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

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"Entia non sunt multiplicanda praeter necessitatem"
— Ockham's Razor

"Padre, Señor del cielo y de la tierra, te doy gracias porque has ocultado todo esto a los sabios y entendidos y se lo has revelado a los que son como niños."
— Matthew 11:25

Abstract

This paper presents a novel cosmological framework interpreting the vacuum as a system of harmonic oscillators, resonating at relativistic scales and manifesting properties that unify aspects of quantum mechanics and general relativity. By modeling the vacuum through an equivalent RLC circuit, fundamental constants, including the speed of light c, gravitational constant G, and fine-structure constant α, are derived as emergent properties of this oscillatory vacuum structure, revealing a dynamic structure within the vacuum, and linking oscillatory vacuum states to the emergence of gravitational and electromagnetic phenomena.

Based on this framework, they are postulated explanations for the cosmological constant, observable gravitational phenomena, and large-scale structure, proposing a resonance-based expansion model of the universe consistent with current cosmological observations. By re-envisioning the vacuum as an active, resonant medium, this model offers a unified theoretical basis that could integrate quantum mechanics, relativity, and cosmology, with implications for both fundamental theory and potential observational validation.

Finally, the model further explores energy exchange across a hypothesized matter-antimatter boundary, conceptualized as a "quantum black hole" network, which would induce spacetime curvature and give rise to gravitational and electromagnetic interactions, postulating itself as a significant step toward a complete and consistent "Theory of everything".

Contents

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 five key stages, each corresponding to a separate part of this Paper:

1. 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.
2. Secondly, the theoretical framework is used to derive novel relationships among fundamental constants, which in turn offers insights into the connections between electromagnetic and gravitational phenomena.
3. In the third part, they are explored further interpretations and derivations based on the previous sections.
4. In the fourth part, it is developed a novel framework for the electromagnetic phenomena, and hypothesized the emergence of subatomic particles from vacuum properties.
5. Finally, the framework is extended toward a somewhat speculative but cohesive cosmological proposal, where it is hypothesized the matter-antimatter interaction and energy exchange through a network of "quantum black holes".

By interpreting spacetime curvature, gravitational and electromagnetic interactions as emergent from vacuum oscillations, this framework opens new pathways for reconciling quantum mechanics with general relativity, and succeeds in showing how gravitational and electromagnetic forces are rooted in the vacuum's inherent structure.

Furthermore, 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 [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, and well-known formulas and equations of harmonic oscillation, we will derive insightful and profound relationships between fundamental constants, spacetime structure, and the emergence of gravitational and electromagnetic 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 Vacuum energy and the maximum current I_{max}

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

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

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.

Later in the paper, we will relate I_{eff} to the effective time constant of the system, establishing a direct connection between the oscillatory behavior and temporal characteristics of the system. This relationship will allow us to extract significant conclusions regarding the interplay between the system's phase dynamics and energy dissipation rates. By analyzing I_{eff} as the effective time constant, we will provide deeper insights into the harmonic balance of the system and its implications for relativistic expansion processes.

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 of 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 [16].

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 (3.4). 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, together with our previous analogy of α as the reciprocal of the quality factor Q (3.4), allows us to relate the fine-structure constant α to the ratio of gravitational constant G and the vacuum permittivity μ_0:

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

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.

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 is not explicitly performed in each case, 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 Oscillatory Systems

As we have already seen, in engineering and physics, harmonic oscillators in mechanical, rotational, and electrical systems are often equivalent due to their shared mathematical models [10]. 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, as we had obtained just before.

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 in the previous section that $[G] = [\mu_0]$ (3.5), which in the physical reality has dimensions $[HL^{-1}] = [MT^{-2}LI^{-2}]$. On the other hand, through Newton's Law of Gravitation, 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 fundamentally 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 $I_{max} = c$, with both I_{max} 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 $[\mathrm{T}^{-1}]$; 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.

Introduction to the Following Sections

The remaining sections of this Part I: General Framework, present key postulates forming the conceptual foundation of many interpretations that we postulate throughout this paper. These postulates, while inherently speculative, are constructed on reasonable physical and mathematical arguments. They integrate coherently with the results and derivations developed throughout the paper, offering a unified framework for interpreting quantum and relativistic dynamics. Importantly, these postulates are not definitive truths but rather theoretical propositions subject to interpretation and further validation. Nevertheless, their consistency with the derived results lends credence to their plausibility.

Rather than presenting these postulates as foundational or strictly necessary assumptions, they emerge naturally as interpretations derived from the equations and relationships obtained throughout this work. The postulates represent the most reasonable and consistent explanations for the mathematical results and physical dynamics explored in the subsequent sections. By framing these ideas as emergent from the derived equations, rather than as prior axiomatic truths, we aim to highlight their interpretative nature. This approach underscores that the postulates are not prescriptive but descriptive, serving to unify the results within a coherent theoretical framework.

The first postulate introduces the concept of an elementary spacetime differential $dx = \frac{1}{2}$, derived from Heisenberg's uncertainty principle, suggesting a quantized structure of spacetime. This idea, while speculative, aligns with the probabilistic nature of quantum mechanics and the discrete behaviors observed in quantum systems.

The second postulate explores the integral $\int c\,dc$ as a transformation operator linking potential and kinetic forms of spacetime. This interpretation extends to oscillatory modes of the vacuum, providing a framework to connect mass, energy, and charge with dynamic spacetime properties.

The final section examines the ubiquitous factor of 2 in vacuum dynamics, interpreting it as arising from fundamental polarization states inherent in quantum oscillatory systems. This reinterpretation ties the factor 2 to symmetry properties, spin dynamics, and the relativistic behavior of vacuum oscillations.

These sections together propose a speculative yet logically consistent framework for understanding the interplay between quantum mechanics, general relativity, and vacuum dynamics.

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 and in certain quantum-probabilistic contexts.

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 try to 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 can be assigned 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 reflects 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:

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

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, is a latent form that can become dynamically active, and this transformation process is embedded in $\int c\,dc$.

Temporal Interpretation of $\int c\,dc$

Other hand, from a temporal perspective, we can 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. In this sense, 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 a certain 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 context, 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 maintain dimensional consistency. We will see in the next section that we can relate it to the two polarization states of light, which emerge naturally as a direct consequence of the vacuum's isotropic and oscillatory properties. The equivalence between $\int c\,dc$ and $\int t\,dt$ highlights the geometric and temporal symmetries embedded in spacetime. As light propagates, its polarization states correspond to orthogonal degrees of freedom in the vacuum, which are supported by the vacuum's intrinsic ability to mediate oscillations across all temporal and spatial scales. These polarization states are thus not arbitrary but arise as manifestations of the underlying symmetries captured by the integral's structure.

In this sense, the two degrees of freedom associated with light's polarization can be interpreted as a natural result of integrating time over time, $\int t\,dt$. This operation introduces a two-fold structure that mirrors the orthogonality of the electric and magnetic field components in light. Each polarization state reflects one "dimension" of this temporal summation, corresponding to distinct but complementary contributions to light's overall energy propagation. The vacuum, with its inherent symmetry, supports this duality by enabling the coexistence of two independent modes of oscillation.

The integral $\int t\,dt$, like $\int c\,dc$, thus encapsulates the vacuum's ability to generate and sustain these dual polarization states. By summing over all temporal intervals, the vacuum effectively defines the oscillatory framework that gives rise to light's orthogonal polarization components. This view aligns with the broader interpretation of this Paper of the vacuum as a resonant, isotropic medium, where spacetime geometry and relativistic effects combine to produce observable electromagnetic phenomena. These polarization states emerge as fundamental aspects of the vacuum's oscillatory dynamics, highlighting the deep connection between temporal integration, spacetime structure, and the nature of light itself.

Finally, 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.

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

This integral arises 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):**

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

  where $I_{min} = e \cdot c$ represents the minimum 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 potential 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 potential 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 $\int c\,dc$ arises as a transformational operator within our framework, mobilizing latent or potential forms of spacetime—whether mass, energy, 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 mainly in the context of relationships involving electromagnetic interactions [26]. 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 electromagnetic interactions.

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 the 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 [23], 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 -quantum-probabilistic- 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 [27] [28], 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 [29].

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 that contributes to the energy stored in the system, which in turn follows the expression for the energy in a capacitor [30]

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

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.

Let us show how can be established the relationship postulated. 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 [31], with elementary charge e and radius R, which can be expressed [31] 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 [32] 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 $r = \frac{1}{2}$, 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 -spacetime- re-balancing action in response to energy density differences. The oscillatory vacuum acts as a medium that transfers energy through quantum harmonic oscillators, creating spacetime curvature as a natural outcome to mantain equilibrium. Here, G is proportional to ϵ_0, reflecting the vacuum's capacity for energy exchange and its effect on spacetime deformation.

At the last part of the paper, we will postulate an underlying mechanism for the emergence of gravity based on matter-antimatter interactions. This approach suggests that the gravitational force arises as a macroscopic manifestation of these fundamental interactions, providing a novel perspective on the origin of gravitational phenomena. By linking gravity to matter-antimatter dynamics, we aim to offer a cohesive explanation that integrates quantum mechanical and relativistic principles, trying to sheed light on the deeper connections between these fundamental forces and the structure of spacetime.

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} (3.5), 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 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 The double nature of G as a voltage and a force: gravity as an electromotive force $\mathcal{E}$

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 [33], 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 an electromotive force $\mathcal{E}$

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.

Moreover, from the above, we can postulate that G (and gravitational force in a general sense) behaves as an electromotive force $\mathcal{E}$. Electromotive force (EMF) is a cornerstone concept in electromagnetism, describing the potential difference that drives electric current through a circuit. Classically, EMF can be expressed as:

$$\mathcal{E} = I \cdot R,$$

where $\mathcal{E}$ represents the voltage across the circuit, I is the current, and R is the resistance. Therefore, the equality obtained before supports this postulate, and we will see throughout this Paper more equations supporting this claim. As we have mentioned, the fact that G incorporates the elementary charge e, the speed of light c, and vacuum geometry underscores its electromagnetic foundation. This duality has profound implications:

- It shows that gravitational forces are not fundamental but emerge from oscillatory energy exchanges within the vacuum.
- It implies that G is a measure of the vacuum's energy storage and transfer capabilities, connecting gravitational dynamics to electromagnetic wave propagation.

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.

8.3 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 [34] quantifies the opposition that an inductor presents to changes in current. It is expressed as:

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

where ω_0 is the angular frequency of the oscillation, and L is the inductance. Drawing on the dimensional similarity between G (the gravitational constant) and inductance, we investigate whether $X_L = G \cdot c$ can be interpreted as an effective inductive reactance in the vacuum at the natural angular frequency c. This analogy offers a framework for exploring more connections between gravitational and electromagnetic phenomena, potentially unifying them within an oscillatory vacuum model.

It can be verified numerically that:

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

This suggests a dimensional connection between G, the speed of light c, and an inductive reactance $X_L \approx \frac{1}{16\pi}$. Here, X_L emerges as an effective reactance that represents the vacuum's opposition to changes in the flow of electromagnetic energy. To determine whether this relationship reflects a deeper physical basis or is merely coincidental, we examine its consistency with the vacuum model and explore its implications.

Equating the expressions derived for G earlier, we can postulate that:

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

This relationship leads us to:

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

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:

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

This result supports the consistency of X_N with the numerical approximations and dimensional analysis presented earlier. While alternative constants may yield slightly different values, $X_N = \frac{1}{16\pi}$ is adopted here due to its theoretical relevance and its role in subsequent developments throughout this framework. With this postulate, we can state that:

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

Interestingly, this relationship matches part of the pre-factor 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. As a geometrical and physical quantity, X_N encapsulates the vacuum's reactive properties, linking gravitational and electromagnetic constants to spacetime's underlying structure, and has the potential to bridge the gap between classical and relativistic frameworks through the oscillatory nature of spacetime as a foundation for universal constants.

8.4 Gravity as an Emergent Phenomenon from Vacuum Fluctuations

In this subsection, we explore gravity as an emergent phenomenon originating from vacuum energy fluctuations. By modeling the vacuum as a system of harmonic oscillators, we investigate how the interplay between the electric and magnetic energy densities of vacuum fluctuations relates to the gravitational constant G. Within this framework, as we have seen in previous sections, the vacuum's total energy density, E_{vac}, can be understood as the sum of contributions from electric and magnetic components, expressed as:

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

To capture the equilibrium state of this energy partition, we introduce a new constant J, representing the balanced energy density per mode of vacuum oscillation. Specifically, J corresponds to the energy density contributed by either the electric or magnetic component of the vacuum when the system is in equilibrium. This balance is a natural consequence of the harmonic oscillator model, where energy is evenly distributed between kinetic and potential components. Analogously, the electric energy density corresponds to the potential energy of the vacuum, while the magnetic energy density corresponds to its kinetic energy.

From the above equation, and under equilibrium conditions, we define J as:

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

Here, J encapsulates the fundamental scale of energy density in vacuum oscillations, where electric and magnetic contributions are equal. This equilibrium condition not only characterizes the vacuum's structured energy density but also serves as a key parameter for understanding how gravitational effects emerge from these oscillations.

Linking J to the Gravitational Constant G

We now explore the connection between J and G in terms of the vacuum's total energy density. Consider $\rho_{vac_E} = \frac{\rho_{vac}}{c^2}$, the vacuum energy density measured in J/m^3, which describes the energy per unit volume of the vacuum, and which we have derived from ρ_{vac} using Einstein's equation $E = m \cdot c^2$. Using the previously established relationship:

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

and considering the definition of J, we derive the following:

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

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. In this context, $4\pi G \rho_{vac_E}$ reflects the gravitational field strength arising from the structured energy density of the vacuum.

Interpreting G as an Integral over vacuum's gravitational flux

We postulate that we can express G with the integral:

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

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:

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

And, replacing with $I_{eff} = \frac{e \cdot c}{2}$, the above can be rewritten as:

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

This result is consistent with the well-established relationship between the vacuum permittivity ϵ_0, the vacuum permeability μ_0, and the speed of light c, given by:

$$c^2 = \frac{1}{\mu_0 \epsilon_0}.$$

For our expression for G to be valid, we note that we must have that:

$$\frac{1}{\epsilon_0} = \mu_0 c^2,$$

which indeed is true by the previous expression for c; this ensures the dimensional consistency of G in the derived forms.

Emergence of Gravity through Vacuum Fluctuations

With this framework, the integral

$$G = \int 4\pi G \rho_{vac_E}\, dc,$$

captures how the relativistic vacuum energy drives spacetime curvature, resulting in emergent gravitational phenomena. The term $4\pi G \rho_{vac_E}$ represents the gravitational flux density due to vacuum energy fluctuations, where ρ_{vac_E} is the vacuum energy density, and c reflects the relativistic scaling of these contributions over time or frequency modes. This integral thus ties the gravitational constant G to the cumulative effects of vacuum fluctuations across spacetime.

In this model, the vacuum is interpreted as a dynamic system of quantum harmonic oscillators, with its energy density partitioned between electric and magnetic components. These fluctuations generate a structured energy density ρ_{vac_E}, which drives the curvature of spacetime. The term $4\pi G\rho_{vac_E}$ reflects the aggregated contributions of these oscillations to the gravitational field, analogous to the role of mass-energy density in the Einstein field equations. Here, G emerges as the coupling constant that relates the flux of vacuum energy to spacetime curvature, ensuring coherence with relativistic constraints.

As vacuum energy density arises from the zero-point motion of quantum fields, gravity naturally emerges as a macroscopic manifestation of these microscopic oscillations. The harmonic oscillator model provides a unified framework in which G aggregates the localized vacuum fluctuations to the large-scale curvature of spacetime, grounding the gravitational force in the dynamic interplay of quantum and relativistic effects.

In this way, gravity is revealed as an emergent phenomenon, rooted in the vacuum's oscillatory and relativistic nature. The gravitational constant G encapsulates this fundamental interplay, acting as a bridge between quantum vacuum fluctuations and the relativistic structure of spacetime. This perspective highlights the profound role of vacuum fluctuations in shaping the macroscopic gravitational field and provides a consistent framework linking quantum field theory and general relativity.

8.5 Reinterpreting Newton's Gravitational Law and the Role of Mass

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 $[G] = \frac{\text{m}^3}{\text{kg}\cdot\text{s}^2}$, representing the proportionality constant governing the strength of gravitational interactions.

In our framework, gravity is not viewed as a fundamental force but rather as an emergent phenomenon arising from spacetime deformation, consistent with general relativity. However, in this work, we propose a specific quantum mechanism as the underlying driver of gravitational interactions, derived from our vacuum oscillatory model.

Linking Masses to the Curvature of Spacetime

In our model, energy-mass and charge can be linked to the curvature of spacetime. Just as charges distort the electromagnetic field, leading to the electrostatic force as an emergent property of that curvature, masses create distortions in spacetime itself. These distortions give rise to gravity, which can be viewed as analogous to the electrostatic force in this unified framework.

Since masses interact via the vacuum's inductive properties, their presence distorts spacetime much like charges distort the electromagnetic field. This distortion corresponds to the curvature of spacetime around the masses, propagating through the vacuum. The gravitational force between two masses is then a result of spacetime attempting to restore equilibrium, analogous to how electromagnetic field distortions equalize in response to charges.

Dimensional Analysis of Masses and its interpretation as Geometrical Parameters

In this model, we reinterpret the dimensions of mass $[M]$ as geometrical, with $[M] \equiv [L] = [T]$. This gives mass a spatial interpretation, treating it as a manifestation of spacetime curvature. The product of two masses m_1 and m_2 therefore has the dimensions:

$$[m_1 \cdot m_2] = [L]^2.$$

Revisiting Newton's law, the gravitational force between two masses is given by:

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

where r is the distance between the masses. The term $\frac{m_1 m_2}{r^2}$ represents the interaction strength between the two masses over a distance r. Since both $m_1 \cdot m_2$ and r^2 have dimensions $[L]^2$, their ratio becomes dimensionless:

$$\left[\frac{m_1 m_2}{r^2}\right] = \frac{[L]^2}{[L]^2} = 1.$$

Thus, $\frac{m_1 m_2}{r^2}$ is a dimensionless quantity, showing that the masses and their separation r are geometric parameters influencing the curvature of spacetime.

Interpreting masses as geometric factors implies that the gravitational force is not a result of intrinsic properties of masses but rather a consequence of the spatial configuration of energy within spacetime. Just as charges influence the curvature of electromagnetic field lines, masses determine the curvature of spacetime. In this sense, masses m_1 and m_2 reflect the geometry of spacetime interaction, with G governing the strength of the emergent gravitational force.

The product $\frac{m_1 m_2}{r^2}$, being dimensionless, encapsulates the spatial relationship between the masses. Here, the vacuum mediates the interaction between these geometrical masses, with G acting as the proportionality constant that emerges from the vacuum's oscillatory dynamics. This interpretation aligns gravity with electromagnetism, both arising from distortions in the vacuum mediated by geometric parameters, whether masses or charges.

8.6 The hypothesis of Gravity as an Emergent Effect of Spacetime Deformation from Quantum Energy Exchange

In the final part of this Paper, we propose that spacetime deformations arise from two possible primary sources: (i) the expansion of the vacuum, and (ii) the energy exchange between our universe and an antimatter counterpart universe through quantum harmonic oscillators, mediated by Quantum "black" holes. While speculative, we will present several arguments supporting this hypothesis. However, it is important to acknowledge that the question remains open, as the hypothesis relies on some non-conclusive arguments and remains rooted in the broader aim of unifying recent discoveries in cosmology, quantum mechanics, and gravitational physics under a common theoretical framework.

Regarding the second source of curvature, Quantum "black" holes are not traditional black holes but rather micro-scale "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 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 particle-antiparticle interactions leading to 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. As it is directly proportional to ϵ_0, it quantifies the effective "flexibility" 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.

Gravity as a Casimir effect driven by matter-antimatter boundaries

The above hypothesis opens the door to drawing a strong parallel to the Casimir effect, where boundaries in a quantum vacuum restrict vacuum fluctuations, resulting in a measurable force. In the context of gravity, masses (and their corresponding anti-masses in the antimatter universe) could act as boundaries that confine and modulate the vacuum energy fluctuations occurring between the two universes. These boundaries would limit the permissible quantum states of the vacuum, creating gradients in energy density that manifest as spacetime curvature.

Within this framework, masses do not intrinsically "generate" gravity but instead define the spatial boundaries that structure the vacuum energy exchange. The gravitational constant G emerges as a macroscopic measure of the flexibility of spacetime under the influence of these confined vacuum fluctuations. The term $\frac{m_1 m_2}{r^2}$ in Newton's law reflects the spatial configuration of these boundaries and the resultant energy density gradient, while G encodes the vacuum's ability to mediate this interaction.

This boundary-driven perspective aligns gravity with quantum phenomena, situating it as a large-scale manifestation of the microscopic interactions of vacuum energy. In this view, the observed gravitational force would not be fundamental, but rather a consequence of the cumulative effects of spacetime curvature shaped by constrained quantum fluctuations across the Quantum "black" hole network. This reinterpretation underscores the unifying theme of the hypothesis: gravity, much like the Casimir effect, emerges from the interplay of vacuum energy, spacetime boundaries, and the inherent quantum structure of the universe.

In summary, this hypothesis supports that gravity could emerge as a macroscopic manifestation of the quantum energy exchange between our universe and an antimatter universe. The masses m_1 and m_2, positioned within this network, induce localized spacetime deformation acting as geometric boundaries of the energy exchanges mediated by Quantum "black" holes. 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.

Note: Self-consistency of the model in a four-dimensional framework

While the hypothesis of gravity arising from quantum energy exchanges between our universe and an antimatter counterpart universe introduces an additional dimension to facilitate these interactions, it is important to emphasize that the framework presented so far remains self-consistent within a four-dimensional spacetime. The results derived in this paper are compatible with a vacuum with inherent oscillatory properties, capable of generating spacetime curvature and energy fluctuations without requiring higher-dimensional structures or inter-dimensional exchanges.

Within this four-dimensional framework, vacuum energy fluctuations naturally confine and resonate as it expands. This confinement arises from the vacuum's intrinsic ability to self-organize into oscillatory modes that produce curvature gradients. These internal resonances and oscillations generate spacetime deformations analogous to those attributed to higher-dimensional energy exchanges. The vacuum's oscillatory nature ensures that energy densities are modulated in a manner consistent with the observed macroscopic behavior of gravity, eliminating the need for invoking dimensions beyond the four-dimensional structure of spacetime.

The self-consistent four-dimensional nature of this framework can be further understood by drawing analogies to classical systems of coupled oscillators. In such systems, the boundaries and internal dynamics confine energy within specific modes of vibration, creating quantized energy states. Similarly, the vacuum confines its energy fluctuations through its inherent quantum-probabilistic structure. The role of Quantum "black" holes, in this context, can be reinterpreted as points of maximum resonance within the vacuum's four-dimensional configuration. This confinement produces effects that mimic the energy densities and curvature gradients expected from higher-dimensional models, ensuring that the framework remains sufficient within the four-dimensional spacetime paradigm.

