

Generalization of the Dirac's Equation and Sea

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Abstract:

Newton's second law is motion equation in classic mechanics that does not say anything about the nature of force. The equivalent formulations and their extensions such as Lagrangian and Hamiltonian do not explain about mechanism of converting Potential energy to Kinetic energy and Vice versa. In quantum mechanics, Schrodinger equation is similar to Newton's second law in classic mechanics. Quantum mechanics is also extension of Newtonian mechanics to atomic and subatomic scales and relativistic mechanics is extension of Newtonian mechanics to high velocities near to velocity of light too. Schrodinger equation is not a relativistic equation, because it is not invariant under Lorentz transformations. Dirac expanded The Schrodinger equation by presenting Dirac Sea and founded relativistic quantum mechanics.

Generalization of the Dirac's Equation and Sea

In this paper by reconsidering the Dirac Sea and his equation, the structure of photon is investigated and it is made an attempt to answer these following questions:

- 1- What is the relation between photon and its electromagnetic fields?
- 2- Does force have physical existence or it is just a mathematical tool to describe physical interactions?
- 3- What is the mechanism of converting potential energy to kinetic energy and vice versa?
- 4-What is the relation between gravity and electromagnetics?
- 5-What is the relation between Weyl fermions and Dirac fermions?

Keyword: Fermion, relativistic, photon, graviton, color charge, magnetic color, sub quantum energy, virtual photon

Klein-Gordon Equation

The Klein-Gordon equation is the first important step from non-relativistic quantum mechanics towards relativistic quantum mechanics. The Klein-Gordon equation is a relativistic version of Schrodinger equation¹ that was presented as follows²:

$$E^2 = p^2 c^2 + (mc^2)^2 \quad (1)$$

In quantum mechanics, momentum of a particle P (to plane wave, to wave vector) is given as $P = \hbar k$ in which k is wavenumber and $\hbar = \frac{h}{2\pi}$. Moreover, a particle with energy E has the frequency ω that is indicated by relation $E = \hbar\omega$. So by interpreting quantum mechanics operators, we can write:

$$P \rightarrow -i\hbar\nabla, \quad E \rightarrow i\hbar\frac{\partial}{\partial t} \quad (2)$$

Then the relativistic form of Klein-Gordon Equation will be expressed as follows:

$$\frac{1}{c^2} \frac{\partial^2}{\partial t^2} \psi - \nabla^2 \psi + \frac{m^2 c^2}{\hbar^2} \psi = 0 \quad (3)$$

¹ - Schrödinger's equation — what is it? <https://plus.maths.org/content/schrodinger-1>

² - Relativistic Quantum Mechanics, <http://hitoshi.berkeley.edu/221B-S02/Dirac.pdf>

The Klein-Gordon Equation, <http://www.mysearch.org.uk/website1/html/538.Klein-Gordon.html>

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The solutions of this equation is complex values of wave function $\psi(t, x)$. By taking radical from both sides of relation (1), we have:

$$E = \pm \sqrt{p^2 c^2 + (mc^2)^2} \quad (4)$$

It is natural that we try to use relativistic form of Klein-Gordon equation by using the nature of energy in special relativity (in relation (1)), so combining the relations (1, 2 and 3) and neglecting from negative part of relation (4) (because the negative energy is meaningless), we have:

$$E = \sqrt{p^2 c^2 + (mc^2)^2} \quad (5)$$

Then, by putting just mechanic quantum operators for momentum and energy in relation (5), we will have the following equation:

$$\sqrt{m^2 c^4 - \hbar^2 \nabla^2 c^2} \psi = i \hbar \frac{\partial}{\partial t} \psi \quad (6)$$

