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A Novel Theory of a 4D Space: Unifying Quantum Mechanics and Relativity

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Abstract: ***This paper introduces a framework to the novel Theory of Space that seeks to unify quantum mechanics and special relativity by redefining the fourth dimension as an energy-dependent longitudinal parameter. The theory posits that quantum systems oscillate between observable three-dimensional (3D) space and the energetic fourth dimension $\lambda p = C\tau$, where $\tau = h/E$ is Planck's periodic time. It offers a new explanation for quantum superposition, the measurement problem, and entanglement through random 3D projections from a 4D superposition, thus removing the necessity for observer-induced collapse theories or many-worlds interpretations. It resolves the wave particle duality by treating quantum oscillating space and compact entities (e.g., mass particles or pulsed fields) as coexisting. The Bell's inequality violations are addressed via a fourth-dimensional locality during the oscillation, preserving 3D causality of entangled particles. The model also reinterprets relativistic effects as scale changes driven by energy and proposes a gravitational mechanism via an inward space flow proportional to energy content. A testable prediction is provided through a photon tunneling experiment, demonstrating sinusoidal probability variations. Additional prediction for no time dilation during free fall body's is made. This framework offers a unified, realistic, and local description of quantum and relativistic phenomena, with implications for future experimental validation.***

Keywords: Quantum mechanics, special relativity, 4D oscillation, space-time unification, quantum measurement

1. Introduction

The Theory of Space, proposed by Mazzini [1,2,3,4,5,6], offers a unified framework for quantum mechanics (QM) and special relativity (SR) by redefining the fourth dimension as an energy-linked longitudinal parameter, $\lambda_p = C\tau$, where C is the speed of light and $\tau = h/E$ is Planck's periodic time, identified as the proper time in Lorentz's formalism [7] and corresponding to a relativistic cycle. This section refines the theory by addressing key quantum and relativistic phenomena through the proposed oscillation of quantum systems between observable 3D space and the energy-linked fourth dimension.

1.1 Four-Dimensional Space-Energy Manifold

In relativity, space and time undergo contraction or dilation due to energy content, necessitating that coordinates x, y, z, t incorporate energetic effects. Planck's periodic time, $\tau = h/E$, serves as the relativistic cycle (intervals), distinct from Minkowski's time of events, Ct, which increments continuously [8] and contains the accumulation of past time dilations. The Theory of Space redefines the fourth longitudinal dimension as the proper wavelength, $\lambda_p = C\tau$, which remains constant absent interactions, unlike Minkowski's time. The temporal dimension t, governing the rate of physical changes, accumulates intervals of τ plus a fractional phase of the 3D-4D oscillation, as detailed below. Unlike spatial coordinates, the time variable t is not involved in a longitudinal dimension but instead tracks the system's temporal evolution. A core postulate is that quantum space oscillates between observable 3D space (x, y, z) and the energetic fourth dimension (λ_p), manifesting energy intermittently in 3D, consistent with Planck's quantization [9] and Einstein's physical quantization [10]. Compact entities (e.g., particles or pulsed fields) appear in 3D only when their quantum space is present, forming two coexisting entities: the oscillating quantum space and the dependent compact entity. This resolves the wave-particle duality by eliminating the notion of a single entity with contradictory properties. The wave function describing this dynamic uses complex numbers, with the real part representing 3D and the imaginary part the fourth dimension:

$$\psi(x, y, z, \lambda_p, t), \text{ where } \lambda_p = C\tau,\ \tau = h/E \tag{1}$$

Position is defined in 3D, while total energy and momentum reside in the fourth dimension, leading to Heisenberg's Uncertainty Principle [9] due to their phase difference, which also causes noncommutativity in measurement order.

1.2 Superposition and 3D Projection

The 3D presence is a projection from the 4D realm, occurring intermittently at a rate set by τ. The 4D wave function holds all eigenstates in superposition, but each 3D projection randomly manifests a single eigenstate without influence from prior projections unless an interaction (e.g., energy emission or absorption) or observation conditions the system. This addresses philosophical concerns about orthogonal state coexistence, observer-induced wave function collapse, and many-worlds interpretations [12]. The wave function is:

$$\psi(x, y, z, \lambda_p, t) = \sum_{i=1}^{n} c_i \phi_i(x, y, z, \lambda_p, t) \tag{2}$$

where c_i are complex coefficients, and $|c_i|^2$ is the probability of the i^{th} eigenstate in 3D, satisfying:

$$\sum_{i=1}^{n} |c_i|^2 = 1 \tag{3}$$

The random sequence of 3D projections generates the arrow of time by forming an irreversible series of eigenstates due to nature´s core randomness [5]. Post-interaction, the system resets to a new 4D superposition, projecting randomly a new sequence of eigenstates, increasing the distribution of 3D states and supporting the second law of thermodynamics. In this view, entropy reflects nature´s tendency to progressively manifest its presence in 3D through the diversification of all their eigenstates. The 3D presence probability, accounting for inertial changes, is:

$$P_3 (t) = \cos^2 (\pi Ct \lambda_p) \quad (4)$$

Upon observation, the probability density for a specific eigenstate is:

$$P_3 (x, y, z, t) = |\psi (x, y, z, \lambda_p, t)|^2 \cos^2 (\pi Ct / \lambda_p) \quad (5)$$

replacing the Dirac delta function to maintain probabilistic consistency with QM.