9 RLC Circuit Dynamics and Fundamental Timescales in Vacuum Oscillations

9.1 Effective Current as a Fundamental Timescale

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

$$I_{\text{eff}} = \frac{1}{2} \cdot Q_0 \cdot \omega_0 = \frac{e \cdot c}{2}(3.3)$$

where Q_0 represents the maximum charge displacement in the oscillatory system, and ω_0 is the angular frequency of the natural oscillations. This relationship defines the effective current I_{eff} as proportional to the product of elementary charge e and the speed of light c, divided by 2.

Note that, from the postulated 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 expression offers insight into the oscillatory dynamics of the vacuum by linking the effective current I_{eff} to the parameters of a hypothetical RLC circuit. Specifically, noting that $[\epsilon_0] = [C]$ and $\left[\sqrt{\frac{3}{5}4\pi}\right] = [R]$, we have that $I_{\text{eff}} = C \cdot R = RC$, where R and C denote the resistance and capacitance. And we will see how RC represents a characteristic time constant analogous to the response timescale in classical circuits.

Characteristic Time Constant in Oscillatory Systems

In an electrical circuit, the product RC defines a characteristic time constant $\tau = RC$, which governs the system's transient response. For example, in a simple RC circuit, τ determines the time required for a capacitor's voltage to reach approximately 63% of its final value following a step input. When applied to an oscillatory system, this time constant characterizes the natural rate of energy transfer and dissipation.

In the context of our vacuum model, RC emerges as a fundamental timescale, dictating the speed of oscillations between electric and magnetic energy states. This interpretation implies that the vacuum's oscillatory behavior operates within a defined cadence, naturally constrained by the interplay of R (damping) and C (storage).

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, and R. 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.

9.2 The maximum current I_{max} and the "speed" of light c

From the above, we have a good hint on which could be I_{max}. Recall (from Section 2) that velocity in a translational 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.

Conclusion

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 maximal current amplitude that maintains stable oscillations within the vacuum, while $\frac{e \cdot c}{2}$ 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.

Finally, by interpreting c as both a velocity and a maximum current, the model unifies the relativistic and oscillatory descriptions of spacetime. The constants e and c emerge as intrinsic to the vacuum's oscillatory structure, emphasizing spacetime as an emergent harmonic medium. This framework aligns with the broader view that universal constants derive from fundamental oscillatory dynamics, reinforcing the stability and coherence of spacetime at relativistic scales.

10 Derivation of the elementary charge e

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

The quality factor Q of a series RLC circuit is given by the expression

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

where ω_0 is the angular resonant frequency, L is the inductance, and R is the resistance. As we have established that $\alpha = \frac{1}{Q}$, $L = \mu_0$, $R = \sqrt{\frac{3}{5}4\pi}$ and $\omega_0 = c$, 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 expression $G = \frac{e \cdot c}{2} \cdot \sqrt{\frac{3}{5}4\pi}$, we have that

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

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

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

From the above fundamental relationships, solving for the elementary charge e, there can be derived the expressions

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

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

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

The fine-structure constant α can be expressed through the identity:

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

This formulation connects α to fundamental quantities in electromagnetism and vacuum oscillatory dynamics. In a universe expanding at relativistic velocities, it is natural to interpret $dc = dt$, with the speed of light c serving as the differential of time. Other hand, in classical electromagnetism, the integral of current over time, $\int I \, dt$, yields the total charge transported. Analogously, $\int I_{min} \, dc$ can be interpreted as an effective minimum "charge," where $I_{min} = e \cdot c$ represents the minimum current associated with oscillations in the vacuum.

Therefore, the integral formulation shows that the fine-structure constant α represents the cumulative effect of vacuum oscillatory modes. Specifically, the integral $\int c \, dc$ serves as a transformative operator within spacetime, converting potential forms such as charge e, mass m, or potential energy into dynamic or kinetic forms. For charge, the relation $\alpha = e\int c\,dc$ illustrates how the elementary charge e transforms into a "kinetic charge" that accumulates through oscillatory modes, enabling interaction with the electromagnetic field. This aligns with the interpretation of α as an emergent property that captures the cumulative contributions of all vacuum oscillations.

Moreover, the integral $\int I_{min}\,dc$ encapsulates the 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 and represents the ratio of stored potential energy to kinetic energy dissipated within the vacuum oscillators. Thus, $\alpha = \frac{1}{Q}$ reflects the total effect of the oscillatory energy distribution within the vacuum, integrating all possible electromagnetic modes.

Vacuum oscillations and the Role of the Photon in Energy Mediation

The vacuum itself can be understood as a collection of electromagnetic oscillatory modes, each contributing to the total potential energy. The photon's role within this framework is to mediate these oscillations, transferring energy between modes and matter. The integral $\int I_{min}\,dc$, where $I_{min} = e \cdot c$, captures the cumulative effect of these oscillatory contributions. This integral directly relates to the quality factor Q, which quantifies the sharpness of resonance within the oscillatory system. Since $\alpha = \frac{1}{Q}$, the fine-structure constant reflects the total energy distribution of the vacuum oscillators as mediated by photons.

In this context, the photon plays a central role as the quantum carrier of electromagnetic energy. Each photon, with energy $E = \hbar\omega$, encapsulates the oscillatory dynamics of the electromagnetic field. The integral $\int c\,dc$ serves as a transformative operator that modulates how this energy is dynamically transferred and accumulated.

Within the vacuum framework, photons mediate the interaction between electromagnetic waves and matter. The energy they carry is inherently potential, as it is stored within the oscillatory modes of the electromagnetic field. When interacting with matter, this potential energy transitions into kinetic forms, exemplified in processes such as absorption, emission, and scattering. The fine-structure constant α, as expressed by $e\int c\,dc$, embodies this transition, acting as a measure of how the photon's energy is dynamically redistributed within a relativistic framework.

Relativistic Interpretation: α as the Reciprocal of a Lorentz Factor

When photons interact with matter, their potential energy transitions into kinetic energy of charged particles. This transformation can be interpreted as a contraction-to-de-contraction effect: potential energy, inherently relativistic, becomes distributed as kinetic energy within a slower-moving frame. The fine-structure constant α captures this transition as a dimensionless scaling factor, ensuring coherence between the relativistic and classical domains.

Building on this, we will show in the third part of this paper that α can be interpreted as the reciprocal of a Lorentz factor γ, which modulates how photons transfer energy from the relativistic domain, where they inherently exist at the speed of light c, to the classical kinetic regime of matter, where velocities are typically much smaller than c. Therefore, $\alpha = \frac{1}{\gamma}$ ensures energy conservation and coherence as potential energy is redistributed across these domains.

Conclusion

The fine-structure constant α integrates contributions from all vacuum oscillatory modes, balancing temporal accumulation (as an effective charge) with relativistic scaling effects. The photon, as the carrier of electromagnetic energy, mediates this balance, facilitating the transformation of energy from oscillatory vacuum modes into dynamic, kinetic expressions in matter. By framing α as both a measure of vacuum oscillatory dynamics and a relativistic scaling factor, this interpretation unifies the photon's role with the fine-structure constant, highlighting their intertwined contributions to light-matter interactions and energy transitions across relativistic and classical regimes.

11 On Planck's constant h: interpretations, derivations, and relationships

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

Photons are the quanta of electromagnetic energy, and Planck's constant h governs their wave-particle duality. Specifically, h relates a photon's linear momentum p to its wavelength λ through the de Broglie relation:

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

In this context, as numerically and theoretically makes sense and will be validated in further sections, we 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 to a three-dimensional expansion of the vacuum permittivity ϵ_0, suggesting that the fundamental quantum of action, as reflected in the relationship between linear momentum and wavelength, can be associated to the electromagnetic properties of the vacuum. Photons, as quantized oscillations of the vacuum, carry a linear momentum that reflects the vacuum's electromagnetic properties; and thus, the ability of the vacuum to permit electric field lines in a three-dimensional spacetime.

The postulated equivalence uncovers a deep connection between the fundamental constants of nature and the geometry of space, and 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.

11.2 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 as the main contributor to spacetime curvature.

$\hbar$ 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 $\hbar$:

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

This quantization emerges from the requirement that a particle's wave function in a rotational 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 [35]. 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 [36]. 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 arising from vacuum oscillations as the Driver of Spacetime Curvature

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 [37]. 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 [38].

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, either from a four dimensional, self-resonant vacuum oscillating as it expands, or when viewed as the quantum of the energy exchanged between our universe and an antimatter universe. We will show in later sections how this energy generates a spacetime deformation that is reflected either in a capacitive form (that we perceive as gravitational force) or an inductive form (that we perceive as electromagnetic force), where the oscillatory vacuum modes act as quantum harmonic oscillators mediating this interaction. As a result, E_0 is not strictly energy in the classical sense, but an effect that mobilizes the vacuum into dynamic deformation.

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 arises from the oscillatory behavior in the vacuum, where particle-antiparticle pairs and quantum fields fluctuate continuously. However, rather than being merely kinetic, E_0 serves as a driver of gravitational curvature by setting a dynamic equilibrium in the vacuum's structure.

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 arising from 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.

11.3 Derivations of Planck's constant h and its relationship with other universal constants

From the fine-structure constant formula (3.4), and substituting with the results obtained in previous sections (10.1), 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 the gravitational constant G and $\frac{h \cdot c}{2}$, which equals $2\pi E_0$ (which can be conceptualized as some linear form of zero-point energy) 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

$$\frac{G}{\alpha} = \mu_0 \cdot \alpha = h \cdot c \int c \, dc = \frac{h \cdot c}{2} \cdot c^2$$

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 interesting 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.

11.4 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 $I_{max} = c$, if we consider c as the measure of time, we have that

$$V_{max} = \mu_0 \cdot \frac{dc}{dc} = \mu_0$$

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

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

We can re-express the above as

$$\frac{G}{\alpha} = h \cdot c \int c \; dc \tag{19}$$

This equation establishes a profound link between gravity, the energy of photons, and the oscillatory nature of the vacuum. Here, $h \cdot c$ represents the energy of a photon, the fundamental quantum of electromagnetic radiation, while the integral $\int c\,dc$ captures the cumulative contribution of all oscillatory modes of the vacuum. This suggests that gravitational interactions emerge as an effect of the vacuum's collective quantum behavior, with photons acting as localized packets of energy that embody the vacuum's oscillatory dynamics. The integral further signifies the summation over all possible configurations of these oscillatory modes, tying gravity to the energy spectrum of the vacuum.

This formulation highlights the inherent connection between gravitational force and zero-point energy, the vacuum's lowest energy state arising from perpetual quantum oscillations. By coupling G to $h \cdot c$, the equation suggests that spacetime curvature and gravitational effects arise from the vacuum's oscillatory structure, mediated through photons. In this unified perspective, the vacuum serves as the foundation for both electromagnetic and gravitational phenomena, with the constants of nature interwoven through the vacuum's intrinsic properties. This view reinforces the idea that gravity is not fundamental but emerges from the collective energy dynamics of the quantum vacuum.

Solving for G, and operating with the equivalences already found before (19), 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 $G = \int 4\pi G \rho_{vac_E} \; dc$. Then, we can equate to obtain that

$$G = \int 4\pi G \rho_{vac_E} \; dc = \zeta \cdot \left(\frac{1}{Z_0}\right)^3 \tag{20}$$

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.

11.5 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) (8.2). If we extend this analogy by considering amplitude as a representation of spacetime curvature, it implies a profound insight into why mass-energy 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 [39].

The Inseparable Link between Mass-energy, Charge, and Spacetime Curvature

Thus, the analogy leads to the conclusion that mass-energy, 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-energy, 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.

11.6 Setting the quantum of reactive and active 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.

Reactive power is associated with the periodic exchange of energy in reactive components in some RLC circuit, akin to the oscillation of mechanical systems where momentum plays a key role. Therefore, the derived interpretation of h works well from the oscillatory RLC circuit analogy perspective.

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.

Vacuum's gravitational flux as the quantum of active-kinetic power

From the previous derived relationships, we can derive P_{kin} from P_{pot}:

$$P_{kin} = h \cdot c^2 = \frac{4\pi G \rho_{vac_E}}{\alpha}$$

This expression for the quantum of active-kinetic power bridges fundamental concepts of quantum mechanics, general relativity, and vacuum energy. The term $h \cdot c^2$ represents the kinetic counterpart of the vacuum's energy. By interpreting Planck's constant h as the quantum of potential-reactive power and incorporating the speed of light squared (c^2), this formulation reflects the transition of oscillatory vacuum energy into active-kinetic energy. The connection to $\frac{4\pi G \rho_{\text{vac}_E}}{\alpha}$ highlights the influence of the vacuum energy density (ρ_{vac_E}) on spacetime through gravitational flux. In summary, this equation encapsulates how vacuum oscillations and energy density generates curvature, modulated by α, thereby linking quantum properties of the vacuum to its macroscopic gravitational effects.

Therefore, the equation ties the vacuum's energy density to spacetime curvature, governed by general relativity, while P_{kin} represents the active power driving physical manifestations of this curvature. In this context, P_{kin} can be viewed as a measure of the vacuum's ability to translate its internal energy oscillations into observable dynamical effects, such as the generation of electromagnetic or gravitational waves.

11.7 From Quantum Oscillations to Gravitational Flux

Based on the previous results, we can describe in a general manner the process of gravitational flux generation through vacuum oscillations. The process begins with the linear momentum of photons, represented by Planck's constant h, which encapsulates the fundamental quantum of action. Photons, as discrete quanta of energy, can be seen as localized oscillatory points within the vacuum. These oscillations represent the dynamic interplay of potential and kinetic energy at the quantum level, where h serves as a measure of the minimum unit of momentum associated with these oscillatory states. This interpretation aligns with the de Broglie relation $p = h/\lambda$, linking h to the localized momentum of the oscillatory vacuum. The oscillatory behavior of the vacuum (and thus, the momentum carried by photons) has two possible main sources that could indeed be complementary: (i) the expansion of the universe at relativistic velocities, and / or (ii) the energy exchange between our universe and an anti-matter anti-universe through an interdimensional boundary.

The transformation of this momentum into energy, while still somewhat mysterious, is described by the factor c^2, following Einstein's mass-energy equivalence $E = mc^2$. By multiplying h by c^2, the oscillatory momentum is converted into an equivalent energy density. This step reflects how quantum oscillations within the vacuum manifest as measurable energy, transitioning from a purely potential-reactive state into active-kinetic energy capable of influencing physical phenomena such as electromagnetic or gravitational waves. Thus, $h \cdot c^2$ encapsulates this dynamic transition of quantum states into kinetic energy.

The appearance of the Lorentz factor, expressed as its reciprocal α, incorporates relativistic effects into the transformation of the relativistic motion of photons to the non-relativistic frame; the oscillations are stretched or diluted, reducing the effective energy transfer. This relativistic scaling ensures that the energy and momentum dynamics of the vacuum are consistent with spacetime transformations, connecting localized oscillations to macroscopic gravitational flux.

Finally, the effective gravitational flux is expressed as $4\pi G\rho_{\text{vac}_E}$, where ρ_{vac_E} represents the vacuum energy density, and the formula reflects the gravitational flux through the surface of a sphere as derived from Gauss Law. This term ties the quantum-level oscillations of the vacuum to its large-scale gravitational influence, as the vacuum energy density generates curvature in spacetime.

Therefore, the relationship:

$$h \cdot c^2 = \frac{4\pi G\rho_{\text{vac}_E}}{\alpha},$$

shows that the oscillatory quantum states of the vacuum, through relativistic modulation, drive an effective gravitational flux. This connection bridges the quantum properties of the vacuum with the macroscopic curvature effects predicted by general relativity, providing a unified view of how energy transitions across scales within the structure of spacetime.

12 Derivation of Vacuum Energy Density $\rho_{\textbf{vac}}$

The product of magnetic flux Φ and angular frequency ω provides a powerful physical measure of *energy transfer rate* in oscillatory systems. In classical electromagnetic contexts, such as RLC circuits or oscillatory fields, $\Phi \cdot \omega$ encapsulates the dynamic energy exchange between magnetic and electric fields. In this section, we build on this classical understanding to derive the vacuum energy density, ρ_{vac}, by linking $\Phi \cdot \omega$ to quantum harmonic oscillations.

The magnetic flux Φ, defined as $\Phi = L \cdot I$ (where L is inductance and I is current), represents the magnetic field's contribution to the oscillatory system. When multiplied by angular frequency ω, the product $\Phi \cdot \omega$ describes the rate of change of magnetic flux. According to Faraday's Law, this rate is proportional to the induced electromotive force (EMF), EMF $\approx \Phi \cdot \omega$, which serves as the effective energy per unit charge driving the current in the system. In oscillatory systems, $\Phi \cdot \omega$ thus reflects the energy density exchanged between electric and magnetic fields.

Transitioning to the quantum framework, we can interpret $\Phi \cdot \omega$ as representing the zero-point energy of a quantum harmonic oscillator. For a single mode of oscillation, the zero-point energy is given by:

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

where $\Phi = \frac{\hbar}{2}$ is the magnetic flux quantum, and $\omega = c$ is the angular frequency. This establishes a direct connection between the oscillatory energy density in classical systems and the quantized energy levels of the vacuum.

To determine the vacuum energy density, we consider the effective resistance $R = \sqrt{\frac{3}{5}4\pi}$, representing the system's ability to stabilize oscillatory energy flows, which we have derived previously, related to the self-energy of a sphere (8.1). Then, we can postulate that:

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

This result encapsulates the vacuum's dynamic energy density as a balance of quantum oscillations and the system's effective resistance, linking classical and quantum descriptions of energy transfer.

12.1 Vacuum Energy Density as the Reactive Current

The expression $\rho_{\text{vac}} = \frac{\Phi \cdot \omega}{R} = \frac{\frac{1}{2}\hbar c}{\sqrt{\frac{3}{5}4\pi}}$, derived for vacuum energy density, aligns with the generalized form of Ohm's Law in electromagnetic systems:

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

This consistency of $\rho_{\text{vac}} = \frac{\Phi \cdot \omega}{R}$ with Ohm's Law has profound implications:

- **Quantum Oscillations:** The vacuum energy density originates from discrete oscillatory quanta ($\Phi \cdot \omega$), consistent with zero-point energy in quantum mechanics.
- **Energy Regulation:** The resistance R represents the vacuum's ability to stabilize these oscillations, preventing runaway energy accumulation.
- **Observable Effects:** The derived ρ_{vac} connects the vacuum's energy density to measurable phenomena, such as electromagnetic interactions or spacetime curvature via gravitational flux.

The expression $\rho_{\text{vac}} = \frac{\Phi \cdot \omega}{R}$ links vacuum energy density to the electromotive force (EMF) in oscillatory systems, drawing an analogy to a reactive current in a resistive circuit. Here, $\Phi \cdot \omega$ represents the quantum of oscillatory energy transfer in the vacuum, akin to the induced EMF driving a current in classical electromagnetic systems. The effective resistance R of the vacuum stabilizes these oscillations, modulating the energy density and preventing runaway fluctuations. This working mechanism arises naturally from the vacuum's oscillatory nature, with energy density acting as a reactive current that oscillates between potential and kinetic states, regulated by R to maintain equilibrium. This process encapsulates the vacuum's role in driving energy exchanges that manifest as observable phenomena like electromagnetic interactions or spacetime curvature.

By interpreting vacuum energy density as a reactive current regulated by an effective resistance, this analogy provides a unified perspective linking classical electromagnetic systems to quantum vacuum fluctuations. This formalization reinforces the dynamic, oscillatory nature of the vacuum and its role in energy transfer across scales.

12.2 Deriving more expressions of vacuum's energy density

Using the standard values of the constants involved, the postulated equation 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 [40], which yielded a value of $5.96 \times 10^{-27} kg/m^3$ for the vacuum energy density.

Note that, from the previous 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

$$8G = \frac{1}{2\pi \cdot c} = \rho_{vac} \tag{21}$$

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.

12.3 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 [40].

The proposed method, along with the inner consistency with other results obtained throughout this Paper, provides a solution to the long-standing "vacuum catastrophe" [41] 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, showing the unification of gravitational and electromagnetic forces under a shared quantum mechanical foundation, and 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.

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

13.1 The Equipartition Theorem and its Applicability

The equipartition theorem [42] [43] is a foundational result in statistical mechanics, describing how energy is distributed among the degrees of freedom of a system in thermal equilibrium. The original idea of equipartition was that, in thermal equilibrium, energy is shared equally among all of its various forms; for example, the average kinetic energy per degree of freedom in translational motion of a molecule should equal that in rotational motion.

The equipartition theorem makes quantitative predictions. Like the virial theorem, it gives the total average kinetic and potential energies for a system at a given temperature, from which the system's heat capacity can be computed. However, equipartition also gives the average values of individual components of the energy, such as the kinetic energy of a particular particle or the potential energy of a single spring.

For a classical system with f quadratic degrees of freedom, such as translational, rotational, or vibrational modes, the total internal energy U is given by:

$$U = \frac{f}{2} k_B T.$$

Applicability of the Equipartition Theorem

The equipartition theorem applies to systems where the energy can be expressed as a sum of quadratic terms in the generalized coordinates and momenta. These systems include, but are not limited to:

- Ideal gases, where the kinetic energy of particles is quadratic in their velocities.
- Harmonic oscillators, where the potential energy and kinetic energy terms are quadratic in displacement and momentum, respectively.
- Rotational systems, where the rotational kinetic energy depends quadratically on angular velocities.

13.2 Boltzmann constant as a direct function of zero-point energy

Based on the equipartition theorem, in the context of our proposed framework where the vacuum is modeled as a dynamic system of harmonic oscillators expanding at relativistic velocities, it makes sense both theoretically and empirically to postulate that the Boltzmann constant k_B is given by:

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

This postulate can be derived as follows. For each oscillator, the average energy is:

$$\langle E \rangle = \frac{\hbar\omega}{2}$$

that is, the zero-point energy. When incorporating relativistic corrections, such as the Lorentz factor γ, the equipartition theorem states that the temperature T in a relativistic system relates on average to the kinetic energy of oscillators as:

$$k_B T = \gamma m c^2,$$

Substituting by $\gamma = \frac{1}{\alpha}$ and $mc^2 = 2\pi E_0$, we get that

$$K_B T = \frac{2\pi E_0}{\alpha}$$

If we set $T = 1$ to set k_B as the quantum of thermodynamic scaling from energy to temperature, we get that

$$k_B = \frac{2\pi E_0}{\alpha}$$

Therefore, by using the equipartition theorem, the thermodynamic properties of the vacuum, such as internal energy, entropy, and specific heat, can be systematically derived. This approach reinforces the postulate that the Boltzmann constant k_B acts as a universal scaling factor that links quantum and thermodynamic phenomena, further justifying its expression in terms of fundamental constants.

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.

13.3 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 the oscillatory behavior of the vacuum to its thermodynamic behavior.

This dimensionality aligns with the equivalent 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.

13.4 Interpreting k_B in Terms of relativistic Effects and de-angularized zero-point energy

The factor 2π in the expression $k_B = \gamma \cdot 2\pi E_0$ plays a pivotal role in bridging angular and linear representations of physical quantities within the proposed framework. This factor arises naturally from the relationship between the reduced Planck constant $\hbar$ and the Planck constant h, where $h = 2\pi\hbar$. In the context of harmonic oscillators, the zero-point energy $E_0 = \frac{\hbar\omega}{2}$ is derived using angular frequency ω. The inclusion of 2π transforms angular frequency-based quantities into their linear frequency counterparts, aligning the quantum oscillatory properties of the vacuum with macroscopic thermodynamic quantities. Thus, 2π serves as a conversion factor that ensures the Boltzmann constant k_B accurately reflects the relationship between temperature and energy density in systems where both quantum and relativistic effects are significant. This factor emphasizes the transition from microscopic (quantum oscillators) to macroscopic (thermodynamic) interpretations, reinforcing the dimensional consistency of k_B in the proposed model.

