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Article

Connecting Quantum Mechanics and General Relativity: The Role of Electromagnetic Spacetime

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Abstract: We propose a novel framework for understanding quantum phenomena through the lens of a modified electromagnetic spacetime, governed by Einstein field equations. By assuming the existence of an electromagnetic spacetime that adheres to these modified equations and provides the Coulomb force law in weak-field approximations, we explore the derivation of Maxwell's equations and highlight the necessity of incorporating spin to validate these equations. We derive the wave equation for the normalized transverse metric and establish its equivalence with the de Broglie wave proposition, suggesting a relationship between this metric and the particle's wavefunction. This approach offers a classical explanation for several quantum phenomena, including the double-slit experiment, entanglement, tunneling, non-locality, and wavefunction collapse. Additionally, it posits a method to visualize atomic orbital structures in line with quantum mechanical predictions. Our findings suggest that the foundational principles of quantum mechanics can be interpreted as linearized approximations of general relativity applied to electromagnetic spacetime. While this theory does not yet extend to the correlations between general relativity, quantum electrodynamics (QED), and quantum chromodynamics (QCD), it provides a valuable visualization tool for physicists and advances our understanding of the unresolved challenges linking quantum mechanics with general relativity.

Keywords: general theory of relativity; quantum mechanics; maxwell's equations; weak-field approximations; collapse of wave function; visualization of quantum mechanics

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1. Introduction

General theory of relativity and quantum mechanics are the two pillars of modern physics and the best theories for describing how the world works. General relativity explains how the world works on large cosmic scales, whereas quantum mechanics describes how the world works on smaller microscopic scales. We know general relativity is extremely accurate in describing the world on a large scale. We also know that quantum mechanics is extremely accurate experimentally. Many attempts have been made to merge the two theories, but past approaches have not been successful. Currently, the research for finding a theory that merges both quantum mechanics and general relativity is focused on discovering the quantum properties of gravity.

Any classical theory that can merge general relativity and quantum mechanics must satisfy the fundamental tenets of both theories. It should satisfy the speed of light limit, Maxwell's equations, and spacetime curvature. It should also satisfy energy quantization, the de Broglie wavelength of matter waves, and provide a classical explanation of the experimental evidence of quantum phenomena. If such a theory is successful in explaining all these, it should also shed light on some unanswered questions, such as what is electron spin, the collapse of the wavefunction, and essentially why quantum mechanics works.

This paper attempts to merge quantum mechanics and the general theory of relativity by providing a classical explanation and visualization of quantum mechanical observations. We will explain some of the early quantum physics discoveries by using knowledge from developments made in the field of general relativity in the 1960s. We'll start with Einstein's field equations and try to derive Maxwell's equations as weak-field approximations (with some assumptions). We will examine the conditions under which general relativity can provide Maxwell's equations when derived from weak-field approximations.

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We will also provide an interpretation of quantum mechanics that can explain some interpretational inconsistencies, such as the measurement problem, the collapse of the wavefunction, and quantum decoherence. Additionally, we will cover the locality, causality, and determinism aspects. We will also discuss the wave nature of both particles and waves in the Young's double-slit experiment.

2. Methodology

Einstein's special theory of relativity starts with the assumption that the speed of light is constant for observers in any reference frame. This conclusion was primarily drawn from Maxwell's equations of electromagnetism. However, none of Maxwell's equations are used to derive the ideas of length contraction and time dilation. Even his famous equation $E=mc^2$ derivation uses Planck's law of energy quantization, but not Maxwell's equations.

The force of gravity, as defined by Sir Isaac Newton, follows an inverse square law relationship. Coulomb's force law also follows the inverse square law relationship. Maxwell, along with uniting the properties of magnetism, formalized the inverse square law relationship in the form of linear equations combining electricity and magnetism into a single entity, electromagnetism. Einstein's field equations give a more accurate description of gravitation and also describe Newton's laws as a weak-field approximation of Einstein's field equations.

Let us, for a moment, assume that we somehow knew that the speed of light is constant for observers in every reference frame. This can be based purely on Michelson-Morley's experiments or other evidence (but not because of Maxwell's equations). In that case, we would still be able to arrive at the conclusions made by Einstein in his special theory of relativity and also derive the general theory of relativity. So, we can also assume, for a moment, that Maxwell's equations are not fundamental equations for electromagnetism, but that Einstein's general theory of relativity is, under certain conditions.

In the first section of the paper, we'll define an electromagnetic spacetime and draw an equivalent (modified) geodesic equation (following the non-equivalence principle) and (modified) Einstein field equations for such spacetime. We'll discuss the implications of modified field equations (Schwarzschild and Kerr metrics). We will show that Maxwell's equations can be described as the linear approximation of these modified Einstein field equations. We'll also discuss the challenges with this derivation and suggest potential solutions.

