A unified cosmology proposal: Vacuum as a system of harmonic oscillators expanding at relativistic velocities within an Antimatter universe

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Abstract

This paper introduces a novel cosmological framework that interprets the vacuum as a dynamic system of harmonic oscillators, expanding at relativistic velocities and interacting with an antimatter anti-universe. By modeling the vacuum as an RLC circuit, it is proposed that the vacuum itself behaves as a resonant system of harmonic oscillators. Within this framework, they are derived new relationships between fundamental constants—including the speed of light c, gravitational constant G, and fine-structure constant α— showing that these constants arise from the vacuum's intrinsic properties and oscillatory dynamics.

Based on the relationships derived within this framework, it is proposed a novel mechanism of energy exchange across the boundary between matter and antimatter domains, through quantum gaps conceptualized as a "Quantum "black" hole" network. These "holes" in the boundary facilitate energy transfer, generating local spacetime deformations that we perceive as gravitational and electromagnetic interactions. It is showed that spacetime curvature and force interactions are emergent phenomena, stemming from quantum fluctuations within the vacuum as it oscillates and expands. By reinterpreting the vacuum as an active, resonant medium, it is offered a cohesive framework that may unify quantum mechanics and general relativity while aligning with observed cosmological expansion.

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Part I: General Framework

1 Introduction

The fundamental constants of nature [1] —such as the speed of light, the gravitational constant, and the fine-structure constant— are cornerstones of modern physics. Despite their universality and invariance, their origins and interrelationships remain elusive. Physicists have long sought a unified framework [2] that could explain these constants and reveal the deeper symmetries of the universe.

A key challenge in this quest is the enigmatic nature of the vacuum [3]. Traditionally viewed as an empty background, recent theoretical and experimental advancements suggest that the vacuum is a dynamic and complex entity influenced by quantum fluctuations, electromagnetic interactions, and gravitational fields [4]. This has significant implications for our understanding of fundamental forces and spacetime.

In this paper, it is proposed a novel approach to reveal the relationships and true nature of cosmological constants by interpreting the vacuum as a system of harmonic oscillators [5]. By modeling the vacuum as an RLC circuit [6] —a resonant system characterized by resistance (R), inductance (L), and capacitance (C)— they are derived new relationships between fundamental constants. This framework allows, and naturally leads to, exploring the intricate interplay between electromagnetic and gravitational forces, and their connection to the vacuum's intrinsic properties, such as electric permittivity ϵ_0 and magnetic permeability μ_0 [7].

The process unfolds in four key stages. Firstly, it is established a theoretical framework that models the vacuum's dynamics through the RLC analogy, allowing for a reinterpretation of vacuum energy and cosmic phenomena through harmonic oscillation. Secondly, this model is used to derive novel relationships among fundamental constants, which in turn offers insights into the connections between electromagnetic and gravitational phenomena. In the third part, they are explored further interpretations and derivations based on the previous sections. And finally, these insights are extended toward a somewhat speculative but cohesive cosmological proposal. By interpreting spacetime curvature and gravitational interactions as emergent from vacuum oscillations, this approach opens new pathways for reconciling quantum mechanics with general relativity and suggests that gravitational and electromagnetic forces are rooted in the vacuum's inherent structure.

Through this model, it is aimed to reveal not only how spacetime curvature and force interactions could emerge from oscillatory properties within the vacuum, but also which is the nature of the cosmological constant, the dark energy or black holes. In re-framing the vacuum as an active, resonant medium, we are able to develop a consistent and unified theoretical foundation that could advance our understanding of the fundamental nature of the universe, laying the groundwork for a new interpretation of cosmological phenomena and potentially guiding future empirical exploration.

2 An Introduction to Harmonic Oscillatory Systems

2.1 Introduction

A harmonic oscillator is a system that, when displaced from its equilibrium position, experiences a restoring force proportional to the displacement. This force leads to periodic oscillations around the equilibrium position. Harmonic oscillators are foundational in physics, describing behaviors in a variety of systems, including mechanical, electrical, and quantum systems, due to their simple yet powerful dynamics.

The simplest mechanical example is a mass attached to a spring, where displacement from equilibrium results in a restoring force that is directly proportional to the displacement. This force creates oscillatory motion, with a frequency determined by the system parameters—specifically, the mass and the spring's stiffness (or spring constant). Other classic examples of harmonic oscillators include pendulums (under small-angle approximations), vibrating strings, and resonant electrical circuits, all of which exhibit sinusoidal oscillations governed by similar principles.

Mathematically, the dynamics of a harmonic oscillator are described by a second-order differential equation:

$$\frac{d^2x}{dt^2} + \omega^2 x = 0,$$

where x is the displacement, ω is the angular frequency of oscillation, and the solution $x(t) = A\cos(\omega t + \phi)$ represents sinusoidal motion. Here, A is the amplitude of oscillation, and ϕ is the phase, which depends on initial conditions. The frequency ω depends on system-specific parameters, such as mass and stiffness in mechanical oscillators, or inductance and capacitance in electrical circuits [8].

Harmonic oscillators are of particular importance because they represent a fundamental model for understanding a wide range of physical phenomena. Due to their simplicity and universality, they serve as a basis for more complex interactions and are widely applied in technology, from timekeeping in clocks to frequency tuning in radios and stabilization in lasers.

In this work, harmonic oscillators form the backbone of the proposed vacuum model, where the vacuum itself is showed to be an interconnected system of oscillators. This reinterpretation allows us to describe the vacuum's energy density and dynamic properties as arising from a network of oscillators, characterized by parameters analogous to resistance, inductance, and capacitance (RLC components) in electrical systems. Through the application of the foundational principles of harmonic oscillation, we will derive insightful and profound relationships between fundamental constants, spacetime structure, and the emergence of gravitational interactions.

2.2 Components of Different Harmonic Oscillator Systems and Their Equivalences

Harmonic oscillator systems, irrespective of their physical nature, share fundamental components that contribute to their oscillatory behavior. This universality allows us to draw meaningful analogies across different physical domains, which is particularly valuable for modeling complex systems like the vacuum. The tables below (Table 1 and Table 2) illustrate these analogies by comparing key components, relationships, and formulas for three types of harmonic oscillator systems: translational mechanical, rotational mechanical, and series RLC circuit systems [9] [10].

The analogies highlighted in these tables underscore the remarkable unity underlying oscillatory systems. By assigning equivalent values to analogous parameters across different types of oscillators, we can reproduce identical behavior—whether in waveform, resonant frequency, or damping characteristics—across translational, rotational, and electrical domains. Thus, these analogies serve not merely as pedagogical tools but as a foundation for deeper insights, particularly in modeling the vacuum as an ensemble of harmonic oscillators.

Translational Mechanical	**Rotational Mechanical**	**Series RLC Circuit**
Equivalent Components		
Mass m	Moment of inertia J	Inductance L
Damping coefficient b	Rotational damping coefficient b_r	Resistance R
Spring constant k	Torsional spring constant k_r	Inverse of capacitance $\frac{1}{C}$
Displacement x	Angular displacement θ	Charge q
Velocity $v = \dot{x}$	Angular velocity $\omega = \dot{\theta}$	Current $i = \dot{q}$
Amplitude A	Amplitude Θ_0	Voltage V_0

Table 1: Analogous components in translational mechanical, rotational mechanical, and series RLC circuit systems

Translational Mechanical	**Rotational Mechanical**	**Series RLC Circuit**
Main Formulas and Relationships		
Resonant Frequency		
$\omega_0 = \sqrt{\frac{k}{m}}$	$\omega_0 = \sqrt{\frac{k_r}{J}}$	$\omega_0 = \frac{1}{\sqrt{LC}}$
Differential Equation		
$m\ddot{x} + b\dot{x} + kx = 0$	$J\ddot{\theta} + b_r\dot{\theta} + k_r\theta = 0$	$L\ddot{q} + R\dot{q} + \frac{1}{C}q = 0$
Attenuation Factor α		
$\alpha = \frac{b}{2m}$	$\alpha = \frac{b_r}{2J}$	$\alpha = \frac{R}{2L}$
Quality Factor Q		
$Q = \frac{m\omega_0}{b}$	$Q = \frac{J\omega_0}{b_r}$	$Q = \frac{\omega_0 L}{R}$
Damping Factor ζ		
$\zeta = \frac{b}{2\sqrt{mk}}$	$\zeta = \frac{b_r}{2\sqrt{Jk_r}}$	$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}$
Relaxation Time τ		
$\tau = \frac{2m}{b}$	$\tau = \frac{2J}{b_r}$	$\tau = \frac{2L}{R}$
Inductive Reactance at Resonance X_N		
$X_N = \frac{k}{Q}$	$X_N = \frac{k_r}{Q}$	$X_N = R \cdot Q$
Force F		
$F = -kx$	$F = -k_r\theta$	$F = -\frac{q}{C}$
$F_{max} = kA$	$F_{max} = k_r\Theta_0$	$V_{max} = \frac{q_{max}}{C}$
Potential Energy U		
$U = \frac{1}{2}kx^2$	$U = \frac{1}{2}k_r\theta^2$	$U = \frac{1}{2}\frac{q^2}{C}$
$U_{max} = \frac{1}{2}kA^2$	$U_{max} = \frac{1}{2}k_r\Theta_0^2$	$U_{max} = \frac{1}{2}\frac{q_{max}^2}{C}$
Kinetic Energy T		
$T = \frac{1}{2}mv^2$	$T = \frac{1}{2}J\omega^2$	$T = \frac{1}{2}Li^2$
$T_{max} = \frac{1}{2}mA^2\omega_0^2$	$T_{max} = \frac{1}{2}J\Theta_0^2\omega_0^2$	$T_{max} = \frac{1}{2}L(\omega_0 q_{max})^2$

Table 2: Main formulas and relationships in translational mechanical, rotational mechanical, and series RLC circuit systems

This section lays the groundwork for our primary approach, in which we conceptualize the vacuum as an RLC-like system of oscillators. Building on the analogies established here, we proceed to derive relationships among universal constants and explore the vacuum's role in generating electromagnetic and gravitational interactions.

3 Vacuum as an RLC Circuit of Harmonic Oscillators

An RLC circuit [11] [12] [13] [14] consists of three primary components: a resistor R, an inductor L, and a capacitor C, often driven by an external voltage source V. The capacitor stores electric charge and energy in the form of an electric field, while the inductor stores magnetic energy. The resistor, in turn, dissipates energy as heat, introducing a damping effect on the oscillations within the circuit. These components collectively define a harmonic oscillator with a natural resonant frequency $\omega_0 = \frac{1}{\sqrt{LC}}$, where L and C represent the inductance and capacitance, respectively.

When driven by a sinusoidal voltage source at a frequency matching the circuit's natural frequency, the system reaches resonance: the current and voltage oscillate in phase, resulting in maximum energy transfer. However, introducing resistance alters the behavior of the circuit by damping the oscillations, reducing the amplitude of current at resonance, and shifting the system's peak frequency. In practical applications, some resistance is unavoidable even if a discrete resistor component is absent, as materials inherently introduce resistive effects.

This RLC resonant behavior serves as an analogy for modeling the vacuum, where the vacuum's electromagnetic properties—permeability μ_0 and permittivity ϵ_0—play roles analogous to inductance and capacitance, respectively. In the following subsections, we will establish equivalences between each component in an RLC circuit and specific universal constants, starting with the speed of light c.

3.1 The Speed of Light c as the Resonant Frequency of the system of harmonic oscillators

To model the vacuum as an RLC circuit, we consider L and C as the inductance and capacitance of the system, corresponding to the magnetic and electric energy storage capacities of the vacuum. Here, inductance L represents the magnetic energy storage, while capacitance C represents the electric energy storage.

The differential equation governing the electric and magnetic fields in the vacuum mirrors that of a harmonic oscillator, with a natural frequency given by [15]:

$$\omega_0 = \frac{1}{\sqrt{LC}}.$$

Substituting the values of L and C with the vacuum's intrinsic electromagnetic constants μ_0 (the magnetic permeability) and ϵ_0 (the electric permittivity), we obtain the well-known expression for the speed of light in a vacuum [16]:

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}.$$

This analogy suggests that the vacuum behaves as a resonant system, where electromagnetic waves propagate at a fixed speed c, determined by the vacuum's inherent properties. In this framework, the speed of light is not an arbitrary constant but an emergent property of the vacuum's structure as a resonant harmonic oscillator system. This interpretation provides a foundation for exploring other universal constants in terms of vacuum properties as a system of harmonic oscillators.

3.2 The energy of vacuum and the maximum current I_{max}

For an RLC circuit, the total energy is expressed as [17]:

$$E_{LC} = \frac{1}{2}\frac{Q^2}{C} + \frac{1}{2}LI^2$$

Other hand, the traditional formula for vacuum energy density [18] is:

$$E_{vac} = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)$$

One can identify immediately the great similarities between both formulas. Both formulas represent total energy as a sum of two components. In the RLC circuit, energy is distributed between the electric field of the capacitor and the magnetic field of the inductor, whereas (similarly) in the vacuum, energy is distributed between the electric field E of a capacitance parameter ϵ_0 and the magnetic field B of an inductance parameter μ_0.

Therefore, we can observe that vacuum energy density can be considered analogous to the total energy of an RLC circuit if we identify:

- The electric energy in the vacuum $\left(\frac{1}{2}\epsilon_0 E^2\right)$ corresponds to the energy stored in the capacitor $\left(\frac{1}{2}\frac{Q^2}{C}\right)$.
- The magnetic energy in the vacuum $\left(\frac{1}{2}\frac{B^2}{\mu_0}\right)$ corresponds to the energy stored in the inductor $\left(\frac{1}{2}LI^2\right)$.

Substituting into the total energy formula for an RLC circuit, we have that:

$$E_{vac} = \frac{1}{2}\mu_0 I^2 + \frac{1}{2}\frac{e^2}{\epsilon_0} \tag{1}$$

We can extract some interesting insights. For instance, it is interesting to analyze the value of I for which the electric energy in the vacuum equals the magnetic energy in the vacuum. Then we have that

$$E_{vac} = \mu_0 I^2 = \frac{e^2}{\epsilon_0} \tag{2}$$

Operating, we have that

$$I^2 = \frac{e^2}{\epsilon_0 \mu_0}$$

As $\frac{1}{c^2} = \epsilon_0 \mu_0$, we can substitute to get that

$$I^2 = e^2 c^2$$

And finally, we have that

$$I = e \cdot c$$

This is consistent within our analogy. In an RLC circuit, the charge Q on the capacitor and the current I in the circuit are related through the time derivative. Specifically, the current I is the time derivative of the charge Q:

$$I(t) = \frac{dQ(t)}{dt}$$

For sinusoidal oscillations, we can express the charge Q and the current I as:

$$Q(t) = Q_0 \cos(\omega t)$$

$$I(t) = -Q_0 \cdot \omega_0 \sin(\omega t)$$

where Q_0 is the maximum charge on the capacitor.

From these equations, we can see that the peak current $I_{\max}$ (the maximum value of $I(t)$) is:

$$I_{\max} = Q_0 \cdot \omega_0$$

Then, with the equivalence $e = Q_0$ and $c = \omega_0$, we have the equality obtained above.

3.3 The Minimum Theoretical Current in Vacuum Oscillations I_{min}

The expression $I_{\text{max}} = e \cdot c$ serves as the minimum theoretical current in the context of the vacuum's harmonic oscillations because it is directly associated with the foundational energy density of the vacuum, which arises from the intrinsic oscillatory nature of spacetime itself. In a traditional RLC circuit, energy is exchanged cyclically between the capacitor and inductor as the system oscillates, with current oscillating in time due to the transfer of charge. Similarly, in the vacuum, electromagnetic energy is distributed between electric and magnetic field components, with energy density tied to the vacuum's capacitance (ϵ_0) and inductance (μ_0). The vacuum, therefore, behaves as a resonant RLC circuit, where the energy density oscillates at a frequency c, yielding a corresponding baseline current of $I_{\text{min}} = e \cdot c$.

Furthermore, $I_{\text{min}} = e \cdot c$ represents the minimal or baseline current because it is the *lowest stable oscillatory current* that sustains vacuum energy density, which we can analogize to the minimum oscillation in a system of quantum harmonic oscillators. In the absence of any external forces or disturbances, the vacuum energy density achieves its lowest stable configuration, oscillating at a characteristic frequency of $\omega = c$. Thus, I_{min} should be viewed not as an "extreme" current but as the baseline oscillatory current sustaining the minimal vacuum energy. This current corresponds to the fundamental vacuum state, establishing I_{min} as the floor rather than a peak of oscillatory behavior within this framework.

Since this current is derived from the vacuum's harmonic oscillations at c (where c acts as a fundamental frequency), it is inherently tied to the natural oscillatory state of the vacuum itself. In this interpretation, $I_{\text{min}} = e \cdot c$ reflects the intrinsic resistance to perturbation in the vacuum, maintaining a stable, self-regulating energy flow. As such, any deviations or fluctuations above this current level would represent additional, higher-energy states induced by localized phenomena (e.g., particle interactions or boundary-driven oscillations like those near quantum black holes). Consequently, $I_{\text{min}} = e \cdot c$ signifies the *minimum theoretical oscillatory current* necessary to sustain vacuum energy density, as it encapsulates the self-maintaining, baseline current of the vacuum in its ground state.

The effective minimum current of the system of harmonic oscillators I_{eff}

In an ideal RLC circuit, oscillations between the electric and magnetic energies produce a phase shift between the capacitor and inductor components. Specifically, at resonance, the peaks of magnetic energy (related to I^2) and electric energy (related to Q^2) occur at slightly offset points in time. This phase difference effectively means that the system's peak current amplitude does not achieve the full theoretical value of $e \cdot c$, but rather an effective amplitude averaged over the oscillatory period. This effect is analogous to the natural division in energy sharing that results from sinusoidal oscillations, where each phase—electric and magnetic—reaches its peak alternately, leading to an effective current amplitude reduced by a factor of $\frac{1}{2}$.

Thus, assigning the effective current as $I_{\text{eff}} = \frac{e \cdot c}{2}$ reflects this inherent phase-related equilibrium in the system. Although $e \cdot c$ might theoretically represent a maximum in the absence of oscillatory phase effects, the resonant conditions of the RLC circuit effectively produce a peak amplitude of $\frac{e \cdot c}{2}$ due to this division in energy distribution. This interpretation aligns with the observed properties of harmonic oscillators, where the system's oscillatory nature naturally yields an effective current that balances the contributions from both magnetic and electric energy components.

Application to E_{vac} and consistency with empirical results

It can be noted that, substituting the accepted values for the universal constants into the expression for E_{vac} as defined in this subsection, we have that

$$E_{\text{vac}} \approx \frac{1}{2}\rho_{\text{vac}},$$

where ρ_{vac} is the vacuum energy density measured in kg/m^3, with an approximate value of 5.94×10^{-27} kg/m^3.

3.4 The fine-structure constant α as the reciprocal of the quality factor Q of the system of harmonic oscillators

The fine-structure constant α [19] can be expressed as the ratio of two energies:

- the energy needed to overcome the electrostatic repulsion between two electrons a distance of d apart
- the energy of a single photon of wavelength $\lambda = 2\pi d$ (or of angular wavelength d)

Therefore, we have that

$$\alpha = \left(\frac{e^2}{4\pi\varepsilon_0 d}\right) \Big/ \left(\frac{hc}{\lambda}\right) = \frac{e^2}{4\pi\varepsilon_0 d} \times \frac{2\pi d}{hc} = \frac{e^2}{4\pi\varepsilon_0 d} \times \frac{d}{\hbar c} = \frac{e^2}{4\pi\varepsilon_0 \hbar c} \tag{3}$$

Other hand, in the context of an RLC circuit, the quality factor or Q factor [20] is a dimensionless parameter that describes how underdamped an oscillator or resonator is. It is defined as the ratio of the initial energy stored in the resonator to the energy lost in one radian of the cycle of oscillation. Therefore, we have that

$$Q \stackrel{\text{def}}{=} 2\pi \times \frac{\text{Energy stored}}{\text{Energy dissipated per cycle}} = 2\pi f_r \times \frac{\text{Energy stored}}{\text{Power loss}} = \omega_0 \times \frac{\text{Energy stored}}{\text{Power loss}}$$

Where f_r is the resonance frequency. The factor 2π makes Q expressible in simpler terms, involving only the coefficients of the second-order differential equation describing most resonant systems, electrical or mechanical. In electrical systems, the stored energy is the sum of energies stored in lossless inductors and capacitors; the lost energy is the sum of the energies dissipated in resistors per cycle. In mechanical systems, the stored energy is the sum of the potential and kinetic energies at some point in time; the lost energy is the work done by an external force, per cycle, to maintain amplitude.

The analogy between α as the reciprocal of the Q factor becomes clear if we establish the following equivalences:

- Energy dissipated per cycle $\sim \frac{e^2}{4\pi\varepsilon_0 d}$
- Energy stored $\sim \frac{d}{\hbar c}$

While the typical interpretation aligns the energy to overcome repulsion with stored energy and the photon energy with energy dissipated/transferred, we propose viewing it from the opposite perspective:

- **Photon energy as stored field energy:** Photons, as quanta of the electromagnetic field, represent the energy inherently stored in the field.
- **Overcoming repulsion as dissipative energy:** Bringing electrons closer changes the electromagnetic field configuration, requiring energy to alter the field structure—analogous to dissipating energy to modify the system.

This perspective offers valuable and fundamental insights:

- **Field-Centric Approach:** It emphasizes the electromagnetic field as a fundamental entity, with particle interactions as field manifestations of changes in the field.
- **Energy Flow and Transformation:** It suggests that electromagnetic interactions involve energy flow within the field, rather than purely particle-photon exchanges.

Now, let us consider the vacuum interactions as a series RLC circuit. In series RLC circuits, we have that

$$Q = \frac{1}{R} \cdot \sqrt{\frac{L}{C}}$$

We can substitute and equate to obtain

$$\alpha = \frac{e^2}{4\pi\varepsilon_0 \hbar c} = \frac{1}{Q} = R \cdot \sqrt{\frac{\epsilon_0}{\mu_0}}$$

Numerically, to match the current value of α, it is needed to plug a value of $R \approx 2.749$. The nature of this resistance element is discussed throughout the Paper, and connected to the spatial configuration of the system of harmonic oscillators.

3.5 The Gravitational Constant G as the Effective Inductance of the system of Harmonic Oscillators

In RLC circuits, the concept of effective inductance, L_{eff}, helps model non-idealities and energy losses within an inductor. Such losses can arise from various mechanisms, including resistance in the wire (ohmic losses), core losses (if the inductor has a magnetic core), and radiation losses at higher frequencies. In an idealized scenario, an inductor stores energy solely in its magnetic field and releases it back to the circuit without any losses. However, real inductors always experience some degree of energy dissipation due to these inherent resistances and other factors, meaning that not all stored energy returns to the circuit.

To account for these losses, we introduce the concept of effective inductance, L_{eff}, allowing us to represent a real inductor with losses as an ideal inductor with a slightly altered inductance value. By incorporating these losses, L_{eff} enables accurate circuit analysis, reflecting how dissipative elements impact the inductive properties of the system.

In our model, we propose an analogy between the gravitational constant G and the effective inductance L_{eff}, interpreting G as an inductive property arising from vacuum interactions. This interpretation positions gravity as a form of reactive interaction in a vacuum system, with G reflecting the equivalent "inductive loss" associated with energy transfer in the vacuum.

To show how we can arrive to this analogy, we start relating ideal inductance L and effective inductance L_{eff} through the quality factor Q, which measures how "lossy" an inductor is:

$$Q = \sqrt{\frac{L}{L_{eff}}}.$$

This identity can be directly derived from the equation $Q = \frac{1}{R} \cdot \sqrt{\frac{L}{C}}$ that we have already seen before. Squaring both sides gives:

$$Q^2 = \frac{L}{R^2 \cdot C}.$$

By substituting the vacuum parameters $L = \mu_0$ and $C = \epsilon_0$ (the vacuum permeability and permittivity), we obtain:

$$Q^2 = \frac{\mu_0}{R^2 \cdot \epsilon_0}.$$

The expression $R^2\epsilon_0$ has dimensions of inductance $[H]$, since:

$$\left[R^2\epsilon_0\right] = \left[\Omega^2 \cdot F\right] = [H]$$

Since the term $R^2\epsilon_0$ has the dimensions of inductance $[H]$, we identify L_{eff} as:

$$L_{eff} = R^2 \cdot \epsilon_0.$$

Numerically, using the accepted values for ϵ_0 [21] and an approximate value for $R \approx 2.749$, we find that $L_{eff} \approx 6.691 \times 10^{-11}$, which closely matches the value of the gravitational constant G [22].

Postulating that $L_{eff} = R^2 \cdot \epsilon_0 = G$ implies that the gravitational constant G represents an effective inductance in the system of oscillators. This perspective aligns with interpreting gravitational interactions as a form of energy dissipation or loss in the inductive behavior of the vacuum. Thus, G is not only associated with energy transfer but also contributes to the overall inductive impedance at resonance in the vacuum oscillator model.

This interpretation allows us to relate the fine-structure constant α to the gravitational constant G in terms of the quality factor Q:

$$\alpha = \sqrt{\frac{G}{\mu_0}}.$$

This quotient is dimensionless within our framework, as both G and μ_0 have the same dimensions, aligning with the interpretation of α as a dimensionless parameter measuring the energy coupling in the electromagnetic field.

3.6 Expressing the Main Classical Elements of RLC Circuits in Terms of Universal Constants

In a series RLC circuit, several key parameters help characterize system behavior, particularly its response to oscillations and damping. These primary parameters are the quality factor Q, the damping ratio ζ, the natural frequency ω_0, the damping attenuation α_{att}, and the exponential time constant τ. Each parameter offers insights into the oscillatory and dissipative characteristics of the circuit, and analogies with universal constants suggest deeper connections within the vacuum model.

Quality Factor Q: The quality factor represents how underdamped an oscillator is and describes the ratio of energy stored to energy dissipated per cycle. Higher Q values indicate lower energy losses, associated with more sustained oscillations.

Damping Ratio ζ: The damping ratio describes the degree of damping relative to critical damping. It provides insight into how quickly oscillations decay, with higher ζ values leading to faster attenuation of the oscillatory behavior.

Natural Frequency ω_0: This is the frequency at which the system oscillates in the absence of damping, reflecting the inherent resonant frequency of the system.

Damping Attenuation α_{att}: The damping attenuation factor represents the rate at which the oscillations decay over time. It is related to the damping ratio and the natural frequency.

Exponential Time Constant τ: The time constant τ measures the time required for the oscillations to decay to a fraction of their initial amplitude, often used to characterize the rate of exponential decay.

Using the relationships established in previous sections and standard formulas for RLC circuit parameters, we can express these elements in terms of universal constants:

$$Q = \frac{1}{2\zeta} = \frac{\omega_0}{2\alpha_{att}} = \frac{\tau\omega_0}{2}.$$

Since we have previously defined $Q = \frac{1}{\alpha}$, and using the relationship between Q and α involving universal constants, we find:

$$Q = \sqrt{\frac{\mu_0}{G}} = \frac{2}{e \cdot c^2}$$

This relation implies that the damping ratio ζ can be expressed as:

$$\zeta = \frac{\alpha}{2} = \frac{1}{2}\sqrt{\frac{G}{\mu_0}} = \frac{e \cdot c^2}{4}$$

For the damping attenuation factor α_{att}, we have:

$$\alpha_{att} = \zeta \cdot \omega_0 = \frac{\alpha \cdot c}{2} = \frac{1}{2}\sqrt{\frac{G \cdot c^2}{\mu_0}} = \frac{e \cdot c^3}{4}$$

Finally, the exponential time constant τ is given by:

$$\tau = \frac{1}{\alpha_{att}} = \frac{2}{\alpha \cdot c} = 2\sqrt{\frac{\mu_0}{G \cdot c^2}} = \frac{4}{e \cdot c^3}$$

In the next section, we will delve into the implications of the relationships and framework we have already established, exploring the dimensional consistency of the analogies we have already posed and its consequences.

4 Dimensional Analysis and Its Implications

Throughout this paper, we have derived several important relationships that suggest underlying consistency in the dimensional framework of our model. Although dimensional analysis was not explicitly performed in each subsection, dimensional consistency has been carefully maintained as a guiding principle. Here, we consolidate this analysis, validating the coherence of the established equivalences within our framework.

Dimensional Consistency Across Oscillator Systems

In engineering and physics, harmonic oscillators in mechanical, rotational, and electrical systems are often equivalent due to their shared mathematical models. For instance, and as we have seen at Table 1 in Section 2, the inductance L in an RLC circuit corresponds to mass m in a mechanical oscillator, which allows us to set $[L] = [M]$ and therefore write:

$$[M] = [ML^2I^{-2}T^{-2}].$$

From this, we find that $[L^2I^{-2}T^{-2}]$ is dimensionless, and solving for current I yields:

$$[I] = [T \cdot L^{-1}].$$

Similarly, the resistance R in an RLC circuit is analogous to the damping coefficient b in a mechanical oscillator. Thus, we find that:

$$[MT^{-1}] = [ML^2T^{-3}I^{-2}],$$

which implies that $[L^2I^{-2}T^{-2}]$ is dimensionless, consistently reinforcing our established dimensions for I and C.

Fundamental Equivalence of Space and Time Dimensions

Within this framework, we obtain additional insights into the nature of space and time. On the one hand, we have established that $[G] = [\mu_0]$, which in the physical reality has dimensions $[HL^{-1}] = [MT^{-2}LI^{-2}]$. On the other hand, through Newton's law, G has dimensions $[G] = [M^{-1}T^{-2}L^3]$. Therefore, we can equate to get that

$$[M^{-1}T^{-2}L^3] = [MT^{-2}LI^{-2}]$$

Solving for $[M]$, we have that

$$[M^2] = [L^2I^2]$$

$$[M] = [L \cdot I]$$

And, substituting with $[I] = [T \cdot L^{-1}]$, we finally get that

$$[M] = [T]$$

From this result and the previous ones, we can substitute $[M]$ and $[I]$ in the previous equivalence $[MT^{-1}] = [ML^2T^{-3}I^{-2}]$, to get that $[T^{-4}L^4]$ becomes dimensionless; which, in turn, implies that we have reached the fundamental equivalence

$$[L] = [T]$$

The above implies that, within the analogy and context of this Paper, space and time are interchangeable in some fundamental way. This breaks the conventional distinction between the spatial and temporal dimensions and leads us to consider all four dimensions (three spatial and one temporal) as being equivalent within our framework.

By doing this, we treat the universe as a 4-dimensional object with equivalent dimensions, where the dynamics of both space and time contribute equally to the evolution of the universe.

4.1 Dimensional Consistency within Specific Systems: RLC Circuits and Mechanical Translational Oscillators

Although the general dimensional framework proposed in this paper treats space and time as interchangeable, it is important to acknowledge that the dimensional consistency of relationships still depends on the physical systems in which the relationships are applied. Specifically, in systems like RLC circuits or mechanical harmonic oscillators, the dimensions of the physical quantities involved follow the specific conventions of those systems, and dimensional consistency should be respected within their contexts.

A paramount example is the speed of light c, that has dimensions of velocity in translational mechanical system (and thus, it becomes dimensionless within that framework when using the $[L] = [T]$ equivalence), but as the natural angular frequency in an RLC circuit still has dimension $[T^{-1}]$.

Then, for instance, in the mechanical translational system, we will establish later that $I = c$, with both I and c being dimensionless. However, within the RLC circuit system, we have that $I = Q_0 \cdot \omega_0 = e \cdot c$, with c having dimension $[T^{-1}]$. Both e and I mantain the same dimensionality within both frameworks, acting as a "sanity check" of the coherence of the developed framework and equivalences established.

Another interesting example is the case of the fine-structure constant α. As the reciprocal of the quality factor Q, the formula is given by:

$$\alpha = \frac{R}{\omega_0 \cdot L} = \frac{R}{c \cdot \mu_0}$$

In an RLC circuit, $\omega_0 = c$ represents the resonant angular frequency, which has dimensions of inverse time [T^{-1}]; L represents inductance, which in this framework has dimensions of time [T], and R is the resistance with dimensions $[M \cdot T^{-1}]$, becoming dimensionless when setting $[M] = [T]$. When these quantities are substituted into the formula for α, the dimensions cancel out, making α dimensionless within the framework of RLC circuits.

On the other hand, by definition, $\alpha = \frac{e^2}{2\epsilon_0 hc}$. As it is a ratio of two energies, this expression must be dimensionless. We will see that the dimensions of the constants involved within an RLC circuit framework are $[e] = [T^2]$, $[h] = [T^3]$, $[\epsilon_0] = [T]$, $[2] = [T]$ and $[c] = [T^{-1}]$, whereas the dimensions within a traslational mechanical framework are $[e] = [T]$, $[h] = [T]$, $[\epsilon_0] = [1]$, $[2] = [T]$ and $[c] = [1]$. In both cases, we obtain that α is a dimensionless parameter.

Therefore, it is essential to check the dimensional consistency of relationships within the context of the concrete system that is being involved. The dimensions of physical quantities within these systems must align with the established conventions to ensure the relationships are physically meaningful. In this sense, we will perform occasional "sanity checks" when needed to ensure that dimensional consistency holds within a particular framework.

4.2 The different dimensionality of Potential and Kinetic Energy

It is important to highlight that, within the framework presented in this paper, we propose two distinct dimensionalities for energy forms: (1) potential energy forms, such as mass, elementary charge, and static potential energy, which directly impact spacetime, and (2) kinetic energy, which represents energy exchange without lasting effects on spacetime. This distinction aligns with our interpretation of energy in relation to vacuum oscillations and spacetime dynamics.

Potential Energy and Its Dimensionality in Spacetime

We assign potential energy forms, such as mass m, elementary charge e, and static potential energy, the dimensions of spacetime itself, $[L] = [T]$. This assignment reflects their role as entities that inherently "participate" in and interact with spacetime structure. In classical and relativistic contexts, mass and energy are sources of spacetime curvature, and elementary charge generates electromagnetic fields that influence the vacuum and spacetime geometry. Thus, potential energy forms are linked to permanent deformations in spacetime, such as gravitational curvature or electromagnetic influence, giving them dimensions that embed them within spacetime itself.

Kinetic Energy as a Dimensionless Quantity

In contrast, we treat kinetic energy as dimensionless within our framework. Kinetic energy represents the active or transient aspect of energy in a system, often associated with motion or oscillatory behavior. Unlike potential energy forms, which result in measurable spacetime deformation, kinetic energy is interpreted as a manifestation of energy exchange that does not directly alter spacetime structure. This dimensionless interpretation aligns with the view that kinetic energy represents an oscillatory or dissipative process within spacetime, rather than a source of intrinsic curvature.