Another 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 de-angularized zero-point energy of the quantum harmonic oscillators, adjusted adequately with the Lorentz factor in the context of vacuum expanding at relativistic velocities.

13.5 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.

13.6 Reinterpreting Entropy in Light of the Boltzmann Constant

In traditional thermodynamics, entropy [44] 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.

For a classical system with f quadratic degrees of freedom, such as translational, rotational, or vibrational modes, the total internal energy U is given by:

$$U = \frac{f}{2} k_B T.$$

Substituting $U = \frac{2\pi E_0}{\alpha}$ and $T = 1$, we have that

$$\frac{2\pi E_0}{\alpha} = \frac{f}{2} k_B.$$

Which yields the important result

$$f = 2$$

Based on the above, 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 (quadratic degrees of freedom) 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 some plausible interpretations for the nature of these states. Among these possible interpretations, the interpretation of 2 representing distinct quantum polarization states provides the 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 the quantum 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.

14 Derivation of the Casimir Constant C_c

14.1 The Casimir Effect and the Casimir Constant

The Casimir effect [45] 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 $\frac{\pi^2 \hbar c}{240}$, 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.

14.2 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 (in this specific case) the total Casimir force as:

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

14.3 The Casimir Constant C_c in Our Model and Its Implications

Using our model, we can directly relate the Casimir constant to the zero-point energy and the quantized structure of spacetime. Specifically, we postulate that the minimal Casimir force per unit area is given by the zero-point energy multiplied by the fundamental quantum of spacetime, $\frac{1}{16\pi}$ (21.2), and divided by a quantized differential area $A = d^2 = \frac{1}{4}$. 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:

$$\frac{F_{C_{min}}}{A} = \frac{\frac{\hbar c}{2}}{16\pi \frac{1}{4}} = \frac{\frac{\hbar c}{2}}{4\pi}.$$

Thus, in our formulation, the Casimir constant is directly derived from this expression, grounding it in the intrinsic energy of the vacuum:

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

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

As we have already seen with the gravitational constant G and we will see with Coulomb's constant k_e, the Casimir constant C_c has dimensions of force.

Justification Based on Zero-Point Energy and Electromotive Force (EMF)

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 [46] [47] 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.

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

15.1 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 [48]. 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 [49]. 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 [50] [51], 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.

15.2 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:

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

Where we recall that we have $[G] = [\mu_0] = [\frac{h \cdot c}{2}] = [V]$, using the relationship $h \cdot c = \mu_0 \cdot ec$ and $I_{\text{eff}} = \frac{e \cdot c}{2}$ as the current, and establishing that

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

Where $L = \mu_0$ is the inductance, and $dt = dc$.

Additionally, we interpreted previously:

- $\frac{h}{2}$ as the quantum of magnetic flux Φ within a coil.
- e as the elementary charge.

Using again $I_{eff} = \frac{e \cdot c}{2}$, 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 $[4] = [T^{-2}] = [L^{-2}]$ as the reciprocal of a differential of area.

15.3 Interpretation of the Cosmological Constant Λ as power Intensity

Taking into account the insights of previous subsection, in the framework of this paper, we propose interpreting the cosmological constant Λ as a form of *power intensity*, defined as the power per unit area $\Lambda = \frac{P}{A}$ where A represents a quantized 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 $\Lambda = \frac{P}{A}$ as power intensity 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.

15.4 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:

$$\rho_{\text{vac}} = \frac{1}{2\pi c^3} \tag{22}$$

where c is the speed of light.

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

$$\Lambda \cdot c^2 = 8\pi G \rho_{\text{vac}} \tag{23}$$

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

$$\Lambda = 8\pi \cdot \frac{1}{16\pi c} \cdot \frac{1}{2\pi c^3} \cdot \frac{1}{c^2} = \frac{1}{4\pi c^6} \tag{24}$$

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

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.

15.5 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 described by 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 $\frac{e \cdot c}{2} \cdot \frac{h \cdot c}{2}$. Dimensionally, this product is equivalent to $I_{eff} \cdot V_{min}$, representing some minimum real power of the system.

Thus, the gravitational flux $4\pi G\rho_{vac}$ can be interpreted as the 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 (6).

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 ρ_{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:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{25}$$

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:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = 0 \tag{26}$$

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:

$$T^{\text{vac}}_{\mu\nu} = -\frac{\Lambda c^4}{8\pi G} g_{\mu\nu} \tag{27}$$

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:

$$\rho_{\text{vac}} c^2 = \frac{\Lambda c^4}{8\pi G} \tag{28}$$

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

$$\rho_{\text{vac}} = \frac{\Lambda c^2}{8\pi G} \tag{29}$$

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

$$4\pi G \rho_{\text{vac}} = \frac{\Lambda c^2}{2} = \Lambda \int c \; dc \tag{30}$$

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.

16 Derivation of Hubble's Parameter H_0

16.1 Introduction to the Friedmann Equations

The Friedmann equations [52] [53] [54] 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:

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

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.

16.2 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 in certain contexts (4). 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

$$H^2 = 4\pi G\rho_{\text{vac}} \tag{31}$$

where ρ_{vac} is the vacuum energy density measured in kg/m^3. It can be checked that the equality is numerically consistent with the most recent measurements [55] [56] [57] [58].

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.

16.3 Hubble Parameter and Its Analogy to RLC Circuits and Self-Resonant Dynamics

The modified Friedmann equation $H^2 = 4\pi G\rho_{\text{vac}}$ can be analyzed through the lens of an RLC circuit. In this analogy, the vacuum gravitational flux ($4\pi G\rho_{\text{vac}}$) corresponds to the real power source driving the circuit, while the Hubble parameter H represents the resulting oscillatory flow of energy, akin to the current. The curvature of spacetime acts as an inductive component, storing the momentum of expansion, while the volumetric scaling of spacetime resembles the capacitive effect, which accumulates energy as the universe expands. This perspective highlights how the interplay between vacuum energy and spacetime curvature governs the dynamics of expansion.

The self-resonant universe framework complements this analogy by interpreting H^2 as the energy density associated with spacetime oscillations, driven by vacuum energy fluctuations. These oscillations sustain the resonance of spacetime, ensuring that expansion is dynamically maintained rather than merely inertial. The dimensional equivalence $[L] = [T]$ suggests that these oscillatory dynamics are uniform across all four dimensions, connecting local quantum fluctuations to the global curvature and expansion of the universe.

Reinterpreting $H^2 = 4\pi G\rho_{\text{vac}}$ as a form of gravitational flux density further ties the Hubble parameter to the notion of energy transfer in spacetime. In the RLC analogy, this flux represents the "current" of energy flow modulated by the vacuum energy source. The integral operator $\int c\,dc$, introduced earlier, serves as an analogue to the cumulative effect of current in the circuit, describing the steady transformation of vacuum potential energy into dynamic gravitational flux. This interpretation positions the Hubble parameter as a fundamental measure of how vacuum energy and spacetime curvature orchestrate the expansion of the universe.

17 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.

17.1 Derivation of the Einstein-Hilbert Action with fundamental constants

The Einstein-Hilbert action [59] [60] [61] in General Relativity with a cosmological constant is typically expressed as:

$$S_{EH} = \frac{c^4}{16\pi G} \int (R - 2\Lambda)\sqrt{-g}\, d^4x \tag{32}$$

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.

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

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

$$\rho_{\text{vac}} = \frac{1}{2\pi c^3} \tag{33}$$

where c is the speed of light.

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

$$\Lambda \cdot c^2 = 8\pi G \rho_{\text{vac}} \tag{34}$$

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

$$\Lambda = 8\pi \cdot \frac{1}{16\pi c} \cdot \frac{1}{2\pi c^3} \cdot \frac{1}{c^2} = \frac{1}{4\pi c^6} \tag{35}$$

Substituting the Ricci Scalar with 4Λ, consistent with a De Sitter universe

Our framework naturally aligns with the properties of a De Sitter universe, which is characterized by positive vacuum energy ($\Lambda > 0$) and constant positive curvature [62] [63]. The exponential expansion of a De Sitter universe is driven by the dominance of vacuum energy, and this is consistent with the modified Friedmann equation derived in our framework, $H^2 = 4\pi G \rho_{vac}$. Here, the vacuum energy density directly determines the Hubble parameter, ensuring a steady rate of expansion in the absence of significant matter or radiation contributions. The substitution $\Lambda = \frac{1}{4\pi c^6}$ integrates this relationship into the gravitational action, linking the geometric properties of spacetime with the energy density driving its dynamics.

Moreover, the equivalence $[L] = [T]$ assumed in our framework reinforces the self-consistency of a De Sitter model by treating spatial and temporal dimensions symmetrically. This dimensional symmetry naturally supports the interpretation of De Sitter space as a maximally symmetric solution of Einstein's equations, where the curvature and expansion are uniform across spacetime. The resulting symmetry ensures that vacuum energy fluctuations propagate consistently, sustaining the observed large-scale homogeneity of the universe.

In conclusion, the dominance of vacuum energy (ρ_{vac}) as the source of expansion, and the symmetric treatment of spacetime dimensions all align with the key features of a De Sitter cosmology. This consistency provides a robust foundation for interpreting the observed accelerated expansion of the universe within this framework.

In a De Sitter universe, where the cosmological constant Λ dominates and the vacuum energy drives the dynamics of spacetime, the Ricci scalar R is directly proportional to Λ. Specifically, the curvature of de Sitter spacetime is constant and positive, and it can be shown that $R = 4\Lambda$. This relationship arises from the Einstein field equations in the absence of matter and radiation, where the energy-momentum tensor vanishes ($T_{\mu\nu} = 0$), leaving the curvature entirely determined by Λ. This proportionality reflects the fact that the De Sitter universe is a maximally symmetric solution to Einstein's equations, with constant curvature across spacetime.

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

$$S_{EH} = \frac{c^4}{16\pi G} \cdot 2\Lambda \int \sqrt{-g}\, d^4x \tag{36}$$

Substituting $\Lambda = \frac{1}{4\pi c^6}$, multiplying by the prefactor $\frac{c^4}{16\pi G}$ and substituting $\frac{1}{16\pi G} = c$ from our previous derivations 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. Having this expression into the action demonstrates that the gravitational dynamics are fundamentally tied to the vacuum energy density, consistent with the interpretation of ρ_{vac} as the source of expansion in a De Sitter universe.

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:

$$V = \int \sqrt{-g}\, d^4x \tag{37}$$

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. 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:

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

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

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

$$S_{EH} = 8G \cdot \frac{c}{16} = \frac{G \cdot c}{2} \tag{38}$$

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

17.2 Implications and Consistency within the previous Framework

The result $S_{EH} = \frac{G \cdot c}{2}$ is consistent with our previous derivations and dimensional analysis. 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 G has the dimensions of force, as we have previously established (8.2).

Our derivation of the Einstein-Hilbert action demonstrates the potential of our vacuum-centric model to unify gravity, general relativity, and quantum mechanics. Traditionally a measure of spacetime curvature, the Einstein-Hilbert action in this framework becomes a direct expression of the vacuum's inductive and oscillatory properties. Evaluated over a nearly flat, vacuum-dominated universe with discrete quantized spacetime arising from Heisenberg's uncertainty principle, the action naturally approaches $\frac{G \cdot c}{2}$. This result suggests that the gravitational constant emerges intrinsically from the fundamental properties of the vacuum, highlighting a deep interconnection between gravity and quantum mechanics.

By incorporating the smallest quantum unit of spacetime—defined by the elementary differential $dx = \frac{1}{2}$, reflecting the limits of Heisenberg's uncertainty principle—the Einstein-Hilbert action inherently unifies space and time dimensions at relativistic scales while embedding quantum discreteness within the fabric of spacetime. The volume integral $\int \sqrt{-g}\, d^4x$ thus links the curvature of spacetime to the probabilistic, oscillatory structure of the vacuum. This cohesive framework unites general relativity's geometric description of gravity with the probabilistic nature of quantum mechanics, suggesting that gravitational effects, vacuum fluctuations, and the expansion of the universe are fundamentally interconnected through a quantum-geometric foundation. Such a perspective offers profound insights into the nature of spacetime and its governing forces.

The quantum-geometrical interpretation of Einstein-Hilbert action

From the established relationship $G \cdot c = \frac{1}{16\pi}$, we have that

$$S_{EH} = \frac{1}{32\pi} \tag{39}$$

This result reveals a profound connection between the Einstein-Hilbert action and the quantum-geometrical structure of spacetime 21.2. The factor $\frac{1}{32\pi}$ can be interpreted as arising from the vacuum's discrete quantization, where $\frac{1}{32\pi}$ represents the fundamental quantum-probabilistic, four-dimensional spacetime. In this framework, $\frac{1}{32\pi}$ encapsulates the geometric coupling of gravitational and quantum effects, linking the curvature of spacetime to the quantum oscillatory behavior of the vacuum.

This interpretation aligns with the broader quantum-geometric framework, suggesting that the Einstein-Hilbert action is not merely a classical measure of curvature but a bridge between the discrete nature of quantum mechanics and the continuous geometry of general relativity. By linking S_{EH} to $\frac{1}{32\pi}$, the vacuum emerges as the fundamental medium that integrates gravitational curvature, quantum oscillations, and spacetime dynamics into a unified description of the universe.

18 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.

18.1 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 [14]. 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 (3.4 and standard formulas for RLC circuit parameters [20] [14], 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:

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

18.2 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.

18.3 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

$$\rho = \frac{e \cdot \alpha \cdot Z_0}{4\pi G}.$$

And, re-expressing it more conveniently, we finally have that

$$4\pi G\rho = e \cdot \alpha \cdot Z_0 = e \cdot \sqrt{\frac{3}{5} 4\pi} \tag{40}$$

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.

18.4 A Further Link Between Quantum oscillations, electromagnetic properties and gravitational flux

Additionally, recall the foundational equation $h = \frac{e \cdot \mu_0}{c}$. Multiplying both sides by c^2 yields

$$h \cdot c^2 = e \cdot c \cdot \mu_0 = e \cdot Z_0 = \frac{4\pi G\rho}{\alpha}$$

The relationship $h \cdot c^2 = e \cdot c \cdot \mu_0 = e \cdot Z_0 = \frac{4\pi G\rho}{\alpha}$ provides a good "display button" of the profound link between quantum oscillations, electromagnetic properties, and gravitational flux. On the left-hand side, Planck's constant h, scaled by c^2, encapsulates the fundamental quantum unit of action and its relativistic extension, while the product $e \cdot Z_0$ ties the elementary charge e to the electromagnetic impedance of free space Z_0. This highlights the deep interdependence of quantum and electromagnetic phenomena. On the right-hand side, the term $\frac{4\pi G\rho}{\alpha}$ represents gravitational flux density scaled by the fine structure constant α, linking gravity to the quantum and electromagnetic realms through the vacuum's energy density ρ. This unified expression shows how quantum oscillations, electromagnetic properties, and gravitational effects are not isolated phenomena but are intricately connected through the fundamental constants of nature. Such a relationship provides further evidence of the vacuum's role as a dynamic medium where these interactions converge.

19 Derivation of the electro-gravitational model from the obtained relationships

In this section, we explore the derivation of an electro-gravitational model that links fundamental electromagnetic and gravitational constants to the vacuum's intrinsic properties. By examining the energy stored in capacitors and inductors as analogues for vacuum energy storage, we establish a unified framework that connects the gravitational constant G and Coulomb's constant K to the vacuum's capacitive and inductive behaviors, respectively. These relationships demonstrate how the vacuum's electromagnetic and geometric properties mediate interactions, providing a deeper understanding of the connection between electromagnetism and gravity.

19.1 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 and exhibiting oscillatory behavior. 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 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 from the previously established equivalences

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

and

$$\mu_0 \cdot \alpha = \frac{G}{\alpha}$$

Substituting, we have that

$$\mu_0 \cdot \alpha = \frac{\left(\frac{1}{Z_0}\right)^3}{2}$$

Recalling that we have established μ_0 as having dimensions of voltage, and as α is dimensionless, we have that the right hand side of the equality has dimensions of voltage too.

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 mass (and subsequently, 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 degrees of freedom $[2] = [L] = [T]$ that we have previously linked to polarization states. This is consistent with G having dimensions of force, as we have derived in the previous sections for gravity.

19.2 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:

$$U_L = \frac{1}{2}LI^2,$$

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

$$K = 2 \cdot U_L = \frac{\mu_0 \cdot c^2}{4\pi}.$$

Or, equivalently,

$$K = \frac{\mu_0}{2\pi} \int c \, dc$$

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 as 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.

Part III: Emergence of Fundamental Properties from Vacuum Structure and Dynamics

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

20.1 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 $h = \frac{e \cdot \mu_0}{c}$ 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 to deform:** 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, 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's 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.

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

From the previous postulate $h = \epsilon_0^3$, and the established equivalence $\Lambda = h \cdot e = \frac{1}{4\pi c^6}$, we have that

$$\epsilon_0^3 \cdot e = \frac{\epsilon_0^3 \cdot \mu_0^3}{4\pi}$$

$$e = \frac{\mu_0^3}{4\pi} \tag{41}$$

where e represents a quantum of induced charge. 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 $\int c\ dc$.

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 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.

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

Based on the above and some of the previous derived expressions, 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

$$\alpha = \frac{1}{2}\frac{\epsilon_0^2}{\mu_0^2} \cdot c = \frac{1}{2} \cdot c \left(\frac{1}{Z_0}\right)^4 \tag{42}$$

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

$$\zeta = c \int Y_0^3 \; dY_0 \tag{43}$$

Where ζ is the damping coefficient and $Y_0 = Z_0^{-1}$ 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. This equation aligns with the self-resonant universe framework, where the vacuum's harmonic behavior drives the interactions that underpin fundamental forces.

It is interesting to equate the obtained relationship with the one that we have derived previously, $\alpha = e \int c \; dc$ (14). Equating, operating, and solving for $e \cdot c$, which is equal to I_{min}, we get that

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

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

$$I_{min} = e \cdot c = Y_0^4 \tag{44}$$

This result aligns with our vacuum harmonic oscillator model, where the vacuum's admittance (Y_0) dictates the oscillatory amplitude I_{min}. Specifically, Y_0^4 represents the minimal current sustained by vacuum oscillations across four spatial dimensions, reflecting the vacuum's intrinsic electromagnetic properties.

From the above, the relationship $I_{min} \cdot Z_0 = Y_0^3$ emerges as the fundamental quantum of electric flux within this framework . This interpretation aligns with the role of vacuum admittance Y_0, which governs the ease with which the vacuum propagates electromagnetic oscillations. This flux quantization reveals how the vacuum's geometric and electromagnetic properties are intrinsically linked, reflecting its role as a dynamic medium that mediates electromagnetic interactions. In this sense, Y_0^3 is not merely a numerical result but a profound indicator of the vacuum's oscillatory behavior and its capacity to generate localized energy flows that sustain electromagnetic fields.

Similarly, we can note how the relationship $I_{eff} \cdot Z_0 = \frac{Y_0^3}{2}$ defines the fundamental quantum of voltage in this model. Here, $I_{eff} = \frac{I_{min}}{2} = \frac{e \cdot c}{2}$ represents the effective current associated with these oscillations. The half-factor arises naturally from the harmonic nature of vacuum oscillations, where the effective amplitude reflects the averaged behavior over a complete cycle. The corresponding quantum of voltage, $\frac{Y_0^3}{2}$, encapsulates the energy transfer mediated by the vacuum impedance during these oscillations, linking the vacuum's resonant properties to observable electromagnetic phenomena, and it is dimensionally consistent with Ohm's Law, where $V = I \cdot R$.

Together, these quantized relationships for electric flux and voltage reinforce the self-resonant interpretation of the vacuum, where electromagnetic phenomena emerge from the dynamic interplay between admittance (Y_0) and impedance (Z_0) across oscillatory modes. This quantization bridges the microscopic quantum dynamics of the vacuum with macroscopic electromagnetic fields. It underscores that the vacuum's geometric and oscillatory structure dictates both the flow and potential of electromagnetic energy, unifying these quantities within the quantum-geometric framework. The interpretation of Y_0^3 as the fundamental quantum of electric flux ties directly to the vacuum's oscillatory modes, embedding the dynamics of light propagation and charge interactions into the very structure of spacetime itself.

21 Universal Constants as Probabilistic 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 probabilistic 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-probabilistic constructs.

21.1 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 and probabilistic factors that we have derived previously (8.3) 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 and probabilistic 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 significance.

21.2 On the Quantum-Probabilistic Nature of Spacetime and the Inductive Reactance $\frac{1}{16\pi}$

In the framework of this paper, 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. This factor also serves as an expression of inductive reactance, representing the vacuum's resistance to changes in energy fluctuations, derived from the principles of quantum mechanics, especially Heisenberg's uncertainty principle.

The factor $\frac{1}{16\pi}$ can be interpreted as a fundamental spacetime differential that reflects the probabilistic quantization of spacetime in a four-dimensional framework. Concretely, this factor can be re-expressed as:

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

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

The term $\left(\frac{1}{2}\right)^3$ highlights the discrete nature of the three spatial dimensions, where $\frac{1}{2}$ is 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. This quantization indicates that spacetime may exist as a probabilistic superposition of states rather than a continuous fabric, aligning with Heisenberg's principle by imposing fundamental limits on simultaneous position and momentum measurements.

The additional factor $\frac{1}{2\pi}$ arises from the oscillatory nature of the vacuum. The circular symmetry inherent to 2π is found in closed-loop systems within spacetime's topological features, contributing periodicity that reflects the oscillatory nature of the vacuum and -more speculatively- interactions between matter and antimatter fluctuations. Thus, $\frac{1}{16\pi}$ represents a fundamental differential element of spacetime, expressing its quantized, probabilistic structure within our dimensional framework.

Geometric Scaling, Vacuum Reactance, and Inductive Interpretation of $\frac{1}{16\pi}$

In addition to its geometric-probabilistic interpretation, $\frac{1}{16\pi}$ can be seen as an expression of inductive reactance, a property emerging from the interaction between vacuum parameters and quantum fluctuations. In a three-dimensional vacuum, this reactance characterizes the vacuum's resistance to changes in quantum fluctuation rates, derived from the uncertainty principle's constraints on energy and time. This resistance functions similarly to how a coil resists changes in current in a classical circuit, acting as a "geometric resistance" to fluctuations within the vacuum.

The factor $\frac{1}{16\pi}$, embedded in physical constants, serves as a universal "geometric scaling" arising from both the discrete nature of spatial dimensions and the cyclic symmetry of the oscillatory mechanics within the vacuum. This factor appears in many gravitational and electromagnetic equations, suggesting that $\frac{1}{16\pi}$ mediates interactions between spatial dimensions and the oscillatory behavior of the vacuum. Since this factor modulates constants and field interactions, it underscores the framework's premise that vacuum structure and geometry inherently influence fundamental forces. This scaling bridges large-scale curvature effects of spacetime with underlying quantum properties, aligning with the concept of a dynamic vacuum where energy density and dimensional structure together influence cosmic expansion and curvature phenomena.