Then, we'll describe an event as a simultaneous interaction occurring between the two spacetimes. We'll discuss the quantization rules, noting that the exchange of energy, momentum, and angular momentum is quantized and is a multiple of h (Planck's constant), which can be interpreted as the coupling constant between gravitational and electromagnetic spacetime.

Finally, we will explore the implications of the quantization of properties such as linear momentum and try to briefly explain how the curvature in electromagnetic spacetime can be approximated to de Broglie wavelengths. We will also discuss other implications such as the wavefunction, its collapse upon measurement, and explain the experimental findings of the self-interaction phenomenon observed in the double-slit experiments.

3. Defining Electromagnetic Spacetime

The general theory of relativity explains how energy and momentum curve spacetime and create the effect of gravity. If we imagine that there is an electromagnetic spacetime, then electromagnetism can be a result of its distortion caused by charges and currents. Such a spacetime, which only interacts with electromagnetism, should also have four dimensions (three space and one time). This implies that there are two types of four-dimensional spacetimes: gravitational and electromagnetic. We'll discuss the specifics of these interactions later in the paper.

By drawing some equivalence between the two spacetimes, we can infer that charge is a form of energy and current is a form of momentum in the electromagnetic spacetime. Distortions in the electromagnetic spacetime can be caused by positive and negative charges, with the effects of the

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distortions being opposite to each other. As mentioned in the book [1], the general theory of relativity defines events as a way to represent a fixed point in spacetime. For a point particle, we can imagine electromagnetic spacetime as overlaying the gravitational spacetime and having the same coordinates.

3.1. EM Stress Energy Tensor with Charge and Current Density

To construct modified Einstein field equations for electromagnetic spacetime, we have to define the principle of non-equivalence and create the modified geodesic equation of motion. We'll also need to define the components of the stress-energy tensor. By drawing a direct equivalence between gravitational spacetime and electromagnetic spacetime, we can infer that the electromagnetic stress-energy tensor must be symmetric, and its energy and momentum components will be replaced by charge density and current density as follows.

Defining charge and current density:

- charge density: ρ
- current density or charge flux $\mathbf{j}$

The energy momentum tensor components are constructed such that:

- T_{00}: Charge density (units of charge/unit volume)
- T_{0i}: Charge Flux (units of Current/unit area)
- T_{i0}: Current Density (units of Current/unit area)
- T_{ij}: Current Pressure and Shear Flux (Flux of current density x^i along x^j direction)

3.2. Modified Geodesic Equation

The principle of equivalence will not apply to electromagnetic interactions because the inertia to change position depends on the mass of the particle, while the inertia to respond to the curvature of electromagnetic spacetime depends on the charge of the particle. To update the geodesic equation, each side of the equation must be multiplied by the inertia resisting the change. In electromagnetic spacetime, inertia is the charge of the particle. In gravitational spacetime, inertia is the mass of the particle.

Equation and its terms are

$$m\frac{d^2x^\mu}{d\tau^2} + q\Gamma^\mu_{\alpha\beta}\frac{dx^\alpha}{d\tau}\frac{dx^\beta}{d\tau} = 0 \tag{1}$$

where:

- m is the mass of the particle
- q is the charge of the particle
- x^μ are the coordinates of the particle,
- τ is the proper time,
- $\Gamma^\mu_{\alpha\beta}$ are the Christoffel symbols of the second kind, which are defined as:

$$\Gamma^\mu_{\alpha\beta} = \frac{1}{2}g^{\mu\nu}\left(\partial_\alpha g_{\nu\beta} + \partial_\beta g_{\nu\alpha} - \partial_\nu g_{\alpha\beta}\right) \tag{2}$$

where $g_{\mu\nu}$ is the metric tensor and $g^{\mu\nu}$ is its inverse.

3.3. Modified Einstein Field Equations

Einstein's field equations relate the curvature produced in gravitational spacetime by energy, momentum, and other pressure or shear components. Similarly, the modified field equations relate the curvature produced in electromagnetic spacetime by charges, current densities, and other pressure or shear components.

Equation and its terms are

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi K_e}{c^4}T_{\mu\nu} \tag{3}$$

where:

- $R_{\mu\nu}$ is the Ricci curvature tensor,
- R is the Ricci scalar, which is the trace of the Ricci tensor $R = g^{\mu\nu}R_{\mu\nu}$,
- $g_{\mu\nu}$ is the metric tensor,
- Λ is the cosmological constant,
- K_e is the Coulomb's constant,
- c is the speed of light in vacuum,
- $T_{\mu\nu}$ is the modified stress-energy tensor.

The left hand side represents the curvature of the Electromagnetic spacetime, and the Right hand side represents the EM energy momentum tensor.