4.3 The dimensions of universal constants within the translational mechanical framework

As the usual framework in which the universal constants are considered is the translational mechanical framework, we establish the dimensions of the most important constants that we will consider throughout this Paper within a translational mechanical system of harmonic oscillators:

- **The "speed of light" / resonant frequency c:** As any velocity with dimensions $[LT^{-1}]$, it becomes dimensionless. This is consistent with natural units.
- **Mass:** As already stated, we have $[M] = [T] = [L]$. This is consistent with the fact that, without mass, there is no existence of "length", and therefore "time", dimensions.
- **Energy:** From Einstein's equation $E = m \cdot c^2$, it has dimensions $[L] = [T]$. However, as we have stated before, kinetic energy will become dimensionless within our framework.
- **Electric current:** Becomes dimensionless, as we have that $[I] = [TL^{-1}] = [1]$
- **Resistance:** Becomes dimensionless, as $[R] = [MT^{-1}] = [ML^2T^{-3}I^{-2}] = [1]$
- **Voltage:** By Ohm's law, we have that $V = I \cdot R$. As both I and R are dimensionless, voltage V becomes dimensionless too.
- **Power:** As we have that $P = V \cdot I$, and $P = \frac{V^2}{R}$, power P becomes dimensionless too.
- **Elementary charge e:** As voltage $V = \frac{E}{Q}$ is dimensionless, and we have established that energy has dimensions $[L] = [T]$ within or framework, it also has dimensions $[L] = [T]$. This is also consistent with the fact that $[Q] = [I \cdot T]$ and the fact that $[I] = [1]$.
- **Reduced Planck's constant $\hbar$:** As a quantum of momentum, it has dimension $[L] = [T]$.
- **Planck's constant h:** As it is equal to $\hbar \cdot 2\pi$, based on the fact that 2π is a geometric factor and can be associated to a resistance, it has dimension $[L] = [T]$.
- **Electric permittivity ϵ_0:** As it has dimension $[\epsilon_0] = [M^{-1}L^{-3}T^4I^2]$, it becomes dimensionless. This is consistent throughout the relationships established, and with the interpretation of ϵ_0 as the property of space-time deformation (curvature).
- **Magnetic permeability μ_0:** As it has dimension $[\mu_0] = [MLT^{-2}I^{-2}]$, it becomes dimensionless. This is consistent throughout the relationships established, and with the interpretation of μ_0 as the property of vacuum leading to the necessary energy to be transferred / dissipated to deform / curve the space-time.
- **The cosmological constant Λ:** It has dimension $[T^2] = [L^2]$, as $[M] = [E] = [e] = [h]$ and, as we will see later throughout the Paper, through the relationship $\Lambda = h \cdot e$.
- **The gravitational constant G:** Through Newton's law, G has dimensions $[G] = [M^{-1}T^{-2}L^3]$. Thus, it becomes dimensionless.
- **The fine-structure constant α:** By its definition $\alpha = \frac{e^2}{2\epsilon_0 hc}$. With $[2] = [L] = [T]$ (a dimensionality that we will discuss later on throughout the Paper) and the previous dimensions described, it is dimensionless.

4.4 Concluding Thoughts on Dimensional Consistency

A key insight of our framework is that everything except forms of potential energy, such as mass, energy and charge (and other categories involving them, such as momentum, density, etc) becomes dimensionless, which simplifies many of the traditional physical constants and laws. This profound result suggests that much of the complexity we associate with physical reality — such as resistance, current, voltage, etc — are not truly fundamental, but rather relational constructs to describe mass-energy interaction with the vacuum.

The dimensional analysis performed in our framework shows that mass, energy and charge are the only dimension-bearing entities, while other quantities lose their dimensional character. This leads to a simplification where the observable universe can be interpreted as mass-energy interacting with the spacetime structure. The coherence of this idea with both modern physics and natural units is striking, as it aligns with models that already attempt to normalize key constants to dimensionless values.

The implications of this dimensional collapse extend beyond physics into philosophical realms. If mass-energy is the only dimension-bearing entity in the universe, it suggests that mass-energy plays the central role in shaping our perception of the physical world. Time, space, and fundamental interactions become secondary, emergent properties of mass-energy dynamics. This shifts our understanding of the universe toward a simpler, more unified system where most phenomena are merely manifestations of mass-energy interacting with spacetime, possibly offering a path toward reconciling quantum mechanics and general relativity.

Moreover, this framework offers a conceptual clarity that resonates with the philosophical notion of reductionism: complex phenomena, such as spacetime curvature or electromagnetic interactions, are reduced to the deformation of spacetime mediated by mass-energy. In this view, the universe is not fundamentally governed by a multitude of complex forces and constants, but by a single entity — mass-energy — which generates the observable features of reality through its interaction with -and within- spacetime. This philosophical elegance complements the mathematical simplicity of the theory, and suggests a unified, holistic understanding of the universe's structure, where complexity emerges from a fundamental simplicity rooted in the properties of mass-energy.

5 The Elementary Spacetime Differential $dx = \frac{1}{2}$ Derived from Heisenberg's Uncertainty Principle as a Quantum of Spacetime Structure

In this section, led by the relationships that we have derived -and we will derive- throughout the Paper, we postulate that the factor $\frac{1}{2}$ can be interpreted in some contexts as an elementary differential of spacetime, denoted dx, where x represents spacetime. This interpretation stems from Heisenberg's uncertainty principle, under the assumption that $\hbar$ represents a fundamental quantum of momentum within the context of quantum harmonic oscillations.

Heisenberg's Uncertainty Principle and the Quantum of Momentum

Heisenberg's uncertainty principle, a cornerstone of quantum mechanics [23, 24], places a fundamental limit on how precisely one can know both the position and momentum of a particle simultaneously:

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}.$$

In this framework, Δx represents the uncertainty in position, while Δp represents the uncertainty in momentum.

Now, assume $\hbar$ to be the smallest quantum of momentum. By setting $\Delta p \geq \hbar$, by Heisenberg's uncertainty principle, we have that

$$\Delta x \geq \frac{1}{2}.$$

This implies that $\Delta x = \frac{1}{2}$ is the minimum measurable increment in spacetime under the constraints of the uncertainty principle. This leads to consider the minimum interval $dx = \frac{1}{2}$ as an elementary differential of spacetime, suggesting a discretization where spacetime can be divided into quanta of $\frac{1}{2}$, at least within this quantum mechanical framework.

Interpretation within the Context of Heisenberg's Principle and quantum Harmonic Oscillations

It is important to clarify that $dx = \frac{1}{2}$ as a quantum of spacetime arises specifically from Heisenberg's uncertainty principle and the quantum harmonic oscillator model. In the context of quantum harmonic oscillations, the uncertainty principle reflects inherent fluctuations in position and momentum, with $\hbar$ as the fundamental scale for these fluctuations. Thus, $\frac{1}{2}$ represents the smallest increment of spacetime measurable within this framework, not necessarily a universal quantum of spacetime across all physical contexts.

In this framework, the elementary differential $dx = \frac{1}{2}$ is tied directly to the uncertainty inherent in quantum oscillations, reflecting the probabilistic nature of quantum mechanics. This minimum differential encapsulates the idea that spacetime exhibits quantized behavior at small scales, but only in a framework governed by quantum uncertainties and oscillatory dynamics.

The above suggests that the universe, particularly in the context of expansion at relativistic velocities, may have a quantized structure characterized by a constant momentum. This approach implies that spacetime itself could exhibit quantization, defined by the minimum differential $dx = \frac{1}{2}$ derived from quantum mechanical principles.

We can establish a conceptual link between this discrete quantum structure and the Einstein field equations [25]:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}, \tag{4}$$

where:

- $R_{\mu\nu}$ is the Ricci curvature tensor, which describes the curvature of spacetime.

- R is the Ricci scalar (the trace of the Ricci tensor).
- $g_{\mu\nu}$ is the metric tensor, which encodes the geometry of spacetime.
- $T_{\mu\nu}$ is the energy-momentum tensor, which describes the distribution of matter and energy in spacetime.

In these equations, the factor $\frac{1}{2}$ serves a critical role in balancing contributions from curvature and the metric tensor, ensuring that the Einstein tensor remains consistent with the conservation of energy and momentum in curved spacetime. This factor reflects an intrinsic symmetry in general relativity: it balances spacetime's response to energy distributions, maintaining the necessary conservation laws. In this sense, the constant $\frac{1}{2}$ can be seen as a structural feature that enables spacetime to accommodate matter and energy while preserving fundamental conservation principles.

This balance has an intriguing parallel with the interpretation of $dx = \frac{1}{2}$ as a quantum of spacetime in our framework. Just as the factor $\frac{1}{2}$ in general relativity ensures a consistent structure for energy-momentum conservation, $dx = \frac{1}{2}$ represents a minimal unit in spacetime that encapsulates quantum uncertainty and oscillatory dynamics. Thus, we interpret $dx = \frac{1}{2}$ as a fundamental quantum of spacetime structure that conceptually links the discrete nature of quantum mechanics with the continuous curvature of general relativity. This approach reflects the dual roles of quantum mechanics and relativistic dynamics in shaping the universe's structure, bridging quantum and classical views of spacetime through a shared symmetry.

6 The Use of $\int c\,dc$ as the Transformation from Potential to Kinetic Forms of Spacetime and the Accumulation over Oscillatory Modes

Throughout this paper, we derive several key relationships where the integral

$$\int c\,dc$$

arises as a fundamental and common element. This integral plays a central role by representing the cumulative contribution of all possible oscillatory modes or frequencies of the vacuum, where c denotes the resonance frequency of the vacuum oscillatory system. Integrating over all such frequencies encapsulates the dynamic nature of the vacuum, suggesting that quantities like mass, energy, charge, and physical realities derived of them— as previously derived from the dimensional analysis as the fundamental units of spacetime—emerge as expressions of potential spacetime forms transformed into kinetic effects through vacuum fluctuations.

In this context, we interpret $\int c\,dc$ as an operator that induces transformations from potential to kinetic forms of spacetime, mobilizing intrinsic properties such as mass, energy, and charge. For instance, when applied to mass, which is a form of potential energy, $m\int c\,dc$ yields the well-known expression for kinetic energy if we consider c as a velocity. In general, we propose that:

$$\int c\,dc \rightarrow \text{transforms potential spacetime} \rightarrow \text{into kinetic spacetime (deformation, dynamical effects).}$$

This interpretation implies that the vacuum oscillatory modes facilitate the emergence of dynamical properties in spacetime itself. Each of these potential quantities, whether mass, energy, or charge, serves as a latent form that becomes dynamically active when transformed by $\int c\,dc$.

Dimensional Implications of the Factor $\frac{1}{2}$ in $\int c\,dc$

When evaluating $\int c\,dc$, we obtain an expression proportional to $\frac{1}{2}c^2$. Notably, c^2 is dimensionless in our natural unit framework, which inherently assigns the dimension $[L] = [T]$ to the factor 2 to mantain dimensional consistency. This dimensional assignment to 2 will be discussed further in the final part of the paper.

Temporal Interpretation of $\int c\,dc$

From a temporal perspective, we consider c as the characteristic timescale due to the relativistic expansion of the vacuum, where c acts as both the speed of light and the natural unit of time in this framework. Working in natural units, where $c = 1$, the expression $\int c\,dc$ captures the cumulative impact of time-like contributions from all vacuum oscillatory modes. Integrating over all frequencies in this context effectively sums contributions over corresponding timescales $t = \frac{1}{c}$. This establishes an equivalence between $\int c\,dc$ and $\int t\,dt$, where each oscillatory mode contributes a discrete temporal interval to the evolution of spacetime, resonating with the relativistic nature of the vacuum's dynamics.

In this framework, $\int c\,dc$ carries the dimensions of frequency, $[T^{-1}]$, which aligns with its interpretation as the cumulative frequency of oscillations across all vacuum modes. This frequency serves as a measure of the vacuum's oscillatory contributions to spacetime, encapsulating the vibrational or fluctuating nature of the vacuum. Here, the dimension $[T^{-1}]$ reinforces that these cumulative oscillations contribute directly to the emergence of time within the vacuum structure, suggesting that each oscillatory mode represents a "tick" that drives the unfolding of spacetime.

Interpreting $\int c\,dc$ as a fundamental frequency also positions it as a scaling factor for dynamic interactions within spacetime, modulating how vacuum energy exchanges manifest as gravitational or electromagnetic effects across spacetime intervals. This interpretation resonates with quantum field theory, where fields oscillate with intrinsic frequencies, and vacuum fluctuations inherently carry frequencies tied to energy levels. In this sense, $\int c\,dc$ establishes a baseline for the vacuum's oscillatory behavior, highlighting the role of frequency in shaping both spacetime dynamics and the evolution of observable phenomena.

6.1 Examples of $\int c\,dc$ Transforming Potential to Kinetic Forms

This integral plays a crucial role across several expressions derived throughout this Paper, each demonstrating how potential forms are transformed into kinetic expressions that produce measurable effects in spacetime:

- **Kinetic Energy Emerging from Potential Energy (Mass):**

$$E_{\text{kinetic}} = m \int c\,dc.$$

  Here, the expression $m \int c\,dc$ yields the familiar equation for kinetic energy, $E = \frac{1}{2} m \cdot c^2$, showing how kinetic energy arises from the transformation of the latent potential form of mass into a dynamic expression. This transformation is mediated by vacuum fluctuations across all possible oscillatory modes, with the integral encompassing various timescales over which the equivalence between mass and energy operates within the vacuum.

- **Fine-Structure Constant and Current Distribution (Elementary Charge Transformation):**

$$\alpha = e \int c\,dc = \int I_{\max}\,dc,$$

  where $I_{\max} = e \cdot c$ represents the maximum current in the vacuum oscillatory system. In this expression, α can be interpreted as the "kinetic" form of the elementary charge e, transformed via the integration over oscillatory frequencies c. In electromagnetism, electric charge Q is given by $\int I\,dt$, the integral of current over time. Similarly, α reflects the cumulative distribution of vacuum oscillators contributing to the transformation of the static charge e into a kinetic, dynamic form that interacts within the electromagnetic field.

- **Gravitational Constant as an Emergent Effect from Vacuum Fluctuations:**

$$G = J \int c\,dc = \int 4\pi G \rho_{\text{vac}}\,dc,$$

  where J is the equilibrium energy of the vacuum. In this expression, G emerges from the cumulative gravitational flux produced by the vacuum energy, with $\int c\,dc$ transforming the equilibrium energy into an active gravitational effect, deforming spacetime in response to mass-energy distributions. Here, the integral across all oscillatory modes quantifies the dynamic gravitational response of spacetime positioning G as an emergent property of the vacuum's structure.

- **Vacuum's Gravitational Flux and the Cosmological Constant Λ:**

$$4\pi G \rho_{\text{vac}} = \Lambda \int c\,dc,$$

  where Λ is the cosmological constant. This relationship shows how the cumulative contribution of vacuum oscillatory modes, represented by $\int c\,dc$, relates to the cosmological constant Λ, encapsulating the vacuum's gravitational flux. In this case, Λ emerges as a global parameter quantifying the transformation of the vacuum's potential energy density into kinetic, large-scale curvature effects, manifested as spacetime expansion.

In summary, the integral $\int c\,dc$ serves as a transformational operator within our framework, mobilizing latent or potential forms of spacetime—whether mass, energ, charge, or physical realities derived of them—into kinetic forms that induce observable deformations in spacetime. This interpretation provides a unified perspective in which vacuum oscillations drive the emergence of dynamical spacetime properties, fundamentally linking the vacuum's oscillatory nature to the dynamic structure of spacetime itself.

7 The ubiquitous Factor of 2 as Polarization States in Vacuum Dynamics

In several key expressions throughout this work, a factor of 2 having dimensions $[2] = [L] = [T]$ appears in the context of relationships involving energy and the fine-structure constant α. A deeper examination of the physical context and the underlying symmetry of the vacuum oscillators suggests that the factor 2 could be appropriately interpreted as arising from polarization states.

7.1 Polarization States as a Fundamental Symmetry in Oscillatory Systems

The interpretation of the vacuum as a system of quantum harmonic oscillators expanding at relativistic velocities aligns naturally with the concept of polarization states. In electromagnetic wave theory, each wave mode possesses two distinct polarization states, such as horizontal and vertical polarizations. These polarization states correspond to independent degrees of freedom in the oscillatory behavior of the field, leading to a factor of 2 in expressions involving energy and other quantities.

Given that the vacuum is modeled as an ensemble of harmonic oscillators in this work, it is plausible to associate the factor of 2 with the two fundamental polarization states of each oscillator. This interpretation is supported by several key considerations:

- **Relativistic and Quantum Symmetry**: The presence of a factor of 2 in relationships involving he fine-structure constant α is indicative of a deeper underlying symmetry. Polarization states, particularly in the context of relativistic oscillatory systems, provide a natural explanation for this symmetry, as they are inherent to every electromagnetic field. Each polarization state corresponds to an independent degree of freedom that influences the overall dynamics of the oscillators. Although typically dimensionless, as the factor 2 can be interpreted as representing the two independent polarization states of the system, it contributes to the system's dimensional scaling in terms of the observed quantities, aligning with both length $[L]$ and time $[T]$ scales in relativistic contexts.

- **Universality in Oscillatory Systems**: In various physical systems, such as electromagnetic waves and quantum fields, polarization states are a fundamental degree of freedom. The factor of 2 in these cases often reflects the inherent symmetry and duality of oscillatory behavior. By associating this factor with polarization, we provide a more universal interpretation that extends beyond specific particle interactions.

Reinterpreting the factor 2 as related to polarization states has significant implications for the consistency and coherence of this framework. By tying the factor 2 to a fundamental degree of freedom associated with oscillatory modes, we provide a robust explanation for its ubiquitous appearance in key expressions. This reinterpretation is particularly relevant in the following contexts:

- **Expressions with the Fine-Structure Constant**: In the relationships where the factor 2 appears alongside the fine-structure constant α, polarization states offer a symmetry-based explanation that aligns with the relativistic dynamics of vacuum oscillators. The factor 2 can be seen as reflecting the dual polarization states of each oscillator, which influence the observed relativistic effects in the expanding vacuum.

- **Thermodynamic and Quantum Consistency**: By associating the factor 2 with polarization states, we establish a direct connection between the degrees of freedom of the vacuum oscillators and their thermodynamic properties. This interpretation supports the entropy expression $S = k_B \cdot \ln(2)$, where the two accessible Quantum states correspond to the two polarization states of each oscillator.

In conclusion, the interpretation of the factor 2 as related to polarization states provides a universal and symmetry-based explanation within this framework. It reflects the fundamental degree of freedom inherent to the oscillatory behavior of the vacuum and aligns with the relativistic and quantum properties of the system. The polarization interpretation enhances the coherence of the model and provides a clearer physical basis for the role of this factor in key relationships.

This reinterpretation also reinforces the conceptual link between the polarization symmetry of the vacuum oscillators and their thermodynamic and relativistic behavior, offering new insights into the fundamental nature of vacuum fluctuations and their role in shaping the structure of spacetime.

7.2 Spin as a manifestation of quantum angular momentum $\frac{\hbar}{2}$ and the discrete nature of spacetime

In quantum mechanics, spin is introduced as an intrinsic form of angular momentum associated with particles, and for spin-$\frac{1}{2}$ particles, such as electrons, the magnitude of this spin is given by:

$$S = \frac{\hbar}{2}.$$

This quantization of angular momentum implies that the particle possesses a fundamental, irreducible unit of "rotation" or intrinsic angular momentum that cannot be subdivided further. This half-integer spin distinguishes particles like electrons from classical rotating objects and is central to quantum mechanical phenomena, including the Pauli exclusion principle and magnetic moment quantization.

Spin and the Discrete Nature of Spacetime

If we consider spacetime as inherently discrete or quantized, as we have postulated before, then spin may not simply be an intrinsic property of particles, but rather an emergent result of the particle's interaction with this underlying discrete spacetime framework. We have introduced the concept of a fundamental "quantum cell" or discrete interval of spacetime, denoted by $dx = \frac{1}{2}$, to represent the minimum quantized unit of spacetime that may impose binary states on any entity within that cell.

Under this interpretation, spin arises from the interaction between particles and the quantized structure of spacetime. Specifically:

- **Discrete Spacetime Intervals**: We have postulated that spacetime is divided into elementary, irreducible units, each with a minimum differential interval $dx = \frac{1}{2}$. This discrete interval imposes binary polarization states on any entity within the cell, which manifest as spin-up and spin-down orientations in the case of spin-$\frac{1}{2}$ particles.
- **Spin as a Vacuum-Induced Quantum State**: By modeling the vacuum as structured by discrete, polarized cells, we propose that spin is not an isolated intrinsic property of particles but an emergent behavior shaped by this structured vacuum. Each particle's spin state corresponds to an alignment with the binary polarization within each cell, creating two accessible states that align with the observed quantization of spin.

Linking $\frac{\hbar}{2}$ to Polarization States in Quantum Harmonic Oscillators

Within the framework of quantum harmonic oscillators, the quantization of angular momentum as $\frac{\hbar}{2}$ can be interpreted as a manifestation of a two-state polarization system in spacetime. Each vacuum oscillator exhibits a binary polarization symmetry, analogous to spin-up and spin-down states in particles. Under this interpretation:

$$S = \frac{\hbar}{2} \tag{5}$$

represents not only the intrinsic spin of particles but also the minimum quantum of angular momentum arising from the polarized, discrete structure of spacetime itself.

This approach treats spin-$\frac{1}{2}$ as a manifestation of polarization symmetry in the vacuum, where each elementary quantum of spacetime, $dx = \frac{1}{2}$, restricts the particle to two possible states within that interval. Thus, spin is a reflection of the underlying polarization structure, with $\frac{\hbar}{2}$ serving as a fundamental unit that scales the angular momentum associated with these discrete intervals of spacetime.

7.3 The g-Factor as a Manifestation of Quantum Polarization States and the discrete nature of spacetime

We have proposed that spin is a manifestation of the vacuum's two intrinsic polarization states, which define the binary degrees of freedom in each vacuum oscillator. This discrete polarization structure is fundamental to the behavior of spin-$\frac{1}{2}$ particles, like the electron, and contributes directly to the magnetic dipole moment (g-factor). The polarization states influence both the spin and the magnetic moment, with the factor of $g = 2$ arising as a natural consequence of the relativistic coupling between the electron and the polarized vacuum. Furthermore, this same vacuum structure underlies the emergence of the elementary charge e, which we will show to be connected to the relativistic energy of the vacuum. Together, these insights reveal that both spin and charge are not isolated particle properties, but unified aspects of the vacuum's polarized and relativistic structure.

The dirac equation and the g-factor in the context of relativistic mechanics

The Dirac equation [26] [27], which governs the relativistic behavior of spin -$\frac{1}{2}$ particles like the electron, is given by:

$$(i\gamma^{\mu}\partial_{\mu} - mc)\psi = 0, \tag{6}$$

where γ^{μ} are the Dirac matrices, ψ is the four-component spinor field representing the electron, m is the rest mass of the electron, and c is the speed of light. This equation accounts for both the relativistic energy of the electron and its intrinsic angular momentum (spin), without the need to introduce spin manually as in non-relativistic quantum mechanics.

To derive the magnetic dipole moment from the Dirac equation, we consider the interaction of the electron with an external electromagnetic field. This is done by replacing the canonical momentum p_{μ} with the gauge-invariant momentum $p_{\mu} - eA_{\mu}$, where A_{μ} is the four-potential of the electromagnetic field. The modified Dirac equation in the presence of an electromagnetic field becomes:

$$(i\gamma^{\mu}(\partial_{\mu} - ieA_{\mu}) - mc)\psi = 0. \tag{7}$$

In the non-relativistic limit (low energies compared to the rest mass energy mc^2), this equation reduces to the Schrödinger-Pauli equation with an additional term that describes the interaction between the electron's spin and the magnetic field $\mathbf{B}$. The relevant interaction term for the magnetic dipole moment is:

$$H_{\text{int}} = -\frac{e}{m}\mathbf{S} \cdot \mathbf{B}, \tag{8}$$

where $\mathbf{S}$ is the spin operator and $\mathbf{B}$ is the magnetic field. From this expression, the magnetic dipole moment μ_s associated with the electron's spin is given by:

$$\mu_s = g\frac{e}{2m}\mathbf{S}, \tag{9}$$

where g is the *g-factor* that describes the proportionality between the magnetic moment and the electron's spin [28].

The Dirac equation predicts that the value of the *g-factor* for a free electron is exactly $g = 2$. This result deviates from the classical expectation (where $g = 1$) due to the relativistic treatment of the electron's spin, which inherently couples the spin to the magnetic field in such a way that the magnetic dipole moment is effectively doubled. Thus, the factor of 2 can be traced back to the relativistic quantum mechanics of spin-$\frac{1}{2}$ particles as described by Dirac's equation, where spin arises not as an intrinsic property of isolated particles, but as a response to the underlying polarized structure of the vacuum.

Within our framework, this factor of 2 reflects a deeper interaction between the electron and the discrete, polarized nature of the vacuum itself. Each vacuum oscillator—modeled as a quantum harmonic oscillator—supports two fundamental polarization states, much like the orthogonal polarization modes in electromagnetic waves. These two polarization states manifest as the degrees of freedom that the electron's spin aligns with, revealing that spin is not just an intrinsic particle property, but an emergent behavior shaped by the polarization symmetry of the vacuum. In this sense, the electron's magnetic dipole moment and the associated g-factor $g = 2$ emerge naturally from its coupling to these polarization states in the vacuum, which define the relativistic structure and quantization of spacetime itself.

Furthermore, we will show at the last part of this Paper how the elementary charge e also arises in connection with the vacuum's polarized structure and relativistic dynamics, and how it can be expressed as:

$$e = 2 \cdot \frac{m_0}{m_0 \cdot c^2 \cdot \gamma},$$

linking e to the relativistic energy of a system with rest mass m_0. This expression implies that charge is not an isolated fundamental quantity but an emergent property associated with the mass-energy dynamics of the vacuum, modulated by relativistic effects. Thus, the factor of 2 found in both the elementary charge and the g-factor reflects a fundamental symmetry in the vacuum, rooted in its two polarization states and the discrete spacetime interval $dx = \frac{1}{2}$. This interpretation unifies the electron's magnetic properties with the relativistic structure of spacetime, presenting spin as a manifestation of the vacuum's intrinsic polarization states.

This unified view provides a coherent interpretation of the g-factor as an expression of vacuum polarization symmetry, wherein observable quantities such as the elementary charge and magnetic dipole moment arise from the interaction between particles and the polarized quantum structure of the vacuum. The factor of 2 is thereby not an arbitrary doubling, but a consequence of the two-state symmetry in vacuum oscillators, which imposes a binary polarization that underlies both spin and charge.

By linking the g-factor to the quantum polarization states intrinsic to the vacuum, we deepen our understanding of how vacuum fluctuations and the discrete structure of spacetime determine fundamental particle properties. This framework also clarifies the ubiquitous appearance of the factor 2 in key thermodynamic and relativistic expressions, suggesting it as a signature of the underlying quantum structure of the vacuum, where polarization states and relativistic energies converge to shape the properties we observe in nature.

With this section, we conclude the general framework of our Paper. In the subsequent sections, we will develop the derivation of relationships between universal constants within the General Framework established.

Part II: Derivation of universal constants within the General Framework

8 Gravity as an emergent phenomenon from vacuum fluctuations

8.1 Derivation of the Gravitational Constant G in terms of ϵ_0

In this subsection, we propose a connection between the gravitational constant G and some effective capacitance leading to the energy required to assemble a sphere of charge with a uniform charge density.

Specifically, we consider G as proportional to the capacitance C, and the energy stored in the system follows the expression for the energy in a capacitor [29]

$$U = \frac{1}{2}CV^2$$

where V is the voltage (potential) produced by the charge. This framework leads to the idea that gravity is an emergent phenomenon related to the energy stored in the system, which in turn we have related with the electromagnetic properties of the vacuum.

Consider the energy U required to assemble a sphere of charge with a uniform charge density, also known as the self-energy of some sphere [30], with elementary charge e and radius R, which can be expressed [30] as

$$U_{sphere} = \frac{3}{5} \cdot \frac{e^2}{4\pi\epsilon_0 r} \tag{10}$$

The energy U in a capacitor is related to its capacitance C and the potential V by:

$$U = \frac{1}{2}CV^2$$

The potential (voltage) V at the surface of the sphere [31] is:

$$V = \frac{1}{4\pi\epsilon_0}\frac{e}{r}$$

We propose that the gravitational constant G can be understood as the effective capacitance of the stored energy within the vacuum, which plays a role in the vacuum's ability to store and distribute energy. Concretely, we can express G in terms of the self-energy U and the potential V as:

$$G \cdot \frac{1}{2} = \frac{U}{V^2}$$

Substituting the expressions for U and V, we have:

$$G \cdot \frac{1}{2} = \frac{3}{5}4\pi\epsilon_0 r$$

Using $r = \frac{1}{2}$, which is reasonable based on the spacetime differential that we have set in Section 5 of the General Framework part, this simplifies to:

$$G = \frac{3}{5}4\pi\epsilon_0 \tag{11}$$

Note that, numerically, with the current accepted value for ϵ_0 [21], we have that

$$\frac{3}{5} \cdot 4\pi\epsilon_0 \approx 6.6759 \times 10^{-11}$$

Which is indeed pretty close to the established value of G [22].

This postulate implies that G is proportional to the permittivity of free space ϵ_0, implying that the gravitational constant is linked to the vacuum's ability to store and distribute energy, much like a capacitance in an electrostatic system.

Gravity as a Rebalancing Force from Vacuum Oscillations

Based on the equation above -and some others that we will derive later-, we postulate that the gravitational force emerges from the vacuum's rebalancing action in response to the energy density difference between matter and antimatter. The oscillatory vacuum acts as a medium that transfers energy through quantum harmonic oscillators, creating spacetime curvature as a natural outcome of maintaining equilibrium. Here, G is proportional to ϵ_0, reflecting the vacuum's capacity for energy exchange and its effect on spacetime deformation.

This view aligns with general relativity's interpretation of gravity as spacetime curvature but provides an underlying mechanism: the vacuum "pulls" matter due to the interactions with the antimatter dimension.

Geometric Implications for R in Our Framework

Using the previous expression for the effective inductance L_{eff}, our postulate can be stated as

$$R^2\epsilon_0 = \frac{3}{5}4\pi\epsilon_0 = G$$

From the above equality, we have that

$$R^2 \cdot \epsilon_0 = \frac{3}{5}4\pi\epsilon_0$$

$$R^2 = \frac{3}{5}4\pi$$

$$R = \sqrt{\frac{3}{5}4\pi}$$

Which, indeed, numerically yields $R \approx 2.745$, a value very close to 2.749. Therefore, assuming that our derivation is correct, R could be associated to the geometric factor $\sqrt{\frac{3}{5}4\pi}$, which acts as a resistance in our analogy.

The geometric factor R The geometric factor $R = \sqrt{\frac{3}{5} \cdot 4\pi} \approx 2.745$ arises naturally from the spherical geometry of a uniformly charged sphere, specifically in the expression for the energy required to assemble such a sphere with a uniform charge density. This factor reflects the spatial symmetry and energy distribution inherent to spherical systems, capturing how energy is stored and distributed in a spherically symmetric configuration.

In our framework, R represents more than a simple geometric factor; it serves as an effective resistance within the vacuum's oscillatory system. Analogous to resistance in an RLC circuit, R dictates the rate and efficiency of energy exchange between matter and antimatter components mediated through quantum harmonic oscillators. This "resistive" quality is not one of energy dissipation per se, but rather a structural constraint on how oscillations propagate across the vacuum. The spatial configuration defined by R thus impacts the system's capacity for sustaining energy oscillations, which we interpret sometimes as gravitational effects.

This interpretation of R as a "geometric resistance" implies that the vacuum has an inherent structure influencing energy transfer. By defining a spatial configuration that regulates the interaction potential of the vacuum, R shapes the gravitational interactions observed at macroscopic scales, linking the spherical symmetry of vacuum energy to the emergent properties of spacetime curvature.

Conclusion

In this framework, the gravitational constant G acts as a measure of the vacuum's efficiency in facilitating energy exchanges between matter and antimatter through oscillations, similar to a potential difference or voltage in an electrical circuit. This analogy provides insight into gravity as an emergent phenomenon driven by vacuum oscillations that establish spacetime curvature as a response to energy exchanges.

8.2 Interpretation of the Effective Current $I_{\text{eff}} = \frac{e \cdot c}{2} = RC$ as a Fundamental Timescale

We have previously derived in the General Framework part that, within our framework,

$$I_{\text{eff}} = \frac{1}{2} \cdot Q_0 \cdot \omega_0 = \frac{e \cdot c}{2}$$

Note that, from the relationship $G = \frac{e \cdot c}{2} \cdot \sqrt{\frac{3}{5} 4\pi}$ and the derived relationship $G = \frac{3}{5} 4\pi\epsilon_0$, we get that

$$\frac{e \cdot c}{2} = \frac{G}{\sqrt{\frac{3}{5} 4\pi}} = \epsilon_0 \cdot \sqrt{\frac{3}{5} 4\pi}.$$

This relation provides insight into the oscillatory dynamics of the vacuum by equating the effective current $I_{\text{eff}} = \frac{e \cdot c}{2}$ to the product RC, where R and C denote the resistance and capacitance in a hypothetical series RLC circuit that models vacuum oscillations.

Characteristic Time Constant and Oscillatory Systems

The product RC in an electrical circuit represents a characteristic time constant for the system. In a simple RC circuit, this time constant, $\tau = RC$, determines how quickly the circuit responds to changes. Specifically, it describes the time required for the voltage across the capacitor to reach approximately 63% of its final value after a step change. In the context of an oscillatory system, this time constant reflects the natural rate at which energy is transferred or dissipated within the system. When we apply this analogy to our vacuum model, RC becomes the fundamental timescale that defines the response speed of the vacuum's oscillations between electric and magnetic energy states.

Dimensional Analysis of RC as Time

The product RC has the dimension of time:

$$[RC] = [\Omega] \times [F] = \frac{\text{kg} \cdot \text{m}^2}{\text{C}^2 \cdot \text{s}} \times \frac{\text{s}^2 \cdot \text{C}^2}{\text{kg} \cdot \text{m}^2} = [\text{s}],$$

confirming that RC indeed represents a time constant. Thus, interpreting $\frac{e \cdot c}{2} = RC$ implies that the effective current I_{eff} can be understood in terms of a fundamental timescale associated with the vacuum's oscillatory dynamics.

Effective Current as a Fundamental Timescale in the Vacuum Model

In the context of the paper's RLC vacuum model, the equation $I_{\text{eff}} = \frac{e \cdot c}{2} = RC$ signifies that this effective current represents the intrinsic rate at which energy shifts between electric and magnetic forms in the vacuum. As an effective current amplitude, I_{eff} embodies the steady-state oscillatory current needed to maintain resonance within the vacuum's harmonic system, thereby providing a stable energy exchange mechanism.

This characteristic timescale RC or $\frac{e \cdot c}{2}$ logically aligns with the vacuum model because it sets a natural cadence for vacuum oscillations, constrained by fundamental constants e, c, R, and C. The constant c, typically seen as a velocity limit, in this context becomes a limiting current amplitude essential to sustaining the oscillations that propagate energy within spacetime. This interpretation implies that c not only governs the maximum signal speed but also serves as a baseline for the effective current amplitude in a relativistic framework.

Furthermore, by interpreting I_{eff} as the oscillatory rate at which vacuum states exchange energy, we recognize this characteristic time as fundamental. It encapsulates the response speed intrinsic to the vacuum's structure, controlled by the interplay of electric and magnetic states. Hence, I_{eff} establishes a natural fundamental timescale that dictates how the vacuum responds to and sustains oscillations under relativistic constraints, grounding it within the framework of harmonic oscillators in vacuum.

The maximum current I_{max}

From the above, we have a good hint on which could be I_{max}. Recall (from Section 2) that velocity in a traslational mechanical system is analogous to the current in some series RLC circuit. Then, in the context of a universe expanding at relativistic velocities, it makes sense to postulate that

$$I_{max} = c$$

As we have mentioned, the postulate is grounded in the analogy between the current in an RLC circuit and velocity in a translational mechanical system. In the context of a universe expanding at relativistic velocities, the speed of light c represents the limiting speed for any physical process. Since the current I in an RLC circuit is analogous to velocity, it is reasonable to assume that the maximum current in the system must correspond to the universal constant c. This interpretation aligns with the relativistic framework, where c not only sets the upper limit for velocity but also plays a foundational role in defining spacetime intervals and interactions in the vacuum oscillatory system.

Furthermore, from a physical standpoint, assigning c as the maximum current ensures that the vacuum's electromagnetic properties remain consistent with the dynamics of the universe. In a vacuum-based model where spacetime and energy emerge from oscillatory behavior, c as the maximum current naturally reflects the inherent limit on how fast oscillations can evolve while propagating. This maximal current corresponds to the fundamental timescale associated with vacuum fluctuations, linking it to both the speed of light and the dynamics of the vacuum's expansion. Therefore, the postulate preserves the coherence of the system's behavior at relativistic scales and supports the idea that vacuum oscillations are inherently bound by the universal constant c.