In conclusion, the factor $\frac{1}{16\pi}$ encapsulates spacetime's quantized, probabilistic structure as an ensemble of discrete states rather than a static continuum. This interpretation reinforces the vacuum as a dynamic, oscillatory field with properties arising from the quantum and geometric interplay between dimensions. It simplifies the model by providing a self-sufficient four-dimensional framework that harmonizes cosmic and quantum scales, suggesting that fundamental properties directly emerge from the universe's inherent topology and dimensional symmetries.

21.3 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 can be 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, it can be checked -we will not do it now for the shake of briefness- that these constants can in turn be expressed as purely geometric factors. This implies, for instance, 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-probabilistic 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-probabilistic 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.

Part IV: Electromagnetic Properties and mass as Emergent Features of the Quantum Vacuum

Introduction and Motivation

In this part, we will explore the nature of fundamental electromagnetic and particle properties —including the fine-structure constant α, the behavior of electromagnetic waves, and the fundamental particles mass— as emergent features arising from the quantum vacuum structure and dynamics. While the framework is innovative and explores new ground, it builds upon established principles and relationships derived throughout this paper, and offers robust theoretical foundations. We detail a brief summary of the content of the next sections.

Firstly, the fine-structure constant α plays a central role in quantifying the strength of electromagnetic interactions and has often been seen as an inherent, dimensionless constant. In this framework, however, we interpret α as the reciprocal of a Lorentz factor, linking it to relativistic effects within the vacuum. This reinterpretation of α offers novel insights into electric flux and the nature of elementary charge, postulating that these properties could emerge from the vacuum's expansion at velocity c.

Secondly, the nature of electromagnetic waves is re-examined here. We propose that photons represent quantized oscillatory states of an expanding vacuum. This theoretical model explains the particle-based interpretation of light, treating the photon as a quantized energy packet that captures the vacuum's oscillatory and propagative properties. Electromagnetic waves become an expression of the vacuum's intrinsic oscillations rather than a stream of particles, providing a unified perspective that bridges quantum and relativistic descriptions of light.

Finally, we investigate the origin of the fundamental particles mass as an emergent property derived from vacuum interactions and geometry. Building on previously developed expressions, we examine how the fundamental particles mass are equivalent to confined energy quantum volumes in the vacuum, influenced by α and other geometric spacetime factors. This framework points towards a redefinition of mass as a field-based property that emerges from the vacuum's fundamental characteristics.

Collectively, these topics postulate that electromagnetic properties —traditionally viewed as intrinsic to particles— actually result from complex interactions within the quantum vacuum that expands at velocity c. This view reshapes our understanding of particle properties as emergent features of the vacuum's structure and relativistic dynamics, with far-reaching implications for both quantum field theory and cosmology. This part is therefore dedicated to analyzing the electromagnetic model within the proposed framework, drawing connections between vacuum structure, particle interactions, and the fundamental nature of electromagnetic phenomena.

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 between light and matter. We postulate that α reflects the dynamic interaction in which potential energy embedded in electromagnetic waves at the speed of light c, converts to non-relativistic energy when interacting with matter. During this transition, the non-relativistic energy undergoes a de-contraction effect as it decelerates to the non-relativistic (or classical) speeds typical of particles with mass.

Rationale from Light-Matter Energy Interactions

In the vacuum-RLC circuit model, α represents the ratio of energy dissipated to energy stored within the vacuum, often linked to the conservation efficiency of energy in the oscillatory dynamics of the vacuum field. Here, however, we reinterpret this as the scaling that naturally occurs when electromagnetic waves deliver energy to matter. Upon interaction, this energy translates into non-relativistic energy, but due to the relativistic-to-non-relativistic shift, a contraction-to-de-contraction effect arises. This effect is quantified by the fine-structure constant α, marking the change from the wave's relativistic frame to the non-relativistic energy distribution within matter.

The Lorentz factor γ, given by:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}},$$

describes how relativistic effects scale time, space, and energy at high velocities. In this context, we propose that:

$$\alpha = \frac{1}{\gamma} = \sqrt{1 - \frac{v^2}{c^2}},$$

postulating that α serves as the reciprocal of the Lorentz factor when electromagnetic waves transfer energy to slower, massive particles. As $v \to c$, $\alpha \to 0$, implying that the energy scaling is maximized as particles approach light speed, while at lower, non-relativistic velocities, α becomes finite, indicating a transition to classical energy distributions.

Justification Based on Energy Scaling in Light-Matter Interactions

For electromagnetic interactions, the fine-structure constant α is defined by:

$$\alpha = \frac{e^2}{4\pi\epsilon_0 \hbar c}.$$

This expression characterizes the interaction strength of electromagnetic forces and acts as a ratio between the potential and kinetic energy states in light-matter interactions.

Interpreting Potential and Kinetic Energy in the Vacuum Framework

Traditionally, the energy between two charges separated by a distance r is considered potential energy:

$$U_{\text{potential}} = \frac{e^2}{4\pi\epsilon_0 r}.$$

This potential energy arises from the separation of charges and is stored in the electromagnetic field. Meanwhile, the energy associated with particle motion or field fluctuations represents kinetic energy, expressible in the quantum vacuum as:

$$U_{\text{kinetic}} = \frac{2\pi\hbar c}{r}.$$

However, we can reinterpret these terms by noting that electromagnetic waves embody the vacuum's potential energy, while interactions with charges (or configurations within the field) represent kinetic energy, as they involve energy transfer within a field actively engaged with matter. Consequently, when charges interact and cause electromagnetic exchanges, they do so through this kinetic, active energy.

In an oscillatory framework, the system's energy oscillates between potential and kinetic forms while remaining conserved. Equilibrium is achieved when the electromagnetic waves' potential energy,

$$U_{\text{potential}} = \frac{2\pi\hbar c}{r},$$

balances with the kinetic energy from charge interactions, given by:

$$U_{\text{kinetic}} = \frac{e^2}{4\pi\epsilon_0 r}.$$

Assuming conservation of energy and oscillatory behavior, equilibrium implies:

$$\frac{e^2}{4\pi\epsilon_0 r} = \frac{2\pi\hbar c}{r}.$$

In practice, however, this equality is modified by a scaling factor, leading to:

$$\frac{e^2}{4\pi\epsilon_0 r} = \alpha \cdot \frac{2\pi\hbar c}{r},$$

where α naturally emerges as:

$$\alpha = \frac{e^2}{4\pi\epsilon_0 \hbar c}.$$

Interpreting α as the Reciprocal of the Lorentz Factor

The interpretation of α in terms of a Lorentz factor bridges the high-speed characteristics of electromagnetic waves with the slower, non-relativistic dynamics of matter. In this model, α modulates the interaction strength between these differing scales, balancing energy transfer across relativistic (electromagnetic waves) and non-relativistic (matter) domains. Thus, the fine-structure constant acts as a scaling factor, ensuring energy conservation and harmony between the components of light-matter interactions, allowing energy to decelerate and distribute as non-relativistic energy within the matter.

As a result, α is in reality a Lorentz factor reciprocal, scaling the energy transition from the high-speed regime of electromagnetic waves to the relatively static realm of material interactions.

In summary, we view α as a dimensionless constant that quantifies the effective interaction strength between electromagnetic waves and matter, encapsulating the effect of relativistic scaling. This approach frames α as a natural bridge between electromagnetic waves, with their inherent speed c, and the kinetic characteristics of matter at classical speeds. Thus, α functions as a Lorentz factor-like modulator, facilitating coherent energy exchange and ensuring equilibrium within relativistic and classical interaction regimes.

22.2 Electric Flux of the Elementary Charge as Total Relativistic 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

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = \mu_0 \cdot 2\alpha \tag{45}$$

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.

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:

$$\Phi_E = \mu_0 \cdot 2\alpha$$

Given that μ_0 represents a voltage, that the factor 2 has dimension $[L] = [T]$, and that α is dimensionless, we have a dimensional consistency between the expression 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.

Gravitational force as an electromotive force $\mathcal{E}$ arising from vacuum's relativistic energy

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

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{A} = 2 \cdot \frac{G}{\alpha} = \frac{G}{\zeta} \tag{46}$$

The above aligns with our previous postulate of gravitational force as an electromotive force $\mathcal{E}$ (8.2). The definition of electromotive force (EMF) in electromagnetism is given by the line integral of the electric field over a closed path C:

$$\mathcal{E} = \oint_C \vec{E} \cdot d\vec{l}.$$

This equation represents the total "voltage" or potential difference induced along a closed loop, driven by the electric field. Now, recall that we defined α as:

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

Rewriting G in terms of α and μ_0:

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

Returning to the EMF definition:

$$\mathcal{E} = \oint_C \vec{E} \cdot d\vec{l}.$$

From the above, we have that

$$\mathcal{E} = \oint_C \vec{E} \cdot d\vec{l} = \mu_0 \cdot \alpha = \frac{G}{\alpha} = \frac{h \cdot c}{2} \cdot c^2$$

This expression connects the electric field's line integral (EMF) to the vacuum's properties and relativistic effects via α. It shows that the energy-driving role of G naturally extends to its interpretation as an electromotive force. The physical implications of this equivalence are profound, showing that G emerges from the interplay between vacuum geometry, relativistic effects, and electromagnetic interactions.

Therefore, it arises again that G governs the relativistic potential driving interactions across a closed path. This interpretation reinforces the idea that G acts as an EMF, particularly within a theoretical structure where vacuum dynamics drive the interaction between electric flux, relativistic energy, and spacetime geometry. Within this framework, oscillatory behaviors of the vacuum, treated as a system of harmonic oscillators, inherently generate field variations. These variations produce an effective EMF, which manifests as the gravitational interaction.

Therefore, and as we have already stated in previous sections, we postulate that vacuum oscillations, driven by quantum fluctuations and relativistic interactions, induce coherent resonances that give rise to gravitational phenomena. These oscillations generate flux variations analogous to those in Faraday's law. Consequently, gravitational force emerges as an induced EMF through the vacuum's oscillatory dynamics, regulated by the same laws that govern electromagnetic flux.

The above aligns with the self-consistent RLC-like model described throughout this work, reinforcing the centrality of vacuum fluctuations and their field-like interactions as the mechanism behind not only gravitational phenomena but also their deeper unification with electromagnetic forces. The emergence of G as an EMF reflects the fundamental connection between magnetic flux variations within the vacuum and spacetime deformation.

Electric Flux as the total relativistic energy of the vacuum

The above can be seen even more clearly. The relativistic total energy of the vacuum can be 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. 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

$$\Phi_E = E_{\text{Total}} \tag{47}$$

This establishes a direct equivalence between the electric flux and the relativistic total energy of the vacuum, showing that what we observe as electromagnetic flux is the manifestation of the relativistic energy of vacuum.

Interpretation of Electric Flux as an Emergent Property of Vacuum Expansion

The results obtained suggest that the electric flux associated with the elementary charge, Φ_E, can be understood as an emergent phenomenon directly tied to the relativistic total energy of the vacuum. Specifically, the equivalence $\Phi_E = E_{\text{Total}}$ indicates that the electric field generated by an elementary charge is not merely a local, isolated effect, but rather a manifestation of the underlying energy dynamics of the vacuum itself, which exhibits an oscillatory behavior at the speed of light c. This interpretation is consistent with the framework presented, where fundamental constants and fields arise as a result of the vacuum's intrinsic properties.

We can link this result to our previous equivalence between electromagnetic flux and Y_0^3 (20.3). Interpreting Y_0^3 as the quantum of electric flux, which equals the total relativistic energy of the vacuum, underscores that the vacuum admittance (Y_0) in three dimensions encapsulates the relativistic nature of energy propagation through the vacuum. The cubic dependence reflects the vacuum's energy transfer capability across its three spatial dimensions, governed by the intrinsic properties of light speed c, vacuum permeability μ_0, and permittivity ϵ_0. Hence, the vacuum admittance (and thus, all the vacuum's electromagnetic properties) inherently arise from relativistic energy considerations, where the oscillatory behavior of the vacuum at c enables the propagation of both electric and magnetic fields as manifestations of the same underlying oscillatory dynamics.

Electric flux, when framed within this relativistic vacuum energy context, demonstrates that fundamental electromagnetic quantities arise from the vacuum's intrinsic oscillatory behavior. This unification ties classical electromagnetism to the relativistic structure of spacetime, situating elementary charge and its associated fields within the energetic and geometric properties of the vacuum. Electric flux emerges as a consequence of the vacuum's relativistic energy influenced by factors such as expansion and relativistic motion. Ultimately, this synthesis enriches our understanding of the unification of physical laws and the foundational nature of electromagnetic forces within the framework of spacetime geometry.

22.3 The relationship between vacuum's conductance and α

In previous sections (21.3), we had derived that:

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

Operating with this expression, it can be rewritten as:

$$\mu_0 = \frac{2\cdot\alpha^2}{4\cdot\frac{3}{5}4\pi\cdot\sqrt{\frac{3}{5}4\pi}} = \frac{2\cdot 4\pi\alpha^2}{16\pi\cdot\frac{3}{5}4\pi\cdot\sqrt{\frac{3}{5}4\pi}}.$$

Since $\alpha = \frac{1}{16\pi\cdot\sqrt{\frac{3}{5}4\pi}}$, we can substitute to obtain:

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

Recall that μ_0, in an RLC-electromagnetic system, has dimensions of inductance; $\frac{3}{5}4\pi$ has dimensions of R^2; and $[2] = [L] = [T]$ represents the degrees of freedom due to polarization states. Therefore, we identify the term $4\pi\alpha^3$ as:

$$\left[4\pi\alpha^3\right] = \frac{[L]\cdot[R^2]}{[T]},$$

The product $[L]\cdot[R^2]$ has dimensions of capacitance, but the specific physical meaning depends on the system. It may represent a "capacitance-like" parameter in electromagnetic systems where inductive and resistive properties interact, as it is the case. And capacitance divided by time represents conductance G, providing a direct link to how capacitance contributes to charge flow dynamics over time. Thus, $4\pi\alpha^3$ can be interpreted as a relativistically scaled conductance within the vacuum framework, representing how efficiently charge storage in the system translates to sustained current flow under a given voltage.

The appearance of $4\pi\alpha^3$ as a measure of conductance ties together geometric, electromagnetic, and relativistic properties of the vacuum. The term α^3, interpreted as a scaled factor arising from the Lorentz contraction, encapsulates the vacuum's ability to mediate energy transfer in three spatial dimensions. The spherical geometry (4π) emphasizes the isotropy of energy propagation within the vacuum, while the factor of α^3 modulates this ability according to relativistic effects.

Physically, this relationship highlights how vacuum permeability (μ_0) inherently couples to the vacuum's conductance through relativistic scaling. Furthermore, interpreting $4\pi\alpha^3$ as a conductance reveals a profound connection between electric flux and the vacuum's relativistic geometry, in which the first emerges from the interplay of spacetime geometry, electromagnetic fields, and relativistic effects. This perspective supports the unified view of fundamental forces as manifestations of the vacuum's intrinsic properties, linking conductance to the geometry of spacetime and the relativistic dynamics of energy flow.

Introducing the quantum Hall effect: Classical and quantum perspectives

The Hall effect is a fundamental phenomenon in electromagnetism, where an electric current flowing through a conductor in the presence of a perpendicular magnetic field produces a transverse voltage. This Hall voltage arises from the Lorentz force acting on the moving charge carriers, causing them to accumulate on one side of the conductor, and can be expressed classically as:

$$V_H = \frac{IB}{qnd},$$

where I is the current, B the magnetic field strength, q the charge of carriers, n their density, and d the conductor's thickness. Correspondingly, the Hall resistance is:

$$R_H = \frac{V_H}{I} = \frac{B}{qn}.$$

However, when electrons are confined to two dimensions (e.g., in a semiconductor heterostructure) and subjected to extremely low temperatures and strong magnetic fields, the Hall resistance becomes quantized. This is the quantum Hall effect (QHE), first observed by Klaus von Klitzing in 1980 [64]. In this regime, the Hall resistance takes on discrete values:

$$R_H = \frac{h}{e^2} \cdot \frac{1}{n},$$

where n is the integer "filling factor" corresponding to the number of fully occupied Landau levels. These levels arise due to the quantization of cyclotron orbits of charge carriers in a magnetic field. The corresponding Hall conductance is given by:

$$G_H = \frac{e^2}{h} \cdot n,$$

demonstrating the universal nature of $\frac{e^2}{h}$ as a fundamental unit of conductance [65] [66].

From a classical perspective, the Hall effect reflects the interplay between charge motion, magnetic fields, and the geometry of the system. In the quantum Hall regime, this interplay is profoundly influenced by quantum mechanics, where the discretized Landau levels and their associated degeneracies (related to the area of the system in the magnetic field) determine the transport properties. This geometric interpretation extends naturally to the relativistic and vacuum frameworks described in our theory, where geometric and relativistic scaling factors (e.g., α^3) govern conductance.

The link between the quantum Hall effect and vacuum conductance.

Starting from $\frac{e^2}{h}$, substituting with the derived expressions $e = \frac{\mu_0^3}{4\pi}$ and $h = \epsilon_0^3$, and considering also $\epsilon_0 = 2\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$ and $\alpha = \frac{1}{16\pi\cdot\sqrt{\frac{3}{5}4\pi}}$, we have that

$$\frac{e^2}{h} = \frac{\frac{\mu_0^6}{16\pi^2}}{8\mu_0^6 \cdot \frac{3}{5}4\pi \cdot \sqrt{\frac{3}{5}4\pi}} = \frac{2 \cdot 16\pi}{\left(16\pi \cdot \sqrt{\frac{3}{5}4\pi}\right)^3} = 8 \cdot 4\pi\alpha^3$$

This equality emphasizes the shared geometric foundation of the quantum Hall effect and the relativistic vacuum framework. The factor 8 derives from the volumetric scaling $(dx)^3 = \left(\frac{1}{2}\right)^3$, connecting the discrete nature of vacuum geometry to the quantized nature of conductance. This relationship suggests that the quantum Hall effect can be viewed as a manifestation of the vacuum's intrinsic conductance derived from relativistic effects and geometry under specific boundary conditions.

The similarity between the expressions for conductance $\frac{e^2}{h} = 8 \cdot 4\pi\alpha^3$ and the relationship between the gravitational constant G and the vacuum energy density $\rho_{vac_E} = 8G$ is notorious. In both cases, the factor 8 emerges from the discretization of space-time volumes, specifically $(dx)^3 = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$, which implies that both relationships are fundamentally rooted in the geometry of space-time. The term $\frac{e^2}{h}$, conventionally interpreted as a quantum of conductance, gains a richer interpretation when considered in light of its equality with $4\pi\alpha^3$: it represents a conductance density, encapsulating the ability of the system to conduct charge per unit of relativistic and isotropic volumetric scaling. This reinterpretation underscores a unifying theme: the fundamental constants governing charge flow and energy propagation are manifestations of the vacuum's structure, linking quantum phenomena to the relativistic geometry of space-time.

In summary, by connecting $\frac{e^2}{h}$ to $4\pi\alpha^3$, we reveal a unified framework where conductance quantization and relativistic geometry are manifestations of the same underlying principles of the vacuum's structure.

22.4 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 accounts for the two polarization states of electromagnetic field, 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 2 to account for the two polarization states. This formulation aligns with the notion that the elementary charge is an emergent property of the vacuum, induced by its interaction with relativistic effects.

To further refine this interpretation, note that the effective charge e arises from contributions of two degrees of freedom (e.g., polarization states) within the vacuum. Each degree of freedom contributes a charge $e/2$, which, when combined, results in the observed elementary charge:

$$e = e_1 + e_2 = \frac{e}{2} + \frac{e}{2}.$$

Thus, while the vacuum's intrinsic polarization states or oscillatory modes generate charges $e/2$, the observed charge e reflects the contributions from both degrees of freedom. This interpretation naturally connects to the symmetry inherent in the vacuum's electromagnetic properties and its self-resonant structure.

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 within the relativistic structure of the vacuum.

Moreover, note that we have

$$e = 2 \cdot \frac{m_0}{m_0 \cdot c^2 \cdot \gamma} \tag{48}$$

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 2 polarization states. This relationship implies that the elementary charge e emerges directly from the mass-energy dynamics in a relativistic-non-relativistic framework of interaction.

The nature of the effective current $I_{eff} = \frac{e \cdot c}{2}$

Note that the above gives raise to the effective current

$$I_{eff} = \frac{e \cdot c}{2}$$

Where $\frac{e}{2} = \frac{\alpha}{c^2}$ is the elementary charge corresponding to each polarization state, and 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. Hence, 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 a function of the dynamic relativistic 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 fundamentally connected to the relativistic energy 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 is a manifestation of the way mass-energy interacts with spacetime in relativistic-non-relativistic frameworks. 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 due to relativistic-non-relativistic interactions.

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.

Some additional reflections

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 emphasizes the relativistic nature of the charge. Since γ depends on the relative velocity between observers, the formula links the elementary charge to the 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. We will examine this emergence of elementary charge in the next section.

23 Derivation of the Elementary Charge e as Induced by Vacuum Fluctuations

23.1 Derivation of the elementary charge from zero-point energy and vacuum's energy density

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 how the elementary charge e emerges from the cumulative contribution of vacuum oscillations. We postulate that $\frac{\hbar}{2}$ 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 the vacuum's relativistic energy into the induced electric charge.

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

$$\int 4\pi G \rho_{vac} \; dc = \frac{3}{5} 4\pi \epsilon_0 \tag{49}$$

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

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

$$\int \rho_{vac} \; dc = 2 \cdot \sqrt{\frac{3}{5} 4\pi} \cdot e \tag{50}$$

The integral $\int 4\pi G \rho_{\text{vac}} \, dc$ represents the accumulation of gravitational flux over time, where the vacuum energy density ρ_{vac} serves as the source term for the gravitational field, highlighting the role of energy density in driving gravitational interactions. Conversely, the integral $\int \rho_{\text{vac}} \, dc$ describes the temporal accumulation of electric flux (derived from Gauss Law), where ρ_{vac} is interpreted as the vacuum charge density or an analogous quantity.

These integrals underscore the dual nature of ρ_{vac}, acting as the source for both gravitational and electromagnetic fields within their respective frameworks. While gravitational flux depends on the total energy density, electric flux arises from the associated charge density or equivalent parameter. Thus, the difference between these integrals lies in the scaling factors and the nature of the fields, reflecting the interplay between vacuum properties, fundamental forces, and spacetime geometry.

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.

23.2 Derivation of the Elementary Charge e from Planck's constant h as the displacement field D

The best approach to derive the elementary charge e as induced by vacuum fluctuations is to consider Planck's constant h as representing a quantum displacement field induced by fluctuations in the vacuum. The integral of this displacement field over an effective surface area then yields the elementary charge e.

The Quantum Displacement Field h and Effective Area in Vacuum Polarization

In this framework, we express the integral of the quantum displacement field over a spherical surface as:

$$\oint_S \mathbf{D} \cdot dA = \oint_S h \cdot dA$$

where $dA = 4\pi r^2$ is the surface area of a sphere. Here, h plays the role of a quantum displacement field, which induces charge through vacuum fluctuations. We consider the radius $r = 2\alpha \cdot c$, which reflects a fundamental length scale set by the fine-structure constant and the speed of light, c. This choice is significant, as it suggests a region where vacuum polarization effects accumulate, producing a net induced charge Q_{induced} as a result of these fluctuations.