The proportionality constant $\frac{8\pi K_e}{c^4}$ is equal to 2.7964×10^{-23} . Compared with the gravitational spacetime, this ratio is 10^{20} times larger (proportionality constant in EFE is 2.0766×10^{-43}. Because of this, we can observe such distortions at scales much smaller than cosmic scales (in case of gravitation).

For electromagnetic spacetime, there are two types of energies or charges: positive and negative. Hence, there will be two such modified equations, and the resultant will be the difference between the equations for the two charges. This implies that the cosmological constant term will be canceled out.

3.4. Schwarzschild Metric and EM Black Holes

The Schwartzchild solution for the modified Einstein field equations is as follows:

$$ds^2 = -\left(1 - \frac{2K_eQ}{c^2r}\right)c^2dt^2 + \left(1 - \frac{2K_eQ}{c^2r}\right)^{-1}dr^2 + r^2\left(d\theta^2 + \sin^2\theta\, d\phi^2\right) \tag{4}$$

where:

- K_e is the Coulomb's constant,
- Q is the charge,
- c is the speed of light,
- r, θ, and ϕ are the spherical coordinates.

It shows that if the charge is concentrated within a radius less than a certain limit, it behaves like a black hole in electromagnetic spacetime (although it may have a normal mass in gravitational spacetime).

This hypothetical Schwarzschild black hole in the positive electromagnetic field will act like the nucleus of a heavy atom. An electron trapped in the electromagnetic pull of such a singularity would end up in an orbital closer and closer to the nucleus; however, it would take the electron an infinite amount of time, with respect to us (a distant observer), to reach the event horizon. As a result, the electromagnetic radiation emitted via $E = h\nu$ will become more and more red-shifted, and we might not detect it. Any incident light will not be reflected as it would be absorbed the moment it crosses the event horizon. Essentially, it will behave like a particle that doesn't interact with electromagnetic radiation, and only the gravitational effects will be visible. The properties of such bodies are somewhat similar to the dark matter postulated in astronomical observations.

3.5. Kerr Metric and Magnetism

The kerr solution for the modified Einstein field equations is as follows:

$$ds^2 = -\left(1 - \frac{2K_eQr}{\rho^2c^2}\right)c^2dt^2 + \frac{\rho^2}{\Delta}dr^2 + \rho^2d\theta^2 + \left(r^2 + a^2 + \frac{2K_eQra^2\sin^2\theta}{\rho^2c^2}\right)\sin^2\theta\, d\phi^2 - \left(\frac{4K_eQra\sin^2\theta}{\rho^2c^2}\right)c\,dt\,d\phi \tag{5}$$

where:

- $\rho^2 = r^2 + a^2\cos^2\theta$
- $\Delta = r^2 - \frac{2K_eQr}{c^2} + a^2$

- K_e is the Couluob constant,
- Q is the Charge of the rotating object,
- c is the speed of light,
- $a = \frac{J}{Qc}$ is the specific angular momentum (angular momentum per unit charge) of the object,
- r, θ, and ϕ are the Boyer-Lindquist coordinates.

For the case of rotating black holes, the dtdϕ component is responsible for the gravito-magnetic behavior of the spinning spherically symmetric body (the frame-dragging effect). If we assume that electromagnetic spacetime follows the modified Einstein field equations, then a similar dtdϕ component will be responsible for magnetism. Below, we'll try to derive Maxwell's equations from modified Einstein field equations.

3.5.1. Deriving Maxwell Equations

The analogy between electromagnetism and gravitation has a long precedence. The analogy was first established by Oliver Heaviside in 1893, when he proposed the gravito-electromagnetism equations (GEM). After Einstein published his general theory of relativity, the wave solution to Einstein's field equations was first discussed by Einstein in 1916. Josef Lense and Hans Thirring, in 1918, worked out the application of the weak field limit to rotating gravitating objects, resulting in the frame-dragging effect (Lense-Thirring precession). As we have previously set analogous Einstein field equations for electromagnetic spacetime, we'll try to derive Maxwell's equations from them. A reference for most of the derivation is mentioned here [1], where the authors have derived gravito-electromagnetism from Einstein's field equations.

We derive the weak field approximation for modified Einstein field equations by drawing the analogy from EFE weak field approximation calculations. Considering the perturbations created are small, the metric will look like flat spacetime + a weak perturbation.

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \tag{6}$$

If we introduce the following replacement

$$\bar{h}_{\mu\nu} = h_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}h \tag{7}$$

where $h = \eta^{\mu\nu}h_{\mu\nu}$ is the trace of $h_{\mu\nu}$. Then the modified Einstein field equations transform to the form as mentioned below.

$$\Box\bar{h}_{\mu\nu} = -\frac{16\pi K_e}{c^4}T_{\mu\nu} \tag{8}$$

after imposing the transverse gauge condition $\bar{h}^{\mu\nu}_{,\nu} = 0$.

