \text{ J} \tag{37}$$

Which is a very small number, but given that Avogadro's number is $6.022 \times 10^{23}$ particles per mole, it does not take many grams of matter before the energy requirement becomes enormous.

Why it is so enormous has to do with the Neper frequency, which may be calculated from equations (25) and (35).

$$\sigma = \frac{\omega_0}{2\pi}\zeta = 4.56 \times 10^{15} \text{ Hz} \tag{38}$$

Note that this frequency is just beyond the range of visible light, in the near ultraviolet spectrum, $65.7 \text{ nm}$. It is reproducible and within the realm of modern technologies. Unfortunately, it only applies to electrons. For a proton, the frequency is more than 3 orders of magnitude higher at, $\sigma_{proton} = 8.4 \times 10^{18} \text{ Hz}$, with an energy of $35 \text{ keV}$. This is in the hard X-ray/Gamma-ray spectrum, where matter begins to become transparent.

If by some means not yet devised, engineers can provide a way to reduce the relative Neper frequency and reduce the amount of relative damping within matter, such matter will become lighter. It will inflate and eventually become *buoyant* in the gravitational field of the Earth.

In regards to an accelerating spaceship, a means by which to reduce the relative damping that is increasing throughout the ship as $v \to c_0$, will increase the maximum velocity and reduce the mass to be transported. The cosmic speed limit will be lifted and the dream of warp drives and starships become realistic endeavors.

On the other hand, if engineers were to increase the Neper frequency to increase relative damping, objects would gain weight, contract and become denser. The possibility of a box that is *bigger on the inside* becomes not so unimaginable if objects shrink as they enter the box, and are then preserved by a reduced clock-rate.

Most importantly, applying gradients to the potential will allow the invention of devices which can control gravity. At which time, artificial gravity and anti-gravity become a reality.

## 6. CONCLUSION

It was shown that a correlation exists between the observations used in GR to determine space-time curvature and the relative radiative damping factor of the quantum mechanical harmonic oscillator, which affects our measuring devices. The relative frequency and energy varies as a function of the damping factor, in accordance with the metric coefficients. It was shown that the damping factor can take the form of the gravitational potential, by matching it to the Schwarzschild solution of GR and calculating the frequency shift of the Compton frequency of the electron, at the surface of the Earth.

Variations in frequency, and therefore in the energy of the oscillator, affects the mean-square fluctuations in *length, velocity, acceleration* and *power* of the oscillator. Resulting in what is perceived and interpreted as space-time curvature in the classical theory.

Note that this model rules out certain geometries in GR. For example, shift-only space-times where length contraction occurs without time dilation, or vis versa. The two are linked by the same statistical processes that govern quantum mechanics and determine the mean-square fluctuations of matter.

In GR, a gravitational field has negative energy density. Meaning, its energy density is less than that of the surrounding vacuum. In the Engineering Model of Quantum Gravity presented here, matter is inflated to its *maximum* relative ground state energy by the ZPF, only when it is in a vacuum far from other matter, i.e., in the local frame of the distant observer. As two objects are brought close together, their respective fields and power spectrums overlap, such that interference occurs that damps the resonant frequencies in both objects. Increased local vacuum energy density increases the radiative damping. Thereby lowering the relative energy (frequency) of the composite oscillators below their normal value and allowing them to attract each other gravitationally.

From a cosmological perspective here on Earth, if the relative damping in our solar system were increasing linearly with time, such that the length of 1 meter were contracting by just $6.935$ nm/century relative to the distant galaxies and supernova, it would appear from our perspective that the universe is expanding. Light arriving from the distant past is redshifted, because our local measuring devices have contracted. When we measure the increasing velocity of expansion across great distances, far into the distant past, to when matter was in a hotter, more inflated state. What will be measured is the Hubble constant. [16]

Consider matter which is cooling from a hotter, less dense state in the distant past. This would be a natural thermodynamic process for matter to undergo. However, there would be no way to measure such a small effect locally, because there is nothing local that is unaffected by this. The only references to compare to are the distant stars. Therefore, the Hubble constant may be evidence that such a process is taking place and, that the thermodynamic energy of the universe is actually running down as it should be. Matter absorbs higher frequency photons from the ZPF and emits lower frequency photons due to accelerations.

The opposite conclusion would be reached if matter were inflating rather than contracting. In such a scenario, the universe would appear to be getting smaller. This is how a warp drive would be described. Matter is inflated by a warp field which makes the distance from point A to point B in the universe, *literally shorter in scale*, relative to the reference frame of the inflated ship.

This engineering model firmly establishes a viable solution to quantum gravity for engineers within the standard model of Quantum Electrodynamics. It opens the door to new innovations that might permit artificial gravity or anti-gravity technologies to be invented. Through the use of stimulated emission, increased or reduced radiative damping, or by amplification of the resonant driving fields that inflate matter to higher ground state energies. Engineers now have a new set of old, familiar tools to work with when thinking about gravity and Metric Engineering. [3]

What was presented herein puts gravity in the hands of engineers, who could potentially advance such technologies as; warp drive, artificial gravity and anti-gravity, from pure speculation, to achievable endeavors in our lifetime. It is my sincere hope that others will see the value in this engineering approach and continue this work until plausible technology can be developed, and beyond.

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