1.3 Double-Slit Experiment and Interference

The double-slit experiment illustrates phase-dependent interference. The quantum system splits into two components, ψ_1 and $\psi 2$, which interfere, producing destructive interference at a 90-degree phase shift. The compact particle appears randomly within the interfered 3D space, reflecting the 4D superposition of possible positions. The wave function is:

$$\psi = \psi_1 e^{-ik_1 \cdot \mathbf{r} + ik\lambda - i\omega t} + \psi_2 e^{-ik_2 \cdot \mathbf{r} + ik\lambda - i\omega t} \quad (6)$$

where $\mathbf{r} = (x, y, z)$, k_1, k_2 are 3D wavevectors, $k = 2\pi/\lambda_p$, and $\omega = 2\pi C/\lambda_p$. The 3D probability density P_3 is:

$$P_3 (x, y, z, t) = |\psi_1 + \psi_2|^2 = |\psi_1|^2 + |\psi_2|^2 + 2|\psi_1\psi_2| \cos (\Delta k \cdot \mathbf{r}) \quad (7)$$

where $\Delta k = k_1 - k_2$. This formulation captures the interference pattern without requiring a dual-natured entity.

1.4 Entanglement and Locality

For multi-particle systems, the joint wave function persists despite 3D separation, as particles oscillate coherently at the same rate and phase in the fourth dimension, $P_1 (t) = P_2 (t) = \cos^2 (\pi Ct/\lambda_p)$. This ensures conservation of energy, momentum, and charge, explaining Bell's inequality violations [13] via 4D locality, addressing Einstein's nonlocality concerns [14]. The joint wave function is:

$$\psi_{12} (x_1, x_2, \lambda_p, t) = 1/\sqrt{2} \, (\phi_1 (x_1, \lambda_p) \, \phi_2 (x_2, \lambda_p) - \phi_2 (x_1, \lambda_p) \, \phi_1 (x_2, \lambda_p)) \cos (\pi Ct /\lambda_p) \quad (8)$$

1.5 Relativistic Energy and Gravity

The oscillation between 3D – 4D contributes with a kinetic energy in the fourth dimension, i.e., with the known equation $m_o C^2$; where m_o is the rest mass. This mechanism generates gravitational effects independent of the observer, similar to those described in General Relativity [15]. In the proper frame, zero 3D kinetic energy is compensated by the relativistic proper mass, $m_p = \gamma m_o$, where $\gamma = 1/ \sqrt{(1-v^2/C^2)}$. The 4D momentum is $p_4 = m_o C$, and the total energy is:

$$E^2 = (m_o C^2)^2 + (pC)^2 = (1/\gamma \, m_p C^2)^2 + (m_p \, v \, C)^2 \quad (9)$$

where $p = m_p v$. The time evolution follows:

$$i \hbar \, \partial\psi \, \partial t = -I \hbar (\nabla + \partial \, \partial\lambda_p) \, \psi + V (x, y, z, \lambda_p) \, \psi \quad (10)$$

Each fluctuation to the 4^{th} D, the missing quantum space is replaced by the surrounding 3D space, generating an inward space flow proportional to energy.

$$E: \nabla \cdot \vec{v}_s = - GE \, C^2 r^2 \quad (11)$$

where $\vec{v}_s$ is the space flow velocity, mimicking Newton's gravitational law [16]. The quantum system's volume is Planck's area ($\hbar$ G/C^3) multiplied by λ_o.

1.6 Experimental Validation

The theory predicts a sinusoidal tunneling probability in a photon experiment, where a photon tunnels through a moving mirror displaced by fractions of λ_p [2]. The probability is:

$$P \text{ tunnel } (x_m) = \sin^2 (2\pi x_m/ \lambda_p) \quad (12)$$

where x_m is the mirror displacement. Figure 1 illustrates this, showing a sinusoidal pattern, confirming the 3D-4D oscillation hypothesis if experimentally verified. Figure 1: Tunneling probability P tunnel versus normalized mirror displacement x_m/λ_p, exhibiting sinusoidal behavior due to 3D-4D oscillations.

2. Conclusion

This article presents a unified framework integrating quantum mechanics and special relativity through a novel interpretation of the fourth dimension as an energy-dependence oscillation. By addressing the measurement problem, wave-particle duality, wave function collapse, and nonlocality within a single theoretical model. The study provides a promising path towards reconciling two foundational scientific theories. The 4D oscillation model aligns with experimental evidence, such as Thomson experiment [16], Bell tests [17] and numerous observations of single eigenstate; aside, it offers testable predictions via the tunneling experiment and time dilation during free fall [4]. Future work should focus on refining the model´s gravitational implications and designing practical additional experiments to validate 4D locality and gravitational effects.

Declarations

The author declares no conflicts of interest regarding the publication of this paper.

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