Justification for h as the Quantum Displacement Field

The choice of Planck's constant h as the quantum displacement field in this context is based on several properties of h that align naturally with the characteristics of a displacement field in the vacuum. Firstly, h represents the quantum of linear momentum for the photon, which inherently carries the potential for electromagnetic energy. This aligns with the interpretation of h as a displacement field because, at the quantum level, the momentum of photons embodies the capacity for energy transfer in discrete units. This discrete nature reflects the way in which vacuum fluctuations may polarize to induce a quantized charge, as described by the elementary charge e.

Additionally, the appearance of $\frac{h}{2}$ in the angular form of Heisenberg's uncertainty principle,

$$\Delta\theta \cdot \Delta L \geq \frac{h}{2},$$

provides further support for viewing h as a displacement field, particularly in the context of quantum field fluctuations. In this interpretation, h governs the fundamental limits on angular displacement and momentum, which mirrors the uncertainty in the spatial polarization within the vacuum. The uncertainty relation suggests that h, as the minimal quantum of action, underlies the quantum fluctuations in the vacuum that give rise to the displacement field. Consequently, h as a displacement field embodies the discrete and quantized nature of vacuum polarization effects that lead to the emergence of charge.

Choice of $2\alpha \cdot c$ as the Effective Radius of the Quantum Displacement Field

In the framework of interpreting the elementary charge e as an emergent phenomenon induced by vacuum fluctuations, we propose that the radius $2\alpha \cdot c$ defines a natural boundary for integrating the quantum displacement field. This choice of radius is supported by the interpretation of $\alpha \cdot c$ as a damping attenuation factor per quantum unit of area in the vacuum's electromagnetic field dynamics.

In oscillatory systems, the damping attenuation factor α_{att} quantifies the rate of energy dissipation or decay per unit distance or time. In this framework, we have already stated in previous sections the relationship:

$$\alpha \cdot c = 2\alpha_{\text{att}}(18.1)$$

which suggests that $\alpha \cdot c$ represents a fundamental attenuation factor governing the rate at which quantum fluctuations in the vacuum dissipate or spread over time and space. By incorporating the scaling factor of 2 to α_{att}, which can be related to the reciprocal of the spacetime quantum differential

$dx = \frac{1}{2}$, this relationship indicates that $\alpha \cdot c$ encodes a decay rate that operates per quantum unit of length or time, and $2\alpha \cdot c$ encodes a decay rate that operates per quantum unit of area.

Given this interpretation, we propose that $2\alpha \cdot c$ functions as the effective radius within which the quantum displacement field h acts to induce the elementary charge e. This radius is significant for several reasons:

- **Spatial Extent of Vacuum Polarization Effects**: The radius $2\alpha \cdot c$ marks the region over which vacuum polarization effects are substantial enough to induce an observable net charge. This spatial extent, equivalent to the damping attenuation per unit area, suggests that vacuum fluctuations diminish beyond this boundary, confining the displacement effects of h within a finite volume.
- **Attenuation Per Quantum Area Unit**: By interpreting $2\alpha \cdot c$ as an attenuation rate per quantum area, we establish a natural boundary for the effective action of the displacement field. Within this boundary, the quantum displacement field h operates over an area where vacuum oscillations and polarization are maintained. This view frames $2\alpha \cdot c$ as a measure of how far the quantum field's influence extends, providing a physically motivated region for integrating h over a spherical surface.
- **Consistency with Quantum Geometry and Oscillatory Dynamics**: Finally, this interpretation aligns with the quantized geometric nature of the vacuum. Since $\alpha \cdot c$ represents a unit rate of fluctuation decay, the radius $2\alpha \cdot c$ emerges as a coherent scale at which the quantum field accumulates enough oscillatory energy to manifest as an induced charge. This suggests that $2\alpha \cdot c$ encapsulates the spatial and oscillatory dynamics of the vacuum in a self-consistent manner, reinforcing its role as the effective radius for the displacement field's integration.

Thus, by adopting $2\alpha \cdot c$ as the effective radius, we frame the displacement field h as acting within a quantum boundary that reflects the vacuum's intrinsic attenuation properties. This boundary not only defines the extent of vacuum polarization effects but also grounds the integration of the displacement field in the damping characteristics of quantum fluctuations. This approach offers a unified and physically justified basis for interpreting the elementary charge e as a macroscopic manifestation of quantum field dynamics in the vacuum.

The selection of $2\alpha \cdot c$ as the effective radius further connects the vacuum polarization effects to both relativistic and quantum properties of the vacuum. The fine-structure constant α, which quantifies the strength of the electromagnetic interaction, appears in Bohr's radius for the hydrogen atom, $a_0 = \frac{\hbar}{m_e \alpha c}$, where αc appears as a term that governs the spatial extent of the electron's quantum orbit. In our framework, $2\alpha \cdot c$ plays a similar role, defining a spatial scale over which the vacuum polarization effects accumulate.

Furthermore, considering α as the reciprocal of a Lorentz factor $\gamma = \frac{1}{\alpha}$ highlights that the radius $2\alpha \cdot c$ encapsulates both quantum and relativistic aspects of vacuum fluctuations. The factor α scales this radius to account for relativistic contraction effects within the vacuum's polarization field, creating a region where the quantum displacement field h can effectively induce an observable charge. The use of this radius connects the behavior of vacuum fluctuations in a quantized, relativistically scaled volume with the emergence of the elementary charge, e.

Together, interpreting h as the quantum displacement field and adopting $2\alpha \cdot c$ as the effective radius provide a coherent view of how the elementary charge may emerge from the fundamental structure of the vacuum. The displacement field, quantized by h, acts over a scale set by the strength of electromagnetic interactions and the speed of light, aligning both quantum and relativistic properties in the induction of charge within the vacuum.

Calculation of Induced Charge from Quantum Displacement

With this setup, we can evaluate the integral:

$$\oint_S \mathbf{D} \cdot dA = \oint_S h \cdot dA = h \cdot 4\pi(2\alpha \cdot c)^2$$

Substituting $h = \epsilon_0^3$ and $c^2 = \frac{1}{\epsilon_0 \cdot \mu_0}$, operating, we have that

$$\oint_S \mathbf{D} \cdot dA = \oint_S h \cdot dA = \frac{\epsilon_0^2 \cdot 16\pi \cdot \alpha^2}{\mu_0}$$

Substituting $\epsilon_0^2 = 4 \cdot \mu_0^4 \cdot \frac{3}{5}4\pi$ and $\alpha^2 = \frac{1}{\left(16\pi \cdot \sqrt{\frac{3}{5}4\pi}\right)^2}$ we have that

$$\oint_S \mathbf{D} \cdot dA = \oint_S h \cdot dA = \frac{4 \cdot \mu_0^4 \cdot \frac{3}{5}4\pi \cdot 16\pi}{\mu_0 \cdot \left(16\pi \cdot \sqrt{\frac{3}{5}4\pi}\right)^2} = \frac{\mu_0^3}{4\pi} = e$$

This expression represents the cumulative contribution of quantum fluctuations, polarized within the vacuum, that leads to an effective induced charge. Aligning this result with Gauss's law in a dielectric medium, we can interpret this as the net free charge Q_{induced} resulting from vacuum's displacement field.

This relationship implies that the elementary charge e emerges from the effects of vacuum fluctuations, represented by h as a quantum displacement field. In this interpretation, the vacuum behaves as a dielectric, where $\mathbf{D}$ accounts for the quantum fluctuations that polarize the vacuum to produce a net charge.

Together, E_0 and h provide a coherent model for describing the electric properties of the vacuum: E_0 encapsulates the energy density of fluctuations, and h translates these fluctuations into a displacement field capable of inducing charge.

Thus, by expressing h as the quantum displacement field, we establish a unified perspective where the elementary charge arises naturally from vacuum polarization, bridging quantum mechanics and classical field theory.

Interpretation of the results obtained

The integral $\oint_S h \cdot dA = e$ provides a direct link between quantum fluctuations in the vacuum and the emergence of charge, with h functioning as a quantum displacement field. This interpretation becomes more profound when considering the established relationship $h = \epsilon_0^3$, which suggests that h represents a quantized "unit" of vacuum polarization, or the intrinsic capacity of the vacuum to oscillate and carry energy. Within this framework, ϵ_0 quantifies the vacuum's ability to sustain a displacement field that supports electric fields, with $h = \epsilon_0^3$ acting as a measure of the cumulative effects of these fluctuations in a three-dimensional geometry. Consequently, ϵ_0 represents not only the flexibility of spacetime to deform but also the spatial boundary within which quantum fluctuations lead to an induced charge density, connecting vacuum permittivity directly to the scale and extent of polarization effects.

Moreover, the relationship $e = \frac{\mu_0^3}{4\pi}$ reinforces the interpretation of μ_0 as the quantum of energy transfer or dissipation required to generate observable charge. In this view, μ_0 encapsulates the vacuum's response to magnetic fields and the manner in which energy dissipates through oscillations within a spherical distribution, thereby forming an induced charge. Just as ϵ_0 defines a spatial range over which fluctuations affect electric fields, μ_0 defines a spatial region over which energy dissipates in response to these fields. The expression $e = \frac{\mu_0^3}{4\pi}$ thus provides a dimensionally consistent bridge between vacuum permeability and the elementary charge, indicating that e is a product of the vacuum's inherent oscillatory characteristics and the dissipation properties of spacetime.

Taken together, the expressions $h = \epsilon_0^3$ and $e = \frac{\mu_0^3}{4\pi}$ reveal how the fundamental constants of electromagnetism and the quantum vacuum interrelate. ϵ_0 and μ_0, viewed as complementary aspects of the vacuum's ability to support and sustain electric and magnetic fields, define the spatial and energetic boundaries within which quantum fluctuations induce elementary charge. These relationships emphasize that the constants we observe, such as e and h, are not independent quantities but are deeply rooted in the intrinsic properties of spacetime, highlighting the vacuum as a unified, oscillatory medium in which charge, energy, and geometric structure are fundamentally interconnected.

24 Electromagnetic Waves as Oscillations of Vacuum Expanding at Relativistic Velocities

Building on the interpretation of the vacuum as an expanding relativistic medium, we propose that electromagnetic waves can be understood as oscillatory states of this expanding vacuum. In this framework, electromagnetic waves are not disturbances propagating through a static medium but intrinsic oscillations of the vacuum, which exhibits a natural resonance characterized by the angular frequency $\omega_0 = c$ (in natural units). This reinterpretation provides a unified perspective on electromagnetic propagation, relativity, and the fundamental structure of the vacuum.

The Vacuum as an Active, Oscillatory Medium

If the vacuum inherently expands at a relativistic scale determined by c, then electromagnetic waves correspond to oscillatory re-distributions of the vacuum's energy density. Alternating electric ($\mathbf{E}$) and magnetic ($\mathbf{B}$) fields arise as orthogonal modes of these oscillations, with their phase coherence giving rise to the observed properties of light. The parameter c, traditionally interpreted as the speed of light, naturally emerges as the vacuum's angular resonance frequency. Rather than representing a physical velocity of propagation, c reflects the vacuum's intrinsic oscillatory timescale.

In this view, the apparent displacement of electromagnetic waves across spacetime is not a literal propagation but an emergent effect of phase evolution. From the perspective of a non-relativistic observer, this phase coherence creates the illusion of a traveling wave. This interpretation re-frames the vacuum not as a passive backdrop but as an active, oscillatory entity sustaining electromagnetic phenomena.

Oscillatory Redistribution of Vacuum Energy

Electromagnetic waves can be interpreted as continuous re-distributions of the vacuum's relativistic total energy E_{total}, governed by its oscillatory properties. The electric and magnetic fields correspond to orthogonal oscillatory modes, satisfying Maxwell's equations. The classical wave equation for electromagnetic waves, given by

$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} = 0,$$

emerges naturally when c is interpreted as the vacuum's intrinsic resonance frequency scaled by the wavelength. In this framework, c characterizes the fundamental oscillatory behavior of the vacuum. Specifically, the vacuum's angular frequency $\omega_0 = ck$, where $k = 2\pi/\lambda$ is the wavenumber, establishes the proportionality between spatial and temporal oscillations. Substituting this relationship into the general form of wave dynamics, where the second spatial derivative $\nabla^2\psi$ is proportional to the second temporal derivative $\frac{\partial^2\psi}{\partial t^2}$, leads directly to the wave equation with c^2 as the scaling factor. This interpretation reinforces that c is not a physical velocity but rather a measure of the phase synchronization in the vacuum's oscillatory modes, naturally coupling spatial and temporal variations of the electromagnetic field.

The relationship between electromagnetic energy density and electric flux, $\Phi_E = E_{\text{total}}$, follows naturally from this perspective. The flux is not localized solely around charges but arises as a manifestation of the vacuum's intrinsic oscillatory energy dynamics. This interpretation connects electromagnetic propagation directly to the vacuum's structure and oscillatory properties.

Bridging Field and Particle Descriptions

This framework also provides a bridge between the wave and particle descriptions of light. Photons, as quanta of electromagnetic waves, can be interpreted as localized packets of oscillatory vacuum energy. They are not independent entities traveling through space but localized dynamic perturbations of the vacuum's oscillatory state. This interpretation aligns with quantum field theory, where photons are understood as excitations of the electromagnetic field, while extending this view to root their behavior in the vacuum's intrinsic resonance.

From this perspective, photons inherit their properties, such as energy and momentum, from the oscillatory dynamics of the vacuum itself. The equivalence $E = \hbar\omega$ connects the photon's energy to the vacuum's angular frequency of resonance, reinforcing the role of c as the fundamental oscillatory scale.

Cosmological Implications and the Expanding Vacuum

Viewing electromagnetic waves as oscillations of a relativistic, expanding vacuum opens new avenues for exploring cosmological phenomena. If both electromagnetic wave propagation and cosmic expansion are governed by the vacuum's properties, this model suggests a profound connection between local quantum dynamics and large-scale spacetime evolution. For instance:

- The apparent constancy of c across spacetime reflects a universal resonance condition intrinsic to the vacuum.
- The coupling between local oscillatory phenomena (such as light propagation) and global cosmological expansion may offer insights into dark energy and the mechanisms behind the universe's accelerated expansion.

A relativistic expanding vacuum provides a natural framework for reconciling quantum and cosmological phenomena. In this view, the vacuum's oscillatory modes underlie not only electromagnetic propagation but also spacetime fundamental properties.

The relativistic expanding vacuum as the most reasonable framework

A relativistic expansion of the vacuum is the most reasonable framework to support the proposed oscillatory model for several reasons. First, a static or non-expanding vacuum would lack the symmetry inherent in relativistic spacetime, which underpins the observed invariance of the speed of light c. This symmetry ensures that electromagnetic oscillations are universally governed by the same dynamics across all inertial frames.

Without a relativistic expansion, the coupling between spatial and temporal oscillations—central to the emergence of c as the vacuum's natural resonance frequency—may break down, compromising the universality of light's propagation characteristics. Additionally, a static vacuum would need to provide an alternative explanation for phenomena such as the cosmological redshift and the apparent accelerated expansion of the universe.

These observations are naturally explained in a relativistic framework where the vacuum's expansion introduces global dynamical properties, such as an evolving energy density, consistent with dark energy. By contrast, a non-expanding vacuum would necessitate a fundamental rethinking of spacetime structure, potentially leading to inconsistencies with both general relativity and quantum field theory.

Thus, the relativistic expansion of the vacuum offers a cohesive and symmetric foundation for both local oscillatory phenomena, such as electromagnetic waves, and large-scale cosmological effects, making it the most reasonable alternative.

Unifying Electromagnetic and Spacetime Dynamics

In summary, this reinterpretation positions the vacuum as a dynamic, expanding entity with intrinsic oscillatory modes. Electromagnetic waves are then understood as fluctuations of energy density arising from the vacuum's natural resonance. The observed constancy of c follows directly from the vacuum's angular frequency, unifying the properties of light with the fundamental structure of spacetime. This framework provides a coherent interpretation of classical electromagnetic phenomena while offering valuable insights into quantum field theory and cosmological evolution.

25 The Nature of the Photon as a quantized energy packet emergent from the vacuum's oscillatory dynamics

With the proposed theory on electromagnetic waves —where electromagnetic waves are seen as oscillatory expansions of the vacuum itself moving at the speed of light c— we find a pathway to consider photons as quantized energy packets. In this framework, photons are interpreted as emergent properties of the vacuum's oscillatory dynamics rather than discrete particles in the traditional sense. Below, we outline this view in detail and discuss its implications for quantum field theory, wave-particle duality, and cosmology.

25.1 Photons as Emergent Oscillations in the Vacuum

If electromagnetic waves are fundamentally oscillations within the vacuum structure, photons can be viewed as quantized packets of these oscillations, rather than individual particles traveling through space. This interpretation suggests that "photon behavior" arises from the vacuum's inherent ability to sustain quantized energy transfers, which in turn derives from the quantized structure of spacetime. In this sense, photons manifest as localized oscillatory modes in the vacuum, rather than as physical particles.

In this sense, a photon represents a quantized transfer of energy rather than an independent particle. When energy is absorbed or emitted (such as during electron transitions between energy levels), the vacuum's oscillatory field adjusts, producing a discrete energy exchange that we interpret as a photon. This perspective aligns with quantum field theory, where energy appears as quantized excitations of a field. Here, the oscillatory vacuum field itself facilitates these exchanges, rendering the photon as a localized interaction within this oscillatory vacuum structure.

25.2 Implications of the photon as a quantized state of vacuum's oscillations

This field-based interpretation moves away from particle-like notions and toward a model where light represents the vacuum's oscillatory response to energy changes. The "photon" then emerges as an effective quantized energy packet that reflects localized interactions within this oscillatory field, rather than as a free-moving particle. This perspective provides a coherent, unified view of electromagnetic phenomena as vacuum-induced oscillations.

Wave-Particle Duality as an Emergent Phenomenon

In this framework, wave-particle duality is reinterpreted as an emergent phenomenon that arises from the oscillatory properties of the vacuum. The particle-like behavior of photons in experiments such as the photoelectric effect is attributed to discrete energy transfers within the vacuum. In contrast, wave-like behaviors (such as interference and diffraction) emerge naturally from the continuous, oscillatory structure of the vacuum field.

In experiments like the double-slit experiment, this oscillatory field interpretation suggests that the vacuum itself sustains a probabilistic wave pattern. This pattern is then interpreted as particle-like when discrete energy impacts (interpreted as photons) are measured on a screen. By treating photons as expressions of vacuum oscillations, rather than independent particles, we provide an explanation for the "which-way" ambiguity observed in such experiments.

Implications for Cosmology

If photons are not fundamental particles but rather oscillatory states in the vacuum, the energy of these oscillatory states could be tied directly to the vacuum's energy density and structure. Under this interpretation, phenomena like redshift in an expanding universe can be understood as modifications to the vacuum's oscillatory field over cosmological distances, rather than energy losses by individual photons. As the vacuum expands, these oscillatory modes adjust, leading to observable shifts in light frequency without the need for a particle-based explanation for photon "aging" or decay.

Potential Experimental Implications

In this model, the photon's existence is inherently tied to the local and global structure of the vacuum. Testing photon-like behavior at quantum scales—such as in delayed-choice quantum eraser experiments—could reveal aspects of non-locality and entanglement as properties of the vacuum field, rather than attributes of discrete particles.

Experimental research on phenomena such as the Casimir effect or vacuum polarization may offer further insights into how vacuum oscillations behave under various boundary conditions. Observing how photon effects change in confined or altered vacuum states could provide empirical support for this model, emphasizing the photon's nature as a quantized energy packet linked to vacuum properties.

Conclusion

This model preserves the successes of QED and wave-particle duality but reinterprets them within a field-centric, vacuum-based framework. In this sense, the photon is an emergent feature of how the vacuum field responds to energy transfers.

This approach offers a unified perspective on light, matter interactions, and the structure of space-time, potentially bridging classical and quantum descriptions in a novel way. By viewing photons as emergent properties, we gain a deeper understanding of electromagnetic waves as intrinsic oscillations of the vacuum itself.

26 The emergence of fundamental particles from Vacuum's structure

26.1 Introduction

Recent advancements in quantum field theory, cosmology, and the study of the quantum vacuum provide compelling evidence that particles such as electrons, protons, and photons derive their properties not from isolated characteristics but from their interactions with a dynamic, structured vacuum [67]. Vacuum's role in defining particle properties is underscored by studies on vacuum fluctuations and zero-point energy, where the interaction of fields within the vacuum manifests as observable particle phenomena [68]. Moreover, the interplay of vacuum geometry and fundamental constants has been shown to underpin key relationships in particle physics and cosmology.

This section develops a theoretical framework for interpreting the mass of fundamental particles as emergent properties of the quantum vacuum. Building on the relationships derived throughout this Paper, we establish a unified perspective where mass is intrinsically tied to vacuum structure and spacetime deformation. This approach aligns with contemporary investigations into the origin of mass-energy equivalence in systems governed by quantum and relativistic principles [69] [70].

The central hypotheses are built around key equivalences that bridge particle properties with vacuum dynamics. For the electron, its mass m_e is hypothesized to relate to the photon's effective relativistic mass $m_{\text{ph rel}}$ through the Coulomb constant K_e:

$$m_e = 2 \cdot m_{\text{ph rel}} \cdot K_e. \tag{51}$$

Similarly, the proton's mass m_p is hypothetically derived by coupling the energies of the photon E_{ph} and electron E_e, modulated by the Lorentz factor γ (the reciprocal of the fine-structure constant α):

$$m_p = \frac{1}{2} \cdot K_e \cdot E_e \cdot E_{\text{ph}} \cdot \gamma. \tag{52}$$

Finally, the neutron's mass is hypothesized to be related to electron's mass through the relationship:

$$m_n = \frac{m_e \cdot \gamma}{S_{EH} \cdot \frac{3}{5} 4\pi} \tag{53}$$

Where S_{EH} is the Einstein-Hilbert action, or, as we have already established, the quantum-probabilistic, four-dimensional spacetime fundamental quantum.

These equations not only encapsulate the vacuum's capacity to induce particle properties but also unify fundamental particles as complementary byproducts originating from the same underlying vacuum structure.

This framework links to the seminal work of quantum field theory, which posits that particles arise from quantized field excitations, as well as recent proposals that emphasize the geometric and electromagnetic aspects of the vacuum [71]. In this context, mass emerges as a response of the vacuum to the presence of quantized energy states, with the vacuum acting as a dynamic mediator of geometric and oscillatory constraints.

A notable feature of this framework is its compatibility with the vacuum energy density interpretation, where ρ_{vac} serves as a fundamental scale for understanding mass and charge. By integrating these insights with geometric factors such as the Coulomb constant and Lorentz factor, we reveal that mass is not a static property but a dynamic equilibrium imbricated into the vacuum's intrinsic oscillatory and self-interaction properties.