In relation (6), differential operator ∇ lies under radical that is meaningless. If we expand under the radical (left hand side of relation (6)), we will have³:

$$\sqrt{m^2 c^4 - \hbar^2 \nabla^2 c^2} = mc^2 \sqrt{1 - \left(\frac{\hbar}{mc} \nabla\right)^2} = mc^2 \left[1 - \frac{1}{2} \left(\frac{\hbar}{mc} \nabla\right)^2 + \frac{1}{8} \left(\frac{\hbar}{mc} \nabla\right)^4 + \dots \right]$$

By neglecting from third term onwards, we will have:

$$i \hbar \frac{\partial}{\partial t} \psi = mc^2 \left[1 - \frac{1}{2} \left(\frac{\hbar}{mc} \nabla\right)^2 \right] \psi = \left(mc^2 - \frac{\hbar^2}{2m} \nabla^2 \right) \psi \quad (7)$$

$$i \hbar \frac{\partial}{\partial t} \psi = \left(mc^2 - \frac{\hbar^2}{2m} \nabla^2 \right) \psi \quad (8)$$

³ - Tobias Gleim, "Klein-Gordon and square-root operator equations for two-spinors and scalars: perturbation calculations for hydrogen-like systems" <https://arxiv.org/ftp/quant-ph/papers/0602/0602047.pdf>

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Equation (8) is the same Schrodinger equation in which the first term in right hand side is the zero rest energy of a particle⁴. It is obviously seen that this equation is not invariant under Lorentz transformations, because in this equation, derivative with respect to time is first degree and with respect to place is second degree. Therefore, it is non-relativistic. Moreover, it was neglected from negative section of relation (4) due to not being acceptable of negative energy. But Dirac did not ignore existence of negative energy.

Dirac equation

In 1928, Paul Dirac published a paper entitled "The Quantum Theory of the Electron" that presented relativistic form of wave equation for electron in which it became the main instruction for obtaining Dirac equation⁵. Dirac equation is generalization of Schrodinger equation to compute wave function of particles that is consistent with special relativity too. Dirac extended this equation based on Klein-Gordon equation that had efficiency in interpretation of states with negative energy, it means that it covered negative part of equation (4). Therefore; Dirac presented his equation as follows:

$$[p_0 + \rho_1(\sigma, P) + \rho_3 mc]\psi = 0 \quad (9)$$

In which ρ_1, ρ_3 has been taken from Pauli matrices⁶. Dirac equation justifies wave function of particles with half integer spin like fermions (the same as electron), while Klein-Gordon equation is considered for particles with spin of zero (like certain mesons). Dirac also could predict existence of anti-matter with his equation that later it was verified with experiment too. 30 years later in 1958, Dirac suggested the main form of his equation by publishing a book as follows:

$$(\beta mc^2 + \sum_{j=1}^3 \alpha_j cp_j)\psi(x, t) = i\hbar \frac{\partial \psi(x, t)}{\partial t} \quad (10)$$

In which $\psi(x, t)$ is a wave function for an electron with zero rest mass m with space-time coordinates x, t . The elements p_1, p_2, p_3 are coordinates of momentum that are recognized as momentum operators in Schrodinger equation. There basic physical constants reflect properties and virtues of relativity and quantum mechanics.

⁴ - The Klein-Gordon equation, https://www.eng.fsu.edu/~dommelen/quantum/style_a/kg.html

⁵ - Dirac P. A. M., "The Quantum Theory of the Electron", Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character 117 (778): 610–24. , Published 1 February 1928
<http://rspa.royalsocietypublishing.org/content/royprsa/117/778/610.full.pdf>

⁶ - Mario Bacelar Valente, "The Dirac equation, the concept of quanta, and the description of interactions in quantum electrodynamics", http://philsci-archive.pitt.edu/8366/1/The_Dirac_equation,_the_concept_of_quanta,_and_the_description_of_interactions_in_quantum_electrodynamics.pdf

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The smallest representation of a_i and β is as 4×4 matrices and they can be produced by using Pauli matrices σ_i as sub matrices as follows⁷:

$$\beta = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad \sigma_i = \begin{pmatrix} 0 & \sigma_i \\ \sigma_i & 0 \end{pmatrix} \quad (11)$$