Conclusion

Therefore, we have seen that the effective current $I_{\text{eff}} = \frac{e \cdot c}{2}$ serves as a fundamental rate for the vacuum's oscillatory behavior, analogous to a limiting "velocity" in spacetime dynamics. In this model, c represents the minimal current amplitude that maintains stable oscillations within the vacuum, while the product RC functions as the characteristic time constant of the system, dictating the natural period of these oscillations. By equating I_{eff} to RC, the model connects the time constant of an RLC circuit with the vacuum's inherent oscillatory timescale, tying both the damping effects (associated with R) and energy storage capacity (associated with C) directly to the vacuum's properties. This results in a balanced oscillation rate that maintains a consistent distribution between electric and magnetic energy components.

The interpretation of $I_{\text{eff}} = \frac{e \cdot c}{2} = RC$ thus implies that the oscillatory nature of the vacuum is intrinsically linked to fundamental constants. This effective current, I_{eff}, emerges as a unifying factor governing interactions within the vacuum, suggesting that constants like e and c are rooted in the vacuum's oscillatory structure. Altogether, this model supports a view of spacetime as an oscillatory medium where universal constants arise from underlying harmonic behavior, reinforcing the stability and relativistic coherence of spacetime.

8.3 The double nature of G as a voltage and a force

As numerically makes sense, we can postulate that

$$G = I_{eff} \cdot R$$

Substituting, we get that

$$G = \frac{1}{2} \cdot e \cdot c \cdot \sqrt{\frac{3}{5} 4\pi}$$

And the above simplifies to

$$G = e \cdot c \cdot \sqrt{\frac{3}{5}\pi} \tag{12}$$

Note that, from Ohm's Law [32], we have that $V = I \cdot R$. As a result, we get that G can be assigned dimensions $[G] = [V]$.

However, we could have used I_{max}, to obtain that

$$G = \frac{1}{2} \cdot Q_0 \cdot I_{max} \cdot R$$

As we have established that $\frac{1}{2}$ can be related to some fundamental length quantization, and $[Q_0 \cdot I_{max} \cdot R] = [Q_0 \cdot V] = [E]$, we get that $[G] = [\frac{[E]]}{[L]} = [F]$.

The analogy between voltage in an RLC circuit and force in a mechanical translational oscillator plays a key role in unifying the behaviors of electric and mechanical oscillators. Specifically, modelling the vacuum as a resonant system of harmonic oscillators, akin to an RLC circuit, implies that electromagnetic parameters such as voltage V and current I are mirrored by mechanical parameters like force F and velocity v. This analogy is consistent with the obtained result that the gravitational constant G, when derived through vacuum properties, could exhibit dimensions analogous to both voltage and force, thus connecting the two oscillatory systems. Given that G is derived from intrinsic properties of the vacuum as described by the oscillatory model, it is consistent with its interpretation as a force-driving parameter in a mechanical context and as a voltage-driving parameter in an RLC-like circuit.

The dimensional duality of G supports the idea that the vacuum's oscillations and interactions can be understood as an interdependent electric-mechanical system. For example, in the RLC model, voltage V can be interpreted as the energy per unit charge, while in the mechanical system, force F can be interpreted as the energy per unit displacement. This dimensional equivalence allows the gravitational constant G to bridge these two interpretations, representing both the strength of the vacuum's oscillatory force and the driving potential (voltage) behind the oscillatory charge displacement. In both cases, G functions as a measure of interaction strength, dictating the rate at which energy is exchanged within the system's oscillations.

Therefore, by interpreting the vacuum as a system of harmonic oscillators, we can leverage this electric-mechanical analogy to explore a consistent, unified model where constants like G emerge naturally from the system's intrinsic oscillatory properties.The duality of G as both a voltage and force constant reinforces its fundamental role in the vacuum's structure, supporting the notion that gravitational forces and electromagnetic potentials are intrinsically linked within a unified oscillatory framework.

Interpreting the gravitational constant G as a force

The result that the gravitational constant G has dimensions of force, $[G] = [F]$, can be understood as a natural consequence of the framework developed in this paper, where vacuum oscillations and electromagnetic phenomena are closely linked to gravitational interactions. This dimensional interpretation reflects the idea that gravity, as an emergent phenomenon, arises directly from the dynamics of vacuum fluctuations that induces spacetime deformation, whose effects can be interpreted as a force. Additionally, by expressing G as a product of fundamental quantities, such as charge e, the speed of light c, and the geometric factor $\sqrt{\frac{3}{5}\pi}$, we connect gravitational interactions directly to the electromagnetic properties of the vacuum.

This result also highlights the idea that gravitational force, within this framework, is not a separate fundamental interaction but rather an emergent effect caused by the vacuum's electromagnetic structure. The appearance of the factor $e \cdot c$ further strengthens this connection. As G is proportional to the fundamental quantities associated with the vacuum, it suggests that gravitational forces are a manifestation of the vacuum's capacity to store and transfer energy, much like forces in classical electromagnetism. Therefore, assigning G dimensions of force fits naturally within the unified treatment of electromagnetism and gravity.

In the context of general relativity, this result offers a fresh perspective on how spacetime curvature is related to vacuum fluctuations. Traditionally, general relativity describes gravity as the curvature of spacetime in response to the energy-momentum tensor, with G governing the strength of this interaction. This is aligned with interpreting G as a force within the vacuum, where we can view spacetime curvature as an emergent property resulting from the vacuum's oscillatory dynamics. The vacuum itself, through its fluctuations and oscillations, exerts a force that deforms spacetime, leading to the observed gravitational effects. This perspective aligns with the broader idea that gravity emerges from more fundamental interactions within the vacuum, potentially offering new insights into the relationship between quantum mechanics and general relativity.

Finally, in this framework, gravity can be interpreted as analogous to the Casimir effect, where forces arise due to fluctuations in the quantum vacuum. The Casimir effect occurs when quantum vacuum fluctuations between two conducting plates create an attractive force due to the restriction of electromagnetic modes. Similarly, gravity can be viewed as a manifestation of vacuum fluctuations, where the presence of mass alters the local vacuum state, leading to an effective force analogous to the Casimir force. This analogy offers a compelling bridge between quantum field theory and gravity, reinforcing the idea that gravity, like the Casimir effect, originates from the underlying structure of the quantum vacuum.

8.4 Relationship between the Gravitational Constant G and the Speed of Light c through the Natural Inductive Reactance X_N

In an RLC circuit, the inductive reactance X_L [33] is defined as the opposition that an inductor presents to changes in current, given by:

$$X_L = \omega_0 \cdot L,$$

where ω_0 is the angular frequency and L is the inductance. Since G has dimensions comparable to inductance, we explore whether an analogy can be established between G and an effective inductive reactance in the vacuum at the natural frequency.

It can be verified numerically that:

$$G \approx \frac{1}{16\pi \cdot c},$$

which suggests a dimensional relationship between G, c, and an inductive reactance $X_L = \frac{1}{16\pi}$. This expression invites an exploration of whether this relationship is coincidental or if it suggests a physical basis. Assuming G has dimensions of inductance and $c = \omega_0$, we find that the proportionality constant $\frac{1}{16\pi}$ could serve as an effective inductive reactance X_N in our vacuum model.

Equating the expressions derived for G earlier, we find:

$$\frac{3}{5}4\pi\epsilon_0 \sim \frac{1}{16\pi \cdot c}.$$

This relationship leads us to:

$$\frac{3}{5}4\pi \cdot 16\pi \approx \sqrt{\frac{\mu_0}{\epsilon_0}} = Z_0,$$

where Z_0 is the impedance of free space, suggesting that G and c are linked through a vacuum-based reactance concept.

Finally, it can also be verified that

$$\sqrt{\frac{3}{5}4\pi} \cdot 16\pi \approx \frac{1}{\alpha} = Q$$

Defining a Natural Inductive Reactance X_N

Based on the above derivations, we define a constant X_N as a natural inductive reactance at the resonance frequency, such that:

$$X_N = R \cdot \alpha = R^2 \sqrt{\frac{\epsilon_0}{\mu_0}}.$$

This reactance X_N arises as a geometrical factor that quantifies the vacuum's opposition to changes in the energy flow of electromagnetic waves, analogous to how inductive reactance operates in a circuit. It suggests that the vacuum behaves similarly to an inductor, resisting changes in electromagnetic energy flow by storing it in a magnetic field. The magnitude of this inductive reactance is related to the fundamental constants G and c, linking gravitational and electromagnetic properties within the vacuum.

Thus, we postulate that:

$$G = \frac{X_N}{\omega_0}. \tag{13}$$

Numerically, substituting our previous values, we find:

$$X_N = \sqrt{\frac{3}{5} 4\pi} \cdot \alpha \approx \frac{1}{50} \sim \frac{1}{16\pi}.$$

Therefore, the expression has been numerically and dimensionally verified to be consistent. The approximation is more accurate when using alternative constants in place of 16π, but we adopt $X_N = \frac{1}{16\pi}$ due to its theoretical relevance, and the ulterior developments throughout other sections that will show that it is a reasonable value for X_N. With this postulate, we can state that:

$$c = \frac{1}{16\pi G}.$$

Interestingly, this relationship matches the prefactor in the Einstein-Hilbert action:

$$S = \frac{c^4}{16\pi G} \int R\sqrt{-g}\, \mathrm{d}^4 x.$$

This prefactor, $\frac{c^4}{16\pi G}$, is essential in recovering Newton's theory of gravity from general relativity in the non-relativistic limit and aligns with our cosmological framework. This suggests that the inductive reactance X_N not only has theoretical significance in our model but also fits into the broader context of gravitational theory.

8.5 Gravity as an Emergent Phenomenon from Vacuum Fluctuations

In this subsection, we explore *gravity* as an emergent phenomenon that arises from vacuum energy fluctuations. Within the framework of the vacuum modeled as a system of harmonic oscillators, we show that the balance between the electric and magnetic energy densities of the vacuum is deeply related to the gravitational constant G.

We define a new constant J as the equilibrium energy density of the vacuum, representing the point where the electric and magnetic energies of vacuum fluctuations are balanced. This constant is defined by:

$$J = \frac{E_{\text{vac}}}{2} = \frac{\rho_{\text{vac}}}{4} = \frac{1}{2}\frac{e^2}{\epsilon_0} = \frac{1}{2}\mu_0 (e \cdot c)^2.$$

Thus, J represents a balanced energy density where the partition between electric and magnetic contributions in vacuum oscillations is equal.

Linking J to the Gravitational Constant G

Next, we explore the connection between J and G in terms of the vacuum's total energy density. Using the previously established relationship $c = \frac{1}{16\pi G}$, we derive:

$$J \cdot c = \frac{\rho_{\text{vac}}}{4 \cdot c^2} \cdot c = \frac{\rho_{\text{vac}}}{4 \cdot c} = \frac{16\pi G \rho_{\text{vac}}}{4} = 4\pi G \rho_{\text{vac}}.$$

Here, ρ_{vac} is the vacuum energy density, measured in J/m^3, describing the energy per unit volume of the vacuum. This expression just stays that vacuum's gravitational flux, as defined by Gauss's law for gravity, is related to vacuum energy density -as it could be expected-, thereby defining the strength of gravity through its contribution to the overall vacuum energy balance.

Interpreting G as an Integral over vacuum's gravitational flux

We can now express G with the integral:

$$G = J \int c \, dc = \int 4\pi G \rho_{\text{vac}} \, dc,$$

indicating that *gravity* can be interpreted as an integral of the vacuum's gravitational flux, following Gauss's law applied to vacuum energy density across all frequency modes. Evaluating this integral, we derive G in terms of the balanced energy density J, combined with the speed of light c, as follows:

$$G = \frac{1}{2} J \cdot c^2 = \frac{1}{4} \frac{I^2}{\epsilon_0} = \frac{1}{4} \mu_0 \cdot c^2 \cdot I^2.$$

In natural units where $c = 1$, space and time are treated symmetrically -as it happens within our framework-, allowing integrals like $\int c \, dc$ to represent contributions from vacuum fluctuations over time. This perspective positions c not only as the speed of light but as a fundamental measure of time intervals.

Emergence of Gravity through Vacuum Fluctuations

With this framework, the integral $\int 4\pi G \rho_{\text{vac}} \, dc = G$ describes how the relativistic vacuum energy drives spacetime curvature, resulting in emergent gravitational phenomena. The term $4\pi G \rho_{\text{vac}}$ reflects the vacuum fluctuation contributions to the gravitational field, with c representing the time evolution and relativistic constraints on these effects.

Thus, as vacuum energy density arises from quantum harmonic oscillations, gravity can be linked to the fundamental interplay of vacuum fluctuations, with G capturing the effective field that emerges from the structured energy density in the vacuum.

8.6 Consequences of G as an Emergent Effect and the Interpretation of Gravity

Traditionally, Newton's law of gravitation is expressed as:

$$F = G \frac{m_1 m_2}{r^2},$$

where F is the gravitational force between two masses m_1 and m_2, G is the gravitational constant, and r is the distance between them. In this classical framework, G has units $[G] = \frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}$, and represents the proportionality constant that governs the strength of gravitational interaction.

In our framework, gravity is not viewed as a fundamental force but as an emergent phenomenon due to spacetime deformation, akin as it postulates general relativity theory. But in this Paper, in addition to performing checks which validate general relativity theory, we propose the concrete quantum mechanism that our derivations suggest as the driver of gravitational force as a spacetime deformation.

8.6.1 Gravity as an Emergent Effect of Spacetime Deformation from Quantum Energy Exchange

We analyze it in the final part of this Paper, but we propose that this spacetime deformation arises from the energy exchange between our universe and an antimatter counterpart universe through quantum harmonic oscillators, mediated by Quantum "black" holes. These Quantum "black" holes are not traditional black holes but rather microscale "bridges" between our universe and an antimatter universe, emerging from the quantization of spacetime itself. This quantization causes the "distance" between matter and antimatter universes to become finer at quantum scales, much like the holes in a mesh, creating points of energy exchange that produce the spacetime deformation yielding an effect that we interpret as gravity.

In this framework, each Quantum "black" hole behaves as a localized region where the energy states of our universe and the antimatter universe overlap, allowing for the transfer of energy through quantum harmonic oscillations. This energy exchange deforms spacetime locally, creating a gradient in spacetime curvature. The quantity of matter increases the intensity of matter-antimatter interactions within these Quantum "black" holes, leading to a stronger gravitational effect as more energy is transferred across the spacetime boundary.

The gravitational constant G represents the scale of this interaction. It quantifies the effective "stiffness" of spacetime in response to these oscillatory exchanges between universes. Thus, the gravitational force between two masses m_1 and m_2 does not arise from a direct attractive interaction, but from the collective deformation of spacetime resulting from the oscillatory energy exchanges occurring through the network of Quantum "black" holes.

Within this interpretation, the term $\frac{m_1 m_2}{r^2}$ in Newton's law becomes a geometrical factor that describes the spatial configuration of masses, which modulates the distribution and intensity of Quantum "black" hole interactions between them. Each mass, rather than being a source of gravitational force, acts as a spatial concentration of energy that enhances the rate of quantum energy exchange across the boundary with the antimatter universe. Consequently, gravity is an emergent property of the spacetime deformations generated by these interactions.

8.6.2 Linking Gravity to Vacuum Oscillations and the Quantum "black" hole Network

The oscillatory energy exchanges between our universe and the antimatter universe create a persistent network of micro-wormholes or "Quantum "black" holes" through which vacuum energy fluctuations propagate. As matter accumulates in specific regions, the density of these oscillatory exchanges increases, leading to a localized curvature in spacetime. This deformation is interpreted as gravitational attraction, as regions of higher matter concentration result in a denser network of Quantum "black" hole interactions and thus stronger spacetime curvature.

In this sense, gravity is analogous to a *Casimir-like effect*, where the vacuum energy fluctuations between the matter and antimatter universes generate an effective force. The gravitational constant G, therefore, is not a standalone force constant but an emergent property that quantifies the strength of spacetime curvature induced by the Quantum "black" hole network. The effective gravitational force felt between two masses is the result of spacetime deformation due to oscillatory vacuum energy exchanges across this network.

In summary, gravity emerges as a *macroscopic manifestation* of the quantum harmonic oscillations between our universe and an antimatter universe. The masses m_1 and m_2, positioned within this network, induce localized spacetime deformation through Quantum "black" hole interactions. The gravitational constant G defines the scale of this deformation, with the term $\frac{m_1 m_2}{r^2}$ serving as a dimensionless geometrical factor. This interpretation provides a unified view of gravity as a consequence of spacetime's intrinsic quantum structure, linking the dynamics of vacuum energy oscillations with the macroscopic phenomenon of gravity.

9 Derivation of the elementary charge e

9.1 Derivation of the elementary charge e and its relationship with the fine-structure constant α

For some series RLC circuit, we have that

$$Q = \frac{\omega_0 L}{R}$$

Substituting, we have that

$$\alpha = \frac{1}{Q} = \frac{R}{\omega_0 L} = \frac{\sqrt{\frac{3}{5}4\pi}}{c \cdot \mu_0}$$

Other hand, as $\epsilon_0 = \frac{1}{c^2 \cdot \mu_0}$ and we have established that $G = \frac{3}{5}4\pi\epsilon_0$, we can substitute to have that

$$G = \frac{3}{5}4\pi\frac{1}{c^2 \cdot \mu_0}$$

From the derived expressions, we have that

$$e \cdot c \cdot \sqrt{\frac{3}{5}\pi} = \frac{3}{5}4\pi\frac{1}{c^2 \cdot \mu_0}$$

Operating, we have that

$$e \cdot c^2 = \frac{2\sqrt{\frac{3}{5}4\pi}}{c \cdot \mu_0} = 2\alpha$$

Which can be re-expressed as

$$\alpha = \frac{1}{2}e \cdot c^2 \tag{14}$$

As as result, from the above relationships, solving for e, there can be derived two interesting expressions:

$$e = \frac{G}{c\sqrt{\frac{3}{5}\pi}}$$

$$e = \frac{2\alpha}{c^2}$$

9.2 An Interpretation of the Identity $\alpha = \frac{1}{2}e \cdot c^2$

Note that:

$$\frac{1}{2}e \cdot c^2 = e\int c\,dc = \int I_{\max}\,dc = \frac{1}{Q} = \alpha.$$

In the context of a universe expanding at relativistic velocities, it is natural to consider $dc = dt$, with the speed of light c serving as the differential of time. In electromagnetism, the integral of current over time, $\int I\,dt$, yields a total charge. Here, interpreting $\int I_{\max}\,dc$ analogously suggests that the fine-structure constant α can be viewed as an effective "charge," where $I_{\max} = e \cdot c$ represents the maximum current associated with the vacuum oscillations.

Crucially, and as we have stated in the last section of the General Framework part, $\int c\,dc$ here serves as a transformative operator within spacetime, acting to convert potential forms of spacetime (such as charge e, mass m, or energy) into kinetic or dynamic expressions. For instance, in the case of charge, $\alpha = e\int c\,dc$ reflects the transformation of the elementary charge e into a kinetic form that accumulates through oscillatory modes, yielding an effective "kinetic charge" that dynamically interacts with the electromagnetic field. This approach aligns with the interpretation of α as an emergent property capturing the cumulative effects of vacuum oscillations.

The integral $\int I_{max}\,dc$ represents the cumulative distribution of current across a spectrum of vacuum oscillations, yielding the reciprocal of the quality factor Q. The quality factor Q describes the sharpness of resonance as a measure of the ratio between the stored potential energy and the kinetic energy dissipated within the vacuum oscillators. In this sense, α represents the total effect of the oscillatory energy distribution within the vacuum, emerging from the contributions of all possible electromagnetic modes.

Moreover, in the third part of this paper, we will interpret α as the reciprocal of the Lorentz factor. This suggests an additional interpretation: α functions as a "scaling factor" that modulates the contributions from each vacuum oscillator within a relativistic framework. By integrating over the oscillatory contributions and maintaining relativistic consistency, α emerges as both an effective "kinetic charge" and a relativistic scaling factor, reflecting the cumulative impact of vacuum energy oscillations.

Therefore, the fine-structure constant α embodies the contributions of all vacuum oscillation modes within the electromagnetic field, integrating both temporal accumulation (as a charge) and relativistic scaling effects.

10 Derivation of the value of Planck's constant h

10.1 Expressing Planck's Constant h in Terms of Vacuum's permittivity ϵ_0

As numerically and theoretically makes sense in further sections, let us postulate that Planck's constant h can be expressed as a function of the vacuum permittivity ϵ_0 as follows:

$$h = \epsilon_0^3 \tag{15}$$

This expression corresponds essentially to a three dimensional expansion of the vacuum permittivity ϵ_0.

The postulated equivalence uncovers a deep connection between the fundamental constants of nature and the geometry of space. The interpretation is that the vacuum permittivity ϵ_0, which measures the ability of the vacuum to permit electric field lines, is linked to the quantum of action h through a volumetric consideration.

This interpretation aligns with the analogy between electrical capacitance and mechanical stiffness in the context of a harmonic oscillator. In an RLC circuit, the inverse of the capacitance $\frac{1}{C}$ is analogous to the stiffness k of a mechanical spring in a harmonic oscillator. Just as the stiffness defines the potential energy stored in a spring, ϵ_0 could define a form of "flexibility" or lack of resistance of the vacuum to changes in its electric field; and more profoundly, quantify the "flexibility" or lack of resistance of spacetime to deformation.

10.2 The Relationship between Planck's Constant and Momentum

This subsection explores how the reduced Planck constant $\hbar$ serves as the fundamental quantum of angular momentum, with implications for understanding both rotational and translational dynamics at the quantum level. In this context, $\hbar$ and h are differentiated as representing angular and linear momentum, respectively. Furthermore, we interpret the zero-point energy E_0 as both an intrinsic kinetic energy and a contributor to spacetime curvature through interactions between our universe and an antimatter counterpart.

$\hbar$ as a Quantum of Angular Momentum The reduced Planck constant $\hbar$ is essential to the quantization of angular momentum in quantum mechanics. The angular momentum L of a system is quantized in discrete units of $\hbar$:

$$L = n\hbar, \quad n = 0, 1, 2, \dots$$

This quantization emerges from the requirement that a particle's wavefunction in a rotationally symmetric potential must be single-valued and continuous. As a result, $\hbar$ sets the minimal angular momentum that can be added or removed in quantum systems, establishing a fundamental unit for rotational dynamics [34]. In this way, $\hbar$ acts as the quantum of angular momentum, governing rotational motion and systems with cyclic or periodic potentials, such as harmonic oscillators.

h and its Relation to Linear Momentum

In contrast to $\hbar$, Planck's constant h can be interpreted as related to linear momentum, particularly through the de Broglie relation:

$$p = \frac{h}{\lambda},$$

where p represents linear momentum, and λ is the wavelength associated with the particle. This expression highlights the wave-particle duality in quantum mechanics, connecting a particle's momentum to its wave properties [35]. Here, h appears in the context of translational motion, aligning more directly with linear momentum than with angular momentum.

For photons and other massless particles, linear momentum relates directly to energy through:

$$E = pc,$$

where c is the speed of light. Substituting $p = h/\lambda$ yields:

$$E = \hbar\omega,$$

where $\omega = ck$ is the angular frequency. This links $\hbar$ directly to the oscillatory behavior of particles, while h applies to linear motion, differentiating the two constants based on the nature of the motion they describe.

Zero-Point Energy E_0 and Its Role in Vacuum Oscillations

The zero-point energy E_0 of a quantum harmonic oscillator, given by

$$E_0 = \frac{1}{2}\hbar\omega,$$

represents the irreducible energy present in the system due to quantum fluctuations, even at absolute zero temperature [36]. This energy arises from the Heisenberg uncertainty principle, which states that position and momentum cannot both be precisely determined. Thus, E_0 embodies the kinetic-like energy of the vacuum's oscillatory modes, manifesting as continuous fluctuations even in the absence of external excitation [37].

In the broader framework of this paper, E_0 has a dual role. First, it represents a kinetic component of vacuum energy associated with intrinsic oscillations, aligning with phenomena like the Casimir effect. Second, E_0 contributes to spacetime curvature when viewed as the quantum of the energy exchanged between our universe and an antimatter universe. This energy exchange generates a spacetime deformation that we perceive as gravitational force, where the oscillatory vacuum modes between universes act as quantum harmonic oscillators mediating this interaction.

In this context, E_0 is identified with the kinetic aspect of vacuum energy, corresponding to observable fluctuations. This kinetic energy contributes to the dynamic properties of the vacuum. However, E_0 also plays a fundamental role as an effective force that influences spacetime structure, particularly within the interaction between matter and antimatter universes. This interaction results in spacetime deformation, which we interpret as gravitational force. As a result, E_0 is not strictly energy in the classical sense, but an effect that mobilizes the vacuum into dynamic deformation.

Zero-Point Energy E_0 as a Driver of Spacetime Curvature

The kinetic-like nature of E_0 aligns it with the dynamic properties of the quantum vacuum, arising from intrinsic uncertainties in position and momentum. This energy induces oscillatory behavior in the vacuum, where particle-antiparticle pairs and quantum fields fluctuate continuously.

In our framework, E_0 contributes to spacetime curvature by acting as a mediator of energy exchange between our universe and an antimatter counterpart. This exchange of vacuum energy through quantum harmonic oscillators at a microscopic level produces a cumulative effect that deforms spacetime, resulting in gravitational phenomena. Thus, rather than being merely kinetic, E_0 serves as a driver of gravitational curvature by setting a dynamic equilibrium in the vacuum's structure.

In the context of general relativity, energy density, including E_0, curves spacetime, and if E_0 pervades the vacuum, it represents an intrinsic curvature source. This aligns zero-point energy with the cosmological constant, suggesting that E_0 induces gravitational effects on a cosmological scale by continuously influencing spacetime geometry.

Summary

Both interpretations of zero-point energy, as kinetic energy and as a driver of spacetime curvature, are integral to understanding the universe. While E_0 manifests as a kinetic component at the quantum level, contributing to quantum fluctuations, its role as a source of spacetime deformation positions it as a force in cosmology. This dual nature provides a bridge between quantum mechanics, where zero-point energy drives microscopic oscillations, and general relativity, where E_0 acts as an underlying force shaping the large-scale structure of spacetime.

10.3 More derivations of Planck's constant h and its relationship with other universal constants

From the fine-structure constant formula, and substituting with the results obtained in previous subsections, we have that

$$h = \frac{e^2}{2\varepsilon_0 \alpha c} = \frac{\frac{3}{5} \cdot 16\pi \cdot \epsilon_0^3 \mu_0}{2\varepsilon_0 \alpha c} = \frac{4 \cdot \frac{3}{5} \cdot 4\pi\epsilon_0 \cdot \epsilon_0 \mu_0}{2\alpha c} = \frac{2G}{\alpha \cdot c^3}$$

Just reordering, we get then that

$$h \cdot c = \frac{2G}{\alpha \cdot c^2} = Q \cdot \frac{2G}{c^2} \tag{16}$$

Where, as Q and c^2 are dimensionless, the equation shows that $2G$ and $h \cdot c$ are related in a way similar to mass and energy in Einstein's equation $E = m \cdot c^2$, with an additional factor (the quality factor of the system). Indeed, the above can be reexpressed as

$$\frac{G}{\alpha} = \mu_0 \cdot \alpha = h \cdot c \int c \, dc$$

This expression, as α is dimensionless, implies that $[G] = [\mu_0] = [\frac{h \cdot c}{2}]$. It is specially insightful, as it relates many universal constants. The right side of the equation, $h \cdot c \int c \, dc$, represents the transformation of a photon's intrinsic energy ($h \cdot c$) into an expression of dynamic energy that influences spacetime indirectly by contributing to electromagnetic flux and gravitational effects. The term $h \cdot c$ highlights the photon's role as a quantum of potential energy. In our framework, photons carry a "potential" nature in that they are the source of electromagnetic interactions, influencing fields and forces in spacetime. The operator $\int c \, dc$ translates the photon's static potential (electromagnetic source) into a more kinetic form, as electromagnetic flux or gravitational effects.

Substituting $\frac{1}{\alpha} = \sqrt{\frac{\mu_0}{G}}$ and expressing in terms of ϵ_0 and μ_0, we have that

$$h = \frac{2G}{\alpha \cdot c^3} = \frac{2G}{c^3} \cdot \sqrt{\frac{\mu_0}{G}} = \frac{2\sqrt{G} \cdot \sqrt{\mu_0}}{c^3} = \frac{2\sqrt{\frac{3}{5} \cdot 4\pi \cdot \epsilon_0} \cdot \sqrt{\mu_0}}{c^3} = \frac{2\sqrt{\frac{3}{5} 4\pi}}{c^4}$$

Note that, from Einstein's equation $E = M \cdot c^2$, we have that $c^4 = \left(\frac{E}{M}\right)^2$, so we can set that

$$h = \frac{2\sqrt{\frac{3}{5} 4\pi}}{c^4} = \frac{2\sqrt{\frac{3}{5} 4\pi} \cdot M^2}{E^2}$$

Note that all the right hand side becomes dimensionless excepting $[2] = [T]$, which is the term that gives dimensionality to $[h]$.

Another crucial derivation of h is as follows:

$$h = \frac{e^2}{2\varepsilon_0 \alpha c} = e^2 \cdot \frac{1}{2\alpha} \cdot \frac{1}{\varepsilon_0 c} = e^2 \cdot \frac{1}{2\alpha} \cdot Z_0$$

Which, through the relationship $\frac{1}{2\alpha} = \frac{1}{e \cdot c^2}$, can be restated as

$$h = e^2 \cdot \frac{1}{e \cdot c^2} \cdot Z_0 = \frac{e}{c^2} Z_0$$

As we have that $Z_0 = c \cdot \mu_0$, we can substitute to obtain that

$$h = \frac{e \cdot \mu_0}{c} \tag{17}$$

The proposed relationship establishes a deep connection between four fundamental constants that we will discuss in the next subsection.

10.4 Discussion: the fundamental relationship $h \cdot c = e \cdot \mu_0$ and its implications

Interpreting $h \cdot c$ as the quantum of electric potential energy and mass-energy Envision the vacuum as a single-turn "coil", a single, enormous loop representing spacetime itself. Each quantum field contributes to this loop's flux, with the zero-point energy of each field's lowest mode acting as the source of fluctuations that generate the flux. In this analogy, the vacuum is filled with a single fluctuating electromagnetic field associated with a quantized magnetic flux.

If the inductance L is constant, then the voltage through the coil is given by

$$V = L \cdot \frac{dI}{dt}$$

Substituting $L = \mu_0$ and $I = c$, if we consider c as the measure of time, we have that

$$V = \mu_0 \cdot \frac{dc}{dc} = \mu_0$$

Then we get that, within our framework, μ_0 has the dimension of voltage (at the same time as dimension of inductance). This is consistent with G having also both dimensions, as we already postulated before; recall that we have that $\alpha = \sqrt{\frac{G}{\mu_0}}$, and thus we have that $G = \mu_0 \cdot \alpha^2$. As α is dimensionless, both μ_0 and G are dimensionally equivalent.

Other hand, the electric potential energy of some charge Q in an electric field E is given by

$$U = Q \cdot V$$

Where V is the electric potential (voltage). Thus, as we have that $h \cdot c = \mu_0 \cdot e = V \cdot Q$, we have that $h \cdot c = \mu_0 \cdot e$ could be associated to the quantum of electric potential energy within our framework.

Therefore, and bridging the previous subsection, $h \cdot c$ represents the quantum of electric potential energy, directly connecting the intrinsic energy of a photon to its role as a source of electromagnetic interactions. This potential energy, when expressed through the relationship $h \cdot c = e \cdot \mu_0$, becomes linked to a kinetic energy form via the integral $\int c\, dc$, which we interpret as a transformational operator that converts potential energy forms—like charge e or mass-energy—into dynamic expressions that contribute to observable spacetime effects.

Moreover, the equivalence $h \cdot c = e \cdot \mu_0$ suggests that photons not only mediate electromagnetic forces but also bridge the transition from static potential (electric charge or mass) to dynamic kinetic interactions within the vacuum structure. This reinforces our interpretation of the vacuum as a fluctuating, single-turn coil where the combined oscillatory effects manifest as spacetime dynamics, unifying gravitational and electromagnetic interactions through their shared potential-kinetic transformation.

Some more insights on the gravitational constant G From our previous subsection, we have that

$$\frac{h \cdot c}{2} \cdot c^2 = \frac{G}{\alpha} \tag{18}$$

Solving for G, and operating with the equivalences already found before, we have that

$$G = \frac{\alpha}{2} \cdot h \cdot c^3 = \frac{\alpha}{2} \cdot \epsilon_0^3 \cdot c^3 = \alpha \cdot \frac{\left(\frac{1}{Z_0}\right)^3}{2} = \zeta \cdot \left(\frac{1}{Z_0}\right)^3$$

Recall also that we had that $G = \int 4\pi G \rho_{\text{vac}}\ dc$. Then, we can equate to obtain that

$$G = \int 4\pi G \rho_{\text{vac}}\ dc = \zeta \cdot \left(\frac{1}{Z_0}\right)^3 \tag{19}$$

The left-hand side represents gravitational power loss due to vacuum energy, expressed in terms of the rate of energy flow or dissipation resulting from gravitational effects within the system. The right-hand side represents the electromagnetic power dissipation in the vacuum in a three-dimensional volume. In this context, the term $\frac{\left(\frac{1}{Z_0}\right)^3}{2}$, that we can link to a voltage as $[G] = [\frac{\left(\frac{1}{Z_0}\right)^3}{2}]$, reflects the vacuum's admittance to deformation and the associated energy dissipation. Therefore, this equation describes an equivalence between the gravitational power loss, driven by the vacuum energy density, and the electromagnetic power dissipation in the vacuum, where the voltage term quantifies the vacuum's capacity to deform, either by gravitational or electromagnetic effects. This reinforces the fundamental link between vacuum properties, gravitation, and electromagnetism, suggesting that gravitational interactions can be understood in terms of the same energy dissipation (spacetime deformation) mechanisms that govern electromagnetic phenomena.

10.5 Mass, Charge, and Spacetime Curvature in RLC Circuit-Mechanical System Analogy

In the framework of analogies between RLC circuits and translational mechanical systems, inductance (L) is analogous to mass (m), while voltage (V) represents amplitude. We have derived that both the gravitational constant G and the vacuum's permeability μ_0 can be interpreted as having dimensions of both inductance and voltage simultaneously. This implies that within the mechanical framework, both constants relate to mass and amplitude.

Inductance-Mass and Voltage-Amplitude-spacetime curvature Equivalence

In the traditional analogy, inductance in an RLC circuit corresponds to mass in a translational mechanical system. This correspondence arises because inductance represents the system's inertia, resisting changes in current, much like how mass resists changes in velocity. Similarly, voltage corresponds to amplitude, as it drives current in the RLC system, just as amplitude governs the motion in a mechanical oscillator.

We have derived throughout the previous sections that both the gravitational constant G, which governs the strength of gravitational attraction, and vacuum permeability μ_0, which governs the propagation of magnetic fields, seem to emerge with properties corresponding to both **mass** (inertial property) and **voltage** (driving potential). If we extend this analogy by considering **amplitude** as a representation of **spacetime curvature**, it implies a profound insight into why mass and spacetime curvature are inseparably linked. In general relativity, mass induces curvature in spacetime, just as amplitude induces motion in a mechanical system or voltage drives current in a circuit. Therefore, when G and μ_0 are treated as governing both mass and amplitude simultaneously, it reflects the dual role these constants play in both mechanical (mass) and spacetime (curvature) domains.