The general solution of this is a superposition of a particular solution together with the general solution of the wave equation; however, we are only interested in the special retarded solution of (1.2) given by

We may set $T_{00} = \rho c^2$ and $T_{0i} = cj^i$, in terms of the charge density ρ and current $j^i$of the source, so that $j^\mu = (c\rho, j^i) = (c\rho, \mathbf{j})$ is the charge-current four vector of the source. Since, in linear approximation, $T^{\mu\nu}_{,\nu} = 0$, we obtain the continuity equation:

$$\frac{\partial\rho}{\partial t} + \nabla\cdot\mathbf{j} = 0 \tag{9}$$

If we assume that the source consists of a finite distribution of slowly moving charge, with $|\mathbf{v}| \ll c$, then $T_{ij} \simeq \rho v_i v_j + p\delta_{ij}$, where p is the pressure; we see that $\bar{h}_{ij} = O(c^{-4})$, and in the linear approach, we neglect in the metric tensor terms that are $O(c^{-4})$.

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Consequently we get the components

$$\bar{h}_{00} = \frac{4K_e}{c^2} \int_V \frac{\rho(ct - |\mathbf{x} - \mathbf{x}'|, \mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|} \, d^3x' \tag{10}$$

$$\bar{h}_{0i} = -\frac{4K_e}{c^3} \int_V \frac{j^i(ct - |\mathbf{x} - \mathbf{x}'|, \mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|} \, d^3x' \tag{11}$$

$$\bar{h}_{ij} = -\frac{4K_e}{c^4} \int_V T_{ij} d^3x' \tag{12}$$

Using tensor virial theorem, we get

$$\bar{h}_{ij} = -\frac{2Ke}{c^4} \frac{\partial^2}{\partial t^2} I_{ij} \tag{13}$$

Where $I_{ij} = \int_V T_{00} x_i x_j \, d^3x'$
Substituting for potentials

$$\bar{h}_{00} = \frac{4\Phi}{c^2} \tag{14}$$

$$\bar{h}_{0i} = -\frac{4A_i}{c^3} \tag{15}$$

We get the following line element

$$ds^2 = -c^2\left(1 - \frac{2\Phi}{c^2}\right)dt^2 - \frac{4A_i}{c} dx^i dt + \left(1 + \frac{2\Phi}{c^2}\right)\delta_{ij} dx^i dx^j \tag{16}$$

Defining E and B as

$$\mathbf{E} = -\nabla\Phi - \frac{\partial \mathbf{A}}{\partial t} \tag{17}$$

$$\mathbf{B} = \nabla \times \mathbf{A} \tag{18}$$

We get the Maxwell's equations as

$$\nabla \cdot \mathbf{E} = 4\pi K_e \rho \tag{19}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{20}$$

$$\nabla \wedge \mathbf{E} = -\frac{\partial^2 \mathbf{B}}{\partial t^2} \tag{21}$$

$$\nabla \wedge \mathbf{E} = \frac{4\pi K_e \rho}{c^2} + \frac{1}{c^2} \frac{\partial^2 \mathbf{B}}{\partial t^2} \tag{22}$$

However, there is a problem in this derivation. When we use modified geodesic equation to calculate the force, the Lorentz force law comes out as

$$m\frac{d\mathbf{V}}{dt} = q\mathbf{E} + 4q(\mathbf{V} \times \mathbf{B}) \tag{23}$$

The force resulting from the magnetic field component is four times the expected value [2] [3]. In this calculation, we have not included the effect of the particle's spin. Let's see if the modified Lorentz force law (derived above) can be equated to the Lorentz force law of classical electromagnetism if we include the effects of spin.

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3.5.2. Adding Spin in the Linearized Approximation

Let's include spin in our approximations. We will add terms that contribute to the magnetic part because of the spin of the particle. Once we equate the resultant equations with Maxwell's equations, we can arrive at the condition spin of the particle has to satisfy, for modified Einstein Field equations to yield Maxwell's equations.

As mentioned earlier, our line element was of the form

$$ds^2 = g_{00}c^2dt^2 + 2g_{0i}cdx^i dt + g_{ij}dx^i dx^j \tag{24}$$

Using modified geodesic equation 3.2, we get the following space components

$$m\frac{dv_i}{dt} = q\left(\frac{\partial \Phi}{\partial x_i} - 4(\mathbf{V}\times\mathbf{B})_i + 4\frac{\partial A_i}{\partial t} - 2v_i\frac{\partial(2\Psi+\Phi)}{c\partial t}\right) \tag{25}$$

Where $\Psi = \frac{g_{ij}-1}{2}$.
Replacing the value of E and B set as before, we get

$$m\frac{dv_i}{dt} = q\left(-\mathbf{E}_i - 4(\mathbf{V}\times\mathbf{B})_i + 4\frac{\partial A_i}{\partial t} - 2v_i\frac{\partial(2\Psi+\Phi)}{c\partial t}\right) \tag{26}$$