Such that each element is a 2×2 matrix that can completely written as follows:

$$\beta = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \quad (12)$$

$$\sigma_1 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad \sigma_2 = \begin{bmatrix} 0 & 0 & 0 & -i \\ 0 & 0 & i & 0 \\ 0 & -i & 0 & 0 \\ i & 0 & 0 & 0 \end{bmatrix} \quad \sigma_3 = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix} \quad (13)$$

Now, by combining equations (1) and (10), it can be investigated difficulty of explaining negative energy by a different approach⁸:

$$E^2 = p^2 c^2 + (mc^2)^2 = (\beta mc^2 + \sum_{j=1}^3 \alpha_j cp_j)^2 \quad (14)$$

For a particle in special case $p = 0$, we will have:

$$E^2 = (mc^2)^2 = (\beta mc^2)^2 \quad (15)$$

By considering β matrix (relation (12)), we can write:

⁷ - Quantum Theory 2015/16, <http://www2.ph.ed.ac.uk/~bjp/qt/rqt.pdf>

⁸ - ANDREW ERIC BRAINERD, "SELF-ADJOINT EXTENSIONS TO THE DIRAC COULOMB HAMILTONIAN" MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 2010, <https://dspace.mit.edu/bitstream/handle/1721.1/61203/701106459-MIT.pdf;sequence=2>

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$$\beta mc^2 \rightarrow \begin{bmatrix} mc^2 & 0 & 0 & 0 \\ 0 & mc^2 & 0 & 0 \\ 0 & 0 & -mc^2 & 0 \\ 0 & 0 & 0 & -mc^2 \end{bmatrix} \quad (16)$$

For eigenvalues and considering $p = 0$ (in equation (4)), we will have⁹:

$$E_+ = mc^2, \quad E_- = -mc^2 \quad (17)$$

Dirac equation predicted existence of a particle with negative energy and he was confronted with unbelievers of physicists. However, in 1932, Anderson¹⁰ discovered this particle in cosmic ray and they called it "positron". Later, pair "electron-positron" was created in the laboratory by photon decay process. A photon with high energy loses all its energy $E = h\nu$ in collision with nucleus and creates pair "electron-positron". Positron is a particle that has all the same properties of electron except in electric charge and the sign of its magnetic moment. Because electric charge of positron is positive. Existence of negative energy in Dirac equation was not pleasant for physicists. Nevertheless, negative energy in this equation caused that Dirac discussed on negative energy in general and published it through a paper in 1930 (before discovery of positron) entitled: "Theory of Electrons and Protons"¹¹.

Dirac Sea

Dirac Sea is a theoretical model that introduces vacuum as a sea of infinite particles with negative energy. Dirac presented this model in 1930 for the first time. Dirac used this model to explain quantum states of negative energy in his equation and in order to justify relativistic electrons. Dirac ratiocinated that all states of negative energy have been occupied by electrons in which they are not a part of the nature. It means that there exists a Sea of electrons with negative energy beyond the nature. He also ratiocinated that with a high energy photon, we can take apart an electron with negative energy from this Sea and convert it to an ordinary electron with positive energy.

Inexistence of negative energy means existence of positive energy, thus the hole behaves in a way that as if it is a particle with positive energy. On the other hand, inexistence of negative charge means existence of positive charge. This hole-particle alike electron has positive charge that was called positron.