The possible implications of these hypothesis extend from our understanding of atomic and subatomic structures, to the cosmology general behavior. If fundamental particle masses can be derived from first principles tied to the vacuum's geometry and energy, this would imply an important step in the path toward unifying quantum and relativistic perspectives, underscoring the profound role of the vacuum as the foundational entity governing from particle properties to cosmological phenomena, and offering new insights into the nature of mass, charge, and spacetime itself.

26.2 A Foamy Analogy: Particles as Bubbles in the Quantum Vacuum

The emergence of particles from the quantum vacuum can be conceptually understood through an analogy with the formation of foam in a fluid system. Imagine hot water rapidly interacting with a cooler, quiescent surface. This interaction generates foam —discrete bubbles arising from the interplay of temperature gradients, pressure, and surface tension. Similarly, particles emerge as localized, quantized excitations within the vacuum, stabilized by the dynamic balance of oscillatory and relativistic effects.

The Vacuum as a Dynamic Medium

In this analogy:

- The *hot water* represents high-energy relativistic oscillations in the vacuum.
- The *quiet water* symbolizes the vacuum's ground state—a smooth, low-energy configuration.
- The resulting *foam*, composed of discrete bubbles, serves as a model for particles emerging from the vacuum as localized energy states.

Just as foam is not continuous but consists of distinct, interconnected bubbles, particles are quantized, discrete entities that reflect the structured dynamics of the quantum vacuum. Each bubble forms due to external conditions, much like particles emerge from the vacuum under specific energetic and geometric constraints.

Quantization and Stability of Bubbles

Foam is inherently quantized; each bubble is a distinct, localized feature of the system. Analogously, particles are quantized excitations of the vacuum, with properties such as mass and charge arising from their interaction with the vacuum's intrinsic structure:

- **Discrete nature:** Each bubble corresponds to a localized oscillatory state of the vacuum, akin to a particle with well-defined energy and mass.
- **Stabilization:** Bubbles are stabilized by the balance of internal pressure and surface tension. In parallel, particles achieve stability through a balance of relativistic dynamics and vacuum oscillatory effects.

The quantization of bubbles reflects the discrete nature of particle states in quantum fields, where mass and energy emerge from the vacuum as stabilized configurations.

Interaction and Collective Behavior

Foam is not merely a collection of isolated bubbles. The dynamics of one bubble influence its neighbors through shared boundaries and pressures. Similarly, particles interact within the quantum vacuum:

- **Forces and interactions:** The vacuum mediates interactions between particles, analogous to the forces acting between bubbles in foam. For instance, electromagnetic forces are akin to the surface tension connecting bubbles.
- **Interconnection:** Just as foam forms a network of bubbles, particles collectively shape the matter through their mutual interactions.

This interconnected nature emphasizes that particles are not isolated entities but are part of a dynamic network shaped by the vacuum's properties.

Emergence from Oscillations

The formation of foam results from energy gradients at the interface of hot and quiet water. Similarly, particles emerge from oscillations in the vacuum at relativistic velocities:

- The properties of each particle are not intrinsic but arise from the interaction of oscillatory modes in the vacuum.
- Particles stabilize as localized features, much like bubbles capture localized energy within a frothy fluid system.

This analogy illustrates the emergence of matter as an interplay between energy, geometry, and oscillatory dynamics in the vacuum.

Connecting the Analogy to matter arising from vacuum's structure

While the analogy of foam provides a useful visualization, it must be interpreted within the constraints of quantum mechanics and relativity. However, despite these differences, the analogy effectively captures the essence of how discrete entities can emerge from a dynamic medium and offers an intuitive perspective on the emergence of particles from the quantum vacuum. By visualizing particles as discrete, stabilized "bubbles" in a dynamic, interconnected medium, we gain insight into the vacuum's role as a mediator of mass, energy, and interactions. While simplified, this analogy underscores the profound interplay of quantum fields, geometry, and relativistic effects in shaping the fundamental building blocks of matter.

The precise mechanisms through which the vacuum generates matter remain outside the scope of this work and are subject to further investigation. However, in the following subsections, we will present specific relationships that highlight the profound connection between matter and the vacuum's structure. These relationships underscore the pivotal role of the vacuum in shaping the properties of particles, offering insights into the interplay between mass, energy, and spacetime geometry.

26.3 Photon Momentum and its Effective and relativistic Mass

Interpretation of $\hbar$ as the Angular Momentum of the Photon

In quantum mechanics, $\hbar$ represents the fundamental quantum of angular momentum, encapsulating the intrinsic oscillatory properties of quantum systems. For a photon, $\hbar$ is often interpreted as a measure of intrinsic angular motion, even though the photon itself lacks rest mass.

To formalize this idea, we begin with the relationship between the photon's energy E_{ph} and the Planck constant, expressed as $E_{ph} = h \cdot c$, where h is the Planck constant. Combining this with Einstein's energy-mass equivalence $E = m \cdot c^2$, we can associate an effective mass-like property scale to the photon. Specifically, by rewriting $\hbar$ in terms of mass and velocity, we have:

$$\hbar = m_{ph} \cdot c, \tag{54}$$

where m_{ph} denotes an effective "angular" mass-like property associated with the photon. This angular mass-like property, m_{ph}, captures the interplay between the photon's energy and its oscillatory degrees of freedom. While the photon does not have rest mass, this angular mass-like property emerges as a property reflecting its intrinsic momentum and the angular nature of its interactions with spacetime. Thus, m_{ph} serves as a mass equivalent tied to the photon's quantum angular momentum, effectively parametrizing its oscillatory energy contribution in a relativistic context.

Photon's Relativistic Mass Interpretation

This angular mass-like property m_{ph} can be extended to include relativistic effects, yielding a relativistic mass for the photon:

$$m_{\text{ph rel}} = m_{ph} \cdot \lambda = \frac{\hbar}{c \cdot \alpha}. \tag{55}$$

Here, $m_{\text{ph rel}}$ represents the photon's relativistic mass-like property, which incorporates the scaling effect of α. In this interpretation:

- α acts as a modulating factor, tying the photon's properties to the vacuum's geometry and expansion.
- $m_{\text{ph rel}}$ provides a framework for understanding the photon's mass-like behavior in relativistic regimes, even in the absence of rest mass.

This relativistic mass highlights the photon's dual role as both a quantum excitation of the electromagnetic field and a geometric feature of spacetime. By linking $m_{\text{ph rel}}$ to α, we establish a deeper connection between the photon's momentum, its angular nature, and the vacuum's structural properties.

Reinterpreting Angular Mass in Context

The concept of angular mass-like property introduced here provides a new perspective on the photon's interaction with spacetime. Unlike rest mass, which measures inertia in response to linear forces, this angular mass-like property reflects the photon's coupling to rotational or oscillatory modes of spacetime. This interpretation aligns with the quantum mechanical view of photons as carriers of angular momentum (e.g., spin or polarization), as well as their relativistic propagation through spacetime.

From a geometric perspective, this angular mass-like property can be seen as an emergent property arising from the vacuum's inherent oscillatory symmetries. It serves as a bridge between the quantum properties of photons (e.g., $\hbar$) and their relativistic behaviors, such as energy and momentum transfer in curved or expanding spacetime.

This reinterpretation not only clarifies the role of $\hbar$ in characterizing the photon's quantum dynamics but also provides a natural framework for extending the concept of mass to systems traditionally considered massless.

26.4 Electron Mass as an Emergent Property of Vacuum's Oscillatory Structure

In this subsection, we explore how the electron mass m_e can be derived as an emergent property of the vacuum's geometric and oscillatory structure. By examining the electron as a localized oscillatory state within the vacuum, we link its mass to fundamental constants and the spatial confinement of charge within a spherical geometry. This approach highlights the interplay between electromagnetic properties, vacuum polarization, and harmonic oscillations, providing a unified framework for understanding m_e.

Our derivation proceeds as follows:

- First, we calculate the integral of the electric flux through a spherical surface enclosing an elementary charge, revealing the geometric role of vacuum permittivity ϵ_0 in defining the electron's confinement scale.
- Second, we incorporate a scaling factor $(1/2\pi)^4$ that arises from the vacuum's harmonic oscillatory nature and is directly related to the dimensional reduction in Fourier series representations. This factor quantizes the energy scaling in the vacuum, allowing us to bridge classical and quantum perspectives.
- Finally, we combine these results to derive an expression for m_e that emphasizes its emergence as a field-induced property tied to the vacuum's intrinsic structure.

This derivation underscores the profound connection between the electron's mass and the vacuum's ability to sustain localized oscillations, unifying geometric, electromagnetic, and oscillatory dynamics within a coherent framework that originates mass.

The Integral of Electric Flux and Charge Confinement

The electric flux Φ_E through a spherical surface of radius R enclosing an elementary charge e is given by:

$$\Phi_E = \frac{e}{\epsilon_0}.$$

Now, consider an integral of the electric flux over some spherical surface, $\oint_S \Phi_E \, dA$. This integral quantifies the total electric flux distributed across the spherical geometry and represents the interaction of the enclosed charge with the vacuum's structure. We can express it as:

$$\oint_S \Phi_E \, dA = \frac{e}{\epsilon_0} \cdot 4\pi r^2 \tag{56}$$

$2\pi\epsilon_0$ as the "radius" of the elementary charge spherical confinement Now, we need to find a suitable "radius". Recall the expression $2\pi\epsilon_0$, which we postulated before to be equivalent to:

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

This equivalence reflects the deep interplay between the vacuum's magnetic permeability μ_0, its permittivity ϵ_0, and its geometric characteristics. Based on the reasons detailed below, and the numerical fit with the measured electron's mass, we find that $2\pi\epsilon_0$ comes naturally and empirically as the radius of the charge confinement:

- **Geometric and Electromagnetic Symmetry:** The term $4\pi\mu_0^2 \cdot \sqrt{\frac{3}{5}4\pi}$ encapsulates both the spatial extent of the vacuum's electromagnetic properties and the topological packing of its oscillatory modes. The factor $4\pi\mu_0^2$ can be interpreted as a measure of spatial extension, akin to the surface area of a sphere scaled by the magnetic permeability μ_0. The additional factor $\sqrt{\frac{3}{5}4\pi}$ introduces a correction related to the vacuum's spherical packing efficiency, arising from its oscillatory configuration in three-dimensional space.

- **Consistency with RLC Circuit Analogies:** Within our framework, $2\pi\epsilon_0$ can also be interpreted as the product of a resistance 2π and capacitance ϵ_0. In an RLC circuit, such a product yields the characteristic timescale, which can be translated into a length scale in dimensional analysis by the equivalence $[L] = [T]$. This interpretation links $2\pi\epsilon_0$ to the vacuum's ability to sustain electromagnetic oscillations, naturally associating it with the radius of the spherical geometry.

- **Scaling Consistency with Quantum and Classical Regimes:** The choice of $2\pi\epsilon_0$ as a radius ensures dimensional consistency when transitioning between classical electromagnetic theory and quantum frameworks. The factor 2π aligns with the natural periodicity of oscillatory systems, while ϵ_0 introduces the vacuum's intrinsic ability to sustain electric fields. This combination provides a coherent bridge between quantized and continuous descriptions of charge and field interactions.

Thus, choosing $2\pi\epsilon_0$ as a radius is not an arbitrary choice but rather a natural consequence of the vacuum's electromagnetic and geometric properties. It encapsulates the vacuum's ability to sustain electric field confinement and oscillatory dynamics, making it an ideal parameter for describing the spherical geometry in this framework.

For a sphere of radius $R = 2\pi\epsilon_0$, the total surface area is:

$$A = 4\pi R^2 = 4\pi \cdot (2\pi\epsilon_0)^2 = 16\pi^3\epsilon_0^2.$$

Thus, the integral of the electric flux becomes:

$$\oint_S \Phi_E \, dA = \Phi_E \cdot A = \frac{e}{\epsilon_0} \cdot 16\pi^3\epsilon_0^2 = 16\pi^3 e \cdot \epsilon_0.$$

Harmonic Oscillations and the Fourier Connection

To incorporate the vacuum's oscillatory behavior in the derivation of the electron mass, we introduce the scaling factor $(1/2\pi)^4$. This factor is deeply rooted in the analysis of vacuum oscillations via Fourier transforms and reflects the dimensional reduction and quantization inherent to the vacuum's structure.

Fourier analysis is a fundamental tool for studying oscillatory systems. In the context of vacuum dynamics, the vacuum can be viewed as a harmonic medium with quantized oscillatory modes. When decomposing such oscillations in Fourier space:

- The vacuum energy is distributed across modes of different frequencies, with each mode contributing an amount proportional to the square of its frequency.

- The normalization of the Fourier transform ensures that these contributions are dimensionally consistent. In n-dimensional spacetime, the Fourier representation introduces a scaling factor proportional to $(1/2\pi)^n$.

For the vacuum in four-dimensional spacetime, this scaling factor becomes $(1/2\pi)^4$, naturally emerging in calculations of vacuum energy density. This factor reflects the transition from continuous spatial coordinates to discrete, quantized oscillatory modes in frequency space. In our framework, the scaling factor $(1/2\pi)^4$ is introduced to account for the vacuum's harmonic structure and its contribution to the quantized confinement of the electron. Combined with the integral of the electric flux, this factor ensures dimensional consistency and reflects the transition from a continuous oscillatory system to a localized mass state:

$$m_e = 2 \cdot \left(\frac{1}{2\pi}\right)^4 \oint_S \Phi_E \, dA.$$

This inclusion highlights the interplay between the vacuum's geometric and oscillatory properties, ultimately leading to a coherent expression for m_e. The presence of $(1/2\pi)^4$ encapsulates the harmonic nature of the vacuum's oscillations, ensuring that the derived mass is consistent with both quantum field theory and classical electromagnetic principles.

Finally, incorporating this factor, and the factor 2 that reflects the vacuum polarization symmetries, we postulate that:

$$m_e = 2 \cdot \left(\frac{1}{2\pi}\right)^4 \oint_S \Phi_E \, dA.$$

Where m_e is the electron mass. Substituting the result of the flux integral, we finally get that:

$$m_e = 2 \cdot \left(\frac{1}{2\pi}\right)^4 \cdot 16\pi^3 e \cdot \epsilon_0 = \frac{4 \cdot e \cdot \epsilon_0}{2\pi}.$$

Consistency check: Relation to Bohr Radius and Vacuum Parameters

As some kind of "consistency check" of the postulate, we can relate the radius $2\pi\epsilon_0$ to the Bohr radius a_0, a fundamental physical constant that defines the most probable distance between the nucleus and the electron in a hydrogen atom's ground state [72] [73]. In the context of atomic physics, a_0 represents the characteristic length scale of atomic structure, arising from a balance between the electrostatic attraction of the nucleus and the quantum mechanical confinement of the electron. The Bohr radius is traditionally derived by considering an electron in a stable orbit around a proton, as governed by Coulomb's law for electrostatic force and the principles of quantized angular momentum. Using these principles, the Bohr radius is expressed as:

$$a_0 = \frac{\hbar}{m_e \cdot c \cdot \alpha}.$$

It can be noted that this implies that

$$m_e = \frac{\hbar}{a_0 \cdot c \cdot \alpha}.$$

Using $a_0 = 2\pi \cdot \epsilon_0$, we have that

$$m_e = \frac{\hbar}{2\pi\epsilon_0 \cdot c \cdot \alpha} \tag{57}$$

Which yields the same numerical result as the previous expression for the electron's mass using the electric flux integral.

This equivalence provides a profound link between the geometric confinement of charge in the vacuum and the spatial scale of atomic structure. The identification $a_0 = 2\pi\epsilon_0$ underscores the centrality of vacuum permittivity, ϵ_0, in shaping both atomic dimensions and the electron's mass. It reflects the vacuum's inherent capacity to sustain electric field lines between charges and suggests that atomic structure itself arises from the vacuum's flexibility to accommodate such fields.

Implications for Vacuum Geometry and Oscillations

By framing the electron mass as a result of charge confinement within a spherical geometry, modulated by the vacuum's oscillatory characteristics, we achieve a deeper understanding of how fundamental particle properties arise from the vacuum itself. This approach bridges atomic-scale phenomena and vacuum dynamics, unifying disparate aspects of quantum field theory and classical electromagnetism into a coherent framework.

The vacuum permittivity ϵ_0 is again confirmed as a measure of the effective deformation that the vacuum can sustain. Since atomic interactions are ultimately mediated by the electromagnetic field, the electron's confinement around the nucleus —the Bohr radius— is not merely a consequence of isolated particle properties but emerges from the vacuum's structural response. The atomic structure itself reflects the flexibility of spacetime under electrostatic interaction, where $2\pi\epsilon_0$ represents the spatial scale over which the vacuum can respond to and accommodate an electron's presence.

The above introduces an elegant physical picture of atomic structure. It implies that the electron's positioning and mass is not only determined by quantum constraints but also by how spacetime itself adapts around the charged particle, creating a stable, bounded region that we observe as the electron.

In this view, atomic size and electron orbitals emerge as a balance between quantum mechanical confinement and spacetime's flexibility, with ϵ_0 serving as a natural measure of this flexibility.

Derivation of the electron's mass from Vacuum Energy Density

An equivalent formulation of the electron mass is given by:

$$m_e = 8 \cdot \rho_{\text{vac}} \cdot \alpha \cdot \frac{1}{16\pi} \cdot \frac{1}{\left(\frac{3}{5}4\pi\right)} = \frac{1}{2}\left(\frac{\mu_0}{c \cdot \pi}\right)^2 = 2 \cdot \mu_0^2 \cdot \rho_{vac_E}^2 = \rho_{vac_E}^2 \cdot \frac{\epsilon_0}{\sqrt{\frac{3}{5}4\pi}} = \frac{4 \cdot e \cdot \epsilon_0}{2\pi},$$

where ρ_{vac_E} is the vacuum energy density measured in J$/m^3$, and each term in the expression contributes distinct physical insights into the electron mass as a manifestation of vacuum properties. Specifically, this equation suggests that m_e originates from the quantum of effective mass of the vacuum, localized within a quantized spatial volume:

- **Quantum of effective Vacuum Mass:** The product $\rho_{\text{vac}} \cdot \frac{1}{16\pi}$ can be interpreted as a "quantum of effective vacuum mass" component. Here, ρ_{vac} represents the vacuum energy density, and the factor $\frac{1}{16\pi}$, as we have seen, acts as a quantum-probabilistic-spatial quantization, effectively defining a finite volume or "spacetime quantum" over which this energy is confined. This quantization term reinforces the notion that the electron mass emerges as a localized energy feature of the vacuum.
- **Geometric Scaling Factors:** The factors 8 and $\frac{1}{\left(\frac{3}{5}4\pi\right)}$ are geometric in nature. The factor 8 accounts for the spatial configuration of vacuum energy density within the volume and captures the three-dimensional nature of this confinement. Meanwhile, $\frac{1}{\left(\frac{3}{5}4\pi\right)}$ is associated with the self-energy and spatial confinement of the electron, derived from a spherical distribution factor often encountered in the analysis of self-interacting fields. This factor adjusts for the electron's internal energy structure and suggests that its mass is not merely a sum of local energy densities but includes self-interaction corrections due to spatial confinement effects.

In summary, this formulation shows how the electron mass m_e is a product of the vacuum's internal geometry, effective energy confinement, and self-interaction adjustments. It reflects the inherent structure and energy density of the vacuum, revealing the electron mass as an emergent, quantized feature of the vacuum's self-interacting and spatially confined properties.

More equivalent expressions for the electron's mass and their interpretations

From the above, we can derive the expression

$$m_e \cdot c^2 = 2\left(\frac{\mu_0}{2\pi}\right)^2$$

From this equation, we can again interpret m_e as a confined form of vacuum energy, originating from the coupling between the vacuum's magnetic permeability and the relativistic structure of spacetime. The electron's rest energy emerges from a relativistic effect confined by the vacuum's magnetic structure. Consequently, this interpretation aligns the electron's mass-energy equivalence with the vacuum's capacity to support magnetic fields, implying that the electron's rest mass is "induced" by the magnetic response properties of the vacuum.

From a dimensional point of view, the expression

$$m_e \cdot c^2 = 2\left(\frac{\mu_0}{2\pi}\right)^2$$

offers a consistent interpretation within this framework. Here, $2\left(\frac{\mu_0}{2\pi}\right)^2$ can be viewed as an equivalent expression for the electron's rest energy, derived from an electric potential squared $V^2 = \mu_0^2$ maintained over a duration $t = 2$ and dissipated through a characteristic resistance $R = (2\pi)^2$, or which is the same, power times time, the total energy transferred or work done over time. This relation not only connects the electron's rest energy to electrodynamic quantities but also demonstrates how energy from an electric field configuration translates to a mass equivalent through the factor c^2, in line with Einstein's mass-energy equivalence $E = mc^2$.

This perspective reinforces the idea that the vacuum's magnetic permeability and spacetime characteristics collectively "induce" the rest energy associated with the electron, highlighting the profound link between matter and the vacuum's fundamental electromagnetic properties.

Linking the electron and the photon as quantized energy states

The above derivations offer insights into the relationship between the electron and photon within the vacuum structure. In the context of this model, both the electron and photon are viewed as quantized energy states of the vacuum, distinguished by their interactions with the vacuum's electromagnetic properties. For the photon, we interpret $\hbar$ as the quantum of angular momentum, leading to an effective relativistic mass when coupled with the vacuum's oscillatory structure. In contrast, the electron's rest mass m_e emerges as a localized resonance of the vacuum's oscillatory states, stabilized by interactions with the electromagnetic field and modulated by factors such as α and ϵ_0.

This approach aligns the electron's rest mass and the photon's effective mass as manifestations of the same underlying vacuum properties, differing only in how each interacts with the vacuum's structure. The electron's mass thus reflects a stable resonance within the vacuum, while the photon's properties align with its propagation mode. This unified view connects the electron and photon as emergent features of the same quantum vacuum, with their mass properties modulated by vacuum constants such as μ_0, ϵ_0, and the fine-structure constant α.

Implications for the Nature of Mass and Charge

In this framework, the mass of the electron appears as an emergent property of the vacuum's structure. This perspective suggests several implications:

- **Mass as Vacuum-Induced:** The dependence of mass on purely vacuum-related physical constants highlight that mass can be viewed as a byproduct of the vacuum's energy density and structure. This aligns with interpretations in which mass is generated by vacuum fluctuations and the spatial constraints of quantum fields.

- **Unification of Electromagnetic and Quantum Properties:** The framework developed unites quantum mechanics with electromagnetic field properties, suggesting that both electron mass and charge originate from the same underlying vacuum dynamics. This unification paves our understanding of how mass and charge are interrelated phenomena, both emergent from vacuum interactions.

- **Role of Geometry and Self-Interaction:** The geometric factors involved highlight the importance of spatial confinement and self-energy adjustments in determining mass. These geometric factors show that the vacuum imposes spatial constraints on energy, resulting in stable, quantized mass values like m_e.

Conclusion: Electron Mass as a Field-Induced Property

By expressing the electron mass in terms of vacuum properties and geometric factors, this framework redefines m_e as a quantity that emerges from the quantum vacuum. The expressions derived provide consistent pathways to interpreting the electron's mass as a field-induced property.

This approach suggests that mass arises a macroscopic manifestation of underlying vacuum dynamics. As a result, electron mass —and potentially all mass— can be seen as a byproduct of confined vacuum energy, modulated by quantized volume constraints and geometric self-interaction effects. This view advances a field-based perspective on mass, linking it intimately to the structure and properties of the vacuum, and could help unify the concepts of mass, charge, and field within a coherent, quantum-vacuum framework.