Since the electromagnetic field can be originated by translation and spin, we'll assess the factors for both translation and rotation. Comparing the approximate magnitude of each term with $(\mathbf{V}\times\mathbf{B})$.

$$|\mathbf{B}_{\text{trans}}| \simeq \frac{Qvs}{cr^2} \tag{27}$$

Q is the charge, and v_s is the translation speed.

$$|\mathbf{B}_{\text{spin}}| \simeq \frac{S}{cr^3} \simeq \frac{Qv_{\text{rot}}R}{cr^3} \simeq \frac{\mu}{cr^3} \tag{28}$$

Here μ is the spin magnetic moment, S is the spin angular momentum, and v_{rot} is the rotational speed of the periphery of the object. If we assume that the ∣v∣«c $|\mathbf{v}| \ll c$ and R«r $R \ll r$, we have equations

$$|\mathbf{V}\times\mathbf{B}|_{\text{trans}} \simeq \frac{Qvv_s}{c^2r^2} \tag{29}$$

$$|\mathbf{V}\times\mathbf{B}|_{\text{spin}} \simeq \frac{Sv}{c^2r^3} \simeq \frac{\mu v}{c^2r^3} \tag{30}$$

$$\left|\frac{\partial A_i}{\partial t}\right|_{\text{trans}} \simeq \frac{Qvs^2}{c^2r^2} \tag{31}$$

$$\left|\frac{\partial A_i}{\partial t}\right|_{\text{spin}} \simeq \frac{Svs}{c^2r^3} \simeq \frac{\mu vs}{c^2r^3} \tag{32}$$

$$\left|v_i\frac{\partial(2\Psi+\Phi)}{c\partial t}\right| \simeq \frac{Qvv_s}{c^2r^2} \tag{33}$$

We can see that after replacing the values, under certain definite value of spin, this force law becomes similar to the Lorentz force law. The conditions are imposed on spin terms to exactly cancel out the excess factor of the magnetic field derived from the linear approximation of the modified Einstein field equation. Therefore, for this approach to work, spin must be a necessary condition for particles at the fundamental level. [4]

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3.5.3. Challenges with the Derivation

As we have seen above, we were able to derive Maxwell's equations by proper substitutions. However, when we try to calculate the force, the magnetic term for the force ends up being four times larger than that in the Lorentz force law. However, the introduction of spin in the approximations sets the conditions just right, so that the derived Lorentz force law matches the classical one, making spin an integral part of electromagnetism.

As we already know from the Dirac equation in quantum mechanics, spin is an integral part of the electron [5]. Thus, we had a hint that spin angular momentum plays an important role in the derivation. The latter part of the above derivation emphasizes that if the field equations are to satisfy Maxwell's equations in the linear approximation, there must be a single definite value of spin for the elementary particle. Therefore, we may understand that quantum spin is likely the actual spin of the quantum particle.

For the rest of the paper, let us assume that we have accurately derived the value of spin, and we assume that the modified Einstein field equations for electromagnetism hold. Let us examine the implications of such an addition.

4. Quantized Interactions between Spacetimes

The general theory of relativity defines events as a way to represent a fixed point in spacetime [1]. This representation requires no coordinates; however, we introduce coordinates to order events.

The introduction of electromagnetic spacetime alongside gravitational spacetime builds on this framework, positing that events are fixed points in both spacetimes. Two simultaneous (relativistic) spacetimes can interact with each other and exchange energy and momentum via these events. The energy and momentum transactions are quantized, meaning the energy and momentum transfer between the two fields happens in discrete chunks. The interaction occurs via the transfer of particles that interact with both spacetimes. In the case of electromagnetic and gravitational spacetime, the energy carrier is a photon.

4.1. Fundamental Quantization Relations

The 3 primary discrete (or quantised) interactions are

- Energy quantization
- Orbital and Spin angular momentum quantization
- Linear momentum quantization

Energy quantization is governed by Planck's law, which establishes a relationship between the energy and the frequency of the photon by the formula E=hν. Linear momentum is more clearly stated by de Broglie wavelength relation, which states the wavelength of the matter wave traveling with the momentum P is λ = h/p. Orbital angular momentum quantization was first proposed by Neils Bohr for the hydrogen atom model. The relations is given as $m_e$vr=nh/2π.

We'll discuss these 3 relationships below in detail.

4.2. Energy and Time

Energy quantization by planck's law explains how the energy interacts between the electromagnetic spacetime and the gravitational spacetime. E=hν, or E=h/t, or E X t = h Another interpretation of this formula is that we cannot receive an energy quantum E in a time period less than h/E. There is a minimum time interval in which energy can be transferred. The objective of this interpretation is to limit the wave association of the photon and to understand energy and time as dependent properties.