⁹ - Chapter 15, pages 696-716, Bransden & Joachain, Quantum Mechanics, <http://www.physics.udel.edu/~msafrono/PDF/L23.pdf>

¹⁰ - Carl David Anderson (1905 – 991), Discovery of the Positron, <https://www.aps.org/programs/outreach/history/historicsites/anderson.cfm>

¹¹ - Dirac P. A. M. "A Theory of Electrons and Protons" ROYAL SOCIETY PUBLISHING, 1930, doi: 10.1098/rspa.1930.0013

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In CPH theory¹², by defining the structure of photon, Dirac Sea is a physical fact that not only holds for positron but also it is inseparable part of the nature and even we can conclude Weyl fermions from it. Weyl fermions with spin $\frac{1}{2}$ have zero rest mass alike electrons (in quantum mechanics)¹³. In pair production of "electron-positron", was specified that the expression "negative energy" is not appropriate for these types of particles that later were called anti-particle. In fact, different electrical properties of electron and positron must be investigated in the structure of their producer that it means finding it in the structure of photon.

On the other hand, if a full energy photon (Gamma) that has this virtue that can be converted to two particles with different electric charges and all photons independent of their frequencies, carry electromagnetic energy. This virtue of electromagnetic energy must be investigated in electric and magnetic fields dependent to photon that can be converted to electron and positron with different electric charges.

From the Dirac equation to the photon structure

In pair production of "electron-positron", one photon with spin 1 and at least energy $E = 1.022 \text{ MeV}$ is converted to two fermions, electron and positron with spin $\frac{1}{2}$, each of them with context of energy 0.511 MeV in vicinity of a heavy nucleus so that we have the following relation:

$$\gamma \rightarrow e^{-} + e^{+} \quad (18)$$

Relation (18) is justifiable according to Dirac equation by relations (16) and (17), (Figure 1.A). In pair decay, an electron is combined with a positron and is produced two photons (Figure 1.B).

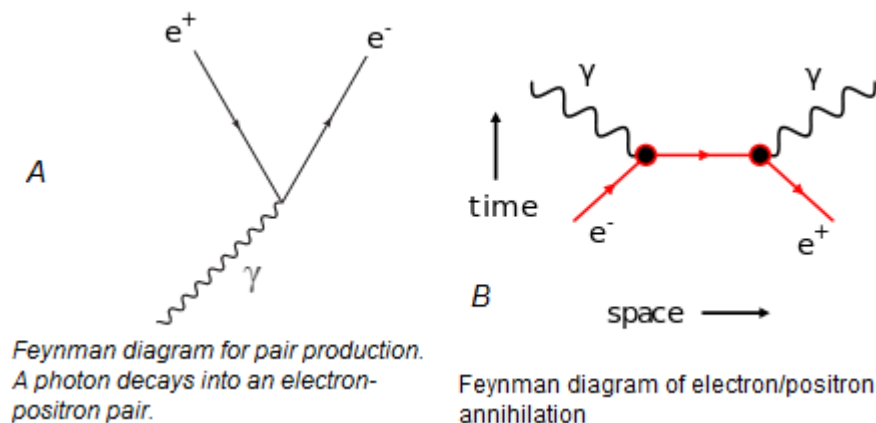


Fig1: Production and decay of pair "electron-positron"

¹² - Creative Particles of Higgs Theory

¹³ - Hamish Johnston, "Weyl fermions are spotted at long last"

<http://physicsworld.com/cws/article/news/2015/jul/23/weyl-fermions-are-spotted-at-long-last>

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In pair decay, reverse of relation (18) takes place and we will have:

$$e^{-} + e^{+} \rightarrow 2\gamma \quad (19)$$

In all physical processes including pair production and decay, it must be held the following conservation laws:

- 1- Electric charge conservation law, pure charge before and after the process must be equal.
- 2- Linear momentum and total energy conservation laws: These rules has made forbidden production of just one photon (Gamma ray). As it is seen in Figure (2), two photon with the same energy move but in two opposite directions. Angular momentum conservation law must be held too. In fact, in the process of "electron-positron" decay, these following relations hold:

$$e^{-} + e^{+} \rightarrow 2\gamma$$

$$E_{2\gamma} = 2m_0c^2 + E_{e^{-}} + E_{e^{+}}$$

$$m_0c^2 = 0.511 \text{ MeV}$$

In which m_0c^2 is zero rest mass of electron (also positron) and $E_{e^{-}}, E_{e^{+}}$ are kinetic energy of electron and positron that are converted to energy of photons ($E_{2\gamma}$) at the time of pair decay.