26.5 The fundamental Relationship Between Photon Energy and Electron Mass

Let us consider the previously postulated equation:

$$m_e = \frac{\hbar}{2\pi\epsilon_0 c\alpha}, \tag{58}$$

This equation suggests a fundamental link between the electron mass and electromagnetic constants. We can explore this relationship further by recalling the concept of the photon's effective relativistic mass $m_{\text{ph rel}} = \frac{h \cdot c \cdot \gamma}{c^2} = \frac{h}{c \cdot \alpha}$, leading to the proportionality:

$$m_e = \frac{m_{\text{ph rel}}}{2\pi\epsilon_0}. \tag{59}$$

To delve deeper into this relationship, we recognize that the term $\frac{1}{2\pi\epsilon_0}$ is directly related to Coulomb's constant K_e, given by:

$$K_e = \frac{1}{4\pi\epsilon_0}.$$

Therefore, we can express:

$$\frac{1}{2\pi\epsilon_0} = 2K_e.$$

Substituting this into our previous equation, we obtain:

$$m_e = m_{\text{ph rel}} \cdot 2 \cdot K_e \tag{60}$$

This formulation highlights a direct proportionality between the electron mass and the photon's effective relativistic mass, scaled by fundamental electromagnetic constants.

Interpreting $2 \cdot K_e$ as Momentum Transfer

In the context of photon-electron interactions, particularly the photoelectric effect, $2 \cdot K_e$ can be interpreted as a factor representing momentum transfer. The factor 2 can be associated with the degrees of freedom related to polarization states of the photon, with dimensions of time, while K_e embodies the strength of the electromagnetic interaction and has dimensions of force. Jointly, we have that $2 \cdot K_e$ is a measuer of force times time, or equivalently, momentum transfer (impulse).

When a photon interacts with an electron, it imparts momentum, effectively transferring an impulse defined by:

$$\Delta p = F \cdot \Delta t,$$

where F is the force exerted, and Δt is the interaction time. The vacuum permittivity ϵ_0 plays a crucial role in modulating this interaction, acting as a mediator that governs the efficiency and discreteness of the momentum transfer.

Relating Impulse to Electron Mass

By interpreting the electron mass m_e as the product of the photon's effective relativistic mass and the momentum transfer, we have:

$$m_e = m_{\text{ph rel}} \cdot \Delta p.$$

This equation suggests that the electron mass emerges from the accumulation of momentum imparted by the photon during the interaction, stabilized by the properties of the vacuum; just as in the photoelectric effect, where the photon's energy and momentum are discretely transferred to the electron.

The electron's mass m_e emerges naturally as the result of this momentum transfer. Some key points that we can summarize from this emergence are:

- **Photon's Effective Relativistic Mass**: $m_{\text{ph rel}}$ serves as the source of the momentum transfer. It embodies the energy and momentum characteristics of the photon relevant to the interaction.

- **Vacuum Permittivity's Role**: $2\pi\epsilon_0$ determines the scale and efficiency of the momentum transfer, ensuring that the interaction is quantized and consistent with electromagnetic laws.
- **Impulse** $2 \cdot K_e$: Reflects the combined effect of the vacuum's mediating properties and the fundamental electromagnetic interaction strength, stabilizing the electron mass as a localized feature within the vacuum.

The interpretation of $\frac{1}{2\pi\epsilon_0}$ as a measure of impulse transfer emphasizes the vacuum's active role in photon-electron interactions:

- **Quantization Support**: The vacuum's structure supports the quantization of energy and momentum exchanges, allowing precise coupling between photon energy and electron dynamics.
- **Geometric and Oscillatory Properties**: The factor $2\pi\epsilon_0$ reflects the inherent geometric and oscillatory characteristics of the vacuum, consistent with electromagnetic wave propagation and interactions.
- **Electron Mass Stabilization**: The emergence of m_e as a stabilized feature underscores the balance between dynamic momentum transfer and the localized confinement of charge, facilitated by the vacuum's permittivity.

The equivalence $\frac{1}{2\pi\epsilon_0} = 2K_e$, interpreted as a measure of impulse transfer, provides a coherent explanation for the relationship between photon and electron masses. It unifies the dynamics of the photoelectric effect with the vacuum's role in mediating electromagnetic interactions. The electron's mass m_e emerges as a direct consequence of the photon's effective mass and the vacuum's ability to regulate impulse transfer through $2\pi\epsilon_0$. This perspective reinforces the view of both the photon and electron as quantized energy states within the vacuum, connected by their mutual interactions and the fundamental constants that govern spacetime dynamics.

Additionally, there are some more reasonable interpretations:

- **Vacuum as the Source of Effective Mass:** In this model, ϵ_0 modulates the vacuum's response to electromagnetic fields and can be viewed as a measure of the vacuum's capacity to support electric fields. Here, m_e can be understood as arising from an interaction between a photon's effective relativistic mass and the vacuum's intrinsic properties. This interpretation aligns with viewing both the photon and the electron as quantized energy packets within the structure of spacetime.
- **Photon and Electron as Quantized Energy Packets:** Both the electron and photon could be seen as distinct manifestations of quantized energy states within the vacuum, where the electron possesses a "rest mass" due to its localized energy concentration and interaction with the vacuum (modulated by ϵ_0), whereas the photon remains massless in a rest frame but acquires an effective mass via relativistic interactions. This could imply a unifying perspective in which both particles are manifestations of vacuum oscillations but differ in their interaction scale and how they acquire inertia or effective mass.
- **The Electron as a Vacuum Resonance Mode:** Alternatively, the electron's mass m_e could be viewed as a resonance of the vacuum's oscillatory states, stabilized through interactions with the electromagnetic field and modulated by α. Here, the electron's mass may emerge as a localized "mode" within a quantized oscillatory structure of the vacuum, distinct from the photon's propagating mode. In this view, ϵ_0 regulates the vacuum's response, allowing a localized state (electron) to emerge with a quantifiable inertia directly linked to the photon's relativistic properties and the vacuum's structure.

Conclusions

In summary, the relationship between the photon's relativistic mass and the electron's rest mass suggests a deep connection between these particles, rooted in the vacuum's intrinsic properties as a quantized and oscillatory medium. This model offers a perspective in which the electron and photon represent different energy states of the vacuum, with their masses determined by fundamental constants such as α and ϵ_0, reflecting the electromagnetic and relativistic properties of the underlying spacetime structure.

26.6 The Masses of the nucleons as Emergent Properties of Vacuum Structure

Introduction

Building on the framework established for the electron's mass, we now explore how the proton's mass m_p and neutron's mass m_n could emerge as a higher-order configuration within the vacuum's electromagnetic structure. Like the electron, the proton and neutron can be viewed as quantized energy states of the vacuum, but their greater masses reflect a more extensive integration of vacuum properties. In this section, we hypothesize how their values could be derived from fundamental constants and specific geometric and interaction-based factors inherent to the vacuum structure.

The expressions proposed are speculative in nature, intended to provide a plausible framework for understanding nucleonic masses within the context of vacuum oscillatory dynamics. These derivations are guided by numerical consistency and theoretical coherence with prior results, serving primarily as illustrative models. While grounded in fundamental physics, the relationships postulated here remain untested and should be interpreted as provisional constructs designed to unify disparate observations under a common theoretical framework.

By drawing parallels to the expressions for m_e, we show that the nucleon masses m_p and m_n can be consistently postulated from diverse expressions involving the vacuum's harmonic oscillatory properties and relativistic interactions with photons and electrons. These derivations exemplify the potential of vacuum-based theories to bridge classical and quantum interpretations of mass generation, despite their current limitations in empirical validation.

Building an expression for proton's mass based on the electron's mass and Bohr's electron's radius formula

As we have derived a theoretically and numerically sound expression for the electron's mass m_e using Bohr radius formula, it is reasonable to hypothesize that analogous principles could guide the construction of expressions for the proton's properties, particularly its mass and radius. While the proton is fundamentally different from the electron —being a composite particle composed of quarks bound by the strong force— it still exhibits well-defined charge distributions and spatial scales that are sensitive to vacuum properties and fundamental constants. By using Bohr's radius formula as a template and incorporating proton-specific parameters, one can explore whether an analogous expression might emerge, linking the proton's mass to its internal structure and interactions with the vacuum. This approach not only provides theoretical insights into mass scaling relationships but also could strengthen the conceptual bridge between quantum electrodynamics and quantum chromodynamics.

For the electron, we had the expression

$$m_e = \frac{\hbar}{a_0 \cdot c \cdot \alpha} = \frac{\hbar}{2\pi\epsilon_0 \cdot c \cdot \alpha} = \frac{m_{\text{ph rel}}}{2\pi\epsilon_0}$$

We can try to derive some expression of the same type, such that

$$m_p = K \cdot \frac{m_{\text{e rel}}}{2\pi\epsilon_0}$$

Where $m_{\text{e rel}} = m_e \cdot \gamma = \frac{m_e}{\alpha}$. Numerically, we find that $K = \frac{1}{2}\rho_{vac_E} \cdot \sqrt{\frac{3}{5}4\pi} = \frac{\mu_0}{4\pi} \cdot \alpha$ suits well. Recall that we have established previously that $E_0 = \frac{\hbar c}{2} = \rho_{vac} \cdot \sqrt{\frac{3}{5}4\pi}$; therefore, applying Einstein's equation and the previous postulates that $\hbar c = m_{ph} \cdot c^2$ and $\frac{1}{\alpha} = \gamma$, we have that

$$m_p = \frac{\hbar c^3}{4} \cdot \frac{m_e \cdot c}{2\pi\epsilon_0 \cdot \alpha \cdot c} = \frac{(m_{ph} \cdot c^2) \cdot (m_e \cdot c^2) \cdot \gamma}{8\pi\epsilon_0}$$

The above can be reexpressed, using Coulomb's constant $K_e = \frac{1}{4\pi\epsilon_0}$, as

$$m_p = \frac{1}{2} K_e \cdot E_{ph} \cdot E_e \cdot \gamma$$

This final result states that the proton's mass, m_p, can be expressed in terms of the Coulomb constant K_e, the photon's energy E_{ph}, the electron's energy E_e, and the Lorentz factor $\gamma = \frac{1}{\alpha}$, related to the fine-structure constant α. This formulation hypothesizes that the proton's mass arises as a coupling of the fundamental energies E_{ph} and E_e, each associated with distinct vacuum excitations: E_{ph} represents the vacuum's quantized linear momentum through the photon, while E_e captures the electron's confined energy within the vacuum. The inclusion of K_e, a measure of electrostatic force within the vacuum, suggests that this coupling occurs through an electromagnetic channel within the vacuum structure.

The presence of γ highlights a relativistic scaling, implying that the proton's mass embodies a relativistic synthesis of photon and electron energies as they interact within the vacuum. This aligns with a view in which the proton mass m_p is not merely a scaled sum of photon and electron energies but rather an emergent, higher-order product of these energies, modulated by the vacuum's intrinsic electromagnetic properties. Thus, the factor γ suggests that the proton mass arises in a framework where both relativistic and quantum vacuum characteristics contribute, with the fine-structure constant α inversely regulating the scale of this interaction.

Furthermore, by relating m_p to $K_e \cdot E_{ph} \cdot E_e$, this result highlights that the proton's mass is tied directly to the electrostatic potential embodied within the vacuum. The appearance of K_e reflects the Coulombic foundation of this structure, reinforcing the notion that nucleonic mass emerges from the vacuum's capability to sustain and integrate multiple energy scales and particle-like excitations. In this framework, m_p signifies a composite interaction, suggesting that the proton's mass is an emergent feature of both electromagnetic and relativistic aspects of the vacuum, collectively shaping the mass scale through the unified presence of photon, electron, and Coulombic constants.

We can conclude that, somehow, the proton's mass arises from a vacuum-mediated interaction between the electron and photon, facilitated by electromagnetic forces (K_e) and relativistic effects (γ). The vacuum acts as a catalyst, enabling the energies of the electron and photon to combine and manifest as the proton's mass. Therefore, in some sense, the proton can be viewed as a collective excitation of the vacuum, involving the electron and photon. The vacuum's energy, modulated by Coulomb's constant and the Lorentz factor, coalesces into a stable, localized entity—the proton.

This interpretation can be illustrated with an analogy: consider a strong current meeting calm water. At their boundary, the contact and friction generate continuous swirls—localized deformations that arise naturally to balance the interaction between the fast-moving and still regions. Similarly, the non-relativistic spacetime can be thought of as a calm medium, while the expanding vacuum and its localized excitations such as photons and electrons represent the strong current interacting with it. The resulting "swirls" in the vacuum are deformations or localized energy structures that stabilize these interactions. The proton's mass (and, in general, all mass) could then be viewed as a stable, emergent structure, shaped by the interplay between electromagnetic forces and relativistic scaling effects within the vacuum. This analogy highlights the role of the vacuum as an active participant, redistributing and integrating energy into a coherent, stable form, analogous to how swirls stabilize the energy transfer between fluid layers.

This interpretation of the proton mass has profound implications for our understanding of particle physics, cosmology, and potentially quantum gravity. It suggests a deeper unification of fundamental particles and forces, where mass emerges as a dynamic property of the vacuum's intricate structure.

Proton Mass as a Vacuum-Mediated Equilibrium Response

In the equation derived before for the proton's mass, we can substitute to obtain an alternative expression:

$$m_p = K \cdot \frac{m_{\text{e rel}}}{2\pi\epsilon_0} = \frac{\frac{\mu_0}{4\pi} \cdot m_e}{2\pi\epsilon_0} = \frac{\mu_0 \cdot m_e}{\epsilon_0 \cdot 8\pi^2} = \frac{1}{2} m_e \left(\frac{Z_0}{2\pi}\right)^2$$

The expression

$$m_p = \frac{1}{2} m_e \left(\frac{Z_0}{2\pi}\right)^2$$

can be interpreted as suggesting that the proton's mass, m_p, emerges as a scaled effect of the electron mass, m_e, modulated by vacuum impedance characteristics. The presence of the factor $\left(\frac{Z_0}{2\pi}\right)^2$, where Z_0 is the vacuum impedance, links the proton's mass to a specific configuration of the vacuum's electromagnetic properties. Within this framework, the impedance Z_0 represents the vacuum's inherent response to electromagnetic fields, encapsulating how electric and magnetic interactions propagate through the vacuum. This scaling factor could signify that the proton mass is a "higher order" or "integrated" response of the vacuum, relative to the electron mass, which itself is emergent from the vacuum's structural characteristics and electromagnetic fields.

If we rewrite the right-hand side in integral form as

$$m_e \int \frac{Z_0}{2\pi} \, d\left(\frac{Z_0}{2\pi}\right),$$

we can also interpret this as an accumulation or summation of vacuum interactions, where each differential element $d\left(\frac{Z_0}{2\pi}\right)$ represents an infinitesimal contribution of the vacuum's electromagnetic impedance. Such an interpretation aligns with a view of mass as a quantized, emergent property derived from the vacuum's response to electromagnetic oscillations. Here, the proton's mass arises as a composite effect of the vacuum's impedance structure, with each incremental impedance layer contributing to the proton's effective inertia. This integral suggests that, unlike the electron, the proton's mass embodies a more "collected" vacuum structure—one that accumulates impedance effects over a defined scale or range of oscillatory modes.

In sum, from this expression we can infer that the proton's mass can be understood as the vacuum's way of restoring equilibrium to a spacetime deformation created by the electron's mass, charge, and the vacuum's electromagnetic properties. When the electron arises within the vacuum as a localized deformation due to its mass and charge, the vacuum, characterized by its impedance Z_0, responds by integrating these effects over a broader range, creating a larger, more stable structure: the proton. This process is like the vacuum "balancing" the localized deformation caused by the electron through a collective response that extends across multiple oscillatory modes of spacetime. The proton's greater mass reflects this cumulative adjustment, serving as a higher-order configuration that restores equilibrium within the vacuum, ensuring the coherence of spacetime and electromagnetic interactions.

Proton Mass as an Emergent Property: Fourier Interpretations

Operating further, we have that the proton's mass can be expressed as:

$$m_p = 2 \cdot \left(\frac{1}{2\pi}\right)^3 \cdot \mu_0 \cdot e, \tag{61}$$

Which, through the relationship $h = \frac{\mu_0 \cdot e}{c}$, becomes also

$$m_p = 2 \cdot h \cdot c \cdot \left(\frac{1}{2\pi}\right)^3 = 2 \cdot \left(\frac{1}{2\pi}\right)^3 \cdot E_{ph}$$

As we have already seen, this expression is consistent with Fourier transforms, particularly in the context of harmonic oscillatory systems. The factor $\left(\frac{1}{2\pi}\right)^3$ naturally arises in Fourier transforms calculations involving oscillatory modes, as the normalization factor in Fourier space for three-dimensional wave-vectors. This normalization ensures consistency between spatial and frequency domains, aligning with how vacuum energy is distributed across oscillatory modes.

The proposed relationship for m_p aligns with the harmonic oscillatory nature of the vacuum and the scaling factors observed in similar derivations:

- **Vacuum Energy and Scaling:** The cubic dependence of $\left(\frac{1}{2\pi}\right)^3$ reflects the three-dimensional nature of vacuum energy distribution in Fourier space, emphasizing the isotropy of vacuum oscillations.
- **Electromagnetic Interaction:** The term $\mu_0 \cdot e = \hbar \cdot c$ connects the proton's mass to the interplay of charge and vacuum response, highlighting how vacuum energy manifests as localized, quantized mass-energy in stable particles like the proton.

The Fourier factor $\left(\frac{1}{2\pi}\right)^3$ reflects that the proton's mass encapsulates a discrete energy state within the continuous vacuum oscillatory spectrum. The presence of $\mu_0 \cdot e$ underscores the electromagnetic basis of the vacuum in defining particle mass, linking m_p to both charge and the vacuum's ability to sustain oscillations. This expression complements prior derivations of m_p in terms of ρ_{vac}, ϵ_0, and α, reinforcing the unified picture of particle mass as arising from the quantized, oscillatory nature of the vacuum.

From other interesting perspective, the proton's mass can be somehow interpreted as a quantized and localized equivalent of "trapped" or confined photon energy within the vacuum. The expression $m_p = 2 \cdot h \cdot c \cdot \left(\frac{1}{2\pi}\right)^3$ suggests that the vacuum acts as a structured medium capable of confining electromagnetic energy into stable configurations. The Fourier normalization factor $\left(\frac{1}{2\pi}\right)^3$ reflects the isotropy and three-dimensional distribution of vacuum oscillatory modes, which together create the conditions necessary for this energy $(h \cdot c)$ to be "trapped" and localized. This perspective highlights the proton as a harmonic resonance within the vacuum's oscillatory spectrum, stabilized by the vacuum's electromagnetic and geometric constraints.

Electron Mass as a Base Scale in the Vacuum Structure

Also, note that we can operate to get that:

$$m_p = \left(\frac{m_e \cdot c^2}{2}\right)^2 = \left(\frac{\mu_0}{2\pi}\right)^4,$$

and also, it can be derived from the previous formulas that

$$m_p = \frac{2 \cdot \rho_{vac_E}^2 \cdot \mu_0 \cdot 2\alpha}{2\pi}$$

Notice that we have established previously that $\mu_0 \cdot 2\alpha = \frac{e}{\epsilon_0}$ (45); substituting, the expression becomes

$$m_p = \frac{2 \cdot \rho_{vac_E}^2 \cdot e}{2\pi\epsilon_0}$$

The expression $m_p = \left(\frac{m_e \cdot c^2}{2}\right)^2$ expresses how the proton mass is related to a "squared" version of the electron's rest energy action, reflecting a higher-order interaction with the vacuum. This interpretation suggests that the electron's rest energy acts as a foundational scale, with the proton mass representing an amplified confinement of this energy due to more intense vacuum interactions, such as those mediated by the strong force within nucleons.

The presence of $\left(\frac{\mu_0}{2\pi}\right)^4$ in the same expression further reinforces this view, highlighting that the vacuum's magnetic permeability μ_0 plays a fundamental role in establishing the mass scale of protons, which emerge from deep interactions with the electromagnetic vacuum structure.

Unified Framework for Particle Masses

By considering all the previous expressions together, we see that the masses of the proton and electron are each derived from common vacuum properties but differ in their respective interactions and confinement factors. The electron mass serves as a base mass from which proton mass can be derived through interaction scaling and confinement adjustments unique to the vacuum's structure. This unified framework reinforces the view that mass is an emergent phenomenon shaped by the vacuum's electromagnetic and geometric properties. It emphasizes the idea that all particle masses can be viewed as specific manifestations of vacuum energy, structured by fundamental constants and geometric factors that govern confinement and interaction strength.

The Mass of the Neutron as an Emergent Property of Spacetime Transformations

As it makes sense both theoretically and numerically, we propose that the neutron's mass m_N arises from the relativistic energy of the electron, modulated by spacetime transformations. Specifically, we express m_N as:

$$m_N = \frac{m_e \cdot \gamma}{S_{EH} \cdot \frac{3}{5} 4\pi},$$

where m_e is the electron mass, $\gamma = 1/\alpha$ is the Lorentz factor associated with the fine-structure constant α, S_{EH} is the Einstein-Hilbert action, and $\frac{3}{5}4\pi$ is a geometric factor arising from vacuum confinement.

The numerator $m_e \cdot \gamma$ represents the relativistic electron mass, highlighting that the neutron originates from the relativistic scaling of the electron's energy. The Lorentz factor γ introduces a direct dependence on α, emphasizing the interplay between quantum and relativistic effects in mass generation.

The Einstein-Hilbert action S_{EH} represents the quantum-probabilistic, four-dimensional spacetime, reflecting how spacetime curvature probabilistically transforms the relativistic electron energy into the neutron configuration. This action introduces a normalization that captures the probabilistic nature of spacetime in the vacuum framework.

Finally, the factor $\frac{3}{5}4\pi$ reflects the efficiency of spherical energy confinement within the neutron's structure. It aligns with earlier discussions of vacuum oscillatory modes and packing factors, suggesting that the neutron's mass is shaped by these geometric constraints.

Interpretation and Implications

This expression suggests that the neutron mass emerges as a higher-order configuration of the vacuum, requiring the relativistic energy of the electron to undergo a spacetime-mediated transformation. The neutron represents a stabilized energy state, shaped by the interplay between relativistic quantum effects, spacetime geometry, and vacuum oscillatory constraints. This perspective aligns with the broader framework of the paper, where particle masses are viewed as emergent properties of the quantum vacuum and spacetime interactions.