When mass is accelerated with respect to a distant observer, its energy changes, and hence its mass increases. However, this is not the case when charge is accelerated in electromagnetic spacetime. We know that charge doesn't increase in magnitude during motion through an accelerated electromagnetic spacetime (electromagnetic field), as the acceleration causes energy to increase, and charge and energy are entities of different spacetimes.

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Instead of charge increasing in magnitude, energy is transferred between electromagnetic spacetime and gravitational spacetime. This energy transfer from electromagnetic spacetime to gravitational spacetime happens discretely.

The energy of the electromagnetic wave is transferred as the energy of the photon by Planck's quantization formula E = hν. Here, Planck's constant can be thought of as the coupling constant between the two spacetimes. Hence, the photon is a force carrier, or more precisely, an energy carrier between the two fields. This can also be the mechanism by which accelerated charges radiate energy. We'll discuss this in a later section [reference].

4.2.1. Behavior of Photons

A 3+1D observer can observe different time and space dimensions of the photon. However, an observer in the photon's hypothetical reference frame (light-like observer) will witness a photon being created and destroyed instantly at the same event in spacetime. In other words, photons are created and destroyed instantly and at the same place in spacetime. Therefore, any experiment with photons in which we are determining which path a photon has taken will not yield a definite path, because for the photon, all paths represent the same spacetime event. Thus, the eventual conclusion by a 3+1D observer will be that the photon must have taken all the paths.

As discussed above, the photon is only formed when electromagnetic spacetime transfers energy to gravitational spacetime (or vice versa). Hence, the instant at which the measurement is taken is the event when energy is transferred between the two spacetimes, and the photon is destroyed, performing some work in the detector. In other words, measurement is defined as the event where energy gets transferred between electromagnetic spacetime and gravitational spacetime.

4.3. Spin Angular Momentum

As we discussed previously, the spin is an integral part of the modified Einstein field equations. In this paper, the term has not been mathematically derived. Hence it is not possible to give exact properties of the quantised spin of the electron. However, from quantum mechanics, we can assume that the spin has to be quantised to effectively describe the atomic orbital structure, as we'll discuss below.

4.4. Orbital Angular Momentum

Angular momentum quantization was first proposed by Neils Bohr for the hydrogen atom model. The relations is given as $m_e v r = \frac{nh}{2\pi}$.

This form can be interpreted that the product of the orbital angular momentum and the angle 2π is quantised. Also, the product of the tangential momentum and the distance traveled in one loop is quantised, which is the condition of linear momentum quantization.

4.4.1. Atomic Orbitals

For the hydrogen atom, the positively charged nucleus creates an attractive positive curvature, which in turn attracts the negatively charged electron. Hence, the motion of the electron around the nucleus would resemble a 3D resonating pattern of the curvature of electromagnetic spacetime. Since angular momentum is quantized with respect to the nucleus, the electron is unable to lose angular momentum and energy, which is why the electron doesn't merge with the nucleus. The electron thus moves on the modified geodesic path, with other factors affecting its trajectory.

The spin of the positively charged nucleus creates a magnetic moment, similar to the frame-dragging effect of a rotating black hole. Thus, the atom is not spherically symmetric. This also enables one prograde and one retrograde orbital, leading to two possible spin states for every resonating pattern of electromagnetic spacetime.

However, the exact position and momentum of the electron will not be clear as angular momentum is quantized, meaning the angular distance θ will have to be a scalar multiple of h/L. Essentially, the electron is a cloud around the nucleus. This helps us understand that an electron does indeed revolve around the nucleus, as a sphere of electromagnetic spacetime curvature distortion. It just does not release energy as the minimum threshold for releasing a photon is not met.

As the atomic number increases, the number of electrons also increases, and the number of volumetric harmonics increases. It is interesting to see that the pattern of the harmonics resembles the probability density (or shell) structures as calculated via quantum mechanics.

4.5. Linear Momentum and Distance

First illustrated by Louis de Broglie, the wavelength of the particle was related to momentum by the relation$\lambda = h/p$. Another interpretation of this formula can be that we cannot have a momentum quanta P in a space interval (or distance) of length less than h/P. This space-time interval for any quantum particle is the basic quanta that affects the curvature of electromagnetic spacetime.

Understanding momentum quantization requires an analogy from the understanding of energy quantization.

We already know antennas have to be of a certain size to capture the signals of certain frequencies. Since Et=constant as per Planck's law, this means the antenna has to stay for a certain minimum time frame to "capture the energy of the photon", given it meets certain size criteria. Similarly, for momentum quantization, we have to understand that if we want to capture momentum, we have to move a certain space long enough with a minimum time gap. That means momentum can be P or zero for observers, depending on whether the above criteria of space or time were met or not.

We can easily create spatial gaps with a width smaller than $\lambda = h/p$ and perform experiments where the particle is allowed to go through the gaps. When these distortions cross the two slits (as if distortions are created by two separate particles), they can interfere with the distortions created by the particle itself, causing self-interference and affecting the aggregate probability of where the particle gets captured by the detector. We'll discuss the double-slit experiment later in the paper.