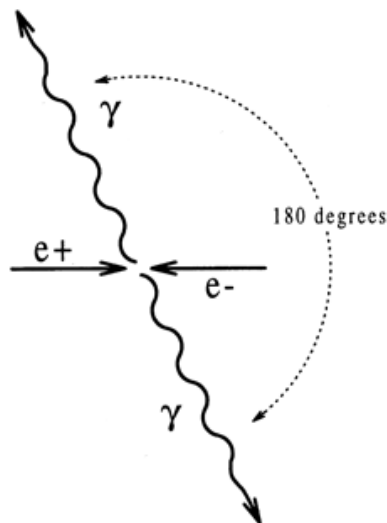


Diagram of electron-positron annihilation, producing 2 511 keV photons leaving in opposite directions.

<http://tech.snmjournals.org/cgi/content-nw/full/29/1/4/F1>

Fig2: In pair decay, two same photons move in two opposite directions.

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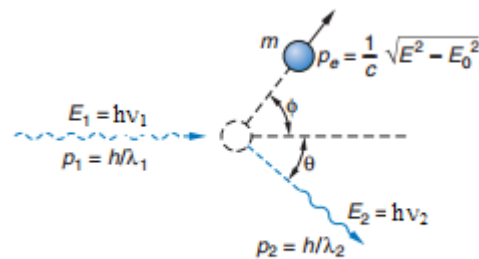
Till here everything is true and it is justifiable and consistent with mechanic quantum laws (and also standard model). But an essential question is considerable. Before proposing the question, it is necessary to pay attention to physical phenomena by more accuracy and a different approach.

In all these processes, matter is converted to energy and vice versa. Are conservation laws (as mentioned above) only related to matter and energy (photon) is just a part of this process or photon is one of the two main players of these processes? On the other hand, energy is converted to matter; matter has some properties including electric charge that energy apparently lacks it (because photon is electrically neutral) or these properties is transferred from energy to matter?

In pair decay, these properties of matter including electric charge also is transferred by another method to the structure of energy (photon) or it is completely wiped out? In the sequel, it is tried to be answered to these questions by investigating some physical phenomena.

Compton Effect

Quantum theory implies that a charged particle obtains energy while striking with a photon. In Compton Effect, photon with initial energy and momentum E_1, P_1 loses a part of its energy and moves with energy and momentum E_2, P_2 and this energy is transferred to charged particle¹⁴. Therefore, both particle and photon continue to their motions in paths that are not necessarily the previous paths (Figure 3).



<https://physics.ucsd.edu/students/courses/spring2015/physics4e/compton.pdf>

Fig.3: In Compton Effect, a part of energy of the photon is transferred to electron.

Photon and gravitational field

A different attitude to the behavior of photon in a gravitational field can help us recognize the nature of electromagnetic energy. Electromagnetic fields around a light ray are not static fields and are much stronger in comparison with gravitational field.

¹⁴ - Derivation of Compton's Equation,
<https://physics.ucsd.edu/students/courses/spring2015/physics4e/compton.pdf>

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When a photon rises or falls down in a gravitational field, its energy (mass) changes. Gravitational force does work (positive or negative) on the photon and as a result, its mass (energy) changes¹⁵. However, energy of photon depends on the energy of its electrical and magnetic fields. Therefore, while increasing energy of the photon in the gravitational field, a part of this work done on the photon is transferred to electrical energy and another part is transferred to magnetic energy. How happens this process while moving into gravitational blue-shift?