Additionally, given that **charge** in some RLC circuit can be related to displacement in the translational mechanical framework, relating displacement to a different kind of spacetime curvature, we further have that charge, like mass, directly influences spacetime curvature. This is consistent with the idea that electromagnetic interactions, driven by charge, also interact with spacetime geometry, as proposed in diverse theories of electrovacuum solutions in general relativity.

The Inseparable Link between Mass, Charge, and Spacetime Curvature

Thus, the analogy leads to the conclusion that mass, charge, and spacetime curvature are not independent entities but are deeply interrelated. Both G and μ_0, by having dimensions corresponding to mass (inductance) and amplitude (voltage), bridge the gap between gravitational and electromagnetic phenomena.

This understanding provides a foundation for interpreting the inseparability of mass, charge, and spacetime curvature. Mass and charge are not just sources of gravitational and electromagnetic fields but are fundamentally linked to the curvature of spacetime itself, reinforcing the idea that gravitational and electromagnetic phenomena are two facets of the same underlying structure. This further supports the unification of gravitational and electromagnetic theories through vacuum properties.

10.6 Setting the quantums of active and reactive power of the system

In the RLC circuit analogy, power can be divided into reactive and active components, where reactive power represents oscillatory energy that does not perform net work and is stored temporarily in the system, while active power corresponds to the energy that is continuously transferred, contributing to net work.

In this subsection, we set some P_{pot} as analogous to reactive power, as it reflects the inherent oscillatory nature of the vacuum energy, where the "potential" energy exists in a constant back-and-forth exchange without performing net work. This aligns with the concept of reactive power in an RLC circuit, which is stored temporarily in the electric and magnetic fields of capacitors and inductors.

In contrast, we set some P_{kin} as analogous to active power, which represents the actual energy dissipated or transferred in the system. The kinetic power P_{kin} reflects the rate at which the vacuum energy transitions to observable effects, such as energy transfer across electromagnetic or gravitational fields. Just as active power in an RLC circuit corresponds to real work done over each cycle, P_{kin} signifies the effective transfer of kinetic energy from the vacuum's oscillatory state to physical manifestations in spacetime.

Planck's constant h as the quantum of reactive-potential power

In our model, the vacuum itself is a source of potential electromagnetic energy, quantized as $E_{\text{pot}} = h \cdot c$. Given that we have the differential time element $dt = dc$ within our framework, we can express the potential power of the vacuum as:

$$P_{\text{pot}} = \frac{dE_{\text{pot}}}{dt} = \frac{d(h \cdot c)}{dc} = h.$$

This indicates that h (Planck's constant) serves as the quantum of this reactive-potential power within the vacuum, where it reflects the discrete nature of the energy transfer across each differential of space or time, validating its interpretation as a fundamental quantum of potential power in the system.

On the other hand, applying the transformation operator $\int c\, dc$, we have that:

$$P_{\text{kin}} = h \int c\, dc = \frac{h \cdot c^2}{2}.$$

From the previously derived relationships, we find that P_{kin} can be expressed in terms of other fundamental constants as:

$$P_{\text{kin}} = \frac{G \cdot \mu_0}{\sqrt{\frac{3}{5}4\pi}} = \frac{\sqrt{\frac{3}{5}4\pi}}{c^2} = \sqrt{\frac{3}{5}4\pi \cdot \epsilon_0 \cdot \mu_0}$$

where, based on previous derivations, G and μ_0 possess the same dimensional qualities, both corresponding to voltage $[V]$. Thus, P_{kin} conforms to the dimensions V^2/R, aligning with power dimensions and verifying the consistency of our derived relationships.

Furthermore, this active-kinetic power is related to the rate of change of kinetic energy over time:

$$P_{\text{kin}} = \frac{dE_{\text{kin}}}{dt},$$

leading to the expression for kinetic energy in the vacuum:

$$E_{\text{kin}} = \frac{G \cdot \mu_0 \cdot c}{\alpha} = \frac{G}{\alpha} = \sqrt{G \cdot \mu_0},$$

Note that $[\sqrt{G \cdot \mu_0}] = [\sqrt{V^2}] = [V]$. This confirms our previous establishment of kinetic energy as the driver or observational and measurable effects in spacetime, as an effective voltage drives the electromagnetic phenomena.

This interpretation of h as a quantum of potential power and P_{kin} in terms of established constants underlines the internal coherence of the framework, linking quantum mechanical principles to the vacuum's potential and kinetic energy states.

Since h is inherently linked to momentum through the de Broglie relation $p = h/\lambda$, we can interpret $P_{\text{pot}} = h$ as a fundamental momentum transfer within the vacuum's energy structure. This reactive-potential power therefore carries not only the interpretation of an energy rate but also implies a discrete transfer of momentum, analogous to photon momentum in electromagnetic interactions. Each quantum of potential power, h, effectively encapsulates the minimum unit of momentum transfer in this system, which aligns with the field's natural oscillatory state.

In contrast, the active-kinetic power P_{kin} is linked to a flux form, reflecting the cumulative effect of these momentum quanta. If we interpret P_{kin} as an effective power flux, it becomes a function of either electromagnetic flux density or a gravitational field flux, modulated by the vacuum's intrinsic properties. As such, P_{kin} may represent a larger-scale, observable effect within a gravitational or electromagnetic framework, where the system's oscillatory nature dissipates or transfers energy across the vacuum.

11 Derivation of vacuum energy density ρ_{vac}

The product of magnetic flux Φ and angular frequency ω has a significant physical interpretation as a measure of *energy transfer rate* in oscillatory or rotational systems. In electromagnetic and mechanical systems where energy exchange occurs between magnetic and electric fields, or kinetic and potential forms, the product $\Phi \cdot \omega$ can be related to energy density and current in the following ways:

1. **Energy Density in Oscillatory Systems:**
   In an RLC circuit, the *magnetic flux* $\Phi = L \cdot I$, where L is the inductance and I is the current, represents the magnetic field strength over a given area. When multiplied by an *angular frequency* ω, the product $\Phi \cdot \omega$ describes the *rate of change of magnetic flux* and, according to Faraday's Law, directly relates to the induced electromotive force (EMF):

   $$\text{EMF} = -\frac{d\Phi}{dt} \approx \Phi \cdot \omega.$$

   This induced EMF reflects the *energy per unit charge* available to drive current, and, when considered across a spatial volume, it characterizes the *energy density associated with oscillatory magnetic fields* in the circuit. In effect, $\Phi \cdot \omega$ encapsulates the rate at which magnetic energy is transformed into electrical energy or vice versa.

2. **Relationship with Current:**
   In electromagnetic contexts, the induced current I can be expressed using a generalized form of Ohm's Law:

   $$I = \frac{\text{EMF}}{R} = \frac{\Phi \cdot \omega}{R},$$

   where R denotes the resistance. This relation reveals that $\Phi \cdot \omega$ functions as an *effective voltage* (or driving force) within the system. Consequently, $\Phi \cdot \omega$ can be interpreted as the *energy density available to sustain current flow*, providing a quantitative measure of the system's ability to drive current against resistive elements.

3. **Energy Density Interpretation:**
   Physically, $\Phi \cdot \omega$ can also be viewed as analogous to *power density*, indicating the rate of energy transfer per unit volume within the magnetic field. In systems with resonant magnetic fields, such as oscillating circuits or rotating magnetic fields, $\Phi \cdot \omega$ characterizes the density of energy fluctuations. Thus, it reflects the energy exchange rate between electric and magnetic fields, showing how resonant oscillations in the vacuum or circuit environment contribute to the energy density.

4. **Analogy with Kinetic and Potential Energy:**
   In mechanical systems, the product $\Phi \cdot \omega$ is analogous to the product of *torque* and *angular velocity*. Torque multiplied by angular velocity represents *power* or energy per unit time. By analogy, in electromagnetic systems, $\Phi \cdot \omega$ can represent the energy transfer rate between magnetic and electric fields, capturing the balance of kinetic and potential-like contributions within oscillatory systems.

In summary, the product $\Phi \cdot \omega$ functions as a measure of *power density* or *energy transfer rate* in resonant electromagnetic systems. It aligns with the concept of induced EMF and thus supports the current in the presence of resistance. Therefore, this quantity provides a measure of the *dynamic energy density* in oscillatory systems, encapsulating the energy exchange rate within magnetic and electric fields and stabilizing oscillatory energy flows.

Within this framework, we can directly associate $\frac{\hbar}{2}$ with a magnetic flux quantum (Φ_0), and the zero-point energy of a quantum harmonic oscillator becomes

$$E_0 = \frac{1}{2}\hbar\omega = \Phi \cdot \omega$$

Setting $R = \sqrt{\frac{3}{5}4\pi}$ as the effective resistance of the system, the vacuum energy density can be expressed from the zero-point energy of a quantum harmonic oscillator and the magnetic flux Φ_0 as:

$$\rho_{\text{vac}} = \frac{\Phi_0 \omega}{R} = \frac{\frac{1}{2}\hbar c}{\sqrt{\frac{3}{5}4\pi}}$$

Using the standard values of the constants involved, the above yields a numerical result of $5.75 \times 10^{-27} kg/m^3$. This result aligns pretty well with the 2015 experimental results obtained by the Planck Collaboration [38], which yielded a value of $5.96 \times 10^{-27} kg/m^3$ for the vacuum energy density.

Note that, from this expression and the equivalences $h = \frac{2\sqrt{\frac{3}{5}4\pi}}{c^4}$, $\hbar = \frac{h}{2\pi}$ and $E = m \cdot c^2$, we can obtain that

$$\rho_{vac} = \frac{2\sqrt{\frac{3}{5}4\pi} \cdot c}{4\pi\sqrt{\frac{3}{5}4\pi} \cdot c^4} kg/m^3 = \frac{1}{2\pi \cdot c^3} kg/m^3 = \frac{c^2}{2\pi \cdot c^3} J/m^3 = \frac{1}{2\pi \cdot c} J/m^3$$

Also, using the equivalences $e = \frac{2\alpha}{c^2}$ and $h \cdot c = e \cdot \mu_0$, we have that

$$\rho_{vac} = \frac{e \cdot \mu_0}{4\pi\sqrt{\frac{3}{5}4\pi}} kg/m^3 = \frac{2\alpha \cdot \mu_0}{4\pi\sqrt{\frac{3}{5}4\pi} \cdot c^2} kg/m^3 = \frac{\mu_0 \cdot \alpha}{2\pi\sqrt{\frac{3}{5}4\pi}} J/m^3$$

We have derived that $\rho_{vac} = \frac{1}{2\pi \cdot c}$. As we had established in previous sections that $G = \frac{X_N}{c} = \frac{1}{16\pi \cdot c}$, we have that

$$8G = \frac{1}{2\pi \cdot c} = \rho_{vac} \tag{20}$$

Note also that, using the equations obtained above, we have that

$$\frac{\mu_0 \cdot \alpha}{2\pi\sqrt{\frac{3}{5}4\pi}} = \frac{1}{2\pi \cdot c}$$

Operating, we get that

$$c = \frac{\sqrt{\frac{3}{5}4\pi}}{\mu_0 \cdot \alpha}$$

This is consistent, as for some series RLC circuit we have seen that $Q = \frac{\omega_0 L}{R}$. Solving for ω_0 yields $\omega_0 = \frac{QR}{L}$, which through the substitutions $Q = \frac{1}{\alpha}$, $R = \sqrt{\frac{3}{5}4\pi}$ and $L = \mu_0$ yields the above result, that enhances the inner consistency of the results obtained.

Interpretation and consequences of the obtained results

In our framework, zero-point energy serves as the minimal energy required to sustain oscillatory stability within the vacuum, akin to an electromotive force (EMF) in traditional RLC circuits. This view diverges from classical interpretations, where zero-point energy is treated as a passive background quantity, by positioning it as an active force that stabilizes the oscillatory vacuum structure. Specifically, we interpret the product of magnetic flux Φ and angular frequency ω as a measure of energy transfer rate or "power density" within the vacuum's oscillatory system. This quantity, $\Phi \cdot \omega$, embodies the zero-point energy's role in the system, providing the minimum dynamic energy needed to support oscillatory stability. By linking zero-point energy to EMF, this framework offers a coherent explanation for the vacuum energy density that aligns with observed values from cosmological data [38].

The proposed method, along with the inner consistency with other results obtained throughout this Paper, provides a solution to the long-standing "vacuum catastrophe" [39] in theoretical physics. The traditional view of vacuum energy density, based on an infinite sum of zero-point energies across all modes of quantum oscillators, leads to an estimated value many orders of magnitude greater than what is observed. By reinterpreting the vacuum as a single, loop-like construct in spacetime, and associating each quantum field with discrete, quantized magnetic flux contributions, we introduce a framework that limits the zero-point energy accumulation. In this model, the curvature factor $\sqrt{\frac{3}{5}4\pi}$ emerges as a "resistance" to magnetic flux, effectively moderating the impact of individual zero-point contributions, thus aligning theoretical predictions for ρ_{vac} with observational values. This result closely matches the vacuum density measured by the Planck Collaboration in 2015, suggesting that the model could offer a viable reinterpretation of vacuum energy that is both theoretically consistent and empirically grounded.

The derived expression for $\rho_{vac} = \frac{1}{2\pi c}$, along with the connection $8G = \frac{1}{2\pi c} = \rho_{vac}$, introduces a new relationship between vacuum energy density, the speed of light c and the gravitational constant G. This alignment reinforces the already established link between vacuum energy density (which arises from quantum harmonic oscillators) and gravitational interactions. By associating G with a quantized magnetic flux, it is reinforced the unification of gravitational and electromagnetic forces under a shared quantum mechanical foundation, thereby supporting the view that spacetime's curvature and electromagnetic properties have a common origin.

Furthermore, the model's compatibility with circuit analogs, where parameters Q, R, and L (interpreted as the fine structure constant α, curvature factor R, and permeability μ_0 respectively) yield consistent expressions for c, adds to its theoretical robustness. This consistency strengthens the proposal that vacuum energy, gravitational coupling, and speed of light share an underlying oscillatory nature in spacetime.

12 Derivation of the Boltzmann constant k_B and its Implications in the Thermodynamic Interpretation of Vacuum

In the context of our proposed framework, where the vacuum is modeled as a dynamic system of harmonic oscillators expanding at relativistic velocities, we postulate that the Boltzmann constant k_B is given by:

$$k_B = \frac{\mu_0}{c^2} = \frac{2\pi \cdot \frac{\hbar \cdot c}{2}}{\alpha} = \frac{2\pi \cdot E_0}{\alpha}$$

The above expression links the Boltzmann constant k_B directly to the quantum oscillatory nature of the vacuum. In this sense, k_B serves as a measure of how the quantum fluctuations of the vacuum contribute to its thermodynamic properties, such as temperature and entropy.

In this section, we explore the physical and conceptual justification for this relationship and its implications for the thermodynamic interpretation of vacuum fluctuations, energy, and entropy, focusing on its connection to quantum mechanics and the zero-point energy of harmonic oscillators.

12.1 Dimensional Consistency and dimensionality of k_B

Temperature, in classical thermodynamics, is a measure of the average kinetic energy of particles within a system. This is traditionally represented by the relation $\langle E_{\text{kin}} \rangle \sim k_B T$, where T is temperature, E_{kin} represents the kinetic energy, and k_B is the Boltzmann constant. Within the standard framework, this association implies that temperature serves as a measure of energy density per degree of freedom.

By treating temperature as fundamentally equivalent to energy, we can reinterpret thermal and energetic phenomena as two manifestations of the same underlying quantum structure of the vacuum. The oscillatory behavior of the vacuum, modeled as a system of harmonic oscillators, enables this unification, as each oscillator's energy states correspond to discrete temperature states within the system. In this light, temperature becomes a measure of the energy density within the quantum oscillations of the vacuum, with its value inherently tied to the oscillatory dynamics of spacetime.

This dimensional equivalence simplifies the expressions of thermodynamic quantities in our model and grounds temperature as a measure of energy that naturally aligns with the dimensional analysis of other fundamental quantities, such as charge and mass, within our cosmological framework.

In classical thermodynamics, the Boltzmann constant k_B typically has dimensions of energy per unit temperature, $[k_B] = \frac{ML^2}{T^2\Theta}$, where M, L, and T denote mass, length, and time, respectively, and Θ represents temperature. As, within the dimensional framework of our paper, temperature is dimensionally equivalent to energy, k_B becomes a dimensionless quantity. This allows for k_B to act as a pure scaling factor that relates electromagnetic properties of the vacuum to its thermodynamic behavior.

This dimensionality aligns with the expression $k_B = \frac{\mu_0}{c^2}$, where both universal constants have been shown to become dimensionless within our framework, resulting in a dimensionless k_B. This provides a natural and consistent interpretation of k_B in our cosmological and thermodynamic framework.

12.2 Linking k_B to the Quantum Harmonic Oscillator and Zero-Point Energy

To further understand the basis of the expression $k_B = \frac{\mu_0}{c^2} = \frac{2\pi \cdot \frac{\hbar \cdot c}{2}}{\alpha} = \frac{2\pi \cdot E_0}{\alpha}$, we can use some of the relationships already developed throughout this Paper. Specifically, we employ the following relationships:

$$\hbar = \frac{e \cdot \mu_0}{c}, \quad e = \frac{2\alpha}{c^2}$$

From these, we can derive the following equivalence:

$$\frac{\mu_0}{c^2} = \frac{2\pi \cdot \frac{\hbar \cdot c}{2}}{\alpha} = \frac{2\pi \cdot E_0}{\alpha}$$

Where E_0 is the zero-point energy of the quantum harmonic oscillator. As both numerically and theoretically makes sense to relate the above to Boltzmann constant k_B, our postulate follows.

12.3 Interpreting k_B in Terms of the Lorentz Factor and Relativistic Effects

An important insight from the derived expression is the presence of the fine-structure constant α, which we will see later that it can be interpreted as the reciprocal of the Lorentz factor. Since α is dimensionless and characterizes the strength of the electromagnetic interaction, it serves as an effective scaling factor that incorporates relativistic effects into the thermodynamic behavior of the vacuum.

Thus, the expression $k_B = \frac{\mu_0}{c^2} = \frac{2\pi \cdot E_0}{\alpha}$ effectively describes the Boltzmann constant as the deangularized zero-point energy of the quantum harmonic oscillators, adjusted adequately with the Lorentz factor in the context of vacuum expanding at relativistic velocities.

12.4 Thermodynamic Implications and Electromagnetic Deformation of Spacetime

The relationship obtained can now be interpreted as a formal connection between the electromagnetic-oscillatory properties of the vacuum and its thermodynamic response. By introducing μ_0 as the quantum of the voltage needed to deform spacetime, which we have seen that is intrinsically related to E_0, we propose that the energy dissipated in these deformations, governed by the quantum harmonic oscillator model, translates directly into thermodynamic quantities such as temperature and entropy. The connection between k_B, μ_0, and the quantum harmonic oscillators implies that the Boltzmann constant governs how the energy employed in these electromagnetic deformations influence the overall thermodynamic state of the vacuum.

12.5 Reinterpreting Entropy in Light of the Boltzmann Constant

In traditional thermodynamics, entropy [40] is understood as a measure of the number of Quantum states available to a system, providing a link between Quantum-scopic disorder and macroscopic thermodynamic properties. Entropy is often expressed in terms of the Boltzmann constant k_B, with the fundamental relation $S = k_B \ln \Omega$, where Ω represents the number of accessible Quantum states. This relation, however, takes on new significance in the context of our model, where k_B is reinterpreted as a dimensionless quantity rooted in the vacuum's electromagnetic properties. This shifts the conceptualization of entropy towards a more fundamental link with the quantum structure of the vacuum.

Entropy as a Measure of Vacuum Fluctuations

In our framework, the vacuum is modeled as a dynamic system of harmonic oscillators, with the zero-point energy E_0 playing a crucial role in determining the thermodynamic properties of the vacuum, including entropy [41]. The redefinition of $k_B = \frac{\mu_0}{c^2}$, combined with the interpretation of E_0, implies that entropy in this context can be viewed as a measure of the vacuum's quantum fluctuations. Each vacuum fluctuation represents a distinct Quantum state, and the entropy can be understood as quantifying the distribution of these fluctuations.

By linking k_B to the electromagnetic permeability of the vacuum μ_0, and consequently to the energy scale of these quantum fluctuations, we reinterpret entropy as emerging directly from the electromagnetic and quantum structure of spacetime. Specifically, entropy quantifies the extent to which vacuum fluctuations contribute to the overall thermodynamic state of the vacuum. In this sense, the vacuum itself, through its inherent quantum oscillations, generates entropy as a natural consequence of its fluctuating Quantum states.

The presence of the fine-structure constant α in the expression for k_B, and its interpretation as a scaling factor incorporating relativistic effects, provides an additional layer of understanding for entropy. In a relativistic framework where the vacuum expands at relativistic velocities, the Quantum states associated with vacuum fluctuations are subject to Lorentz transformations. The entropy of the vacuum can therefore be seen as modulated by relativistic effects, with the Lorentz factor playing a key role in determining how these Quantum states are accessed or altered under relativistic conditions.

The expression $k_B = \frac{2\pi \cdot E_0}{\alpha}$, where E_0 represents the zero-point energy of harmonic oscillators, suggests that entropy is fundamentally tied to the vacuum's capacity to store and dissipate energy through quantum and relativistic fluctuations. As the vacuum deforms under relativistic expansion, the thermodynamic entropy associated with these deformations reflects the changing distribution of vacuum Quantum states.

Entropy as a Quantum-Electromagnetic Measure

We further postulate that the entropy S of the vacuum is given by:

$$S = k_B \cdot \ln(2)$$

Here, the factor 2 represents the two possible Quantum states accessible to each quantum harmonic oscillator. These two states could be interpreted as representing fundamental superposition states of the oscillators, and within our framework, there are multiple plausible interpretations for the nature of these states. Among these possible interpretations, the interpretation of 2 representing distinct quantum polarization states provides a clearer physical basis for the two Quantum states because:

- **Oscillatory Fields:** In any oscillatory field, such as an electromagnetic field, polarization is a fundamental degree of freedom. It is inherently linked to the oscillatory nature of the field, making it a natural candidate for the states of a harmonic oscillator. For example, the electromagnetic field has two polarization states corresponding to orthogonal directions of the oscillating electric field.
- **Direct Superposition:** Quantum polarization states can exist in superpositions. This allows the oscillators to occupy both states simultaneously, reflecting the probabilistic nature of quantum mechanics.
- **Simple and Universal Interpretation:** Polarization applies not just to electromagnetic fields but also to many types of oscillatory systems, making it a simple yet universal interpretation of the two states. And, mathematically speaking, 2 is the minimum integer that we can plug in the entropy formula and give a meaningful result (because $\ln(1) = 0$) in the context of harmonic oscillators, so it makes sense as Boltzmann constant is the basis for entropy calculation.

The reinterpretation of entropy within this framework provides a novel perspective on its role in thermodynamic systems. By grounding the Boltzmann constant k_B in the vacuum's electromagnetic-oscillatory properties, we establish a direct connection between quantum fluctuations, spacetime deformation, thermodynamics and entropy. Entropy, in this context, no longer merely represents a count of Quantum states but becomes a measure of the vacuum's quantum-electromagnetic dynamics, incorporating both relativistic and quantum effects.

This reinterpretation provides deeper insights into the nature of entropy, framing it as a reflection of the underlying electromagnetic-oscillatory structure of spacetime, where quantum oscillations of the vacuum play a central role in governing its thermodynamic behavior. By extending classical thermodynamic principles into this quantum-relativistic domain, we offer a unified perspective on how the vacuum's Quantum-scopic properties give rise to macroscopic thermodynamic quantities such as temperature and entropy.

Part III: Analysis and interpretation of the derived relationships, and more derivations of constants

13 The Vacuum as a System of Harmonic Oscillators: ϵ_0 and μ_0 as the ultimate quantums of nature

13.1 The relationship between ϵ_0 and μ_0

In the previous sections, we have already established a deep connection between vacuum properties and the universal constants and physical realities. In this subsection we will dig a bit more, showing how, at the end, everything that we perceive and measure is a consequence of vacuum properties expanded through the spacetime.

We have already postulated the following relationship for the momentum quantization:

$$h = \epsilon_0^3$$

where h represents a quantum of magnetic flux, momentum, and accumulation of reactive-potential power. Note that ϵ_0 is dimensionless and $[h] = [T]$ within the mechanical translational framework, which could point to some dimensional inconsistency; however, within the RLC circuit framework, we have that $[\epsilon_0] = [T]$ and $[h] = [T^3]$, which is dimensionally consistent. Therefore, in the mechanical translational framework, we have that ϵ_0 acquires dimensionality when considered in a three dimensional framework. Another argument in favor of dimensional consistency is that $[\epsilon_0] = [G]$, which is related to kinetic energy / observable effects of potential energy through the transformational operator $\int c\, dc$.

From the relationship $h = \frac{e\mu_0}{c}$ and the corresponding substitutions of e, α and c in terms of ϵ_0 and μ_0 it can be derived that

$$\epsilon_0^3 = 2\sqrt{\frac{\frac{3}{5}4\pi\epsilon_0}{\mu_0}}\epsilon_0\mu_0^2\sqrt{\epsilon_0\mu_0}$$

$$\epsilon_0 = 2\cdot\mu_0^2\cdot\sqrt{\frac{3}{5}4\pi}$$

Note that the above expression can be rewritten as

$$2\pi\epsilon_0 = 4\pi\mu_0^2\cdot\sqrt{\frac{3}{5}4\pi}$$

Which is meaningful, as the expression $2\pi\epsilon_0$ can be related to some de-angularized quantity; the expression $4\pi\mu_0^2$ can be related to the area of a sphere of radius μ_0; and $\sqrt{\frac{3}{5}4\pi}$ is the geometric factor R.

The above expression sums up the deep interplay between vacuum permittivity ϵ_0, vacuum permeability μ_0, and the geometric factor $R = \sqrt{\frac{3}{5}4\pi}$. Here's a step-by-step interpretation of this expression in the context of the paper's framework:

1. **Vacuum Permittivity ϵ_0 as Spacetime Capacity:** ϵ_0 can be interpreted as the quantum of spacetime's capacity to deform or curve. This aligns with the traditional idea that ϵ_0 measures how much the vacuum can "permit" electric field lines, thus relating to how spacetime accommodates or responds to electromagnetic fields. In this context, $2\pi\epsilon_0$ represents a linearized or reduced form of spacetime deformation capacity. The factor 2π might be indicative of integrating this effect around a certain boundary (similar to integrating around a circle), signifying a total "deformation capacity" across a closed loop, which is consistent in the context of harmonic oscillations.

2. **Vacuum Permeability μ_0 as the Quantum of Energy Dissipation:** μ_0 encapsulates the quantum of energy transferred / dissipated in deforming / curving the spacetime. This is consistent with the traditional view of μ_0 as the measure of how much vacuum reacts to magnetic

fields, indicating how the vacuum stores and dissipates magnetic energy. As a result, in the expression $4\pi\mu_0^2$, the term $4\pi\mu_0^2$ can be seen as relating to the surface area of a sphere of radius μ_0, symbolizing the spatial extent over which this energy transfer / dissipation occurs.

3. **Geometric Factor $R = \sqrt{\frac{3}{5}4\pi}$:** As we have seen, it represents the specific topological or spatial configuration of the vacuum oscillators in an spherical distribution. In other words, R defines how the vacuum's oscillatory nature is "packed" or arranged in the fabric of spacetime. It acts as the scaling factor that modulates how the intrinsic properties of the vacuum (its capacity and permeability) translate into observable phenomena.

Therefore, the expression $2\pi\epsilon_0 = 4\pi\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$ encapsulates the total effect of the vacuum's energy dissipation (magnetic flux) distributed over a spherical geometry, and how the vacuum's energy manifests in spacetime's curvature or deformation, translating the vacuum's intrinsic properties into measurable electromagnetic or gravitational interactions.

Since the vacuum is a system of harmonic oscillators, ϵ_0 and μ_0 can be seen as dual aspects of the vacuum oscillators' behavior. ϵ_0 defines how spacetime can be "stretched" or "deformed," while μ_0 dictates how the energy from this deformation is dissipated. Thus, the expression $2\pi\epsilon_0 = 4\pi\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$ describes a balanced state in which the vacuum's capacity to deform is in harmonic equilibrium with its ability to dissipate energy.

This interpretation provides a deeper insight into how the vacuum's electromagnetic properties are not merely constants but are intertwined aspects of spacetime fundamental nature. The vacuum's ability to permit electric fields and support magnetic fields are two sides of the same coin, reflecting how spacetime oscillates and interacts with energy, and all fundamental forces and constants arise from this deeper vacuum structure, where spacetime itself acts as a resonant medium.

13.2 The relationship between the elementary charge e and vacuum's permeability μ_0

As it is consistent with our previous derivations, we postulate that

$$e = \frac{\mu_0^3}{4\pi} \tag{21}$$

where e represents a quantum of induced charge (or accumulation of kinetic energy). Again, there is the dimensional issue between $[e] = [T]$ and the right hand side being dimensionless; and again, within the RLC circuit framework, the expression is dimensionally consistent. Therefore, in the mechanical translational framework, we have that μ_0 acquires dimensionality when considered in a three dimensional framework. Again, another argument in favor of dimensional consistency is that $[\mu_0] = [G]$, which is related to kinetic energy / observable effects of potential energy through the transformational operator $\int c \; dc$.

13.3 Some more insights and relationships between fundamental constants and vacuum's properties

In both expressions for h and e, the cubic powers indicate a volume dependence, reflecting the three-dimensional nature of the effects that these constants exert in the physical reality.

The constant ϵ_0, the vacuum permittivity, characterizes the ability of the vacuum to store electric energy in an electric field. Therefore, it reflects the vacuum's ability to accumulate potential energy (and thus, to deform) and correlates with the energy stored across a finite region of space.

Similarly, μ_0, the vacuum permeability, reflects the vacuum's ability to support magnetic fields and hence store magnetic energy. The expression μ_0^3, divided by the geometric factor 4π, suggests that the induced charge is related to the accumulation of kinetic energy in the form of magnetic field energy, with the factor 4π typically associated with the spherical symmetry and oscillatory nature of harmonic oscillators.

Other hand, we have already seen that the relationship $h = \frac{e\cdot\mu_0}{c}$ can be re-expressed in terms of ϵ_0 and μ_0:

$$\epsilon_0^3 = 2\alpha\epsilon_0\mu_0^2\sqrt{\epsilon_0\mu_0}$$

Solving for α, we get that

$$\alpha = \frac{1}{2}\frac{\epsilon_0^2}{\mu_0^2}\cdot c = \frac{1}{2}\cdot c\left(\frac{1}{Z_0}\right)^4 \tag{22}$$

Note that the last expression can be re-expressed as

$$\alpha = 2\cdot c\int Y_0^3\ dY_0$$

Or, reordering, more conveniently as

$$\zeta = c\int Y_0^3\ dY_0 \tag{23}$$

Where $Y_0 = Z_0^{-1}$ is the vacuum admittance, which is the vacuum's ability to facilitate the flow of electric current in response to an electric field, analogous to how admittance in a circuit measures the ease with which a current flows under a given voltage.

The integral form shows that the fine-structure constant can be interpreted as the cumulative effect of the vacuum's admittance over a range of possible values. This can be seen as summing up the contributions of different "modes" or states of vacuum admittance, reflecting how the vacuum's ability to conduct electromagnetic energy at different scales or configurations contributes to the overall electromagnetic interaction.

It is interesting to equate the obtained relationship with the one that we have derived previously, $\alpha = e\int c\ dc$. Equating, operating, and solving for $e\cdot c$, which is equal to I_{max}, we get that

$$e\int c\ dc = 2c\int Y_0^3\ dY_0$$

$$e\cdot\frac{c^2}{2} = \frac{c}{2}Y_0^4$$

$$I_{max} = e\cdot c = Y_0^4 \tag{24}$$

This last relationship aligns with our vacuum harmonic oscillator model, where the vacuum's capacity to conduct electromagnetic energy (Y_0) dictates the oscillatory amplitude, I_{max}, achievable within the vacuum. Here, Y_0^4 signifies the maximum current sustained by vacuum oscillations within the four spatial dimensions, reinforcing that electromagnetic phenomena—including the behavior of charged particles and light propagation—arise fundamentally from the properties of the vacuum.

The five dimensionality of the zero-point energy of the quantum harmonic oscillator

Moreover, from the equation $h = \frac{e\cdot\mu_0}{c}$, substituting $e = \frac{\mu_0^3}{4\pi}$ and operating, we get that

$$h = \frac{\mu_0^4}{4\pi\cdot c}$$

$$h\cdot c = \frac{\mu_0^4}{4\pi}$$

$$\frac{\hbar\cdot c}{2} = \frac{\mu_0^4}{(4\pi)^2}$$

$$\sqrt{\frac{\hbar\cdot c}{2}} = \frac{\mu_0^2}{4\pi}$$

Note that, as $e = \frac{\mu_0^2}{4\pi}$, then we have that $e = \sqrt{\frac{\hbar \cdot c}{2}} \cdot \mu_0$. And thus, we have that

$$I_{max} = e \cdot c = \sqrt{\frac{\hbar \cdot c}{2}} \cdot \mu_0 \cdot c$$

As $Z_0 = \mu_0 \cdot c$, we can state that

$$I_{max} = e \cdot c = \sqrt{\frac{\hbar \cdot c}{2}} \cdot Z_0$$

Recall that we have established previously that $I_{max} = e \cdot c = Y_0^4 = \frac{1}{Z_0^4}$. Then, we have that

$$\sqrt{\frac{\hbar \cdot c}{2}} \cdot Z_0 = \frac{1}{Z_0^4}$$

$$\sqrt{\frac{\hbar \cdot c}{2}} = \frac{1}{Z_0^5}$$

Squaring both sides, and noting that $Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$, we finally get that

$$E_0 = \frac{\hbar \cdot c}{2} = \frac{\epsilon_0^5}{\mu_0^5} \tag{25}$$

This expression for E_0 as the zero-point energy captures the interplay between the vacuum's intrinsic electromagnetic properties within a higher-dimensional, five-dimensional framework. The five-dimensionality represented by $\frac{\epsilon_0^5}{\mu_0^5}$ highlights how space-time's capacity for deformation (via ϵ_0) and its energy dissipation response (via μ_0) operate collectively to create a stable zero-point energy across an expanded spatial-temporal context. The use of fifth powers indicates a volumetric, oscillatory behavior extending through a higher-dimensional vacuum structure.

In this five-dimensional interpretation, E_0 can be viewed as a dynamic consequence of oscillatory exchanges within the vacuum, where energy flows within both electric and magnetic modes contribute collectively to the zero-point energy in spacetime. This oscillatory behavior across five dimensions suggests that the vacuum itself maintains a balanced yet fluctuating state, producing the observed effects of spacetime curvature and field propagation that manifest as gravity and electromagnetism.

Building on these results, in the third part of this paper, we postulate that the energy exchange between our universe and an antimatter counterpart—facilitated by Quantum "black" holes—underpins this quantum oscillatory framework. These Quantum "black" holes are understood here as consequences of spacetime quantization, narrowing the separation between matter-antimatter dimensions at the quantum level, much like the fine gaps in a mesh. This increasingly fine separation permits energy exchange and creates fluctuations in spacetime, giving rise to observable gravitational and electromagnetic phenomena as emergent effects of the vacuum's higher-dimensional oscillatory structure.

14 Universal Constants as Topological and Geometric Properties of the Vacuum

Now that we have established most of the main relationships between universal constants, we can observe that the fundamental constants of nature, such as the fine-structure constant α, the elementary charge e, the vacuum permittivity ϵ_0, and the vacuum permeability μ_0, are not arbitrary quantities. Instead, they emerge from the geometric and topological structure of the vacuum. This viewpoint aligns with the model of the vacuum as a system of harmonic oscillators, where these constants are manifestations of the vacuum's intrinsic properties.