5. Implications

5.1. Understanding Wave-Function

We've seen before 3.5.1 that the linearised Modified Einstein field equations yield

$$\Box \bar{h}_{\mu\nu} = -\frac{16\pi K_e}{c^4} T_{\mu\nu} \tag{34}$$

As we are assessing the perturbations of very small particles, we can assume spatial component

$$\Box \bar{h}_{jl} = 0 \tag{35}$$

Expanding the solution in plane waves, we get

$$h_{jl} = A_{jl} e^{i(\omega t - \mathbf{k}\cdot\mathbf{x})} \tag{36}$$

Setting the transverse condition

$$\partial_j \bar{h}_{jl} = 0 \tag{37}$$

Then, we arrive at an equation with solutions of the plane wave in nature

$$k_j \bar{h}_{jl} = 0 \tag{38}$$

Since the equations are for a particle which is spread across a spatial distance $\lambda = h/P$, we can consider the λ as the wavelength of the distortion of the spacetime. This implies wavenumber $k = \frac{2\pi}{\lambda} = \frac{P}{\hbar}$ ($\hbar$ is Dirac's constant). In quantum mechanics, this wave becomes the wave function [3].

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Hence, we can understand that the normalized transverse metric $\overline{h}_{jl}$, is related to the wavefunction. We can now understand that the way we solve for the wavefunction in quantum mechanics is the same way we solve for the metric in the Modified Einstein's Field Equations. We can also infer that the calculations used in quantum mechanics are a close enough linear approximation of modified Einstein Field Equations. Let's see how we can visualize other quantum phenomena.

5.2. Collapse of Wave-Function

In quantum mechanics, it is defined that the collapse occurs when a wave function—initially in a superposition of several eigenstates—reduces to a single eigenstate due to interaction with the external world. As discussed in this paper earlier, the energy gets transferred between the spacetimes only at an event in both spacetimes. The occurrence of that event can be described as the collapse of the wavefunction. Hence, we can define the collapse of the wave function as the quantized transfer of energy or momentum between the spacetimes.

5.3. Particle Creation and Destruction at a Single Event

One of the key concepts in this paper is that the transfer of energy and momentum happens at an event. Such an event creates particles which carry energy and momentum from one spacetime to another. In the case of EM spacetime and Gravitational spacetime, interaction between these two happens via the light quanta - photon.

5.4. Energy Radiation from Accelerated Charges

Maxwell's theory shows that when charges are accelerated, they radiate energy. Here's how we can visualize this process.

Every particle that has intrinsic mass and charge interacts with both spacetimes. If a force is applied to the particle via EM spacetime, energy is transferred from EM spacetime to Gravitational spacetime, changing the motion of the particle in both spacetimes simultaneously.

Adding energy to the gravitational spacetime increases the mass of the particle. However, adding energy to the EM spacetime by increasing the speed of the charge doesn't increase the charge of the particle. So the particle radiates the excess charge via photons, maintaining its constant charge value.

5.5. Quantum Entanglement

If an event creates two particles instead of one, the particles may share some property that preserves the conservation laws. Hence, if we measure the conserved property of one of the particles, we can deduce the property of the other because the creation process follows conservation principles.

5.6. Non-Locality of Particles

As discussed earlier, particles take a certain proper distance in spacetime, and in order to transfer momentum, a proper spatial distance of de Broglie wavelength is required. Essentially, the particle's curvature is spread within this space interval.

We can force the particle to spread out by making it pass through a double slit. This would not create an event (forcing the particle's energy/momentum transfer collapse), but would spread the space interval of the distortion in spacetime. This spreading of spacetime curvature distortion can happen over large spatial distances and can even self-interfere, depending on experimental conditions. However, the transfer of energy or momentum will be a single, discrete event. Hence, the particle will be detected at a certain point, not as a wave.

In Mach-Zehnder interferometer experiments, the photon's curvature distortion is spread along two very different paths and then recombined. The energy of the photon can be transferred via either path. But when the energy is transferred, it happens as a single event in spacetime, causing the entire spread of the curvature to disappear from all of spacetime and be transmitted to a single spacetime coordinate. To an observer, the photon's curvature would disappear from one location instantaneously when the event of measurement occurs.

5.7. Wave-Particle Duality

Since energy and momentum create distortions in EM spacetime, these distortions act like waves at a small enough scale. However, because energy and momentum are quantized, the distortion of EM spacetime doesn't spread out like a wave unless the packet is split into small enough spatial separations or time intervals. It is condensed in a close enough region of spacetime and behaves like a particle. Even if this distortion is spread across a large spatial distance (due to experimental conditions, etc.), the event of transfer of energy/momentum within the fields happens at a single point in both spacetimes.