It is a scientific fact that the vibrating motion of the atoms causes the cloud of electrons to oscillate and this oscillation generates electromagnetic radiation. Since all electromagnetic radiation travels at the same velocity the frequency and wavelength of the generated radiation depends on the frequency of the oscillating electron cloud¹⁶. However, if energy of photon increases in the path of its motion, like blue-shift phenomenon, the frequency of photon increases, therefore, photon is not a solid particle, it is formed of sub quantum energies, and interaction between sub quantum energies inside the photon is the main factor of its frequency. In other words, frequency of the photon is a function of interaction between its internal components of its structure. Therefore, the next step is to recognize sub quantum energies and their properties, so that it can be consistent with experimental conditions.

Sub Quantum energy (SQE)

To explain and define sub quantum energy, it is necessary to analyze the relations (15) and (16). By taking square root from both sides of relation (15), we will have:

$$E^2 = (mc^2)^2 \rightarrow E = \pm mc^2 \quad (20)$$

In general state, equation (20) does not accept any limitation for mass and energy regarding its value. Moreover, in limit of zero mass (zero rest mass of particles), Dirac equation was reduced to Weyl equation¹⁷. Weyl equation predicted the existence of fermions that their rest mass is zero¹⁸, but they have spin $\frac{1}{2}$. Because here, the aim is to investigate and recognize the structure of photon. We reduce β matrix as follows and now we call it matrix A until after computations and necessary conclusions, we choose a special notion for it:

¹⁵ - Miles Mathis, "AN EXPLOSION OF THE POUND-REBKA EXPERIMENT"

<http://milesmathis.com/pound.html>

¹⁶ - Generation of Electromagnetic Waves.

<http://xtide.ldeo.columbia.edu/mpa/Clim-Wat/Climate/lectures/energy/generation.html>

¹⁷ - William O. Straub, "WEYL SPINORS AND DIRAC'S ELECTRON EQUATION" 2005, <http://www.weylmann.com/weyl-dirac.pdf>

¹⁸ - Hermann Weyl, "GRAVITATION AND THE ELECTRON", PALMUR PHYSICAL LABORATORY, PRINCETON UNIVERSITY, Communicated March 7, 1929

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$$A = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad (21)$$

Therefore, the relation (16) changes and converts as follows:

$$Amc^2 \rightarrow \begin{bmatrix} mc^2 & 0 \\ 0 & -mc^2 \end{bmatrix} \quad (22)$$

According to relations (16) and (17) and in a special case that a photon collides with a heavy nucleus with at least energy $E = 1.022 \text{ MeV}$, we can write:

$$E_+ = mc^2, \quad E_- = -mc^2$$

That is called the process of pair production of electron and positron. Therefore, in general case, the relation (22) is reagent of energy for two fermions with spin $\frac{1}{2}$ that one of the possible case describes pair production of electron-positron.

But occurring other cases is possible including photon with energy less than $E = 1.022 \text{ MeV}$ is decayed to two fermions with spin $\frac{1}{2}$, that move with speed of light in which it is describer of Weyl fermions¹⁹ and they are called massless fermions or Weyl fermions²⁰ (or particles with zero rest mass).

According to Compton Effect and gravitational blue-shift, energy of a photon can decrease or increase without changing in its physical properties (except its energy and frequency). It means that whatever is increased to the energy of photon, it has the same total properties of photon (properties of electromagnetic energy). In other words, all photons have common physical properties except the value of energy that again it can be used the relation (22) for them. Therefore, at least electromagnetic energy can be defined as follows:

$$E_{\text{minimum}} = \frac{hc}{\lambda_{\text{max}}}, \text{ where } E_{\text{minimum}} \text{ is detectable} \quad (23)$$

According to relation (2), E_{minimum} includes two parts that it can be written as follows:

¹⁹ - Su-Yang Xu, et, at. "Discovery of a Weyl fermion state with Fermi arcs in niobium arsenide", Nature Physics 11, 748–754 (2015) doi:10.1038/nphys3437