In this section, we will show how all universal constants can be expressed ultimately as purely geometric-numeric constructs.

14.1 The Fine-Structure Constant α and its Geometric Interpretation

The fine-structure constant α plays a fundamental role in characterizing the strength of electromagnetic interactions. A relationship for α in terms of geometric factors that we have derived previously is given by:

$$\alpha = X_N \cdot R = \frac{1}{16\pi} \cdot \sqrt{\frac{3}{5}4\pi}.$$

This expression shows that α emerges naturally from the topological configuration of the vacuum. The term $\sqrt{\frac{3}{5}4\pi}$ relates to the self-energy of a sphere, while the factor $\frac{1}{16\pi}$ requires further analysis regarding its geometric significance.

On the Nature of $\frac{1}{16\pi}$

In the framework of this paper, where we postulate the existence of four spatial dimensions (three familiar spatial dimensions plus an additional matter-antimatter dimension), the geometric factor $\frac{1}{16\pi}$ takes on special significance. It emerges from the underlying topology and geometry of spacetime, particularly as it relates to the discrete quantization of spacetime intervals.

Notably, $\frac{1}{16\pi}$ can be interpreted as a fundamental spacetime differential. In the context of the $(4+1)$ dimensions proposed in this paper, this factor can be understood as:

$$\frac{1}{16\pi} = \left(\frac{1}{2}\right)^3 \cdot \frac{1}{2\pi}.$$

This expression reflects the quantization of spacetime intervals, where $\left(\frac{1}{2}\right)^3$ represents the minimum quantum of spacetime in the three spatial dimensions, and the factor $\frac{1}{2\pi}$ captures the rotational or periodic symmetry of the matter-antimatter dimension.

The power $\left(\frac{1}{2}\right)^3$ corresponds to the discrete nature of the three traditional spatial dimensions, with $\frac{1}{2}$ representing the fundamental unit of spacetime length, derived from Heisenberg's uncertainty principle. By cubing $\frac{1}{2}$, we capture the three-dimensional nature of the vacuum's structure.

The additional $\frac{1}{2\pi}$ factor arises from the topological nature of the matter-antimatter dimension. The circular symmetry described by 2π is inherent to any closed-loop system, such as those found in the topological features of spacetime. In this context, the matter-antimatter dimension contributes periodicity, reflecting the oscillatory nature of the vacuum and the interplay between matter and antimatter fluctuations.

Thus, $\frac{1}{16\pi}$ represents not only a geometric factor but also a fundamental differential element of spacetime within our dimensional framework. It describes how spacetime is quantized, contributing to the universal constants related to the vacuum's topology.

Implications for Universal Constants and Vacuum Energy

The factor $\frac{1}{16\pi}$, appearing across physical constants, reflects a universal "geometric scaling" that arises from both the discrete nature of traditional spatial dimensions and the cyclic symmetry of the matter-antimatter interaction. This factor appears, for instance, in gravitational and field equations, which suggests that $\frac{1}{16\pi}$ plays a role in mediating interactions between spatial dimensions and the oscillatory behavior of the vacuum. Since this factor modulates fundamental constants and field interactions, it underscores the framework's premise that vacuum structure and geometric topology inherently influence physical forces.

In addition, this geometric scaling can be interpreted as a driver of vacuum oscillations, as it encodes the interplay between quantum harmonic oscillations and the cyclical interactions across the matter-antimatter boundary. Consequently, $\frac{1}{16\pi}$ serves as a bridge between the large-scale curvature effects of spacetime and the underlying quantum properties, integrating these scales through a unified geometric factor. This interpretation aligns with the concept of a dynamic vacuum, where the energy density and dimensional structure together contribute to the observed expansion and curvature phenomena.

The implications extend to the vacuum energy density as well, where $\frac{1}{16\pi}$ not only quantizes spacetime but also influences the oscillatory modes of energy. This interpretation supports the hypothesis that dark matter and vacuum energy effects arise from inherent spacetime structure, manifesting as the gravitational pull observed on cosmic scales.

14.2 On the quantum-probabilistic nature of spacetime

The interpretation of $\frac{1}{16\pi}$ as a spacetime differential connects fundamentally with Heisenberg's uncertainty principle, bridging quantum mechanical limits and space-time's geometric structure. The factor $\frac{1}{2}$, as a minimal quantum of spatial dimension, inherently aligns with the uncertainty principle, which dictates that position and momentum cannot both be precisely defined beyond a fundamental limit. In our framework, $\left(\frac{1}{2}\right)^3$ signifies the smallest unit of volumetric space, constrained by this principle, where spatial dimensions discretize in response to quantum fluctuations.

This discrete, minimal quantization hints that spacetime itself may exist as a probabilistic superposition of states, rather than a continuous fabric. With $\frac{1}{2\pi}$ representing the circular-oscillatory symmetry of the matter-antimatter dimension, spacetime can be visualized as an oscillating system where each point encompasses a range of probable states, driven by quantum fluctuations and reflected in Heisenberg's uncertainty limit. Thus, $\frac{1}{16\pi}$ emerges as a fundamental unit that encapsulates spacetime's quantized, probabilistic nature, framing it as an ensemble of discrete states rather than a static continuum.

This view reinforces our interpretation of the vacuum as a dynamic, oscillatory field, with properties that arise from the quantum and geometric interplay between dimensions. The quantization embedded in $\frac{1}{16\pi}$ underscores the deep connections between universal constants, such as α, and the probabilistic structure of spacetime. Here, constants are not arbitrary but intrinsic to the universe's underlying topology and dimensional symmetries, thus supporting the paper's proposal that fundamental properties emerge directly from the universe's inherent geometry and topological structure.

14.3 Deriving a Geometric Interpretation of Other Universal Constants

Having expressed α in terms of geometric factors, we now demonstrate how other universal constants, such as G, μ_0, and ϵ_0, can also be expressed in terms of geometric—purely numerical—constructs.

First, recall that we have derived the following relationships:

$$G = \mu_0 \cdot \alpha^2$$

and

$$G = \frac{3}{5}4\pi \cdot \epsilon_0.$$

Additionally, we have shown that:

$$\epsilon_0 = 4\mu_0 \cdot \sqrt{\frac{3}{5}4\pi}.$$

Equating the two expressions for G and substituting the expression for ϵ_0, we find:

$$\mu_0 \cdot \alpha^2 = \frac{3}{5}4\pi \cdot 4\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}.$$

Solving for μ_0, we obtain:

$$\mu_0 = 2 \cdot \frac{\left(\frac{\alpha}{2\cdot\sqrt{\frac{3}{5}4\pi}}\right)^2}{\sqrt{\frac{3}{5}4\pi}}.$$

As α is expressed in terms of purely geometric factors, it follows that μ_0, being a function of α and other geometric-numeric factors, can also be expressed as a purely geometric factor.

From this last expression, and the relationships between ϵ_0, e, and G with μ_0 that we have previously derived, we see that these constants can in turn be expressed as purely geometric factors. This implies that h and $\hbar$, which depend on ϵ_0, are also expressible as geometric constructs. Ultimately, every universal constant can be reduced to a geometric-numeric construct, stemming from the topology and structure of spacetime.

The relationships outlined above demonstrate that the fundamental constants are not arbitrary but emerge from the geometric and topological properties of the vacuum. This framework aligns with the idea that spacetime itself, through its geometric and topological structure, gives rise to the fundamental constants. These constants are deeply embedded in the vacuum's structure and emerge from the interplay between geometry, topology, and the dynamics of the vacuum oscillators.

Moreover, the geometric-numeric origin of constants such as G, α, μ_0, and ϵ_0 aligns with the quantum-probabilistic model of spacetime, where each point in spacetime represents a probabilistic superposition of states within a discretized structure. The quantization inherent in these constants reflects the finite, smallest units of spacetime intervals that respect Heisenberg's uncertainty principle, implying that spacetime is itself a fluctuating, probabilistic field rather than a continuous background. The constants therefore encode not just geometric relationships but also probabilistic constraints, embedding the fundamental limits of quantum mechanics within the very fabric of spacetime.

This view reinforces the interpretation of spacetime as an active, oscillatory system where universal constants emerge from the probabilistic, discrete, and dynamic interactions of its structure. Such a perspective unifies constants like $\hbar$, G, and α as reflections of spacetime's inherent quantum dynamics, where the geometry and topology of the vacuum are directly responsible for the properties observed in physical constants. Thus, the foundational constants of nature are not extrinsic inputs but are instead the natural consequence of spacetime's underlying probabilistic, quantized structure, which governs the emergence of observable physical laws.

15 Derivation of the Casimir Constant C_c

15.1 The Casimir Effect and the Casimir Constant

The Casimir effect [42] is a quantum phenomenon predicted by Dutch physicists Hendrik B. G. Casimir and Dirk Polder in 1948. It manifests as an attractive force between two uncharged, parallel, conducting plates placed in a vacuum, separated by a small distance. This force arises from the alteration of the vacuum's zero-point energy due to the presence of the conducting boundaries, which modifies the distribution of electromagnetic field modes in the vacuum and leads to a measurable effect even in the absence of external electromagnetic fields.

In classical electrodynamics, the force between two neutral, non-interacting objects is zero. However, quantum field theory introduces the concept of zero-point energy, whereby even the vacuum state possesses fluctuating electromagnetic fields. When two conducting plates are positioned in close proximity, they impose boundary conditions that restrict the allowed wavelengths of these fluctuations between them, resulting in a lower energy density compared to the unconfined space. This difference in energy density creates an attractive force between the plates, known as the Casimir force.

The magnitude of the Casimir force per unit area A between two perfectly conducting plates separated by a distance d is classically given by:

$$\frac{F_C}{A} = -\frac{\pi^2 \hbar c}{240 d^4},$$

where $\hbar$ is the reduced Planck constant and c is the speed of light in a vacuum. This expression shows that the force is inversely proportional to the fourth power of the separation distance, reflecting a rapid increase in strength as the plates are brought closer together.

The Casimir constant in this ideal case, denoted by the dimensionless factor $\frac{\pi^2}{240}$, encapsulates the geometric and material properties of the interacting bodies. However, for real materials and different geometries, this constant may vary, reflecting the complexity of boundary conditions and material responses within the Casimir effect.

15.2 The Classical Approach to the Casimir Force and Derivation of the Casimir Constant

To understand the origin of the Casimir effect, we start with the calculation of the zero-point energy of the electromagnetic field modes confined between two parallel plates separated by a distance d. The zero-point energy $E(d)$ in this setup is given by the sum over all possible quantized modes:

$$E(d) = \frac{\hbar c}{2} \sum_{n=1}^{\infty} (k_n - k),$$

where k_n represents the allowed wavevectors within the confined space between the plates, and k denotes the wavevector in free space, which is unrestricted by any boundaries. The sum $\sum_{n=1}^{\infty}(k_n - k)$ is divergent, a characteristic of vacuum fluctuations.

To handle this divergence, we use a regularization technique involving the Riemann zeta function, yielding a finite expression for the Casimir energy per unit area, A, between the plates:

$$\frac{E(d)}{A} = -\frac{\pi^2 \hbar c}{720 d^3}.$$

From this, the Casimir force F_C is derived by taking the negative gradient of the energy with respect to the separation distance d:

$$\frac{F_C}{A} = -\frac{dE(d)}{dd} = \frac{\pi^2 \hbar c}{240 d^4}.$$

This result demonstrates the standard Casimir force per unit area, arising from boundary-induced modifications of vacuum fluctuations. Now, by considering $A = d^2$, we observe that $\frac{A}{d^4} = d^{-2}$, allowing us to rewrite the total Casimir force as:

$$F_C = \frac{\pi^2 \hbar c}{240 d^2}.$$

15.3 The Casimir Constant C_c in Our Model and Its Implications

In our model, we directly relate the Casimir constant to the zero-point energy and the quantized structure of spacetime. Specifically, we propose that the minimal Casimir force per unit area is given by the zero-point energy multiplied by the fundamental quantum of spacetime, $\frac{1}{16\pi}$, and divided by a quantized differential area $\frac{1}{4}$. Since the zero-point energy per unit quantum of spacetime is $E_0 = \frac{\hbar c}{2}$, the minimal Casimir force per unit area becomes:

$$\frac{F_{C_{min}}}{A} = \frac{\frac{\hbar c}{2}}{4\pi}.$$

Thus, in our formulation, the Casimir constant is directly derived from this expression, grounding it in the intrinsic energy of the vacuum. Substituting $d = \frac{1}{2}$ in our simplified calculation yields:

$$F_{C_{min}} = C_c = \frac{\frac{\hbar c}{2}}{16\pi},$$

showing how the Casimir force manifests as a direct expression of vacuum energy density, influenced by the quantized geometry of spacetime fluctuations.

As we will see later with the gravitational constant G and Coulomb's constant k_e, the Casimir constant C_c has dimensions of force. **Justification Based on Zero-Point Energy and Electromotive Force**

The formulation of the Casimir constant in this model is justified by interpreting zero-point energy as an active EMF sustaining the oscillatory stability of the vacuum. The product of magnetic flux Φ and angular frequency ω, represented by $\Phi \cdot \omega = \frac{\hbar}{2} \cdot c$, offers a measure of the energy transfer rate per unit charge, which can be understood as the effective power density in oscillatory systems. In the context of the vacuum, $\Phi \cdot \omega$ embodies zero-point energy as a fundamental EMF that drives stability across quantized spacetime units.

This formulation connects the energy transfer rate $(\Phi \cdot \omega)$ with the minimal energy density needed to maintain dynamic stability in the vacuum. The zero-point energy per unit quantum of spacetime, $E_0 = \frac{\hbar c}{2}$, multiplied by the spacetime factor $\frac{1}{16\pi}$ and divided by the area $\frac{1}{4}$, results in the expression for the Casimir force per unit area:

$$\frac{F_C}{A} = \frac{\frac{\hbar c}{2}}{4\pi}.$$

This outcome aligns with experimental results [43] [44] and illustrates the vacuum's capacity to sustain a baseline oscillatory force, constrained by its quantized spacetime geometry.

Interconnection with Gravitational Forces and Vacuum Structure

The Casimir constant, in this framework, underscores a connection between vacuum fluctuations and gravitational interactions. Similar to how the Casimir force arises from boundary constraints on vacuum oscillations, gravitational force may be viewed as an emergent result of zero-point energy fluctuations shaped by mass-induced spacetime curvature. Here, the product $\Phi \cdot \omega$, representing magnetic flux and frequency, is analogous to power density in an RLC circuit, resonating with gravitational dynamics. This implies that the Casimir constant $\frac{\frac{\hbar c}{2}}{4\pi}$ serves as a baseline oscillatory force per unit area, analogous to a quantum gravitational influence.

In this unified model, both gravitational and Casimir forces derive from the same quantum principles, where zero-point energy serves as a stabilizing EMF, and vacuum oscillations underlie macroscopic interactions. Consequently, the Casimir constant offers an experimentally measurable foundation for the oscillatory nature of vacuum forces, reinforcing the idea that gravitational and electromagnetic interactions share a foundational quantum mechanical source.

16 Interpreting the Elementary Charge e as Induced by Vacuum Fluctuations

From the relationships we have already derived, we have that

$$\int E_0 \; dc = \frac{\hbar}{2} \int c \; dc = 2 \cdot \frac{3}{5} 4\pi e$$

The above equation expresses that the elementary charge e emerges from the cumulative contribution of vacuum oscillations. As we will see, $\frac{\hbar}{2}$ can be associated to the displacement field $\mathbf{D}$, which provides the fundamental energy scale, and $\int c \, dc$ represents the integral over all possible oscillatory modes of the vacuum, and the transformation of potential energy into kinetic energy.

Note that the right hand side expression is really similar to the one derived for the gravitational constant G in terms of ϵ_0. Recall that we have that

$$\int 4\pi G \rho_{vac} \; dc = \frac{3}{5} 4\pi \epsilon_0$$

Noting that we can derive that $E_0 = \rho_{vac} \cdot \sqrt{\frac{3}{5} 4\pi}$, we can re-express that

$$\sqrt{\frac{3}{5} 4\pi} \int \rho_{vac} \; dc = 2 \cdot \frac{3}{5} 4\pi e$$

$$\int \rho_{vac} \; dc = 2 \cdot \sqrt{\frac{3}{5} 4\pi} \cdot e$$

When considering the integral of vacuum energy density $\int \rho_{vac} \; dc$, as we have established dc as the differential of time within our framework, we can interpret this as a temporal accumulation of energy density due to vacuum fluctuations. This accumulated energy contributes to a displacement field $\mathbf{D}$ by polarizing the vacuum. The temporal integration indicates that this effect builds up over time, much like how a dielectric medium accumulates polarization under a constant electric field.

Therefore, the above relationship can be understood within the context of Gauss's law with a dielectric (such as vacuum fluctuations). We will introduce the electric displacement field $\mathbf{D}$ to account for polarization effects in the vacuum, which induces the elementary charge.

In the presence of a dielectric, Gauss's law is expressed as:

$$\oint_S \mathbf{D} \cdot d\mathbf{A} = Q_{\text{free}},$$

where $\mathbf{D}$ is the electric displacement field, and Q_{free} is the free charge enclosed by the surface S. In this context, we propose that the vacuum behaves like a dielectric medium, with its fluctuations generating a polarization effect that induces an effective charge.

Since the displacement field $\mathbf{D}$ can be interpreted as encoding the effects of vacuum fluctuations, it can be linked directly to the zero-point energy. This gives the relation:

$$\mathbf{D} = \frac{\hbar c}{2}.$$

Now, in the context of a universe expanding at relativistic velocities close to c, we assume that the surface element dA has two components: dc, reflecting the relativistic effect of expansion in vacuum fluctuations, and the infinitesimal change in space, dx, which we have related to $\frac{1}{2}$ through Heisenberg's uncertainty principle in the General Framework part. Thus, the surface integral of the displacement field becomes:

$$\oint_S \mathbf{D} \cdot dA = \oint_S \frac{\hbar c}{2} \; dx \cdot dc = \oint_S \frac{\hbar c}{4} \; dc = Q_{\text{free}}$$

Here, the integral represents the cumulative contribution of vacuum fluctuations in the matter-antimatter energy exchange process, which yields the induced charge Q_{free}.

To compute Q_{free}, we need to account for the spherical distribution of charge. The elementary charge e is a point charge, and Q_{free} represents the charge induced by vacuum fluctuations. In this context, we consider that the vacuum fluctuations induce charge symmetrically around a point charge, such that the free charge enclosed by the spherical surface is proportional to e.

The distribution of charge in a uniformly charged sphere gives the self-energy of the system, with the total charge distributed as:

$$Q_{\text{free}} = \frac{3}{5} 4\pi e,$$

where e is the elementary charge, and the factor $\frac{3}{5}4\pi$ arises from the spherical geometry of the system, consistent with classical results for self-energy distributions of spheres.

Implications of the elementary charge e as being induced by vacuum fluctuations

The above relationship implies that the elementary charge is not an intrinsic property of particles, but rather an emergent phenomenon driven by the interaction between quantum fluctuations and the spacetime structure. In this sense, the charge e is a macroscopic manifestation of the underlying quantum dynamics of the vacuum. This has profound implications for our understanding of the origin of physical constants, and confirms that all of them arise naturally from the vacuum state rather than being independent parameters.

Additionally, this framework introduces a connection between quantum field theory and classical electrodynamics, unifying them through the dynamics of the vacuum. By expressing the displacement field $\mathbf{D}$ in terms of the zero-point energy E_0, we bridge the quantum mechanical world of vacuum fluctuations with the classical notion of charge induction and field generation. This offers a new perspective on classical field equations like Gauss's law, as they can now be viewed as emergent from the underlying quantum vacuum structure. In turn, this could open new avenues for a better understanding of phenomena like the Casimir effect, vacuum polarization, and charge quantization in a unified manner.

17 The cosmological constant Λ within the framework of a system of harmonic oscillators

17.1 Introduction to the cosmological constant Λ

In this section, we explore how the cosmological constant Λ can be interpreted within the context of a system of harmonic oscillators.

The cosmological constant, denoted by Λ, was first introduced by Albert Einstein in 1917 as part of his field equations of General Relativity. At the time, the prevailing view of the universe was that it was static and unchanging. To reconcile his equations with this belief, Einstein added the cosmological constant as a repulsive force to counteract the attractive force of gravity on a cosmic scale. The modified field equations took the form:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

where $R_{\mu\nu}$ is the Ricci curvature tensor, R is the scalar curvature, $g_{\mu\nu}$ is the metric tensor, G is the gravitational constant, c is the speed of light, and $T_{\mu\nu}$ is the stress-energy tensor.

However, in the 1920s, Edwin Hubble's observations of distant galaxies revealed that the universe was not static but expanding. This discovery rendered the need for the cosmological constant unnecessary in Einstein's equations, leading Einstein to reportedly refer to Λ as his "greatest blunder."

Despite this, the cosmological constant was not discarded entirely. It remained a theoretical tool in cosmology, re-emerging in significance with the discovery of the accelerating expansion of the universe in the late 20th century. Observations of distant supernovae and the cosmic Quantumwave background (CMB) indicated that the universe's expansion rate was increasing, suggesting the presence of a form of energy with a repulsive effect—what we now refer to as dark energy. The cosmological constant is currently the simplest and most widely accepted model for dark energy.

Thus, the cosmological constant Λ has evolved from a parameter introduced to maintain a static universe to a cornerstone of modern cosmological theory, providing insights into the nature of the universe's expansion and the elusive dark energy that drives it.

17.2 The cosmological constant Λ as the power per unit area of the system of harmonic oscillators

Power represents the rate of energy transfer or conversion per unit time, or equivalently, the rate at which work is done in a system. In an RLC circuit with resistive (Ohmic, or linear) loads, the power can be expressed as:

$$P = I \cdot V = \frac{V^2}{R}$$

where R is the electrical resistance. This formulation describes how power dissipates through the system based on the voltage and current, or the voltage and resistance, allowing us to derive alternative expressions for power dissipation depending on the components involved.

We postulate that the cosmological constant, Λ, relates to the concept of power times a differential of area, expressed as:

$$\Lambda = \frac{V^2}{Z_0} \cdot dA = \frac{(\frac{h \cdot c}{2})^2}{Z_0} \cdot 4 = h \cdot e = \frac{e^2}{c^2}Z_0$$

We have previously established that $[G] = [\mu_0] = [\frac{h \cdot c}{2}] = [V]$. It is worthy to note that we arrive to the same result using $I_{\text{eff}} = \frac{e \cdot c}{2}$ as the current and establishing that

$$V = L \cdot \frac{dI}{dt} = \mu_0 \cdot \frac{e}{2} = \frac{h \cdot c}{2}$$

Additionally, we interpreted previously that:

- $h = \epsilon_0^3$ as the quantum of magnetic flux Φ within a coil.
- e as the elementary charge.

As $\frac{h}{2}$ is the quantum of magnetic flux Φ within a coil, and taking again $I = \frac{e \cdot c}{2}$, we have that

$$\frac{\Lambda}{4} = \Phi \cdot \frac{dI}{dt}$$

Where $\Phi \cdot \frac{dI}{dt}$ is the power within a coil, and we have that $[4] = [T^{-2}] = [L^{-2}]$ as the reciprocal of a differential of area.

17.3 Interpretation of the Cosmological Constant Λ as power Intensity

In the framework of this paper, we propose interpreting the cosmological constant Λ as a form of *power intensity*, defined as power per unit area, specifically $\Lambda = \frac{P}{A}$ where A represents a differential element of area. This interpretation aligns with the concept of intensity in physics, which measures the rate of energy flow across a surface, thus giving Λ a direct interpretation as a localized energy flux density driving the expansion of spacetime.

- **Intensity and Cosmic Expansion:** Viewing Λ as $\frac{P}{A}$ implies that Λ represents the intensity of energy flow per unit area, actively contributing to the accelerated expansion of the universe. This approach treats Λ as a localized energy flux, where power flows through infinitesimal areas across a cosmic horizon, consistent with the interpretation of Λ as a driver of spacetime expansion.
- **Relation to Energy Density and Pressure:** Standard cosmology often associates Λ with a form of energy density or effective pressure. Interpreting Λ as power per unit area aligns naturally with these definitions, as it provides a measure of distributed energy flow that scales with surface area. This perspective connects the vacuum energy density implied by Λ with a physically meaningful quantity that represents how energy propagates across spacetime.
- **Differential Area Elements and Localized Effects:** By taking A as a differential area element (e.g., dA), we express $\Lambda = \frac{P}{dA}$ as a measure of intensity over localized patches of the cosmological horizon. This differential form of Λ underscores the concept of vacuum energy's microcosmic contributions to cosmic expansion, while also accounting for integrated, large-scale effects observable in the universe's accelerated expansion.

Therefore, defining $\Lambda = \frac{P}{A}$ provides a consistent and physically meaningful interpretation within our framework. It situates Λ as an intensity that connects both the localized dynamics of vacuum fluctuations and the global effects on spacetime geometry, thereby linking the small-scale energy interactions within the vacuum to the expansive behavior of the universe. This interpretation aligns with the RLC circuit analogy by positioning Λ as a measure of energy transfer rate across spacetime, making it analogous to an intensity of energy flux distributed throughout the cosmic medium.

17.4 Derivation of $\Lambda = \frac{1}{4\pi c^6}$ and its interpretation

From previous derivations, we established that the vacuum energy density ρ_{vac} can be expressed in terms of fundamental constants as:

$$\rho_{\text{vac}} = \frac{1}{2\pi c^3} \tag{26}$$

where c is the speed of light.

Using the relationship between the vacuum energy density and the cosmological constant:

$$\Lambda \cdot c^2 = 8\pi G \rho_{\text{vac}} \tag{27}$$

and substituting $\rho_{\text{vac}} = \frac{1}{2\pi c^3}$ and $G = \frac{1}{16\pi c}$, we obtain:

$$\Lambda = 8\pi \cdot \frac{1}{16\pi c} \cdot \frac{1}{2\pi c^3} \cdot \frac{1}{c^2} = \frac{1}{4\pi c^6} \tag{28}$$

Interpretation of the Cosmological Constant $\Lambda = \frac{1}{4\pi c^6}$ as Power Intensity and Curvature Density

In this framework, the expression $\Lambda = \frac{1}{4\pi c^6}$ reveals a multifaceted view of the cosmological constant that integrates both global and local aspects of cosmic expansion. Setting $r = c^3$ highlights a 3D expansion at relativistic velocities, encapsulating a dynamic, volumetric scaling tied to the universe's accelerated expansion. Specifically, interpreting Λ in this way situates it as an effective curvature density, with $4\pi r^2 = 4\pi c^6$ representing the "surface" of an expanding 3D volume at the speed of light, effectively describing the boundary of a relativistic horizon.

With $\Lambda = \frac{1}{4\pi r^2}$ where $r = c^3$, the cosmological constant acquires a direct geometrical interpretation as an inverse-square term, analogous to curvature or density of a spherical boundary in expanding space. This form suggests that Λ describes a density of curvature effects that is inversely related to the effective surface area of the expanding horizon, much like the relationship between surface area and intensity in physical fields. Thus, as the 3D expansion progresses, the curvature density of spacetime per unit surface area decreases, aligning with the diminishing curvature influence over larger cosmic scales—an idea consistent with the observed accelerated expansion of the universe.

Interpretation of Λ as Power Intensity in Expanding Spacetime

When viewing Λ as power per unit area $\left(\frac{P}{A}\right)$, where P represents the power driving cosmic expansion and $A = 4\pi r^2$ is the effective "surface area" of the expanding universe, we find a natural fit. In this form, Λ embodies the intensity of energy flux distributed across the cosmic horizon, providing a measure of energy flow per unit area that scales with the boundary area of expansion. This approach aligns with interpreting Λ as a flux-driven quantity that impacts local regions of spacetime, reflecting the energy density that propels the universe's large-scale expansion. The fact that $\Lambda \sim \frac{1}{r^2}$ further reinforces the idea that as the spatial dimensions expand, the power intensity dissipates across the increased area, thus requiring lower "density" to drive expansion on larger scales.

Dimensional and Physical Implications of Λ as $[L^{-2}]$

Interpreting Λ in terms of $\frac{1}{4\pi c^6}$ also assigns it the dimensions of $[L^{-2}]$, which is characteristic of curvature measures in general relativity. This dimensionality aligns Λ with the concept of spacetime curvature per unit surface area, bridging its role as both a driver of expansion and a measure of how curvature scales inversely with the surface area of expansion. In this view, the choice of $r = c^3$ captures the dynamical, volumetric expansion of spacetime itself, with $\Lambda = \frac{1}{4\pi r^2}$ representing a curvature "intensity" that is distributed across an expanding relativistic volume.

In summary, the expression $\Lambda = \frac{1}{4\pi c^6}$ when viewed as a power per unit area term offers a cohesive way to understand the cosmological constant as both a curvature density and an intensity of energy flux. It provides a physical interpretation in which the large-scale expansion of the universe is driven by a steady energy flow that distributes itself over the expanding boundary, dynamically adjusting the effective curvature density as the volume of the universe grows. This interpretation not only aligns with the curvature requirements of an accelerating universe but also positions Λ as a power density fundamental to the structure and expansion of spacetime itself.

17.5 Checking the postulate with previous derived equations, and Einstein's theory of relativity

Relationship between Λ and the gravitational flux of vacuum

We have already seen that, from the relationship $G = \frac{e \cdot c}{2} \cdot \sqrt{\frac{3}{5}4\pi}$ we get that

$$\frac{e \cdot c}{2} = \frac{G}{\sqrt{\frac{3}{5}4\pi}} = \epsilon_0 \cdot \sqrt{\frac{3}{5}4\pi}$$

Also, reordering the equation for the vacuum energy density $\rho_{\text{vac}} = \frac{1}{2}\Phi_0\omega = \frac{\frac{1}{2}\hbar c}{\sqrt{\frac{3}{5}4\pi}}$, we have

$$\frac{\hbar c}{2} = \rho_{vac} \cdot \sqrt{\frac{3}{5}4\pi}$$

Where $[\rho_{vac}] = [kgm^{-3}]$. Therefore, we have that

$$\frac{e \cdot \hbar \cdot c^2}{4} = \rho_{vac} \cdot G$$

As $\hbar = \frac{h}{2\pi}$, we can substitute to obtain that

$$\frac{e \cdot h \cdot c^2}{8\pi} = \rho_{vac} \cdot G$$

Or, re-expressed more conveniently,

$$\frac{e \cdot h \cdot c^2}{2} = 4\pi G\rho_{vac}$$

On the right-hand side, $4\pi G\rho_{vac}$ represents the gravitational flux from Gauss's law when considering the vacuum's mass density in units of kg/m^3. The left side, $\frac{e \cdot h \cdot c^2}{2}$, can also be expressed as $\frac{e \cdot c}{\cdot}\frac{h \cdot c}{2}$. This is equivalent to $I_{min} \cdot V_{min}$, representing some minimum real power of the system.

Thus, the gravitational flux $4\pi G\rho_{vac}$ can be interpreted as a minimal form of active power inherent in the vacuum. The right hand side of the above equation represents the rate of gravitational energy density transfer within the vacuum, while the left side, $\frac{e \cdot h \cdot c^2}{2}$, captures the minimum power available within the vacuum's electromagnetic and gravitational framework. This suggests that the vacuum, even in its most "inactive" state, generates a continuous, minimal active power that sustains both the structure and expansion of spacetime.

This minimum active power of gravitational flux density provides a foundation for understanding cosmic expansion: as vacuum fluctuations propagate energy throughout spacetime, this active power accumulates to drive the expansion. This minimal power, consistent with the framework of the cosmological constant Λ, effectively contributes to the universe's accelerated expansion by sustaining a steady flux of gravitational energy density that permeates and stretches spacetime. Consequently, Λ not only governs the scale of cosmic intensity but also embodies the active contribution of gravitational flux from the quantum vacuum, amplifying and shaping the observable dynamics of the cosmos.

Given our previous postulate that $\Lambda = h \cdot e$, the above relationship can be reformulated as:

$$\frac{1}{2}\Lambda c^2 = 4\pi G\rho_{vac}.$$

Or, equivalently, in integral form:

$$\int e \cdot c \cdot h \, dc = \Lambda \int c \, dc.$$

Here, $\int c \, dc$ functions as the transformational operator that we previously identified as converting potential forms of energy (such as charge, mass, and energy density) into dynamic or kinetic forms observable in spacetime.

This interpretation is consistent with Λ as an intensity measure, or localized power per unit area, suggesting that it mediates the transformation of vacuum's inherent potential energy into gravitational flux density. Specifically, $\int e \cdot h \cdot c \, dc$ accumulates contributions from the elementary charge and Planck's constant distributed over all possible oscillatory modes (frequencies) of vacuum energy, effectively integrating potential energy contributions into gravitational flux as a function of space and time.

Thus, in this framework, Λ not only sets the scale of gravitational intensity but serves as a bridge between the quantum realm and the gravitational field at cosmological scales. The operator $\int c \, dc$ captures this transformation, emphasizing the role of Λ as a fundamental constant that shapes the large-scale structure of spacetime through continuous energy exchange across vacuum oscillations. This view aligns Λ with gravitational power density, portraying the expansion and curvature of the universe as outcomes of the dynamic interplay between vacuum energy density and the cosmic gravitational field.

Relationship between $\rho_{\mathbf{vac}}$ and Λ in the context of Einstein's theory of general relativity (consistency check)

The relationship between the vacuum energy density ρ_{vac} and the cosmological constant Λ can be derived from the context of Einstein's theory of general relativity, specifically from the Einstein field equations with the inclusion of the cosmological constant.

The Einstein field equation in its most general form, including the cosmological constant Λ, is:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu} \tag{29}$$

where:

- $R_{\mu\nu}$ is the Ricci curvature tensor, which describes the curvature of spacetime.
- R is the Ricci scalar (the trace of the Ricci tensor).
- $g_{\mu\nu}$ is the metric tensor that describes the geometry of spacetime.
- $T_{\mu\nu}$ is the energy-momentum tensor, which describes the distribution of matter and energy in spacetime.

When there is no matter or conventional energy present, i.e., $T_{\mu\nu} = 0$, the Einstein field equation reduces to:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = 0 \tag{30}$$

In this case, Λ can be interpreted as a form of *intrinsic energy* of the vacuum, which acts as a source of spacetime curvature. This vacuum energy is present even in the absence of matter or radiation.

To describe the vacuum energy as a form of energy affecting the curvature of spacetime, we can reinterpret the term $\Lambda g_{\mu\nu}$ as contributing to an *effective energy-momentum tensor* for the vacuum energy. This gives us the following form for the vacuum energy-momentum tensor:

$$T_{\mu\nu}^{\text{vac}} = -\frac{\Lambda c^4}{8\pi G}g_{\mu\nu} \tag{31}$$

This term behaves like a *perfect fluid* with a constant energy density ρ_{vac} and an associated pressure p_{vac} related to the vacuum energy. The vacuum energy behaves like a fluid with *negative pressure*, meaning the pressure p_{vac} is equal to $-\rho_{\text{vac}}c^2$.

Then, the relationship between ρ_{vac} and Λ can be obtained by identifying the term describing vacuum energy in the Einstein field equation with the standard form of a perfect fluid in cosmology. In a universe dominated by vacuum energy, the effective energy density can be expressed as:

$$\rho_{\text{vac}}c^2 = \frac{\Lambda c^4}{8\pi G} \tag{32}$$

Solving for ρ_{vac}, we obtain the relationship between the vacuum energy density and the cosmological constant:

$$\rho_{\text{vac}} = \frac{\Lambda c^2}{8\pi G} \tag{33}$$

Multiplying both sides of this last equation by $4\pi G$, we get that

$$4\pi G\rho_{\text{vac}} = \frac{\Lambda c^2}{2} = \Lambda \int c\, dc \tag{34}$$

As a result, we have derived the same equivalence both from the Einstein field equation with the cosmological constant, interpreting Λ as a manifestation of the vacuum energy, and from the relationships and postulates that we have established throughout the Paper. This result serves as a consistency check for our model, and shows that our propositions and findings do not invalidate, but complement, Einstein's theory for general relativity.