5.8. Quantum Tunneling

In this paper, we consider the quantum particle as a distortion of electromagnetic spacetime spread around a proper spacetime interval. Quantum tunneling can potentially occur if the curvature of spacetime passes through the barrier partially, and then the transfer of energy/momentum happens on the other side of the barrier. When it does, the energy of the entire particle tunnels through the potential barrier.

6. Understanding Experimental Observations

Visualizing the general relativistic view of electromagnetic spacetime helps resolve many foundational quantum phenomena observed during experiments conducted until the 1920s. It provides a classical visualization tool for making testable predictions. Let's explore how we can revisit and visualize some famous experiments.

6.1. Particle in a Box

Revisiting the basic quantum mechanical problem, we'll understand the behavior of a particle in a box surrounded by an infinite energy barrier. Any particle trapped inside that potential well, traveling towards one side of the wall, will feel the effects of the distortions it creates in spacetime. Since we assume the walls have an infinite energy barrier, the spacetime distortions of the particle will reflect off the surfaces and self-interfere. The tendency of the particle in the box will result in it being in a harmonic state with the distortion it creates. Hence, self-interaction will occur if a particle's position or momentum is measured in the box.

6.2. Double Slit Experiment (Photon)

A photon is created when energy transfers from electromagnetic spacetime to gravitational spacetime. Detection occurs when the energy carried by the electromagnetic wave transfers energy at the detector. Before detection, the EM spacetime wave travels through both slits and interferes with itself to produce fringe patterns. The photon is more likely to transfer energy to the region of the detector where the interference is constructive compared to where it is destructive. As long as the energy transfer doesn't happen along the path, fringes will be created.

6.3. Double Slit Experiment (Matter)

A similar phenomenon occurs for matter particles (which essentially have charge). If we introduce spacetime distortion and visualize the particle moving towards the double slit, the distortion will pass through the openings of both slits as if two particles are passing simultaneously.

The distortion passing through both slits will interfere with itself, creating a fringe pattern on the detector screen. Since any form of measurement requires the transfer of energy from electromagnetic spacetime to gravitational spacetime, any form of detection will force part of the energy/momentum to transfer, thus creating decoherence. As long as momentum isn't affected throughout the path, fringe patterns will be created.

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7. On Determinism, Locality, and Causality

This interpretation is non-deterministic. The wavefunction is understood to be linked to the curvature of the respective spacetime, and the collapse of the wavefunction is linked to the transfer of energy/momentum between the fields. How and where this transfer of energy and momentum happens depends on chance. Since the transfer can happen probabilistically, the outcome is non-deterministic.

This interpretation is non-local. Events are the fundamental tool of reasoning. If the energy or momentum transfer is quantized via events, the spread of curvature in space (locality) should not affect the 'transfer' event. It doesn't break the causality of events either. Creation happens at a single event, and the transfer of the particle's energy/momentum also happens at a single event. These two events are causally connected.

8. Limitations

8.1. Recency

In this paper, I was able to classically explain quantum behavior observed almost 100 years ago. It does not include many recent advancements, such as the standard model of particle physics and the associated interactions.

8.2. Maxwell's Equations Approximation and Spin Condition

Modified Einstein field equations do not yield Maxwell's equations in weak field approximations, as the Lorentz force law's force contribution by the magnetic field is off by a scaling factor of 4 unless we include spin as a significant factor affecting the approximations. This makes the presence of spin a mandatory condition for the modified Einstein field equations to describe the electromagnetic spacetime.

9. Conclusion

We started with the assumption that there exists an electromagnetic spacetime that follows modified Einstein field equations and gives the Coulomb force law in weak-field approximations. We expanded this idea to understand and derive Maxwell's equations and postulated the presence of spin as a mandatory condition for the modified field equations to be valid. We also derived the solution for the normalized transverse metric's wave equation. Compared with the de Broglie wave proposition, we were able to establish an equivalence, suggesting that this metric is related to the wavefunction of the particle.

With our understanding of this analogy, we can now provide a classical explanation for the observed quantum phenomena in the famous double-slit experiments and explain other quantum phenomena such as entanglement, tunneling, non-locality, and the collapse of the wavefunction. We can also theorize that this approach can yield a similar atomic orbital structure as proposed by quantum mechanics. Most importantly, we now have a classical way of visualizing quantum phenomena.

Assumptions made 100 years ago based on available experimental data laid the foundations of quantum mechanics. This paper postulates that the foundation of quantum mechanics can be described as linearized approximations of the general theory of relativity applied to electromagnetic spacetime. This theory has not yet included a similar correlation between the general theory of relativity with QED and QCD. However, it can provide physicists with a visualization aid and enhance our understanding of the unresolved problems linking quantum mechanics with the general theory of relativity.

Conflicts of Interest: The authors declare no conflicts of interest.

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