26.7 Interpreting the Relationship Between Fundamental Particles and the Quantum Vacuum

Electron-Proton Mass Ratio as a Reflection of Vacuum Structure

An intriguing relationship emerges when interpreting the proton-to-electron mass ratio in terms of vacuum properties. From the postulated equations $m_e = \rho_{vac_E}^2 \cdot \frac{\epsilon_0}{\sqrt{\frac{3}{5}4\pi}}$ and $m_p = \frac{2\cdot\rho_{vac_E}^2\cdot\mu_0\cdot 2\alpha}{2\pi}$, we have that

$$\frac{m_p}{m_e} = \frac{\frac{2\cdot\rho_{vac_E}^2\cdot\mu_0\cdot 2\alpha}{2\pi}}{\rho_{vac_E}^2 \cdot \frac{\epsilon_0}{\sqrt{\frac{3}{5}4\pi}}} = \frac{\mu_0 \cdot 2\alpha \cdot \sqrt{\frac{3}{5}4\pi}}{\pi\epsilon_0}$$

We have established in previous sections that $\mu_0 \cdot 2\alpha$ equals the electric flux of the elementary charge $\frac{e}{\epsilon_0}$ (45). Thus, substituting, we have that

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

In previous sections, we have established that $2 \cdot e \cdot \sqrt{\frac{3}{5}4\pi} = \int \rho_{vac}\, dc = \rho_{vac} \cdot c$ (23.1). Therefore, we can substitute to finally get that

$$\frac{m_p}{m_e} = \frac{\rho_{\text{vac}} \cdot c}{4\pi\epsilon_0^2}$$

where $\rho_{\text{vac}} \cdot c$ represents a relativistic energy-momentum density derived from the vacuum, and $4\pi\epsilon_0^2$ serves as a geometric factor connected to spacetime's permittivity, ϵ_0. Here, $4\pi\epsilon_0^2$ can be interpreted as the "surface area" of a hypothetical sphere of radius ϵ_0, representing spacetime's flexibility in response to electric field influences.

This expression aligns with the concept that both mass and charge are emergent properties influenced by vacuum characteristics. The proton-electron mass ratio can therefore be viewed as an intrinsic "constraint" of the vacuum structure:

- **Proton-Electron Mass Ratio as a Vacuum Constraint:** The difference between the proton and electron masses may reflect a state of equilibrium within the structured vacuum, where the proton represents a dense, stable configuration of confined vacuum energy that complements the electron's mass and charge properties. In this interpretation, the mass ratio encapsulates a "balanced" response within the vacuum field: a coherent, stable configuration that minimizes the system's overall energy.

- **Equilibrium Point within the Vacuum Field:** The proton-electron mass ratio can thus be interpreted as an equilibrium point achieved within the vacuum's intrinsic structure. In this framework, the electron's presence in the vacuum generates a corresponding high-density "response" that manifests as the proton, with the ratio of their masses reflecting the vacuum's capacity to organize itself into stable, quantized particle configurations. This balance suggests that the vacuum field naturally "seeks" stability by forming particle pairs with complementary properties, both in mass and charge, which further reinforces the proton's role as a stabilizing counterpart to the electron in atomic structures.

- **Unified Stability in the Vacuum Field:** From this perspective, the proton-electron mass ratio can be seen as a fundamental equilibrium that emerges from vacuum polarization effects and energy confinement properties. This relationship indicates that the vacuum does not simply accommodate mass and charge but actively structures itself to maintain a stable, low-energy configuration between complementary entities such as the electron and proton, resulting in a unified field structure that defines fundamental particle properties.

In summary, the proton-to-electron mass ratio is more than a numeric value; it represents an equilibrium point within the vacuum field. This ratio reflects how the vacuum organizes its energy and polarization to support stable, quantized structures, highlighting the fundamental role of the quantum vacuum in determining the properties of matter.

The Neutron's Role in Vacuum-Induced Structure

The neutron, while electrically neutral, plays a key role in stabilizing atomic nuclei. Its mass suggests it is a balanced energy configuration within the vacuum:

- **Nuclear Stability and Neutrality:** Neutrons stabilize nuclei by contributing mass without polarization, buffering electrostatic repulsion between protons.
- **Beta Decay and Charge Separation:** In beta decay, the neutron's transition to a proton and electron reflects the vacuum's ability to shift between neutral and charged configurations, emphasizing the vacuum's dynamic structure.

This framework presents the fundamental particles as emergent structures within the quantum vacuum. Their masses and charges are not independent but are interdependent responses to vacuum dynamics, forming a cohesive, balanced field structure that supports stable atomic configurations. This perspective unifies particle properties as vacuum-induced phenomena, highlighting the quantum vacuum's role in determining fundamental properties of matter.

Concluding Remarks on Vacuum-Induced Particle Properties

The framework presented in this section advances the understanding of fundamental particles as emergent properties of the quantum vacuum. By deriving the masses of the electron, proton, and neutron from the vacuum's geometric and electromagnetic structure, we postulate that these particles are not isolated entities but rather stabilized configurations of energy within the vacuum. The interdependence of their properties, such as the proton-to-electron mass ratio, highlights the vacuum's role as an active mediator that balances mass, charge, and energy across varying scales.

This perspective unifies particle physics with the geometric and dynamic properties of the vacuum, emphasizing the centrality of fundamental constants such as μ_0, ϵ_0, and α. The analogy of particles as localized oscillatory modes within the vacuum illustrates the balance between relativistic and quantum effects that give rise to stable masses and charges. Furthermore, the role of spacetime flexibility, captured through factors like $4\pi\epsilon_0^2$, underscores the vacuum's capacity to mediate and stabilize energy across distinct configurations.

The implications of this work are far-reaching, offering new avenues for exploring the quantum vacuum's role in cosmology and unifying quantum field theory with spacetime geometry. If particle properties can be consistently derived from first principles tied to vacuum structure, this could bridge gaps between quantum mechanics and general relativity. Ultimately, this approach positions the vacuum not merely as a passive background but as the foundational entity governing the emergence of matter, energy, and spacetime.

Part V: Proposal of a Cosmological model based on the General Framework and derived relationships

Note: Self-consistency of the model in a four dimensional framework

Before postulating a model that requires an additional antimatter dimension to facilitate energy exchanges between matter and antimatter universes, it is important to note that the results obtained until this stage of the paper are self-consistent within a $(3+1)$-dimensional vacuum that has an inherent capacity to generate and sustain internal resonances. These resonances give rise to curvature effects and energy fluctuations, without the need for inter-dimensional exchanges of energy.

Within this structure, the zero-point energy originates in the same way that energy is stored in a system of coupled oscillators. The vacuum's $(3+1)$-dimensional resonance produces a field of quantum fluctuations where the minimum energy (or zero-point energy) naturally emerges from the vacuum's self-interaction. In this framework, zero-point energy is generated due to the uncertainty principle, which prevents the vacuum from being in absolute rest. Instead of requiring energy from another universe or an additional dimension, the vacuum confines itself to a minimum-energy state where quantum oscillations cannot disappear, generating a residual energy density that we identify as zero-point energy. These minimum quantum-probabilistic energy generates internal resonances in four dimensions that produce a "confinement effect" that mimics the additional energy typically attributed to an extra dimension. The self-confining nature of the vacuum imposes a limit on fluctuations, similar to the limit that would be expected in a higher-dimensional structure, but without the need for such dimensions.

Similarities with Resonance Effects in Classical Systems

To better understand this plausible internal self-resonance of the vacuum, it is useful to draw an analogy with classical oscillator systems:

- **Analogy with Vibrating Strings:** In a vibrating string fixed at both ends, vibration modes are quantized, and each mode has a defined resonant frequency. Similarly, the $(3+1)$-dimensional vacuum has oscillation modes that are confined and resonate within spacetime, producing a resonance frequency that represents the vacuum's zero-point energy. The geometric factor $\frac{1}{16\pi}$ can thus be interpreted as a quantum-probabilistic coefficient that reflects the self-resonant spatial configuration of the vacuum.

- **Casimir Effect as an Example of Self-Resonance:** This phenomenon resembles the Casimir effect, where zero-point energy is altered by the geometry and boundary conditions of space. Here, the vacuum confines its own energy to a self-resonant $(3+1)$-dimensional structure that does not require an extra dimension to explain the observed zero-point energy density.

This approach interprets the zero-point energy as an internal and self-confining property of the $(3+1)$-dimensional quantum vacuum. The factor $\frac{1}{16\pi}$, in this context, represents the vacuum's capacity to self-resonate and maintain a stable minimum oscillation energy. This four-dimensional model is sufficient to explain the vacuum structure, energy fluctuations, and the generation of zero-point energy without the need for a fifth dimension.

Why does it makes sense to introduce the possibility of an interaction with an antimatter dimension

However, incorporating the postulate that zero-point energy arises from energy exchanges across a matter-antimatter dimension introduces a more dynamic and encompassing explanation of vacuum energy phenomena. While the four-dimensional framework is self-consistent, the addition of a matter-antimatter dimension allows for a broader interpretation that integrates quantum and cosmological effects more seamlessly. Specifically, this inter-dimensional exchange offers a mechanism for sustaining zero-point energy as a continuous, non-local process, implying a deeper connection between opposing states of matter that oscillate across dimensions. This additional layer can provide a more intricate explanation for phenomena like particle-antiparticle pair creation and annihilation, which are essential to our understanding of quantum fluctuations in the vacuum.

More concretely, introducing this fifth dimension let us potentially unify certain cosmological and quantum phenomena. For example, we will show how the exchange across matter-antimatter dimensions might provide an intrinsic mechanism for dark energy or cosmic expansion, linking zero-point energy with cosmological effects in a way that the four-dimensional model cannot fully address. In this scenario, zero-point energy becomes not just a product of isolated quantum fields, but a direct result of large-scale, interdimensional interactions. This alignment between micro and macro scales could offer insights into unresolved questions in cosmology, such as the cause of the accelerating expansion of the universe, which remains elusive in a strictly four-dimensional model. Additionally, we will potentially shed light on the nature of black holes, linking them to regions where the boundary between matter and antimatter is exceptionally thin or even non-existent.

In summary, while the four-dimensional framework provides a minimalist and mathematically elegant approach, the inclusion of a matter-antimatter dimension offers a richer structure that may yield new insights into both quantum field interactions and cosmological dynamics. By extending the model into a fifth dimension, we gain an additional layer of interpretative flexibility, where the zero-point energy can be understood as an active, oscillatory balance across dimensions, potentially leading to a more comprehensive understanding of the universe's foundational forces and structure.

27 Relativistic Expansion within an Antimatter Universe: A Framework for Particle-Antiparticle Interactions

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

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

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

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

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

Recall that we have established previously that $I_{min} = e \cdot c = Y_0^4 = \frac{1}{Z_0^4}$ (44). 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

$$E_0 = \frac{\hbar \cdot c}{2} = \frac{\epsilon_0^5}{\mu_0^5} \tag{62}$$

This expression for E_0 as the zero-point energy captures the hypothetical 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, we explore the possibility that some 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 would permit 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.

27.2 Antimatter as an Extra Dimension

In traditional physics [74], 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 hypothesized extended 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 extended 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 could explain why we don't observe large amounts of antimatter in the universe despite theoretical expectations from the Big Bang.

Black Holes and the Thinning of the Matter-Antimatter Boundary

Given the previous extended framework, we can propose a novel interpretation of black holes [75] 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 is inversely proportional to 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 [76] [77]. 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, as we have that $h = \epsilon_0^3$, we can connect ϵ_0 to be inversely proportional to the "thickness" of the boundary between matter and antimatter. The weakening of the boundary and the increase of the zero-point energy E_0 leads to an increase in ϵ_0, which implies that the spacetime becomes easier to deform (as the boundary becomes "thinner"). And, as we have established that ϵ_0 is linearly proportional to the gravitational constant G, this leads to an increase in the gravitational force. At the same time, the "speed of light" c decreases, as it is inversely related to ϵ_0.

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.

Black Holes as special conduits of universe-anti-universe Energy Exchange

In line with the above, in our extended framework, 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 [78]. 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 [79], 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 [80]. 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 [81]. 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 [82], 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 [83] have revealed that immense amounts of energy are released in the form of gravitational waves [84]. 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) [85] 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 growth of G as the boundary thins may help prevent the formation of true singularities inside black holes [86]. 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 they 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.

27.3 Quantum Harmonic Oscillators as Matter-Antimatter Interactions inside quantum black holes

In this extended 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 become 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 [80] [87]. 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.

In our extended framework, 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 extended model could potentially validate 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 [88] [89].

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.

28 Interpreting Dark Matter as an Emergent Effect of Vacuum Black Holes and Vacuum Energy

As anticipated at the end of the last section, in our extended framework 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.

28.1 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 zero-point energy, and by their intrinsic relationship in our extended framework, quantum-scale black holes, are the primary contributors to dark matter effects on cosmic scales. 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.

28.2 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.

28.3 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.

28.4 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.

28.5 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.

28.6 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.

28.7 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.

29 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.

29.1 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.

29.2 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.

29.3 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.

29.4 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.

29.5 Compatibility of Gravitational EMF Mechanism with Matter-Antimatter Interactions

The proposed mechanism, where gravitational force arises as an electromotive force (EMF) generated by magnetic-like flux variations in the vacuum, is compatible with the framework of matter-antimatter interactions mediated by quantum black holes. This compatibility is rooted in the shared foundation of vacuum oscillations, energy fluxes, and spacetime deformations.

Vacuum Oscillations and Magnetic Flux Fluctuations

The proposed mechanism interprets gravitational force as a consequence of oscillatory dynamics in the vacuum, producing magnetic-like flux variations akin to those in Faraday's law of electromagnetic induction:

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

where $\mathcal{E}$ is the induced EMF and Φ_B is the magnetic flux. These flux variations arise naturally from the behavior of the vacuum, modeled as a system of harmonic oscillators.

In the context of matter-antimatter interactions, quantum black holes mediate energy exchanges that amplify these oscillatory behaviors:

- Quantum black holes act as resonators, amplifying local vacuum oscillations and generating coherent field variations.

- Matter-antimatter annihilation processes produce energy fluxes that deform spacetime, inducing magnetic-like fluctuations in the vacuum.

These flux variations drive the emergence of an effective EMF, which manifests as the gravitational interaction in this framework.

Role of Matter-Antimatter Interactions

Within the proposed theory, matter-antimatter interactions are facilitated by quantum black holes, which serve as conduits for energy redistribution. These interactions create localized oscillations in the vacuum that align with the mechanism for EMF generation:

- The annihilation of matter and antimatter releases energy that propagates as oscillatory disturbances in spacetime.
- These disturbances modulate the vacuum's intrinsic properties, such as permeability (μ_0) and permittivity (ϵ_0), generating localized electromagnetic and gravitational effects.
- Quantum black holes act as points of coherence, enhancing the vacuum's oscillatory response and enabling consistent flux variations.

The interaction of these oscillations with the vacuum's geometric properties reinforces the proposed EMF mechanism, linking the gravitational force to quantum black hole dynamics.

Four-Dimensional Self-Consistency

Both the vacuum oscillation mechanism and the theory of quantum black holes are inherently four-dimensional and self-consistent. The proposed compatibility is maintained through:

- The vacuum as a four-dimensional harmonic oscillator, with quantum black holes acting as perturbative elements inducing resonances.
- Lorentz-invariance, ensuring that the mechanisms proposed remain consistent under relativistic transformations.

This four-dimensional framework integrates quantum black hole dynamics with vacuum oscillations, providing a unified description of gravitational and electromagnetic interactions.

Conclusion

The proposed mechanism, where gravitational force emerges as an EMF generated by magnetic flux variations in the vacuum, is fully compatible with the theory of matter-antimatter interactions mediated by quantum black holes. Quantum black holes enhance and regulate the energy exchange processes that drive vacuum oscillations, ensuring coherence and amplifying the induced EMF. This synthesis demonstrates a robust theoretical foundation linking quantum-scale interactions to macroscopic gravitational phenomena, supporting a unified view of electromagnetic and gravitational forces.

29.6 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.

30 Final Conclusions and Remarks

30.1 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 dimensional framework, both in a conventional $(3+1)$-dimensional cosmology and in an extended $(4+1)$-dimensional cosmology incorporating the matter-antimatter dimension. 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.

30.2 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 hypothesized $(4+1)$-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.

30.3 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.

30.4 Mass-Energy as Spacetime Deformation: A Unified Interpretation

Einstein's general theory of relativity revolutionized our understanding of the universe by showing that mass-energy deforms spacetime, and that this deformation governs the gravitational interaction. In this framework, the presence of mass-energy curves spacetime, creating the phenomena we perceive as gravity. This groundbreaking insight unified the geometry of spacetime with the physical properties of mass-energy, laying the foundation for modern cosmology.

This work builds upon and extends Einstein's theory by taking a crucial step further: mass-energy does not merely deform spacetime; it is itself a manifestation of deformed spacetime. The entities we recognize as mass, energy, and charge are emergent phenomena arising from localized, quantized excitations within the vacuum. These excitations are super-complex accumulations of oscillatory modes in the vacuum, which, when aggregated, give rise to deformations that we perceive as mass, energy, and charge.

In Einstein's framework, spacetime and mass-energy are intimately connected, with mass-energy acting as the source of spacetime curvature. Here, we reinterpret this relationship through the lens of vacuum dynamics: mass-energy is not external to spacetime but is a direct manifestation of its geometry. The quantized excitations within the vacuum are the building blocks of this deformation, creating localized regions where spacetime assumes specific properties—interpreted as the physical quantities of mass, energy, or charge.

The dimensional equivalence $[M] = [L] = [T]$, introduced in the dimensional analysis section, provides the theoretical basis for this reinterpretation. It suggests that mass, length, and time are not distinct entities but interchangeable aspects of the same fundamental spacetime structure. This equivalence is confirmed in the derivations of the electron and proton masses, where vacuum interactions produce discrete, quantized deformations corresponding to the observed masses of these particles. The vacuum, modeled as a system of harmonic oscillators, inherently gives rise to these localized properties through its intrinsic oscillatory dynamics, indicating that what we perceive as mass is simply the geometric expression of vacuum excitations localized in spacetime.

This perspective fundamentally alters our understanding of spacetime and matter. The vacuum, far from being empty, is a dynamic, oscillatory system capable of sustaining localized excitations. These excitations manifest as spacetime deformations, which we observe as physical phenomena such as mass, energy, and charge. Gravity, electromagnetism, and quantum interactions can thus be interpreted as emergent behaviors arising from the interplay of these deformations. Spacetime is no longer a passive stage upon which mass-energy acts. Instead, it becomes the active medium through which all physical phenomena emerge. The properties of the universe—such as the constants G, $\hbar$, and e—are seen as emergent from the vacuum's oscillatory dynamics, further reinforcing the unity of mass-energy and spacetime.

By integrating Einstein's insights into the behavior of spacetime with the quantum dynamics of the vacuum, this model provides a unified view where mass-energy and spacetime are inseparable. What Einstein described as the deformation of spacetime by mass-energy is here reinterpreted as mass-energy being deformed spacetime itself—a continuous interplay of probability, geometry and localized excitations. This view unites quantum mechanics and general relativity within a single conceptual framework, offering a deeper understanding of the universe's fundamental nature.

30.5 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 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.

30.6 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.

31 Comparison of the predicted values of the model with their measured or accepted values

Constant	Model Value	Measured/Accepted Value	Difference (%)
Speed of Light c	298,953,375.96 m/s	299,792,458 m/s [90]	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 [91]	0.875
Impedance of Free Space Z_0	378.992809 Ω	376.7303309 Ω [92]	0.597
Fine-structure Constant α	0.007245186	0.007297353 [93]	0.720
Planck Constant h	$6.87537997 \times 10^{-34}$ J·s	$6.62607000 \times 10^{-34}$ J·s [94]	3.626
Reduced Planck Constant $\hbar$	$1.09425071 \times 10^{-34}$ J·s	$1.05457179 \times 10^{-34}$ J·s [95]	3.626
Elementary Charge e	$1.62133463 \times 10^{-19}$ C	$1.60217000 \times 10^{-19}$ C [96]	1.182
Gravitational Constant G	$6.65467243 \times 10^{-11}$ m³/kg·s²	6.67430×10^{-11} m³/kg·s² [22]	0.295
Casimir constant C_c	$\frac{\pi^2 \cdot \hbar c}{240}$	$\frac{\frac{\hbar c}{2}}{4\pi}$ [46]	0.114
Boltzmann Constant k_B	$1.4187414 \times 10^{-23}$ J/K	1.380649×10^{-23} J/K [97]	2.666
Cosmological Constant Λ	$1.11472916 \times 10^{-52}$ m^{-2}	1.1056×10^{-52} m^{-2} [98]	0.819
Hubble Constant H_0	$2.23189185 \times 10^{-18}$ s^{-1}	2.22×10^{-18} s^{-1} [40]	0.533
Vacuum Energy Density (J/m³) ρ_{vac}	$5.32373794 \times 10^{-10}$ J/m³	5.35×10^{-10} J/m³	0.493
Vacuum Energy Density (kg/m³) ρ_{vac}	$5.95675510 \times 10^{-27}$ kg/m³	5.96×10^{-27} kg/m³ [99]	0.054
Electron mass (kg) m_e	$9.1099994 \times 10^{-31}$ kg	$9.1093837 \times 10^{-31}$ kg/m³ [99]	0.007
Proton mass (kg) m_p	1.65726×10^{-27} kg	1.67274×10^{-27} kg [99]	0.934
Neutron mass (kg) m_n	$1.6765152 \times 10^{-27}$ kg	$1.6749274 \times 10^{-27}$ kg [99]	0.095

Table 3: Comparison of model values for physical constants with their measured or accepted values and the percentage differences.

32 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	$G = R^2\epsilon_0 = \frac{X_N}{c} = \alpha \cdot h \cdot c \int c\, dc$
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 - reciprocal of the quality factor Q			$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} = e \int c\, dc = \frac{1}{\gamma}$
Quality Factor Q (Lorentz factor)			$Q = \gamma = \frac{1}{\alpha} = \sqrt{\frac{\mu_0}{G}} = \frac{\mu_0 \cdot c}{\sqrt{\frac{3}{5}4\pi}} = \frac{2}{e \cdot c^2}$
Inductive Reactance X_N - Quantum-probabilistic spacetime			$X_N = R \cdot \alpha = \frac{R^2}{Z_0} = G \cdot c = \frac{1}{16\pi}$
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			$\Lambda = h \cdot e = \frac{e^2}{c^2 Z_0}$
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}			$P_{kin} = h \cdot \int c\, dc = \frac{\sqrt{\frac{3}{5}4\pi}}{c^2} = \frac{e \cdot c}{2} \cdot \mu_0 = 2 \cdot \frac{4\pi G\rho_{vac}}{\alpha}$
Electron's mass m_e			$m_e = \frac{\hbar}{2\pi\epsilon_0 \cdot c \cdot \alpha} = \frac{m_{\text{ph rel}}}{2\pi\epsilon_0} = 2 \cdot k_e \cdot m_{\text{ph rel}} = m_{\text{ph rel}} \cdot \Delta t$
Proton's mass m_p			$m_p = \frac{1}{2}K_e \cdot E_{ph} \cdot E_e \cdot \gamma = \frac{1}{2}m_e\left(\frac{Z_0}{2\pi}\right)^2 = 2 \cdot h \cdot c \cdot \left(\frac{1}{2\pi}\right)^3 = 2 \cdot \left(\frac{1}{2\pi}\right)^3 \cdot E_{ph}$
Neutron's mass m_n			$m_n = \frac{m_e \cdot \gamma}{S_{EH} \cdot \frac{3}{5}4\pi}$

Table 4: Updated Summary of Analogous Components, Fundamental Constants, and Derived Relationships in the Unified Cosmological Framework

33 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:

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

With a sense of excitement, I shared this observation on an online physics forum, specifically at *Physics Stack Exchange* [100], 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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