The derived relationships show how the energy dynamics within the vacuum influence gravitational interactions on cosmological scales. The integral forms of these equations suggest that the accumulation of quantum mechanical effects over time (represented by the integrals) could give rise to macroscopic cosmological phenomena like the cosmological constant.

18 Derivation of Hubble's Parameter H_0

18.1 Introduction to the Friedmann Equations

The Friedmann equations [45] [46] [47] are a set of equations derived from Einstein's field equations of general relativity, governing the expansion of space in a homogeneous and isotropic universe. These equations are foundational in modern cosmology, providing the framework for understanding the dynamics of the universe on large scales. They describe how the scale factor $a(t)$, which measures the relative expansion of the universe, evolves over time based on the energy content of the universe. The two main forms of energy that influence this expansion are matter (both normal and dark) and the energy associated with the cosmological constant, Λ.

The first Friedmann equation is given by:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} + \frac{\Lambda}{3},$$

where $\dot{a}$ is the time derivative of the scale factor, G is the gravitational constant, ρ is the energy density of the universe, k is the curvature parameter, and Λ is the cosmological constant. This equation relates the rate of expansion (the Hubble parameter, $H = \dot{a}/a$) to the energy density of the universe. The curvature term k determines whether the universe is open, closed, or flat, while the cosmological constant Λ represents the energy density of empty space, commonly associated with dark energy.

The second Friedmann equation, describing the acceleration or deceleration of the universe's expansion, is given by:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p) + \frac{\Lambda}{3},$$

where $\ddot{a}$ is the second derivative of the scale factor and p is the pressure of the universe's contents. Together, these two equations form the backbone of the standard model of cosmology, describing the universe's evolution from the Big Bang to its potential future states.

18.2 Friedmann Equations using the dimensional equivalence $[L] = [T]$

In the previous sections, we established a dimensional equivalence $L = T$ (space = time), which implies that the dimensions of spatial and temporal quantities are fundamentally equivalent. This leads to significant modifications in the Friedmann equations when we reconsider the factors arising from the spatial dimensions.

In standard cosmology, the Friedmann equations are derived under the assumption that the universe has 3 spatial dimensions and 1 time dimension, commonly referred to as a $(3 + 1)$-dimensional spacetime. This distinction is crucial because the geometry of space and the flow of time are treated separately in general relativity. The curvature of space is integrated over 3 spatial dimensions, leading to the factor of 3 in the Friedmann equations. The time dimension, on the other hand, governs the evolution of the universe through the scale factor $a(t)$ and the Hubble parameter H.

The reason we normally use this $(3 + 1)$ structure is based on observations and the framework of general relativity, where the spatial dimensions have different properties compared to the time dimension. Time flows forward (with a thermodynamic arrow of time), while spatial dimensions are symmetric and isotropic (allowing movement in any direction in space). Thus, the standard Friedmann equations describe how the 3D spatial volume expands over time.

However, in the context of this paper, we establish a dimensional equivalence $L = T$, which implies that space and time are interchangeable in some fundamental way. This breaks the conventional distinction between the spatial and temporal dimensions and leads us to consider all four dimensions (three spatial and one temporal) as being equivalent in this new framework.

By doing this, we treat the universe as a 4-dimensional object with equivalent dimensions, where the dynamics of both space and time contribute equally to the evolution of the universe. This symmetry suggests that the spatial curvature and expansion should account for all four dimensions rather than just three, modifying the usual factor of 3 to a factor of 4.

Therefore, the modified Friedmann equation under this framework becomes:

$$H^2 = \frac{8\pi G\rho}{4} + \frac{\Lambda c^2}{4},$$

where c^2 is a necessary factor to convert the cosmological constant into an energy density contribution. As we derived earlier that $\frac{1}{2}\Lambda c^2 = 4\pi G\rho_{\text{vac}}$, we can substitute and simplify to get

$$H^2 = 4\pi G\rho_{\text{vac}},$$

where ρ_{vac} is the vacuum energy density measured in kg/m^3.

The introduction of a factor of 4 in the Friedmann equations reflects a profound shift in our understanding of the geometry of the universe. In this model, space and time are treated as fundamentally interchangeable, leading to a more unified description of the universe's expansion.

From a physical perspective, this implies that both space and time contribute equally to the universe's dynamics, perhaps hinting at a deeper symmetry in the underlying structure of spacetime. This could suggest that our traditional separation of spatial and temporal dimensions is an approximation that breaks down at fundamental scales, such as those governed by quantum gravity or vacuum energy fluctuations.

Additionally, this modified framework offers new insights into the role of vacuum energy in cosmology. The relationship $H^2 = 4\pi G\rho_{\text{vac}}$ strengthens the connection between vacuum energy and the expansion rate of the universe. By considering all four dimensions equivalently, the vacuum energy becomes the central component in the universe's expansion dynamics, possibly providing a more natural and simple explanation for the observed acceleration of the universe.

This expression implies that we can interpret H^2 as a measure of the total gravitational effect of all matter, energy, and curvature present in the universe. This "flow" describes how these sources affect the expansion or contraction of space, and this accelerated expansion conforms to gravitational flux as derived from Gauss's Law.

19 Deriving the Einstein-Hilbert Action from Vacuum Properties

In this section, we show how the Einstein-Hilbert action S_{EH} can be derived from fundamental vacuum properties, consistently with the postulates and relationships developed throughout this paper. Specifically, we show that under some standard assumptions, the Einstein-Hilbert action equals the gravitational constant G. This finding not only links gravity to the vacuum's electromagnetic properties but also provides more evidence into how spacetime curvature and quantum mechanics are unified through vacuum fluctuations.

19.1 Linking the Einstein-Hilbert Action to the gravitational constant G

The Einstein-Hilbert action [48] [49] [50] in General Relativity with a cosmological constant is typically expressed as:

$$S_{EH} = \frac{c^4}{16\pi G} \int (R - 2\Lambda)\sqrt{-g}\, d^4x \tag{35}$$

where G is the gravitational constant, R is the Ricci scalar, and g is the determinant of the metric tensor. The prefactor $\frac{c^4}{16\pi G}$ controls the strength of the curvature coupling, and is derived from Einstein field equations.

19.1.1 Deriving $\Lambda = \frac{1}{4\pi c^6}$

We begin by considering the vacuum energy density, which is related to the electromagnetic properties of the vacuum. In this framework, the cosmological constant Λ arises naturally from the structure of the vacuum. From previous derivations, we established that the vacuum energy density ρ_{vac} can be expressed in terms of fundamental constants as:

$$\rho_{\text{vac}} = \frac{1}{2\pi c^3} \tag{36}$$

where c is the speed of light.

Using the relationship between the vacuum energy density and the cosmological constant:

$$\Lambda \cdot c^2 = 8\pi G \rho_{\text{vac}} \tag{37}$$

and substituting $\rho_{\text{vac}} = \frac{1}{2\pi c^3}$ and $G = \frac{1}{16\pi c}$, we obtain:

$$\Lambda = 8\pi \cdot \frac{1}{16\pi c} \cdot \frac{1}{2\pi c^3} \cdot \frac{1}{c^2} = \frac{1}{4\pi c^6} \tag{38}$$

19.1.2 Substituting the Ricci Scalar with 4Λ

In the Einstein-Hilbert action, the Ricci scalar R represents the curvature of spacetime due to the presence of mass and energy. In a vacuum-dominated universe, where the vacuum energy density drives the dynamics of the universe, it is reasonable to approximate the Ricci scalar R by the cosmological constant Λ. Indeed, in cosmological models with nearly constant curvature (such as *de Sitter* or *anti-de Sitter* spaces) we have $R = 4\Lambda$.

Substituting in the expression for the Einstein-Hilbert action with cosmological constant and operating we get that

$$S_{EH} = \frac{c^4}{16\pi G} \cdot 2\Lambda \int \sqrt{-g}\, d^4x \tag{39}$$

Substituting $\Lambda = \frac{1}{4\pi c^6}$ and multiplying by the prefactor $\frac{c^4}{16\pi G} = c^5$ yields that

$$S_{EH} = \frac{1}{2\pi \cdot c} \int \sqrt{-g}\, d^4x = 8G \int \sqrt{-g}\, d^4x = \rho_{vac} \int \sqrt{-g}\, d^4x$$

This result is already insightful, as it links the action of gravity to the energy density of vacuum, over a spacetime volume and affected by some curvature, as we already postulated before, and in harmony with the postulates of general relativity.

19.1.3 Deriving the value of $\int \sqrt{-g}\, d^4x$

The spacetime volume V in the context of the Einstein-Hilbert action refers to the 4-dimensional integral over spacetime:

$$V = \int \sqrt{-g}\, d^4x \tag{40}$$

The integral represents the four-volume of a region of spacetime, with dimensions determined by the coordinates x^μ (typically one temporal and three spatial dimensions). In standard units, this expression has dimensions of L^4, consistent with a 4-dimensional spacetime integral.

To integrate the temporal dimension in a relativistically expanding universe, we scale it by the speed of light c, unifying the dimensions. This scaling aligns with the common practice in relativistic frameworks to rescale the time coordinate as $x^0 = ct$, treating time in units compatible with the spatial dimensions.

Elementary Spacetime Differential

We have established the elementary spacetime differential $dx = \frac{1}{2}$, derived from Heisenberg's uncertainty principle, where x represents spacetime. This differential can be interpreted as the fundamental quantum unit over which spacetime is measured or traversed. It serves as the building block of spacetime within our framework, particularly at small scales where spacetime may exhibit discrete structure.

This discretization reflects the minimum interval in spacetime, consistent with the assumption of constant momentum in our framework. The smallest possible change in spacetime is tied to this elementary differential, encapsulating the uncertainty relationship between position and momentum.

Scaling the Temporal Dimension as the Speed of Light c

To unify the three spatial dimensions with the temporal dimension, and consistent with previous sections, we establish the speed of light c as a scaling factor for time. By setting $x^0 = ct$, we simplify the integration process in the Einstein-Hilbert action, ensuring consistency in units and aligning with relativistic treatment of time. This approach allows us to retain a four-dimensional action that respects the vacuum's structure in a universe expanding at relativistic velocities.

In this context, the four-volume $\int \sqrt{-g}\, d^4x$ takes into account the relativistic scaling of time, making the action dimensionally consistent with the physical properties of a universe dominated by vacuum energy. Here, each dimension—three spatial and one time scaled by c—is unified, reflecting the symmetry and balance between space and time at relativistic scales. This approach aligns the vacuum properties with the Einstein-Hilbert action, suggesting that the geometry of the universe is inherently influenced by the properties of the vacuum itself.

Establishing the value of $\sqrt{-g}$

Other hand, in the Einstein-Hilbert action of general relativity, the term $\sqrt{-g}$ represents the square root of the negative determinant of the metric tensor $g_{\mu\nu}$. This term is crucial because it ensures that the action is a scalar under coordinate transformations, providing an invariant volume element in spacetime.

In an almost flat universe, spacetime is only slightly curved, and the metric tensor $g_{\mu\nu}$ deviates minimally from the flat Minkowski metric $\eta_{\mu\nu}$. In flat spacetime, the Minkowski metric has components $\eta_{\mu\nu} = \text{diag}(-1, 1, 1, 1)$, and its determinant is $\det(\eta_{\mu\nu}) = -1$. Therefore, the square root of the negative determinant is:

$$\sqrt{-\det(\eta_{\mu\nu})} = \sqrt{-(-1)} = 1.$$

In an almost flat universe, the determinant of the metric tensor g can be expressed as:

$$g = \det(g_{\mu\nu}) \approx -1 + \delta g,$$

where δg represents small deviations from the flat metric determinant. Since δg is negligible, the square root becomes:

$$\sqrt{-g} \approx 1 + \frac{1}{2}\delta g.$$

However, for practical purposes in an almost flat universe, δg is so small that $\sqrt{-g} \approx 1$ is a valid approximation.

Therefore, in the case of an almost flat Minkowski spacetime, and scaling the time coordinate by c, the expression $\int \sqrt{-g}\, d^4x$ reduces to:

$$\int \sqrt{-g}\, d^4x = \frac{c}{16}$$

19.1.4 Establishing $S_{EH} \approx \frac{G \cdot c}{2}$

At the end, we can express the Einstein-Hilbert action as:

$$S_{EH} = 8G \cdot \frac{c}{16} = \frac{G \cdot c}{2} \tag{41}$$

This establishes that, under this vacuum-based framework, the Einstein-Hilbert action is equal to $\frac{G \cdot c}{2}$, linking the action that governs spacetime curvature to the gravitational constant G.

19.2 Implications and Consistency within the previous Framework

The result $S_{EH} = \frac{G \cdot c}{2}$ implies a profound connection between spacetime geometry and the vacuum's electromagnetic structure, and it is consistent with our previous derivations. Force can be viewed as the time derivative of the partial spatial derivative of the action S:

$$F = \frac{d}{dt}\left(\frac{\partial S}{\partial x}\right).$$

Note that, substituting the action by $\frac{G \cdot c}{2}$, and as we have established that $dx = \frac{1}{2}$ and that $t = c$, we get that

$$F = \frac{d}{dt}\left(\frac{\partial S}{\partial x}\right) = G$$

Therefore, we have that the quantum of gravitational force is indeed G, as we have previously established. This result provides a natural way to unify gravity, general relativity and quantum mechanics within a vacuum-centric framework. The Einstein-Hilbert action, traditionally a measure of spacetime curvature, becomes a direct expression of the vacuum's inductive properties. When evaluated over a universe dominated by vacuum, nearly flat, and such that quantum harmonic oscillators become the quantum of spacetime, the action approaches $\frac{G \cdot c}{2}$, showing that the gravitational constant is not merely an empirical factor but emerges from the fundamental properties of the vacuum. This finding supports the broader hypothesis that gravity and quantum mechanics are deeply interconnected through the vacuum's electromagnetic characteristics, with ϵ_0 serving as the bridge between these two fundamental domains of physics.

Further unification of General Relativity and Quantum Physics through Discrete Spacetime Volume

This formulation of the Einstein-Hilbert action, scaled by the speed of light c and incorporating the elementary differential $dx = \frac{1}{2}$ as derived from Heisenberg's uncertainty principle, represents a powerful step toward reconciling general relativity with quantum mechanics. By integrating the smallest quantum unit of spacetime—reflecting the fundamental limit on position and momentum certainty—the volume integral $\int \sqrt{-g}\, d^4x$ not only unifies space and time dimensions at relativistic scales but also embeds quantum discreteness within the fabric of spacetime. This discrete interpretation, where each spatial and temporal increment aligns with quantized uncertainty, inherently links the curvature of spacetime to the oscillatory, quantum structure of the vacuum. Thus, we achieve a cohesive framework where general relativity's geometric description of gravity and the probabilistic nature of quantum mechanics converge, governed by the intrinsic properties of the vacuum. This unified perspective has profound implications for our understanding of spacetime, suggesting that gravitational effects, vacuum fluctuations, and the expanding universe are intertwined through a quantum-geometric foundation.

20 Derivation of a novel electro-gravitational model from the obtained relationships

20.1 Energy stored in a capacitor and its connection to vacuum mass and gravitational constant G

In this subsection, we explore the relationship between the energy stored in a capacitor, the mass associated with vacuum energy, and the gravitational constant G, within the context of a universe expanding at relativistic velocities. We begin by considering the energy stored in a capacitor with a capacitance related to vacuum permittivity and an applied voltage that depends on the vacuum impedance. This energy is then shown to be equivalent to the mass-energy of the vacuum, which leads us to a profound connection with the gravitational constant.

Energy stored in a capacitor The energy U stored in a capacitor is given by the standard relation:

$$U = \frac{1}{2}CV^2,$$

where C is the capacitance, and V is the voltage applied across the capacitor. In our electro-gravitational model, we have established that the capacitance equals the vacuum permittivity ϵ_0, so we have:

$$C = \epsilon_0$$

The applied voltage V is chosen based on the vacuum impedance Z_0, which is the characteristic impedance of free space. The vacuum impedance is given by:

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}.$$

In this model, the applied voltage is related to Z_0 by the following expression:

$$V = \frac{\left(\frac{1}{Z_0}\right)^3}{2} = \frac{\left(\sqrt{\frac{\epsilon_0}{\mu_0}}\right)^3}{2}.$$

This voltage is derived for the previously established equivalence

$$\mu_0 = \frac{\left(\frac{1}{Z_0}\right)^3}{2\alpha}$$

Recall that we have that

$$V = L \cdot \frac{dI}{dt}$$

If we set $L = \mu_0$, and $I = I_{max} = c$, and $t = c$, we get that

$$V = \mu_0$$

As α is an dimensionless factor (that we will relate later to relativistic velocities), then we have that $\mu_0 \cdot \alpha = \frac{\left(\frac{1}{Z_0}\right)^3}{2}$ is a voltage.

Substituting these expressions for C and V into the energy equation, we find that the energy stored in the capacitor is:

$$U = \frac{1}{2}\epsilon_0 \left(\frac{\left(\frac{1}{Z_0}\right)^3}{2}\right)^2 = \frac{\epsilon_0}{8} \cdot \frac{1}{Z_0^6}.$$

As we have that $Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$, the above can be rewritten as

$$U = \frac{\epsilon_0}{8} \cdot \frac{\epsilon_0^3}{\mu_0^3}$$

This expression represents the energy stored in the capacitor, which is now ready to be related to the mass associated to vacuum.

Relating the stored energy to the vacuum mass

Note that, building on the equivalences $\rho_{vac} = \frac{1}{2\pi \cdot c^3}$ and and $h = \frac{\mu_0 \cdot e}{c}$, we have that

$$\rho_{vac} = \frac{\epsilon_0}{2\pi} \cdot \frac{h}{e}$$

Dividing by 16 to account for the four spacetime dimensions term of the vacuum energy density, we have that

$$m_{vac} = \frac{\epsilon_0}{32\pi} \cdot \frac{h}{e}$$

Substituting with $h = \epsilon_0^3$ and $e = \frac{\mu_0^3}{4\pi}$, we get that

$$m_{vac} = \frac{\epsilon_0}{32\pi} \cdot \frac{4\pi\epsilon_0^3}{\mu_0^3}$$

Operating, we have that

$$m_{vac} = \frac{\epsilon_0}{8} \cdot \frac{\epsilon_0^3}{\mu_0^3}$$

And then, we can notice that we have

$$U = m_{vac}$$

The result that the energy stored in a capacitor, U, is equivalent to the mass associated with vacuum energy, m_{vac}, presents profound implications for our understanding of the relationship between electromagnetism and gravitation. This equivalence, derived through a combination of electromagnetic constants such as the vacuum permittivity ϵ_0, permeability μ_0, and the vacuum impedance Z_0, shows that the energy dynamics within an electric field are inherently connected to the mass-energy content of the vacuum. In particular, the fact that $U = m_{\text{vac}}$ reinforces the idea that gravitational effects can be understood as an emergent phenomenon arising from the same underlying principles that govern electromagnetic interactions. This leads to the fact that both gravity and electromagnetism are mediated by the vacuum's capacity to store and dissipate energy within a relativistic framework.

Connecting the vacuum mass to the gravitational constant G

From Einstein's mass-energy equivalence relation, the energy associated with the mass m_{vac} is given by:

$$E = m_{\text{vac}} \cdot c^2.$$

Substituting, we have that

$$E = \frac{\epsilon_0}{8} \cdot \frac{\epsilon_0^3}{\mu_0^3} \cdot c^2$$

Substituting $c^2 = \frac{1}{\epsilon_0 \cdot \mu_0}$, we have that

$$E = \frac{1}{8} \cdot \frac{\epsilon_0^3}{\mu_0^4}$$

Using that we have that $\epsilon_0 = 2\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$, we can substitute to obtain

$$E = \frac{1}{8} \cdot \frac{4 \cdot \frac{3}{5}4\pi \cdot \epsilon_0^3}{\epsilon_0^2}$$

Finally, cancelling terms, we get that

$$E = \frac{\frac{3}{5}4\pi\epsilon_0}{2} = \frac{G}{2}$$

Thus, we have established that the gravitational constant G is the energy equivalent to the mass associated to vacuum energy density, which in turn can be derived using the formula for the energy stored in a capacitor, divided by the quantized spacetime factor. This is consistent with G having dimensions of force, as we have derived in the previous section for gravity.

Interestingly, we have that

$$G = \alpha \cdot h \cdot c \int c \, dc$$

20.2 Energy stored in an inductor and its connection to Coulomb's constant K

In this subsection, we explore the relationship between the energy stored in an inductor, the inductance associated with vacuum permeability, and Coulomb's constant K. This builds on the previous subsection, where we derived the gravitational constant G by relating it to the energy stored in a capacitor. We aim to show that the energy stored in an inductor, when expressed through vacuum properties, is directly equivalent to Coulomb's constant divided by the quantized spacetime.

Energy stored in an inductor

The energy stored in an inductor is given by the standard expression:

$$U_L = \frac{1}{2} L I^2,$$

where L is the inductance and I is the current through the inductor. In the electro-gravitational model, we assume that the inductance is given by the vacuum permeability μ_0, so that:

$$L = \frac{\mu_0}{4\pi}.$$

The choice of inductance $L = \frac{\mu_0}{4\pi}$ is consistent with how vacuum permeability μ_0 governs the magnetic field generation in free space. In classical electromagnetism, μ_0 represents the ability of the vacuum to sustain a magnetic field when an electric current is present. The factor 4π comes from the spherical symmetry of the fields produced by point charges and currents, commonly seen in Coulomb's law and Biot-Savart law.

Inductance is a measure of how much magnetic flux is generated per unit current through a given loop or conductor. In our model, vacuum behaves as a medium that responds inductively to changes in electric and magnetic fields. By setting $L = \frac{\mu_0}{4\pi}$, we capture the vacuum's intrinsic response to currents, where the factor 4π arises naturally from the geometry of field propagation in a spherically symmetric space. This formulation reflects how the vacuum's permeability impacts the inductor's ability to store energy in the magnetic field, aligning with the broader electro-gravitational model that links electromagnetic and gravitational constants to the vacuum structure.

For the current I, we assume that it is equal to $I_{max} = c$. Substituting these values for L and I into the energy expression, we find that the energy stored in the inductor is:

$$U_L = \frac{1}{2} \left(\frac{\mu_0}{4\pi} \right) c^2.$$

This simplifies to:

$$U_L = \frac{\mu_0 c^2}{8\pi}.$$

This expression represents the energy stored in the inductor as a function of the vacuum permeability and the speed of light.

Relating the stored energy to Coulomb's constant K

Next, we relate this stored energy to Coulomb's constant K, which governs the strength of the electrostatic force between two charges. Coulomb's constant is given by the well-known expression:

$$K = \frac{1}{4\pi\epsilon_0}.$$

Noting that we have that $\frac{1}{\epsilon_0} = \mu_0 \cdot c^2$, we can substitute to get that

$$K = 2 \cdot U_L = \frac{\mu_0 \cdot c^2}{4\pi}.$$

Interestingly, note that

$$K = \frac{\mu_0}{2\pi} \int c \; dc$$

Thus, the energy stored in the inductor divided by the quantized spacetime is directly equivalent to Coulomb's constant, which has dimensions of force. This shows that Coulomb's constant arises from the energy stored in the vacuum's inductive response, analogous to how the gravitational constant G was derived from the energy stored in the vacuum's capacitive response.

Given that we have established that K has the dimensions of force, this suggests that Coulomb's constant is not just a scaling factor for the electrostatic interaction but rather represents the inherent force per unit charge that arises from the inductive properties of the vacuum.

By expressing K in terms of vacuum permeability and speed of light, $K = \frac{\mu_0 c^2}{4\pi}$, Coulomb's law can be seen as the manifestation of vacuum-induced magnetic interactions. In this view, the vacuum's inductive capacity, encoded by μ_0, sets the scale for the strength of the electrostatic force, with the speed of light c further reinforcing the relativistic nature of these interactions. Therefore, Coulomb's law can be understood as describing how charges interact through the inductive response of the vacuum, where the force between charges is mediated by the energy stored in the magnetic field induced by the charges themselves.

Linking Charges to the Curvature of Spacetime

In our electro-gravitational model, charges, much like masses in gravity, can be linked to the curvature of spacetime. Just as masses in general relativity distort spacetime, leading to the gravitational force as an emergent property of that curvature, charges can similarly be interpreted as creating distortions or "curvature" in the electromagnetic field. These distortions give rise to the electrostatic force, which can be viewed as analogous to the gravitational force in this unified framework.

Since charges interact via the vacuum's inductive properties, their presence distorts the electromagnetic field much like masses distort the gravitational field. This distortion corresponds to the curvature in the electromagnetic field lines, which propagate through spacetime. The electrostatic force between two charges can then be seen as the result of these distortions attempting to equalize the field, in much the same way that gravity arises from spacetime trying to restore balance in response to mass.

Dimensional Analysis of Charges and Geometrical Parameters

In our framework, we have established that the dimension of charge $[Q]$ is equivalent to $[L] = [T]$, just as we previously established that the dimension of mass $[M]$ also corresponds to $[L] = [T]$. This gives charge a geometrical interpretation, where charges are treated as spatial extents rather than sources of intrinsic electrical properties. Thus, the product of two charges q_1 and q_2 has the dimensions:

$$[q_1 \cdot q_2] = [L]^2.$$

In Coulomb's law, the electrostatic force between two charges is given by:

$$F = K \frac{q_1 q_2}{r^2},$$

where r is the distance between the charges and K is Coulomb's constant. The term $\frac{q_1 q_2}{r^2}$ represents the interaction strength between the two charges over a distance r. Since both the product of charges $q_1 \cdot q_2$ and the square of the distance r^2 have dimensions of $[L]^2$, their ratio is dimensionless:

$$\left[\frac{q_1 q_2}{r^2}\right] = \frac{[L]^2}{[L]^2} = 1.$$

This shows that the expression $\frac{q_1 q_2}{r^2}$ becomes dimensionless, meaning that the charges and the distance between them can now be interpreted as mere geometric parameters, much like the masses in Newton's law of gravitation within our model.

Charges as Geometrical Parameters

Then, with the product of charges divided by the squared distance becoming dimensionless, we reinterpret the charges as geometrical parameters that describe the configuration of the system. This parallels the gravitational case, where masses were shown to be geometric factors that influence the curvature of spacetime. Here, charges influence the curvature of the electromagnetic field lines in spacetime, dictating the strength and configuration of the resulting electrostatic force.

In this sense, the charges q_1 and q_2 reflect the spatial interaction within the electromagnetic field, with the force determined by the geometry of their interaction. As with gravity, the vacuum properties mediate the interaction between these geometric charges, with Coulomb's constant K serving as the governing force that emerges from the vacuum's inductive response. This unification underscores the symmetry between electromagnetism and gravity, both arising from the vacuum's response to distortions caused by geometric parameters, whether they be masses or charges.

Thus, the electrostatic force is a consequence of the geometry of the electromagnetic field in spacetime, with charges treated as spatial quantities. The dimensionless nature of $\frac{q_1 q_2}{r^2}$ further supports this interpretation, showing that the force between charges is a result of spacetime deformation, rather than intrinsic properties of the charges themselves.

Symmetry between K and G

Having established that the gravitational constant G is related to the energy stored in a capacitor, and now showing that Coulomb's constant K is related to the energy stored in an inductor, we observe a profound symmetry between the two constants. Both constants are the fundamental drivers of the fundamental forces in nature —gravity and electromagnetism—, and they emerge from the same underlying vacuum properties in our electro-gravitational model. Specifically:

- The gravitational constant G is linked to the capacitive behavior of the vacuum, where the stored energy in the vacuum's electric field gives rise to gravitational interactions.

- The Coulomb constant K is linked to the inductive behavior of the vacuum, where the stored energy in the vacuum's magnetic field gives rise to electromagnetic interactions.

This symmetry suggests that gravity and electromagnetism are dual aspects of the vacuum's ability to store energy, mediated by electric and magnetic fields, respectively. In this framework, both G and K emerge from the same vacuum structure, further supporting the idea that these two fundamental forces are deeply intertwined.

21 Further Relationships Among Universal Constants

In this final section of Part II, we compile a range of mathematical relationships between universal constants that, while not previously derived, reveal the intricate interconnections that emerge from our framework of the universe as a system of harmonic oscillators. These expressions are not essential to the derivations in earlier sections but offer useful insights into the structural cohesiveness of our theory and serve as a 'sawyer toolbox'—a reference point that situates these relationships within a cohesive framework.

These expressions provide insight into how constants such as the cosmological constant Λ, the speed of light c, and vacuum permeability and permittivity (μ_0 and ϵ_0) interrelate within our model. Additionally, some of these identities parallel known physical laws, such as Gauss's Law, but are contextualized here through the lens of vacuum energy and gravitational flux. By aggregating these relationships, we aim to capture a broader view of the vacuum's role in both quantum-level and cosmological phenomena, illustrating how energy density, flux, and intensity are interconnected within the model's dual quantum and macroscopic dimensions.

21.1 An Alternative Expression for the Cosmological Constant Λ

We have previously discussed the form $\Lambda = \frac{8\pi G\rho}{c^4}$, where $[\rho] = [\mathrm{J/m^3}]$, linking Λ with the energy density ρ of the vacuum. From this relation, we obtain

$$\rho_{vac} = \frac{\Lambda}{8\pi} \cdot \frac{c^4}{G}.$$

By substituting in terms of vacuum properties, such as $\rho_{vac} = 8G\,\mathrm{J/m^3}$, we can further refine the form:

$$\rho_{vac} = \sqrt{\frac{\Lambda}{\pi}} \cdot c^2\,\mathrm{J/m^3},$$

which, via Einstein's mass-energy equivalence $E = M \cdot c^2$, yields

$$\rho_{vac} = \sqrt{\frac{\Lambda}{\pi}}\,\mathrm{kg/m^3}.$$

Numerical evaluation of this expression gives $\rho_{vac} \approx 5.92 \times 10^{-27}\,\mathrm{kg/m^3}$, closely aligning with experimentally determined values, supporting our interpretation of Λ as a measurable manifestation of vacuum properties.

21.2 A Relationship Similar to the Differential Form of Gauss' Law in Electromagnetic Terms

Incorporating these relationships into general relativity, we revisit the Einstein field equations, which relate the energy-momentum tensor $T_{\mu\nu}$ to spacetime geometry:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}.$$

Assuming vacuum energy contributes dominantly through the cosmological constant Λ, we set:

$$\Lambda = \frac{8\pi G\rho}{c^4}.$$

Given that we have also postulated $\Lambda = h \cdot e = \frac{e^2}{c^2} Z_0$, we can equate terms, yielding

$$\frac{8\pi G\rho}{c^4} = \frac{e^2}{c^2} Z_0.$$

Solving for ρ gives

$$\rho = \frac{e^2 \cdot c^2 \cdot Z_0}{8\pi G}.$$

Since we have $e \cdot c^2 = 2\alpha$, substitution gives

$$\rho = \frac{e \cdot \alpha \cdot Z_0}{4\pi G}.$$

In this form, the left side $4\pi G\rho$ represents the gravitational flux from Gauss's law (for a mass density ρ in vacuum), while the right side connects it to electromagnetic terms. This equivalence reinforces the concept that vacuum properties drive both gravitational and electromagnetic phenomena in a unified manner.

Furthermore, since $e \cdot Z_0$ is dimensionally equivalent to $\frac{e \cdot c \cdot Z_0}{c}$, and knowing $I_{min} = e \cdot c$, we recognize that $[e \cdot Z_0] = [E \cdot T^{-1}] = P$, aligning with the power interpretation we established for gravitational flux. Numerical evaluation shows $\rho \approx 5.31 \times 10^{-10}\ \mathrm{J/m^3}$, matching measured values.

21.3 A Further Link Between Quantum Magnetic Flux and Gravitational Flux

Additionally, recall the foundational equation $h = \frac{e \cdot \mu_0}{c}$. Multiplying both sides by c^2 yields

$$\frac{h \cdot c^2}{2} = \frac{e \cdot c \cdot \mu_0}{2},$$

which can be expressed as

$$h \int c\, dc = \frac{1}{2} e \cdot Z_0 = 2 \cdot \frac{4\pi G\rho}{\alpha}.$$

This equation demonstrates that the accumulation of quantum mechanical effects within the vacuum significantly influences gravitational fields, reinforcing the vacuum's role as a bridge between quantum and cosmological scales.

In summary, these relationships further unify our framework by showing how vacuum oscillations and fundamental constants coalesce to shape cosmic dynamics. The identity $h \int c\, dc = 2 \cdot \frac{4\pi G\rho}{\alpha}$ encapsulates the gravitational flux induced by vacuum energy density, suggesting that the universe's large-scale structure emerges from summing quantum oscillatory modes. This perspective strengthens the theoretical bridge between microscopic vacuum properties and macroscopic gravitational behavior, further supporting our unified approach to vacuum-driven cosmology.

Part IV: Proposal of a Cosmological model based on the General Framework and derived relationships

22 A novel interpretation of the nature of the fine-structure constant α and its consequences in electromagnetic interactions

22.1 The Connection Between α and the Lorentz Factor

In this subsection, we propose that the fine-structure constant α acts as the reciprocal of a Lorentz factor γ in the context of electromagnetic interactions.

In the vacuum-RLC circuit model, α represents the ratio of energy dissipated to energy stored within the vacuum. Traditionally, this could be seen as an indicator of how efficiently energy is conserved in the oscillatory dynamics of the vacuum field. However, in our framework, this efficiency factor α can be reinterpreted as the "de-contraction" or "scaling" of the potential energy carried by electromagnetic waves due to relativistic effects, as this energy transforms into kinetic energy when interacting with charges. In this sense, the physical ratio of energy dissipation to storage remains balanced, but relativistic contraction effects produce an effective scaling difference quantified by α.

The Lorentz factor is given by:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}},$$

which quantifies the effect of relativistic speeds on time, space, and energy. Here, we propose that:

$$\alpha = \frac{1}{\gamma} = \sqrt{1 - \frac{v^2}{c^2}},$$

suggesting that α serves as the reciprocal of the Lorentz factor. As $v \to c$, $\alpha \to 0$, indicating that the relativistic effects on the energy scale become more pronounced as velocity approaches the speed of light.

Justification Based on Energy Conservation

In the case of electromagnetic interactions, the fine-structure constant α is defined by:

$$\alpha = \frac{e^2}{4\pi\epsilon_0 \hbar c}.$$

This expression characterizes the strength of electromagnetic interactions and can be interpreted as the ratio between the system's potential and kinetic energy in such interactions.

Reinterpreting Potential and Kinetic Energy in the Vacuum

Traditionally, the energy between two charges separated by a distance r is defined as potential energy:

$$U_{\text{potential}} = \frac{e^2}{4\pi\epsilon_0 r}.$$

This represents the stored energy in the electric field arising from the spatial separation of the charges. Conversely, the energy tied to the motion of particles or fluctuations in the field is often described as kinetic energy, and for the vacuum and quantum field, it can be expressed as:

$$U_{\text{kinetic}} = \frac{2\pi\hbar c}{r}.$$

However, within our framework, we reinterpret these terms: the oscillations of photons or electromagnetic waves constitute the potential energy within the field itself, representing the vacuum's latent capacity to support electromagnetic fluctuations without energy dissipation. Photons and electromagnetic waves thus represent the field's potential, while interactions between charges or configurations in the field signify kinetic energy. When charges interact, they cause dissipation through electromagnetic exchanges, representing the field's kinetic, active energy transfer within this quantum vacuum model.

With this reinterpretation in mind, we need to acknowledge that, in an oscillatory framework, the energy of a system transforms between potential and kinetic forms, yet the total energy remains constant; therefore, equilibrium occurs when the potential energy of photons or electromagnetic waves,

$$U_{\text{potential}} = \frac{2\pi\hbar c}{r},$$

balances the kinetic energy from charge interactions, given by:

$$U_{\text{kinetic}} = \frac{e^2}{4\pi\epsilon_0 r}.$$

Equilibrium Condition and the Role of α

Given that energy is conserved and the system undergoes oscillatory behavior, equilibrium in energy exchange implies that:

$$\frac{e^2}{4\pi\epsilon_0 r} = \frac{2\pi\hbar c}{r}.$$

However, in practice, we find that:

$$\frac{e^2}{4\pi\epsilon_0 r} = \alpha \cdot \frac{2\pi\hbar c}{r}.$$

From this, we recover the fine-structure constant:

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c}.$$

Interpreting α as the Reciprocal of the Lorentz Factor

To interpret the origin of α, we propose that it bridges the relativistic characteristics of electromagnetic waves (which travel at speed c) with the slower, non-relativistic properties of interacting charges. In this framework, α functions as a reciprocal of a Lorentz factor, modulating the relative strength of interactions between the high-speed dynamics of electromagnetic waves and the slower dynamics of matter. Therefore, the fine-structure constant α ensures the conservation of energy by balancing contributions from both relativistic and non-relativistic components.

The emergence of α in the equilibrium condition reflects the inherent need for a scaling factor in interactions between electromagnetic waves and matter, given the relative difference in velocities. As a result, it comes naturally to interpret α as a Lorentz factor that harmonizes energy transfer between the components, effectively linking the potential energy of the electromagnetic field with the kinetic dissipation associated with charge interactions.

In summary, we interpret α as a dimensionless parameter that quantifies the effective interaction strength between light, which moves at c, and matter, which operates at much lower velocities. This approach suggests that α functions analogously to a reciprocal Lorentz factor, modulating the distribution of energy within electromagnetic interactions. This dimensionless constant supports a balanced energy exchange, ensuring equilibrium within the relativistic and quantum frameworks alike. Consequently, α serves as a bridge between the relativistic properties of photons or electromagnetic waves and the non-relativistic nature of matter, enabling a coherent description of electromagnetic interaction strength as influenced by relativistic effects.

22.2 Electric Flux of the Elementary Charge as Relativistic Kinetic Energy

Gauss's law is one of the fundamental equations in electrostatics, relating the electric field flux through a closed surface to the charge enclosed by that surface. Consider a point charge e located at the origin of a coordinate system. According to Coulomb's law, the electric field at a distance r from the charge is radially symmetric and is given by

$$\vec{E}(\vec{r}) = \frac{1}{4\pi\epsilon_0}\frac{e}{r^2}\hat{r},$$

where ϵ_0 is the permittivity of free space, $r = |\vec{r}|$ is the distance from the charge, and $\hat{r}$ is the unit vector pointing radially away from the charge.

To derive Gauss's law, we calculate the electric flux through a spherical surface of radius r centered at the point charge. The electric flux Φ_E through a surface is defined as the surface integral of the electric field:

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A},$$

where $d\vec{A}$ is an infinitesimal area element on the surface S, and $\vec{E}$ is the electric field at that point. For a spherical surface, $\vec{E}$ is always radial and has the same magnitude at every point on the surface.

Gauss's law states that the electric flux through any closed surface S is proportional to the total charge Q_{enc} enclosed within that surface:

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}.$$

In the case of a point charge e, we have $Q_{\text{enc}} = e$, and thus the flux through a spherical surface is

$$\Phi_E = \frac{e}{\epsilon_0}.$$

Now, as we postulated that $e = \frac{\mu_0^3}{4\pi}$ and $\epsilon_0 = 2\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$, we can substitute to get that

$$\vec{E} = \frac{\mu_0^3}{32\pi^2\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}r^2},$$

Simplifying further,

$$\vec{E} = \frac{\mu_0}{32\pi^2 \cdot \sqrt{\frac{3}{5}4\pi}r^2},$$

Assuming an spherical surface S, we have then that

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \frac{\mu_0}{32\pi^2 \cdot \sqrt{\frac{3}{5}4\pi}r^2} \cdot 4\pi r^2 = \frac{\mu_0}{8\pi \cdot \sqrt{\frac{3}{5}4\pi}}$$

Recall that we had that $\alpha = \frac{1}{16\pi \cdot \sqrt{\frac{3}{5}4\pi}}$; therefore, we can substitute to obtain that

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \mu_0 \cdot 2\alpha \tag{42}$$

As we have postulated that $\frac{1}{\alpha} = \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, we can rewrite the above as

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \frac{2\mu_0}{\gamma} \tag{43}$$

In our framework, μ_0, the vacuum permeability, plays a crucial role as it encapsulates the quantum of energy required to deform spacetime. This interpretation is consistent with the fact that μ_0 measures how the vacuum reacts to magnetic fields, indicating how the vacuum dissipates magnetic energy. Since we have postulated that the elementary charge e is induced by vacuum fluctuations, μ_0 reflects the energy necessary for these fluctuations to deform spacetime and induce the charge. The vacuum, acting like a dielectric medium, polarizes in response to electromagnetic fields, which induces a net charge. The expression for the electric flux $\Phi_E = \mu_0 \cdot 2\alpha$ reflects this fundamental relationship, linking the induced electric flux to the energy necessary for these fluctuations to deform spacetime and induce the charge, modulated by the Lorentz factor that arises in the transformation from kinetic to potential energy.

Furthermore, considering that we have previously established μ_0 as a voltage, we can explore the consistency of the above through the relationship between electric flux and voltage expressed by their integral definitions, emphasizing the distinction between integration over a surface ($d\vec{A}$) and over a path ($d\vec{l}$).

The electric flux Φ_E is defined as the surface integral of the electric field $\vec{E}$:

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A},$$

where $d\vec{A}$ is an infinitesimal area element on the closed surface S.

On the other hand, the voltage V between two points is defined as the negative line integral of the electric field along a path C:

$$V = -\int_C \vec{E} \cdot d\vec{l},$$

where $d\vec{l}$ is an infinitesimal vector element of length along the path C.

By comparing the integral definitions, we observe that both electric flux and voltage are dependent on the electric field $\vec{E}$, but they differ in their integration over different domains—$d\vec{A}$ for surfaces and $d\vec{l}$ for paths. This distinction reflects their different physical interpretations:

- **Electric Flux (Φ_E)**: Quantifies the total electric field passing through a surface.
- **Voltage (V)**: Measures the potential difference experienced along a path.

In our previous derivation, we arrived at:

$$\Phi_E = \frac{2\mu_0}{\gamma}.$$

Given that μ_0 represents a voltage, that the factor 2 has dimension $[L] = [T]$, and that the Lorentz factor γ is dimensionless, we have a dimensional consistency between the expression $\Phi_E = \frac{2\mu_0}{\gamma}$ and the integral definitions of voltage and electric flux. Within our framework, the electric flux is effectively a measure of the voltage adjusted by both the differential nature of spacetime and the relativistic effects associate to the energy contraction-de-contraction processes that arise in the electromagnetic interactions. This reinforces the coherence of our theoretical framework, highlighting how fundamental electromagnetic quantities are interrelated through their dependence on the electric field and the geometry of spacetime.

Recall also that we have that $G = \mu_0 \cdot \alpha^2$; therefore, we have that $\mu_0 \cdot 2\alpha = \frac{2G}{\alpha} = \frac{G}{\zeta}$, and thus

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \frac{G}{\zeta} \tag{44}$$

Recall that the relativistic total energy of the vacuum is expressed as:

$$E_{\text{total}} = \frac{m_{vac} \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}},$$

where m_{vac} is the mass associated with the vacuum energy density, and v is the velocity of the vacuum's expansion or interaction. This interpretation aligns with the framework of this paper, where fundamental forces and constants emerge from the properties of the vacuum.

Recall that we have established that $G = 2 \cdot m_{vac} \cdot c^2$, and that $\gamma = \frac{1}{\alpha} = \frac{1}{2\zeta} = \sqrt{1 - \frac{v^2}{c^2}}$. Therefore, we have that

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \frac{G}{\zeta} = \frac{2 \cdot m_{vac} \cdot c^2}{2 \cdot \sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_{vac} \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{e}{\epsilon_0}$$

Then, we have that the crucial relationship

$$\Phi_E = E_{\text{Total}} \tag{45}$$

This establishes a direct equivalence between the electric flux and the relativistic total energy of the vacuum. The equation obtained shows that what we observe as electromagnetic flux is the manifestation of the relativistic energy of vacuum.

As a result, we conclude that electric flux is an emergent phenomenon from the vacuum's relativistic energy. This connection underscores the idea that the electric field generated by an elementary charge is not merely a local phenomenon but is deeply rooted in the vacuum's relativistic energy dynamics. The vacuum energy, influenced by the expansion and the relativistic motion characterized by the Lorentz factor γ, leads to the emergence of electromagnetic fields. Therefore, the electric flux can be seen as a bridge between classical electromagnetism and relativistic physics, highlighting how fundamental forces arise from the interplay between energy, geometry, and the properties of the vacuum. This insight enhances our understanding of the unification of physical laws and the fundamental nature of electromagnetic interactions within the framework of spacetime geometry.

22.3 The elementary charge as the quotient of mass at rest and total relativistic energy

Recall the equation

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \mu_0 \cdot 2\alpha = \frac{e}{\epsilon_0}$$

Note that, solving for the elementary charge e, and as $\epsilon_0 \mu_0 = \frac{1}{c^2}$, we get that

$$e = \mu_0 \epsilon_0 \cdot 2\alpha = \frac{2\alpha}{c^2}$$

As we have established that μ_0 has dimension of voltage V, that ϵ_0 is a capacitance C, that the factor 2 has dimension of $[L] = [T]$, and α equals the reciprocal of the Lorentz factor, then we have that

$$e = \frac{2 \cdot C \cdot V}{\gamma} = 2 \cdot \frac{1}{c^2 \cdot \gamma}$$

The final result $e = 2 \cdot \frac{1}{c^2 \cdot \gamma}$ provides a new interpretation of the elementary charge as a product of the vacuum's electromagnetic properties, encapsulated by its capacitance ϵ_0 and voltage μ_0, divided by the Lorentz factor γ and multiplied by the spacetime 2. This formulation aligns with the notion that the elementary charge is an emergent property of the vacuum, induced by its interaction with relativistic effects.

Therefore, the elementary charge e is intimately tied to the relativistic behavior of the vacuum. Charge is not merely a fundamental property of particles but arises from the interaction of mass-energy in the matter-antimatter realms within the relativistic structure of the vacuum.

Moreover, note that we have

$$e = 2 \cdot \frac{m_0}{m_0 \cdot c^2 \cdot \gamma} \tag{46}$$

As a result, e can be interpreted as the quotient of any mass at rest, and the total relativistic energy of that mass, times the spacetime 2. This relationship implies that the elementary charge e is not a standalone, fundamental quantity but rather emerges from the mass-energy dynamics of the system.

The nature of the effective current $I_{eff} = \frac{e \cdot c}{2}$

Note that he quotient $\frac{\frac{e}{2}=m_0}{m_0 \cdot c^2 \cdot \gamma = \frac{1}{c^2 \cdot \gamma}}$ becomes the elementary electric current, which scaled by the speed of light c gives raise to the effective current

$$I_{eff} = \frac{e \cdot c}{2}$$

Scaling by c is justified in this context because c represents the natural resonant frequency of the vacuum system, inherently linking the electric and magnetic properties of the vacuum. In this framework, c is not just the speed of light but serves as the frequency at which electromagnetic waves propagate through the vacuum. This resonant frequency arises empirically as the rate at which oscillations between electric and magnetic fields maintain a stable relationship in the vacuum, balancing energy storage and transfer. This explains why scaling the elementary current with c, we align the model with observed phenomena, ensuring that effective current I_{eff} is consistent with empirical measurements and our theoretical derivations. The resonance of the vacuum at c thus becomes a foundational aspect of the system, grounding the theoretical framework in observable reality and reinforcing c as the scaling factor that unifies electric, magnetic, and relativistic components in a coherent, resonant system.

The elementary charge as a emergent deformation of spacetime

As a consequence of the above interpretation, the elementary charge is not a static quantity but a function of the dynamic properties of spacetime, influenced by the vacuum's ability to store and transfer energy, which is encoded by the voltage and capacitance of the vacuum itself.

Indeed, we have derived that charge is deeply connected to the relativistic energy of mass and can be understood as emerging from the relationship between mass-energy and spacetime. Given that mass and energy are fundamental sources of spacetime curvature, this equation highlights how charge itself could serve as a manifestation of the way mass-energy interacts with spacetime. In particular, the elementary charge e, which is traditionally viewed as the source of electromagnetic fields, could also be seen as an indicator of the capacity of mass-energy to curve or deform spacetime. This interpretation aligns with the idea that charge, much like energy and mass, is a critical player in the geometry of spacetime and the forces that arise from it.

Furthermore, this connection between charge and the mass-energy ratio suggests that electric charge could be reinterpreted as a localized curvature effect created by mass in spacetime. Since both mass and energy contribute to gravitational fields and spacetime deformation, and charge generates electromagnetic fields, this equation suggests a deeper unification: charge represents not just an isolated electromagnetic property but a manifestation of spacetime deformation caused by mass-energy. The equation $e = 2 \cdot \frac{m_0}{E_{\text{total}}}$ implies that the more energy a system has due to relativistic effects, the smaller the ratio becomes, potentially indicating a decreased ability to locally deform spacetime electromagnetically. This reinforces the idea that charge, mass, energy, and spacetime curvature are interconnected properties, all playing roles in the structure and dynamics of the universe, particularly in regimes of high velocity or strong gravitational fields.

22.4 Some additional reflections

The Dimensional Nature of the Elementary Charge and Spacetime

In the context of our Paper, where space and time are treated as interchangeable dimensions, we have seen that it is natural to describe the elementary charge e as having dimensions related to spacetime. Therefore, the elementary charge may be understood as being intertwined with the spacetime structure.

The presence of the Lorentz factor γ in our formula emphasizes the relativistic nature of the charge. Since γ depends on the relative velocity between observers, the formula links the elementary charge to the relativistic motion of the particles that are "suitable" to have charge. This suggests that the elementary charge is not simply a static property but one that depends on the electron's interaction with spacetime itself, particularly through its relativistic spin and magnetic dipole moment.

Speculative Connections: Matter-Antimatter Symmetry and Quantum Entanglement

While the Dirac equation provides a successful description of the magnetic dipole moment of the electron, the deeper nature of this phenomenon remains an open question in modern physics. It is well established that the magnetic dipole moment is linked to the electron's intrinsic spin, but the fundamental origin of both spin and the associated magnetic moment may be related to underlying symmetries of nature that are not yet fully understood.

One possible avenue of exploration is the connection between the magnetic dipole moment and the symmetry between matter and antimatter. The Dirac equation treats particles and antiparticles symmetrically, predicting the same magnitude of magnetic moment for both electrons and positrons, despite their opposite charges. This suggests that the magnetic moment could reflect a deeper symmetry, perhaps between different dimensions or aspects of spacetime corresponding to matter and antimatter.

Another speculative idea is the potential connection between the magnetic dipole moment and quantum entanglement. While quantum entanglement describes non-local correlations between particles, it relies fundamentally on the concept of spin. In systems of entangled electrons, for example, the spins are correlated in a way that measurements on one particle instantaneously affect the other, regardless of the distance between them. It is conceivable that deeper quantum correlations, potentially involving the quantum vacuum or self-entanglement, could play a role in its nature.

While no current theory directly links the electron's magnetic moment to quantum entanglement or matter-antimatter dimensions, these concepts highlight the possibility that the magnetic moment may be an emergent phenomenon from a more fundamental theory of quantum spacetime. Future developments in quantum gravity, string theory, or other beyond-the-Standard-Model frameworks may reveal new insights into the origin of the electron's magnetic dipole moment.

23 Relativistic Expansion within an Antimatter Universe: A Framework for Particle-Antiparticle Interactions

23.1 Antimatter as an Extra Dimension

In traditional physics [51], antimatter is typically viewed as the mirror counterpart of matter, exhibiting opposite charges but otherwise existing within the same four-dimensional spacetime. However, several modern theoretical frameworks, especially those involving higher-dimensional spaces, suggest that antimatter could correspond to an additional spatial or temporal dimension. Within our framework, antimatter manifests in an unobservable extra dimension that coexists alongside the familiar dimensions of space and time.

It is plausible to interpret antimatter as existing in such an extra dimension, where its behavior, while influenced by familiar physical laws, remains undetected due to its existence outside observable spacetime. The symmetry between matter and antimatter, seen in CPT (charge, parity, and time) invariance, suggests deeper, possibly geometric, properties, that we have glimpsed throughout this Paper. As antimatter occupies an additional dimension, it explains why antimatter remains elusive in large-scale cosmic observations. In this framework, matter and antimatter are symmetric with respect to this extra dimension, maintaining the balance required by the universe's fundamental symmetries.

The consequences of this model could be subtle but profound. The interactions between matter and antimatter occur through quantum fluctuations, but antimatter remains hidden in the "antimatter dimension." This explains why we don't observe large amounts of antimatter in the universe despite theoretical expectations from the Big Bang.

23.2 Black Holes and the Thinning of the Matter-Antimatter Boundary

Given the previous framework, we can propose a novel interpretation of black holes [52] as regions where the boundary between matter and antimatter becomes thinner or nearly non-existent. The weakening of the boundary is reflected in an increase in ϵ_0, which encodes the "thickness" of the boundary, leading to an increase in the zero-point energy and thus influencing the gravitational constant G, as a consequence of the stronger interactions between matter and antimatter.

Black hole boundaries and vacuum state

The concept that physical laws, such as the values of universal constants, change dramatically near black hole boundaries is well supported in both classical and quantum gravity frameworks [53] [54]. Within the event horizon of a black hole, the vacuum state (and hence the properties of the vacuum) could be fundamentally different from those observed in low-energy, flat-space regions.

Thus, an increase in ϵ_0 within the boundaries of the black hole might correspond to a different effective vacuum, where constants like G and c shift due to extreme conditions, aligning with modified or emergent gravitational theories. This is consistent with the idea that black holes represent a breakdown of standard physics, where spacetime itself is deformed to the point that fundamental constants lose their "universal" values.

Therefore, our proposal fits within this picture — especially since ϵ_0 could be viewed as encoding information about vacuum structure, which is subject to dramatic shifts near singularities or horizons.

Boundary Thinning Triggered by High-Energy Processes

We hypothesize that a high-energy process, such as the explosion of a star, acts as a catalyst that weakens the boundary between the universe and the anti-universe at a high-scale level. This massive weakening leads to a significant increase in the strength of particle-antiparticle interactions, which is reflected in the increase of the zero-point energy, $E_0 = \frac{\hbar c}{2}$.

In our model, we can connect ϵ_0 to the "thickness" of the boundary between matter and antimatter. The weakening of the boundary is reflected in an increase in ϵ_0, which implies that the space-time vacuum becomes easier to deform (as the boundary becomes "thinner").

This idea is supported by the analogy between the vacuum's capacitance and the stiffness constant k in a harmonic oscillator. In a system of harmonic oscillators, k is inversely related to capacitance C, so an increase in ϵ_0 reflects a decrease in the resistance to deformation.

This decrease in resistance is reflected most notably through the reduced Planck's constant $\hbar$ (recall that we have that $\hbar = \frac{\epsilon_0^3}{2\pi}$), which in turn affects the zero-point energy $E_0 = \frac{\hbar c}{2}$.

An assessment of the net effect of an increase in ϵ_0 on E_0, G, and c

From the expression $\epsilon_0 = 2\mu_0^2 \cdot \sqrt{\frac{48}{5}\pi}$, we have that $\mu_0 \propto \epsilon_0^{1/2}$. As a result, any increase in ϵ_0 will produce a much weaker increase in μ_0.

Now, we can assess the net effect of an increase in ϵ_0 on E_0, G, and c:

1. **Effect on the Speed of Light c**

   The speed of light is given by:

$$c = \frac{1}{\sqrt{\epsilon_0 \cdot \mu_0}} \tag{47}$$

   Substituting the expression for μ_0:

$$c \propto \frac{1}{\sqrt{\epsilon_0 \cdot \epsilon_0^{1/2}}} = \frac{1}{\epsilon_0^{3/4}} \tag{48}$$

   Thus, we conclude that

$$c \propto \epsilon_0^{-3/4} \tag{49}$$

   Therefore, an increase in ϵ_0 leads to a decrease in the speed of light c.

2. **Effect on the zero-point Energy E_0**

   For E_0, we use the following equation:

$$E_0 = \frac{\epsilon_0^3}{4\pi\sqrt{\epsilon_0\mu_0}} \tag{50}$$

   Substitute the expression for μ_0:

$$E_0 \propto \frac{\epsilon_0^3}{4\pi\sqrt{\epsilon_0 \cdot \epsilon_0^{1/2}}} = \frac{\epsilon_0^{9/4}}{4\pi} \tag{51}$$

   Hence, we have that

$$E_0 \propto \epsilon_0^{9/4} \tag{52}$$

   Therefore, an increase in ϵ_0 results in a higher-than-quadratic increase in the zero-point energy E_0.

3. **Effect on the Gravitational Constant G**

   We have that

$$G = \frac{3}{5} 4\pi \cdot \epsilon_0 \tag{53}$$

   Therefore, G increases linearly with ϵ_0.

Summary of the Net Effect

To summarize the effects of an increase in ϵ_0:

- The energy E_0 increases proportionally to $\epsilon_0^{9/4}$.
- The gravitational constant G increases linearly with ϵ_0.
- The speed of light c decreases proportionally to $\epsilon_0^{-3/4}$.
- The permeability μ_0 increases proportionally to $\epsilon_0^{1/2}$.

Therefore, our hypothesis is consistent with the relationships we have established throughout the Paper.

Black Holes as special conduits of universe-anti-universe Energy Exchange

As a result, black holes represent regions where the matter-antimatter boundary is effectively diminished or even non-existent. These regions facilitate enhanced particle-antiparticle interactions, which contributes to high-energy emissions observed near black holes, and produces an increase in the gravitational force through the gravitational constant G.

In this sense, black holes become strong conduits for energy exchange between matter and antimatter dimensions. As the boundary thins, more vacuum energy is transferred between these realms. One key observational effect that supports this theory is the intense radiation and energetic particle emissions surrounding black holes, including Hawking radiation [55]. The proposed thinning of the boundary allows matter-antimatter annihilation to occur more frequently, producing energy at rates that could explain these extreme emissions. Similarly, gamma-ray bursts [56], which are some of the most energetic events in the universe, might be a manifestation of such boundary-thinning processes.

Moreover, the framework aligns with theories suggesting that black holes are not merely gravitational sinks but could serve as regions for energy exchange between universes or dimensions [57]. In scenarios where the boundary between matter and antimatter diminishes, black holes become strong conduits for vacuum energy transfer between the matter-dominated and antimatter-dominated realms. This energy transfer drives the increase in G, further enhancing gravitational effects in the immediate vicinity.

Implications for Theories of Black Hole Interiors

Inside black holes, general relativity predicts that spacetime curvature approaches infinity at the singularity. In our proposed framework, the thinning or near-collapse of the matter-antimatter boundary could provide a new explanation for the interior structure of black holes. If this boundary ceases to exist inside the event horizon, the interior of the black hole could be viewed as a region where matter and antimatter coexist freely, leading to a breakdown of the standard distinction between particles and antiparticles.

This idea could offer a fresh perspective on the information paradox. If matter and antimatter are allowed to interact freely beyond the event horizon, the annihilation process could facilitate the escape of energy or information back into our universe in ways that standard models of black holes do not account for. This could potentially contribute to resolving the paradox through non-traditional channels of energy release.

Additionally, some quantum gravity models, such as loop quantum gravity, predict that black hole interiors avoid singularities through quantum effects. Our model could support these ideas by suggesting that, as the boundary thins and quantum fluctuations intensify, the zero-point energy may act as a stabilizing factor against singularity formation, or even create a new regime of spacetime with different physical laws.

In this context, our model provides explanations for several observed phenomena:

- **Gravitational Waves**: The mergers of black holes detected by LIGO and Virgo [58] have revealed that immense amounts of energy are released in the form of gravitational waves [59]. In our framework, these waves could be partially driven by the dynamic behavior of the thinning boundary, where increased G in the vicinity of black holes causes amplified gravitational disturbances.

- **Jet Formation**: The collimated jets observed in many active galactic nuclei (AGN) [60] could be linked to the matter-antimatter interactions near the poles of rotating black holes. The thinning boundary may lead to enhanced energy transfer, providing the fuel needed for the formation of relativistic jets of particles expelled from the region around the black hole.

- **Singularity Avoidance**: The exponential growth of G as the boundary thins may help prevent the formation of true singularities inside black holes [61]. Instead of collapsing into a point of infinite density, the interaction between matter and antimatter may create a more complex structure where quantum effects dominate, offering a possible resolution to the singularity problem in black hole physics.

Conclusion

In summary, the proposed framework of black holes as regions where the boundary between matter and antimatter thins offers a fresh perspective on several key aspects of black hole physics. The thinning boundary leads to an exponential increase in the zero-point energy and gravitational constant G, potentially explaining the high gravitational force the have associated, as well as many observed high-energy phenomena near black holes, such as gamma-ray bursts, gravitational waves, and relativistic jets. Moreover, this theory opens new avenues for understanding black hole interiors, suggesting that the interaction between matter and antimatter could prevent singularity formation and contribute to resolving the information paradox through non-traditional energy release channels. By linking these processes to enhanced quantum fluctuations and vacuum energy transfer, this model not only provides a deeper understanding of black holes but also bridges connections between black holes, quantum gravity, and cosmological evolution.

23.3 Quantum Harmonic Oscillators as Matter-Antimatter Interactions inside quantum black holes

In this framework, we propose that quantum harmonic oscillators in the vacuum represent fundamental interactions between matter and antimatter dimensions. At quantum scales, the boundary separating these two dimensions becomes thin or even non-existent, allowing for direct interactions between the quantum fields of matter and antimatter. These oscillatory interactions can be interpreted as sites where matter-antimatter annihilation processes occur, albeit in a highly localized and stable manner, similar to the dynamics observed near black hole horizons.

Matter-Antimatter Interaction Through Thin Boundaries

The concept of a "boundary" between matter and antimatter dimensions is a key aspect of this model. In classical terms, this boundary is typically impenetrable, preventing large-scale matter-antimatter annihilation. However, at the quantum level, the boundary becomes extremely thin or even permeable. This allows quantum harmonic oscillators to form, where matter and antimatter continuously interact across this thinner-boundary region.

These interactions are stabilized by the inherent quantum fluctuations of the vacuum, which prevent complete annihilation and instead generate significant amounts of zero-point energy. The energy associated with these oscillators is significant because, in the absence of a strong boundary, the quantum fields on either side of the boundary can exchange energy freely. This dynamic, where the matter-antimatter boundary is negligible, is highly analogous to the conditions near the event horizon of a black hole, where spacetime curvature becomes extreme, and quantum effects dominate.

Linking Mini Black Holes and Quantum Harmonic Oscillators

quantum black holes have been proposed as candidates for dark matter in certain cosmological models, especially in scenarios where these small black holes formed during the early universe due to high-density fluctuations [57] [62]. These black holes, typically with masses much smaller than stellar black holes, are thought to generate gravitational effects that could account for some or all of the "missing" mass attributed to dark matter. quantum black holes, while not directly observable, exert gravitational influence that could explain the rotational curves of galaxies and other cosmological phenomena.

According to our postulate, the quantum harmonic oscillators can be linked to those quantum black holes, as they are present in regions where the boundary between matter and antimatter is exceptionally thin or even non-existent. In fact, these oscillators could be seen as Quantum "black" holes, with their localized gravitational influence arising not from trapped mass, but from the interaction of matter-antimatter dimensions and the accumulation of zero-point energy. This is consistent with the relationship we have established in previous sections linking the gravitational constant G to the zero-point energy (with ϵ_0 as the main common driver of both).

Indeed, it comes naturally to postulate that the zero-point energy, $E_0 = \frac{1}{2}\hbar\omega$, arises exclusively at these thin-boundary regions, which permeate the vacuum itself. The thinning of the matter-antimatter boundary increases the vacuum's energy density locally, and the resultant curvature in spacetime produces gravitational effects analogous to those attributed to quantum black holes. In essence, the gravitational pull traditionally associated with a quantum black hole could instead be a geometric effect caused by the energy exchange across the matter-antimatter boundary.

Thus, both quantum black holes and quantum harmonic oscillators share the same origin, and are intrinsically related: the first is the boundary for the matter-antimatter interactions, and the latter is the manifestation of those matter-antimatter interactions.

By establishing that quantum harmonic oscillators and quantum black holes are two manifestations of the same underlying reality, our model inherently validates the theory that dark matter effects are generated by these quantum black holes. The gravitational effects traditionally attributed to dark matter can be understood as arising from the same quantum mechanical framework that governs matter-antimatter interactions across thin boundaries. As these quantum oscillators mimic the localized gravitational effects of quantum black holes through zero-point energy accumulation, the gravitational pull observed in dark matter phenomena can be seen as a consequence of this equivalence. Hence, the theory of dark matter being generated by quantum black holes is supported and confirmed by our model, which unifies both perspectives under the same postulate.

Implications for Dark Matter from Gravitational Effects of Zero-Point Energy

The gravitational effects generated by quantum harmonic oscillators in our model provide an alternative explanation for the dark matter phenomenon. In conventional cosmology, dark matter is an unknown form of matter that interacts gravitationally but not electromagnetically, making it invisible to direct detection. The presence of dark matter is inferred from its gravitational influence on galaxy rotation curves, gravitational lensing, and large-scale structure formation [63] [64].

In our framework, the gravitational anomalies attributed to dark matter can be explained by the cumulative effect of the zero-point energy associated with the matter-antimatter interaction. Near regions where the boundary between matter and antimatter is thin or non-existent, such as around these quantum harmonic oscillators, the zero-point energy causes local spacetime curvature, generating a gravitational field. This field, while not associated with traditional matter, mimics the gravitational pull that is currently ascribed to dark matter.

Thus, the gravitational effects usually attributed to dark matter are, in our model, the result of the geometry of spacetime influenced by the matter-antimatter interaction at quantum scales. These effects accumulate across galactic and cosmological scales, producing the same large-scale gravitational phenomena without invoking an additional form of invisible matter. The oscillators, spread throughout the vacuum, could thus collectively generate the "dark matter" effect, with their gravitational pull stemming from the fundamental quantum mechanical properties of the vacuum and the thinning of the matter-antimatter boundary.

24 Interpreting Dark Matter as an Emergent Effect of Vacuum Black Holes and Vacuum Energy

As anticipated at the end of the last section, we propose a novel interpretation of dark matter as an emergent effect of vacuum energy dynamics, shaped predominantly by vacuum black holes, which range from quantum-scale to supermassive sizes, and are sustained through boundary-driven oscillations. Rather than viewing dark matter as an independent form of invisible matter, we suggest that the gravitational effects currently attributed to dark matter arise from vacuum oscillations and localized curvature effects associated with vacuum black holes. This interpretation offers a unified perspective on dark matter phenomena by linking them to the intrinsic properties of vacuum energy, as influenced by matter-antimatter interactions across quantum boundaries.

24.1 Vacuum Black Holes as Sources of Apparent Gravitational Influence

Within our framework, vacuum black holes are regions of intensified matter-antimatter interactions occurring at quantum boundaries. These regions facilitate energy exchange and oscillations that deform spacetime, generating localized gravitational fields. While vacuum black holes can range from quantum to supermassive sizes, quantum-scale black holes are likely the most numerous and pervasive, forming a substantial background influence. This distribution implies that quantum black holes collectively create the majority of gravitational effects associated with dark matter, while larger black holes contribute localized gravitational influences.

The result $H^2 = 4\pi G\rho_{\text{vac}}$ indicates that vacuum energy density is the major driver of the universe's expansion. This suggests that quantum-scale black holes are the primary contributors to dark matter effects on cosmic scales, as they interact continuously with vacuum energy and modulate it through boundary interactions. Thus, the term "vacuum black holes" encompasses this diverse population, with quantum black holes driving the bulk of the "dark matter" gravitational effects and other-sized black holes contributing in specific regions.

24.2 Vacuum Oscillations as a Mechanism for Gravitational Phenomena

The vacuum oscillations generated inside vacuum black holes modulate the energy density of the vacuum, producing additional curvature that mimics the gravitational effects currently attributed to dark matter. These oscillations create harmonic modes of energy fluctuation that influence the surrounding spacetime, giving rise to a gravitational field that does not require the presence of particulate dark matter.

In this model, the oscillations induced by quantum-scale vacuum black holes create localized energy wells that affect the dynamics of celestial bodies within galaxies and larger structures. These vacuum-induced gravitational effects are consistent with the additional gravitational "pull" observed in galactic rotation curves and gravitational lensing effects, traditionally explained by dark matter. Thus, dark matter effects emerge as natural consequences of vacuum oscillations within the vacuum, with quantum-scale black holes producing most of the dark matter-like effects on cosmic scales.

24.3 Emergent Gravitational Effects Across Scales

The cumulative influence of numerous quantum-scale vacuum black holes and their associated vacuum oscillations generates a large-scale gravitational field that mirrors the gravitational influence of dark matter. On cosmological scales, these effects aggregate, producing a gravitational field that stabilizes galactic structures and contributes to the clustering of matter. This framework implies that the gravitational effects observed on galactic and intergalactic scales can be accounted for by the density and distribution of vacuum black holes within the quantum structure of spacetime.

While black holes exist across a spectrum of sizes—from quantum to supermassive —the majority are likely quantum-scale, and many are undetectable due to their weak interaction with observable matter. These smaller black holes form a continuous background influence, producing the gravitational anomalies we associate with dark matter. Larger black holes, although significant, are relatively fewer and primarily observable through direct interactions with matter or high-energy emissions, while the smaller, quantum-scale black holes drive the majority of the universe's dark matter-like gravitational influence.

24.4 Implications for Galactic Rotation Curves and Gravitational Lensing

A major motivation for the dark matter hypothesis has been the observation of galactic rotation curves, where the outer regions of galaxies rotate faster than would be expected based on visible matter alone. In the framework presented here, vacuum black holes and their induced vacuum oscillations generate additional curvature in galactic regions, contributing to an increased effective gravitational field. This enhanced field allows galaxies to maintain high rotation speeds at their edges, consistent with observational data, without the need for a separate form of dark matter.

Furthermore, gravitational lensing—the bending of light around massive objects—can also be interpreted within this model. The density of quantum black holes, especially in regions surrounding galactic clusters, produces additional spacetime curvature, bending light paths as they pass near these regions. This curvature, produced by vacuum energy oscillations and boundary-driven interactions, aligns with the gravitational lensing patterns traditionally ascribed to dark matter halos.

24.5 Vacuum Energy as a Central Component of Cosmic Structure

By framing dark matter as an emergent effect of vacuum energy dynamics, this model positions vacuum energy as a fundamental component of cosmic structure. The relationship between vacuum energy, oscillatory behavior, and vacuum black holes provides a natural explanation for the additional gravitational effects observed on galactic and cosmic scales. The result $H^2 = 4\pi G\rho_{\text{vac}}$ reinforces this by establishing vacuum energy and matter-antimatter interaction as the dominant component of cosmic expansion. In this model, quantum-scale vacuum black holes constitute the primary population interacting with vacuum energy, driving dark matter effects through their boundary interactions.

Furthermore, this model suggests that the distribution and behavior of vacuum black holes—spanning from quantum to supermassive—are essential to understanding cosmic evolution. The density and clustering of these entities influence the gravitational field on both small and large scales, effectively regulating galaxy formation and the stability of galactic clusters. Thus, vacuum energy, shaped by the presence of vacuum black holes, replaces the need for traditional dark matter within a unified cosmological framework.

24.6 Observable Consequences and Future Predictions

This interpretation of dark matter as an effect of vacuum energy oscillations and vacuum black holes has several observational implications:

- **Galactic Rotation Curves**: If dark matter effects are indeed emergent from vacuum oscillations, the rotation curves of galaxies should correlate with regions of higher vacuum energy density or quantum "black" hole activity. Observational studies could explore this correlation to distinguish between dark matter particle models and vacuum-based gravitational effects.

- **Gravitational Lensing Patterns**: Lensing observations around galactic clusters and voids could reveal variations in lensing strength based on the distribution of quantum "black" holes rather than on particulate dark matter halos. The distribution of vacuum oscillations and quantum boundaries might yield lensing patterns distinct from standard dark matter models.

- **Absence of Dark Matter Particles**: This model predicts that searches for particulate dark matter will remain inconclusive. Instead, the gravitational influence attributed to dark matter should align with quantum oscillatory effects in the vacuum, rather than with any detectable particles.

This model suggests that dark matter phenomena arise from the intrinsic properties of the vacuum, shaped by vacuum black holes and boundary-driven oscillations. By linking dark matter effects to vacuum energy and quantum interactions, we propose a framework where the gravitational dynamics observed in the universe emerge naturally from the structure of spacetime itself, without requiring additional forms of invisible matter.

24.7 Summary and Implications for Cosmology

The interpretation of dark matter as an emergent effect of vacuum energy and quantum "black" holes provides a self-consistent and unified cosmological model. In this framework, dark matter is not a separate form of matter but a macroscopic effect produced by vacuum energy dynamics within the quantum structure of spacetime. Vacuum black holes, particularly quantum-scale ones, create the majority of gravitational fields that stabilize galactic structures and influence cosmic evolution.

This reinterpretation simplifies the cosmological model by attributing dark matter phenomena to the existing components of the vacuum and its boundary interactions. The resulting framework aligns with observed phenomena such as galactic rotation curves, gravitational lensing, and large-scale structure formation, offering a comprehensive explanation that requires no additional matter. Future observations and theoretical developments will help validate or refine this interpretation, potentially leading to new insights into the role of vacuum energy in shaping the universe.

25 Cosmological Vision: Unification of Quantum Mechanics, General Relativity, and Quantum "black" hole Theories

This paper proposes a cosmological framework that unifies quantum mechanics, general relativity, and Quantum "black" hole theories, offering a coherent vision of the universe's structure. Central to this model is the idea that the vacuum behaves as a dynamic system of quantum harmonic oscillators, arising from the quantum structure of spacetime itself. These oscillators, mediated by Quantum "black" holes, are the manifestations of the energy exchange between matter and antimatter dimensions, giving rise to zero-point energy, gravitational forces, and electromagnetic fields as emergent phenomena.

25.1 Quantum Harmonic Oscillators and Quantum "black" holes

In our model, the universe consists of two coexisting realms: a matter universe and an antimatter universe, which are separated by a thin boundary. This boundary represents the interface between these two symmetric components of the cosmos, where energy is exchanged between the two domains. The matter and antimatter universes are not entirely isolated from each other, but are dynamically connected through this boundary. Quantum "black" holes, present throughout the quantum structure of spacetime, are regions where this boundary becomes thinner or almost non-existent, acting as portals or conduits that facilitate this energy transfer. These Quantum "black" holes mediate the exchange of quantum fluctuations and energy across the boundary, leading to the generation of zero-point energy.

In this context, the oscillatory behavior of the vacuum, often modeled as quantum harmonic oscillators, arises due to two primary mechanisms:

1. **Relativistic Expansion of the Universe:** The expansion of spacetime at relativistic velocities "stretches" the vacuum, creating baseline oscillations in energy density that manifest as quantum harmonic oscillations. This mechanism is less speculative and aligns with existing models of quantum field fluctuations in expanding spacetimes.

2. **Matter-Antimatter Interaction Across the Boundary:** The energy transfer across the boundary between matter and antimatter universes, mediated by Quantum "black" holes, drives additional oscillations. These interactions intensify vacuum oscillations at quantum scales, producing harmonic modes that characterize the behavior of quantum fields. Each quantum harmonic oscillator can thus be interpreted as a unit of energy exchange across this dynamic boundary.

Together, these mechanisms create a dual causality for the oscillatory behavior observed in quantum fields. The relativistic expansion sets up fundamental oscillations, while the boundary interactions modulate and amplify them, especially in high-energy regions.

The oscillatory interactions across this boundary influence the geometric structure of both universes, giving rise to spacetime curvature and gravitational effects. This model posits that the universe's observable phenomena, including gravity, electromagnetic fields, and spacetime expansion, emerge from the dynamic interplay between these two parallel universes.

25.2 Zero-Point Energy and Gravitational Emergence

The energy exchange between matter and antimatter across Quantum "black" holes generates zero-point energy, which manifests as quantum fluctuations in the vacuum. These quantum fluctuations deform the local geometry of spacetime, and we perceive that deformation as gravitational force. Therefore, gravity is not a fundamental force but an emergent property that arises from the vacuum's deformation, induced by energy flux across the Quantum "black" holes.

This perspective suggests that gravitational interactions are a result of the vacuum's oscillatory structure, where zero-point energy deforms spacetime and creates curvature. The collective behavior of these oscillators generates the macroscopic gravitational fields that we observe, offering a natural explanation for the relationship between quantum fluctuations and gravitational phenomena.

25.3 Expansion of the Universe and Electromagnetic Fields

In our model, the vacuum itself is not a static entity but undergoes expansion at relativistic velocities. This expansion adds to the underlying dynamics of the matter-antimatter boundary and the continuous exchange of energy through Quantum "black" holes. As the boundary between these two universes stretches, it causes the vacuum to expand, carrying with it the oscillatory structure of spacetime.

The expansion of the universe amplifies the vacuum's intrinsic oscillatory modes, influencing how electromagnetic fields evolve. As the relativistic expansion interacts with the vacuum's permittivity and permeability (ϵ_0 and μ_0), it modulates the propagation of these oscillations across spacetime. These oscillations not only contribute to the generation of electromagnetic fields but also shape the curvature and deformation of spacetime itself.

This dual expansion-driven and boundary-driven oscillatory framework provides a direct link between the universe's relativistic expansion and its electromagnetic structure. As the universe expands at relativistic velocities, it amplifies the oscillatory modes of the vacuum, generating electromagnetic fields that propagate through the expanding fabric of spacetime. The interaction between the vacuum's permittivity (ϵ_0) and permeability (μ_0) with the oscillatory structure of spacetime leads to the creation of electromagnetic waves.

These electromagnetic fields are not just byproducts of the expansion but are integral to the spacetime deformation process. The curvature induced by electromagnetic fields interacts with gravitational curvature, unifying the description of these forces as emergent properties of the expanding vacuum. This self-reinforcing system of vacuum oscillators regulates the universe's expansion and curvature, linking the large-scale evolution of the universe with quantum oscillatory dynamics.

Therefore, the expansion of the universe can be understood as a direct consequence of the vacuum's need to balance energy between these dimensions. As energy is exchanged, the universe expands, generating electromagnetic fields and gravitational curvature. The universe's expansion rate, governed by relativistic velocities, reflects the vacuum's capacity to store and transfer energy through these harmonic oscillators.

25.4 Quantum "black" holes and the Macro Universe

This model provides a coherent framework for understanding the connection between Quantum "black" holes and the large-scale structure of the universe. In our cosmological vision, Quantum "black" holes, present throughout the quantum fabric of spacetime, act as the fundamental units that define the vacuum's oscillatory behavior. These quantum "black" holes dominate the quantum scale, facilitating the energy exchange between the matter and antimatter universes and generating zero-point energy.

Observations of large astrophysical black holes, such as those at the centers of galaxies, provide a crucial window into understanding the behavior of their quantum counterparts. The macroscopic properties of black holes—such as their mass, spin, and event horizon structure—are observable through gravitational waves, X-ray emissions, and the behavior of matter around them. These large-scale observations offer important clues about the fundamental processes occurring at the quantum level. For example, the mass accretion and high-energy jets observed around supermassive black holes might be traced back to quantum mechanisms governing energy exchange at the event horizon, where Quantum "black" hole dynamics dominate.

Additionally, the structure of the event horizon in large black holes offers insights into how Quantum "black" holes operate. The event horizon is a region of spacetime where information becomes inaccessible to outside observers. On a quantum scale, this translates to a form of "quantum horizon" where micro black holes form boundaries that confine quantum energy, giving rise to the oscillatory modes that generate zero-point energy and spacetime curvature. The smoothness or fuzziness of the event horizon observed in large black holes could reflect the collective behavior of Quantum "black" holes, where these fundamental oscillators aggregate to form a coherent macroscopic structure.

Furthermore, the emission of Hawking radiation—a phenomenon where black holes emit radiation due to quantum effects near the event horizon—offers a direct link between Quantum "black" holes and large-scale black holes. Observing Hawking radiation in large black holes can help us better understand the interplay between quantum fluctuations, information loss, and the quantum mechanical behavior of spacetime. This could offer a window into the behavior of individual Quantum "black" holes, whose role in creating spacetime curvature is analogous to the collective effects seen in larger black holes.

Another important observational link is the influence of black holes on gravitational waves. Large black holes, particularly those in binary systems, generate ripples in spacetime that are detectable by observatories such as LIGO and Virgo. These gravitational waves carry information about the merger process, spin, and mass of black holes. On a quantum scale, it is conceivable that Quantum "black" holes also produce similar disturbances in the fabric of spacetime, albeit at much higher frequencies. By analyzing gravitational wave patterns from large black hole mergers, we may be able to infer the quantum-scale disturbances that underlie them, revealing more about the nature of spacetime and Quantum "black" holes.

Moreover, the hierarchical structure of black hole formation—from the aggregation of Quantum "black" holes to the formation of supermassive black holes—suggests that large-scale gravitational phenomena are deeply connected to quantum-level processes. The curvature generated by large black holes in galaxies, for example, is likely the cumulative result of countless Quantum "black" holes acting in concert, distorting spacetime at both microscopic and macroscopic scales. The dynamics of black holes on all scales can be understood as arising from the same underlying mechanisms: the energy exchange, curvature generation, and information processing that occur in Quantum "black" holes are amplified and manifested at larger scales.

In summary, the study of large black holes sheds critical light on the behavior of Quantum "black" holes. The mass-energy interactions, horizon structures, gravitational waves, and Hawking radiation emitted by large black holes provide observational evidence that can inform our understanding of the mechanisms operating at the quantum level. By linking these two scales, we gain a clearer picture of how quantum processes give rise to macroscopic gravitational phenomena, offering a unified vision of the universe dynamics across all scales.

25.5 Unifying Quantum Mechanics, General Relativity, and Electromagnetic Fields

Our cosmological model unifies quantum mechanics, general relativity, and electromagnetic theory by treating them as different manifestations of the same underlying vacuum structure. The harmonic oscillators that define the vacuum serve as the bridge between these theories:

- **Quantum mechanics** governs the behavior of these oscillators at small scales, where zero-point energy, uncertainty, and quantum fluctuations dominate.
- **General relativity** emerges from the collective effects of these oscillators at larger scales, where spacetime curvature is driven by vacuum deformation.
- **Electromagnetic fields** arise from the interaction between the vacuum's intrinsic permittivity and permeability and the relativistic expansion of the universe.

To sum up: by conceptualizing the universe as a coherent system of harmonic oscillators, this model provides a holistic framework that integrates quantum mechanics, general relativity, and electromagnetic phenomena. In this vision, Quantum "black" holes embedded within the quantum structure of spacetime drive the oscillatory behavior of the vacuum, facilitating the generation of zero-point energy, spacetime curvature, and gravitational forces as emergent phenomena. The expansion of the universe at relativistic velocities further amplifies these oscillations, giving rise to electromagnetic fields and shaping the universe's large-scale structure. By linking the quantum dynamics of matter-antimatter exchange, the formation of black holes across scales, and the creation of gravitational and electromagnetic fields, this model offers a pathway towards reconciling the fundamental forces of nature and obtaining a holistic physical view of our universe mechanics. It provides a unified description of how the interplay between quantum fluctuations and spacetime curvature governs both microscopic interactions and the macroscopic evolution of the cosmos, bridging the gap between quantum theory and general relativity while incorporating the insights gleaned from observational astrophysics.

26 Final Conclusions and Remarks

26.1 Consistency of the Theoretical Framework

One of the major accomplishments of this work is the internal consistency achieved by merging quantum mechanics and general relativity into a coherent $(4+1)$-dimensional framework, where the additional spatial dimension corresponds to a matter-antimatter symmetry. This higher-dimensional model provides a consistent extension to the conventional $(3+1)$-dimensional cosmology, as reflected in the consistent derivations of some of the constants more directly related to the matter-antimatter interaction.

A fundamental strength of the model lies in its use of the matter-antimatter symmetry as a structural component of spacetime. This additional dimension not only extends the traditional understanding of spacetime but also creates a framework where quantum fluctuations and zero-point energy naturally emerge as sources of curvature, seamlessly linking gravitational phenomena with quantum dynamics. The vacuum, reinterpreted as a system of harmonic oscillators expanding at relativistic velocities, consistently ties together electromagnetic properties, vacuum energy, and the expansion of the universe.

This consistency is reinforced by all derived constants and quantities emerging naturally from the same underlying vacuum structure. The strength of this model lies in the fact that all relationships are derived from simple, well-known, and non-advanced physical concepts, such as the mechanics of harmonic oscillators, RLC circuits, and their fundamental elements—resistance, inductance, capacitance, and oscillatory behavior. By directly plugging the accepted values of universal constants into these basic formulas, we obtain results that are not only consistent with but also remarkably close to experimentally measured values. This direct alignment of theoretical predictions with observed data serves as the strongest consistency check for the validity of the model. The fact that such complex phenomena as zero-point energy, vacuum fluctuations, and spacetime curvature emerge from these simple physical foundations underscores the robustness and internal coherence of the framework, further validating its potential to become a unified theory of physics.

26.2 Integration of Quantum and Relativistic Dynamics

The reinterpretation of fundamental constants as emergent from the vacuum oscillatory system provides a robust foundation for unifying quantum and relativistic domains. The vacuum's role as a dynamic system of harmonic oscillators—modeled analogously to an RLC circuit—creates a bridge between quantum mechanics and general relativity. For instance, the derived expression for the zero-point energy,

$$E_0 = \frac{\hbar \cdot c}{2} = \frac{\epsilon_0^5}{\mu_0^5},$$

illustrates how the intrinsic quantum fluctuations of the vacuum are directly linked to the vacuum's electromagnetic properties within the $(4+1)$-dimensional framework. This coupling between electromagnetic forces and spacetime curvature offers a consistent picture where both the behavior of matter and the vacuum are tightly coupled. It further supports the coherence of the framework across all scales, from quantum oscillations to cosmological expansion.

The use of RLC circuit analogies to describe the vacuum's behavior reinforces the interpretation that gravity and electromagnetism share a common origin in vacuum fluctuations. In this model, the vacuum is treated as a system of harmonic oscillators, where resistance, inductance, and capacitance (RLC) define its electromagnetic and gravitational properties. The analogy is compelling because it allows us to interpret universal constants—such as the gravitational constant G and the fine-structure constant α—as emergent from the vacuum's intrinsic oscillatory behavior. We have been able to show that the electromagnetic and gravitational fields are not separate entities but are both manifestations of the vacuum's dynamic nature. This unified treatment of forces implies that the expansion of the universe and the generation of spacetime curvature can be directly linked to the behavior of vacuum oscillators. The remarkable fact that plugging the values of universal constants into these simple, well-known equations yields results consistent with experimental data further strengthens the case for the fundamental link between gravity and electromagnetism as emergent properties of vacuum fluctuations.

26.3 Dimensional Analysis and Physical Interpretations

One of the hallmarks of the model is its rigorous dimensional analysis, ensuring the internal consistency of all derived relationships. By treating mass, charge, and energy as the only dimension-bearing entities, the model simplifies the interplay between fundamental constants while maintaining coherence across different physical systems. This approach aligns with the general relativity framework, where spacetime is described in terms of curvature, and mass-energy interactions are the source of that curvature. In this model, the dimensional equivalence of mass, length, and time provides crucial insight into the deeper structure of spacetime itself.

By establishing $[M] = [L] = [T]$, the model challenges the traditional separation of spatial and temporal dimensions, suggesting instead that they are interchangeable at a fundamental level. This equivalence leads to a profound reinterpretation of physical quantities: mass, energy, and charge retain their dimensional significance, while other traditionally dimensioned quantities, such as resistance, current, and even the speed of light, become dimensionless in certain contexts. For example, in translational mechanical systems, velocity becomes dimensionless, consistent with natural units in physics where constants such as the speed of light c are normalized. This dimensional collapse simplifies complex systems, reducing them to relationships between mass-energy and the oscillatory structure of the vacuum.

The framework also draws upon the equivalences found in harmonic oscillators and RLC circuits, where inductance and mass, as well as resistance and damping coefficients, share analogous roles. This dimensional correspondence reinforces the consistency of the model: just as the equations governing harmonic oscillators in mechanics and electronics are equivalent, so too are the dimensions of the quantities involved. For example, in the analogy between inductance L in RLC circuits and mass M in mechanical oscillators, the dimensional consistency $[L] = [M]$ holds, ensuring that derived relationships such as $[L^2 I^{-2} T^{-2}]$ becoming dimensionless remain physically valid.

The deeper implication of this dimensional analysis is the collapse of space and time into a unified description, consistent with general relativity's treatment of spacetime as a four-dimensional continuum. In this model, the traditional separation of space and time fades, and the universe is treated as a four-dimensional object in which both space and time contribute equally to the dynamics of the system. This dimensional equivalence is further supported by the internal consistency of the model, where quantities like G, μ_0, and the fine-structure constant α emerge naturally and maintain dimensional coherence when interpreted through the vacuum oscillatory framework.

The rigorous application of dimensional analysis also extends to the modified Friedmann equations and other cosmological relationships derived in the paper. By preserving the fundamental equivalence $[L] = [T]$, the model simplifies the dimensional complexity of large-scale cosmological phenomena, while still aligning with observed data. The fact that the relationships derived within this dimensional framework yield results that are consistent with experimentally measured values, without requiring complex or exotic physical assumptions, reinforces the internal consistency of the model.

In summary, the dimensional analysis presented in this model highlights the consistency and simplicity underlying the vacuum interpretation as a system of harmonic oscillators. By reducing the number of dimension-bearing entities to mass, energy, and charge, and treating other quantities as dimensionless, the model provides a more streamlined view of the physical universe. This reduction does not merely simplify the mathematics, but also offers deeper philosophical insights into the nature of reality: that the complexity of spacetime, gravity, and electromagnetism may be emergent from the simple, coherent dynamics of mass-energy interactions with the vacuum. Finally, this approach to dimensional analysis reinforces the physical validity of the theoretical constructs and ensures that the relationships between electromagnetic, gravitational, and quantum phenomena are deeply interwoven.

26.4 Final Thoughts

The model proposed in this paper transcends the conventional boundaries of physics by offering a unified framework that reinterprets the fundamental constants through the lens of vacuum properties, modeled as a system of harmonic oscillators. At its core, this approach reveals that seemingly disparate constants—such as the gravitational constant G, Planck's constant h, and the elementary charge e—are not isolated entities but are deeply intertwined with the vacuum's intrinsic electromagnetic and quantum structure. This interconnection suggests that the constants that define the universe are not immutable laws but emergent properties of the vacuum itself, reflective of the dynamic processes occurring at the very fabric of reality.

By harmonizing these constants within the framework of an RLC circuit analogy, the model opens a pathway toward a more elegant and holistic theory of physics. It underscores the profound role of the vacuum, not as an inert backdrop, but as an active, oscillatory medium that continuously shapes the evolution of the universe. The vacuum becomes a dynamic entity where zero-point energy, spacetime curvature, and the matter-antimatter symmetry that drives the expansion of the cosmos are all manifestations of its inherent properties. This perspective radically shifts our understanding of the universe: the vacuum, far from being "empty," becomes the fertile ground from which the forces of nature, and perhaps even matter itself, emerge.

Philosophically, this model challenges our notions of what is fundamental in the universe. If gravity, electromagnetism, and quantum phenomena all arise from the same oscillatory vacuum, then the distinction between these forces may be more illusory than real. They are unified expressions of the same underlying reality, a vibrating cosmos that resonates through every level of existence—from the quantum realm to the largest cosmic structures. This vision invites us to reconsider the metaphysical nature of the universe: it suggests that the cosmos is inherently rhythmic, a harmonic symphony of oscillations where even time and space themselves are fluid, interwoven, and responsive to the oscillations of the vacuum.

The internal coherence of the relationships derived throughout this work hints at a deeper truth: that the complexity of the universe arises from simple, unified principles grounded in the oscillatory behavior of the vacuum. This realization suggests that the universe is not a fragmented collection of forces and constants, but a deeply interconnected whole, where every phenomenon is an expression of the same underlying dynamics.

The implications of this model extend far beyond the realm of physics. At its heart, the model challenges the classical dichotomy between matter and void, suggesting instead that the vacuum—what we have traditionally considered "nothingness"—is the most fundamental and active component of the cosmos. This shift echoes ancient philosophical debates about the nature of existence, where "being" and "non-being" are no longer opposites but deeply connected through the continuous oscillation of the vacuum. In this context, the vacuum becomes the "prima materia" from which all forces, energy, and matter emerge.

The fact that all physical phenomena—whether gravitational, electromagnetic, or quantum—are emergent from the same oscillatory vacuum structure implies that the universe operates on a principle of unity and coherence at its deepest levels. This aligns with metaphysical notions of the cosmos as a singular, interconnected whole, where apparent divisions between forces and fields are merely artifacts of our limited understanding. The oscillatory model encourages us to view the universe as an integrated system, where every aspect of reality is a manifestation of the same fundamental process.

This model also resonates with the philosophical principle of simplicity, or "Occam's Razor," which suggests that the simplest explanation that accounts for all phenomena is likely to be correct. The notion that the universe's complexity—spanning from quantum mechanics to general relativity—can be explained through the dynamics of vacuum oscillations provides a powerful example of how simplicity can reveal profound truths. It points to a universe where complexity arises not from an arbitrary collection of forces and constants but from a harmonious interplay of fundamental oscillations that underlie all of reality.

Finally, the implications of this model extend into questions about the nature of time and space themselves. By treating space and time as interchangeable in certain contexts, the model suggests that they are not distinct entities but emergent properties of a deeper oscillatory dynamic. This challenges our everyday intuitions about the linearity of time and the rigidity of space, hinting at a universe where the passage of time and the expansion of space are fluid, responsive to the vibrations of the vacuum. In this sense, time and space may be seen as emergent dimensions, unfolding as part of the vacuum's ongoing oscillatory evolution.

A central question that arises from this model is the origin and nature of the universe-anti-universe relationship. If the cosmos consists of two parallel realities—one dominated by matter and the other by antimatter—what is the origin of this duality? Are we expanding within a larger structure that encompasses both the universe and anti-universe, and if so, what governs the dynamics of this expansion? Moreover, the physical laws that govern the anti-universe remain an open question. Do the same forces, constants, and symmetries apply equally to both realms, or could the anti-universe operate under a different set of physical principles? The exchange of energy across the thin boundary separating these two domains, as proposed by the model, suggests a profound connection, yet the exact mechanisms that dictate how the anti-universe evolves remain speculative. This duality challenges our current understanding of cosmology and suggests that the universe we observe is only part of a broader, more complex reality.

The metaphysical vision offered by this model invites us to reconsider the nature of the universe as a whole. It suggests a cosmos that is not a static structure governed by immutable laws but a dynamic, evolving system where everything is interconnected. This perspective blurs the line between physics and philosophy, offering a unified view where the very essence of existence is rhythm, oscillation, and resonance—a universe that ”sings” at every level, from the quantum to the cosmic. In this framework, matter and antimatter are not merely opposites but part of a cosmic dance, a reflection of deeper symmetries and forces that drive the evolution of the universe and the anti-universe. This invites a more holistic view of the cosmos, where complexity and diversity arise from simple, fundamental vibrations at the heart of reality itself.

26.5 Remarks

In the proposed framework, the values of fundamental constants are derived based on the interpretation of the vacuum as a system of harmonic oscillators. Table 4 below summarizes the values of these constants within the model (the values for which the model is consistent and all the equalities hold), their measured or accepted values, and the percentage differences between them.

The discrepancies between the model's values and the measured ones are hypothesized to arise due to the local effects of curvature in the environment where measurements are taken, such as on Earth. This local curvature affects the observed values of constants, indicating that the measured values may reflect conditions specific to our local spacetime region rather than the intrinsic properties of the vacuum on a universal scale.

Discussion:

The model values align closely with the measured or accepted values, with differences typically under 1%. Notably, constants such as the speed of light (c), vacuum permittivity (ϵ_0), and gravitational constant (G) exhibit differences within a fraction of a percent, suggesting a high degree of accuracy in the model. Larger discrepancies, such as in the Planck constant (h) or Boltzmann constant k_B, might indicate that the effective value of those constants are more affected by the local spacetime, or they could point to aspects of the vacuum's oscillatory nature that are not fully captured by current measurements.

Our hypothesis is that these variations could be attributed mainly to two factors: (i) the curvature of spacetime in Earth's vicinity, and (ii) vacuum's polarization:

- **Curvature in Earth's vicinity:** Earth's gravity and other local factors may introduce curvature effects that influence the measurement of these constants. Therefore, the values measured on Earth might differ slightly from the "ideal" values predicted by a model that considers the vacuum as a system of harmonic oscillators on a cosmic scale.
- **Vacuum's polarization:** In quantum field theory, vacuum polarization refers to the process by which a vacuum behaves like a medium that becomes polarized in the presence of electromagnetic fields, effectively altering the distribution of charges and fields within the vacuum. This phenomenon could introduce slight deviations from the predicted model values, especially in regions where strong electromagnetic fields or gravitational influences distort the vacuum. Since the model relies on vacuum permittivity (ϵ_0) and permeability (μ_0) as key parameters, the polarization of the vacuum may shift these constants slightly, modifying the calculated values of c, h, and other fundamental quantities. These small variations in the vacuum's electromagnetic properties could result in local fluctuations in spacetime geometry and energy density, leading to measurable differences that the model may not fully account for under idealized conditions.

Overall, this table supports the model's potential to harmonize cosmological constants through the interpretation of the vacuum, offering a pathway for reconciling the observed differences through a deeper understanding of the vacuum structure and its interaction with spacetime.

Constant	**Model Value**	**Measured/Accepted Value**	**Difference (%)**
Speed of Light c	298,953,375.96 m/s	299,792,458 m/s [65]	0.281
Vacuum Permittivity ϵ_0	$8.82603343 \times 10^{-12}$ F/m	8.854187×10^{-12} F/m [21]	0.319
Vacuum Permeability μ_0	$1.26773216 \times 10^{-6}$ H/m	1.25664×10^{-6} H/m [66]	0.875
Impedance of Free Space Z_0	378.992809 Ω	376.7303309 Ω [67]	0.597
Fine-structure Constant α	0.007245186	0.007297353 [68]	0.720
Planck Constant h	$6.87537997 \times 10^{-34}$ J·s	$6.62607000 \times 10^{-34}$ J·s [69]	3.626
Reduced Planck Constant $\hbar$	$1.09425071 \times 10^{-34}$ J·s	$1.05457179 \times 10^{-34}$ J·s [70]	3.626
Elementary Charge e	$1.62133463 \times 10^{-19}$ C	$1.60217000 \times 10^{-19}$ C [71]	1.182
Gravitational Constant G	$6.65467243 \times 10^{-11}$ m^3/kg·s^2	6.67430×10^{-11} m^3/kg·s^2 [22]	0.295
Casimir constant C_c	$\frac{\pi^2 \cdot \hbar c}{240}$	$\frac{\frac{\hbar c}{2}}{4\pi}$ [43]	0.114
Boltzmann Constant k_B	$1.4187414 \times 10^{-23}$ J/K	1.380649×10^{-23} J/K [72]	2.666
Cosmological Constant Λ	$1.11472916 \times 10^{-52}$ m^{-2}	1.1056×10^{-52} m^{-2} [73]	0.819
Hubble Constant H_0	$2.23189185 \times 10^{-18}$ s^{-1}	2.22×10^{-18} s^{-1} [38]	0.533
Vacuum Energy Density (J/m^3) ρ_{vac}	$5.32373794 \times 10^{-10}$ J/m^3	5.35×10^{-10} J/m^3	0.493
Vacuum Energy Density (kg/m^3) ρ_{vac}	$5.95675510 \times 10^{-27}$ kg/m^3	5.96×10^{-27} kg/m^3 [74]	0.054

Table 3: Comparison of model values for physical constants with their measured or accepted values and the percentage differences.

27 Summary of relationships established

Here we summarize the main relationships established in our model, linking components of harmonic oscillatory systems to fundamental constants and concepts in cosmology. This table consolidates the core analogies, relevant formulas, and emerging relationships, although it is non-exhaustive:

Translational Mechanical	**Rotational Mechanical**	**Series RLC Circuit**	**Main equivalences established in the framework**
Analogous Components			
Effective Mass m	Effective Moment of inertia J	Effective Inductance L	$G = R^2\epsilon_0 = \frac{X_N}{c} = J\int c\, dc = \alpha \cdot h \cdot c \int c\, dc$
Damping coefficient b	Rotational damping coefficient b_r	Resistance R	$R = \sqrt{\frac{3}{5}4\pi} \approx 2.745$
Effective Spring constant k	Effective Torsional spring constant k_r	Reciprocal of capacitance C	$k_e = \frac{1}{4\pi\epsilon_0} = \frac{\mu_0}{2\pi}\int c\, dc$
Effective displacement x	Effective angular displacement θ	Effective charge q	$e = \frac{G}{c\sqrt{\frac{3}{5}\pi}} = \frac{2\alpha}{c^2} = \frac{\mu_0^3}{4\pi}$
Effective Velocity $v = \dot{x}$	Effective angular velocity $\omega = \dot{\theta}$	Effective Current $i = \dot{q}$ and time constant τ	$I_{eff} = \frac{e\cdot c}{2} = \epsilon_0 \cdot \sqrt{\frac{3}{5}4\pi} = \tau$
Effective amplitude A	Effective amplitude Θ_0	Effective voltage V_0	$V_{eff} = \mu_0 \cdot \alpha = \frac{G}{\alpha}$
Effective action S	Effective angular momentum L	Effective magnetic flux Φ	$h = \frac{e\cdot\mu_0}{c} = \epsilon_0^3$
Resonant Frequency (Speed of light c)			$\omega_0 = \frac{1}{\sqrt{\mu_0\epsilon_0}} = \frac{\sqrt{\frac{3}{5}4\pi}}{\mu_0\cdot\alpha} = c$
Fine-structure constant α)			$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} = e\int c\, dc$
Quality Factor Q (Reciprocal of fine-structure constant α)			$Q = \frac{1}{\alpha} = \sqrt{\frac{\mu_0}{G}} = \frac{\mu_0\cdot c}{\sqrt{\frac{3}{5}4\pi}} = \frac{2}{e\cdot c^2}$
Inductive Reactance at Resonance X_N			$X_N = R\cdot\alpha = R^2\sqrt{\frac{\epsilon_0}{\mu_0}} = \frac{R^2}{Z_0} = G\cdot c$
Some additional Derived Relationships			
Zero-point energy E_0			$E_0 = \frac{\hbar\cdot c}{2} = \frac{\epsilon_0^5}{\mu_0^5}$
Vacuum Energy Density ρ_{vac}			$\rho_{\text{vac}} = \Phi_0\omega = \frac{\frac{1}{2}\hbar c}{\sqrt{\frac{3}{5}4\pi}} kg/m^3 = \sqrt{\frac{\Lambda}{\pi}} kg/m^3 = \frac{1}{2\pi\cdot c} J/m^3 = 8GJ/m^3$
Cosmological constant Λ			$\Lambda = h\cdot e = \frac{e^2}{c^2 Z_0} = \frac{4G}{c^5}\rho_{vac}^2\cdot\pi \approx \frac{G^5}{12}$
Vacuum gravitational flux Φ_G			$\Phi_G = 4\pi G\rho_{vac} = \Lambda\int c\, dc$
Hubble's parameter H			$H^2 = 4\pi G\rho_{vac}$
Boltzmann's constant K_B			$K_B = \frac{2\pi\cdot E_0}{\alpha} = \frac{\mu_0}{c^2}$
Vacuum entropy S			$S = K_B \cdot \ln(2)$
Vacuum electric flux Φ_E			$\Phi_E = \int_S \vec{E}\cdot d\vec{A} = \frac{e}{\epsilon_0} = \mu_0\cdot 2\alpha = \frac{2G}{\alpha} = m_{vac}\cdot c^2\cdot\gamma = E_{Total}$
Active power P_{kin}			$P_{kin} = h\cdot\int c\, dc = \frac{\sqrt{\frac{3}{5}4\pi}}{c^2} = \frac{e\cdot c}{2}\cdot\mu_0 = 2\cdot\frac{4\pi G\rho_{vac}}{\alpha}$

Table 4: Updated Summary of Analogous Components, Fundamental Constants, and Derived Relationships in the Unified Cosmological Framework

28 Epilogue: A Journey of Curiosity and Conviction

The origin of this paper can be traced back to my days in high school, a time when my classmates and I first learned about the formulas for gravitational and electrostatic forces. Like many students, I couldn't help but notice the striking similarities between these two formulas. Both the gravitational force and electrostatic force depend on an inverse-square law, the product of fundamental dimensions of nature (mass, charge), and involve a fundamental constant—G for gravity and k for electrostatics. From that moment on, I had an unshakable intuition that these forces must share a common nature or underlying mechanism, an intuition that, in a way, laid dormant for years but never truly disappeared.

Last year, after ten years spending a considerable amount of time working on unsolved mathematical problems as a hobby, this "open problem" about the unification of gravitational and electromagnetic forces resurfaced unexpectedly in my mind. I decided to take a fresh look, starting with the idea of exploring possible relationships between G and ϵ_0. In the process, I stumbled upon an intriguing relationship that matched numerically very well:

$$G \approx \frac{3}{5} \cdot 4\pi.$$

With a sense of excitement, I shared this observation on an online physics forum, specifically at *Physics Stack Exchange* [75], only to be met with skepticism and downvotes. Despite the reception, I felt strongly that I was onto something and that this idea was worth pursuing further.

Following my intuition, I continued exploring, which eventually led me to the concept of harmonic oscillators. That was when everything started to fall into place. I discovered that:

1. The formula for the speed of light, $c = \frac{1}{\sqrt{\epsilon_0 \cdot \mu_0}}$, was identical to the formula for the resonant angular frequency of a harmonic oscillator $\omega = \frac{1}{\sqrt{C \cdot L}}$.
2. The definition for the fine-structure constant, α, as a ratio of energies, matched the definition of the quality factor Q of an RLC circuit.
3. The formula for energy density had the same structure as the formula for the total energy of an RLC circuit.

These insights revealed an unexpected web of analogies between universal constants and the parameters of RLC circuits firstly and systems of harmonic oscillators later on. Fueled by these findings, I embarked on a comprehensive search to map the relationships among all universal constants and systems of harmonic oscillators parameters, leading to the framework presented here in this paper.

Admittedly, the final part of this paper ventures into more speculative territory, and I accept that some aspects may be subject to revision or even outright refutation. However, I am confident that the core relationships and analogies established throughout this Paper are both solid and meaningful. This journey has shown me the profound value in staying true to one's convictions and following one's curiosity, no matter the initial reception or setbacks along the way.

In closing, I would like to express my gratitude—to God, and to all the great minds and discoveries that paved the way for my exploration. I hope this work inspires others to trust their intuition, to seek out the underlying unity in the universe's laws, and to never give up on the questions that ignite their curiosity.

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