²⁰ - Steven R. Elliott, "Colloquium: Majorana Fermions in Nuclear, Particle and Solid-state Physics", 2014, arXiv:1403.4976v2

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$$AE_{minimum} \rightarrow \begin{bmatrix} +\frac{E_{minimum}}{2} & 0 \\ 0 & -\frac{E_{minimum}}{2} \end{bmatrix} \quad (24)$$

In relation (24), the minus sign does not imply being negative of energy (or negative mass), as positron is not negative energy or mass in pair production. Signs $+$, $-$ in relation (24) show electromagnetic fields around a charged particle and carry the same type of electromagnetic energy that there exists around a charged particle.

Therefore, the photon is formed of two types of positive and negative sub quantum energies that we show them by operators, right wedge \triangleright for positive sub quantum energy and left wedge \triangleleft that are defined as follows:

$$\text{Positive Sub Quantum Energy; } SQE^+ : \triangleright = +\frac{E_{minimum}}{2} \quad (25)$$

$$\text{Negative Sub Quantum Energy; } SQE^- : \triangleleft = -\frac{E_{minimum}}{2} \quad (26)$$

It is obvious that spin of sub quantum energy (SQE) is equal to $\frac{1}{2}$. In general case, relation (22) can be written by using the definition of positive and negative sub quantum energies \triangleright , \triangleleft in which k is a natural number and instead of A , we use γ that is sign or symbol of electromagnetic energy:

$$\gamma = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad (27)$$

$$\gamma mc^2 \rightarrow \begin{bmatrix} k \triangleright & 0 \\ 0 & k \triangleleft \end{bmatrix} \quad (28)$$

In relation (28), $k \triangleright$ is positive virtual photon γ^+ , in which carries positive electrical force and forms positive electric field and $k \triangleleft$ is negative virtual photon γ^- that carries negative electric force and forms negative electric field. Every real photon is formed of two virtual photons. Therefore, we will have:

$$\gamma^+ = k \triangleright, \gamma^- = k \triangleleft \rightarrow \gamma = \gamma^+ + \gamma^- \quad (29)$$

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As charged particles absorb or repulse each other and are ineffective on neutral particles, homonymous virtual photons repulse each other, non-homonymous virtual photons absorb each other and they form quantum energies and it causes two non-homonymous charged particles accelerate towards each other²¹.

Structure of sub quantum energy (SQE)

Now we are in a situation that can have a new look to the structure of photon and define properties of graviton with experimental conditions such that it can be consistent with properties of photon.

Suppose a photon with mass $m = hv/c^2$ and energy $E = hv$ falls from high h toward the earth relative to an inertial reference frame on the surface. Its frequency increases from ν to ν' , in fact, a number of gravitons enter into the structure of the photon such that $\Delta\nu = \nu' - \nu$. So the problem is; how many gravitons enter into the structure of photon to provide at least possible change of the energy of photon (minimum $\Delta\nu$)? So if $\Delta\nu$ is minimum, then how many gravitons has entered into the structure of photon? What properties gravitons must have that they can be compatible with photons identity?

A photon with minimum energy is carrying two perpendicular electric field and magnetic field. The photon is electrically neutral and particles forming the electric field must neutralize each other. So, there are two groups of positive and negative color-charges in structure of photon that form photon's electric field and neutralize each other. Because these electric fields are moving, they create magnetic fields around themselves.

Due to this reason in the CPH Theory, gravitons have properties that when gravity works on photon, can alter the intensity of electric and magnetic fields of the photon. This attitude led to the terms color-charge and magnetic-color in which they have used to define gravitons. In other words, identity of graviton changes without any change in its energy. The above features necessitate that we consider each photon including four groups, two groups carry positive and negative electrical effects and two groups carry magnetic effects. Suppose that a photon with frequency ν and energy $h\nu$ is formed of n_1 elements, so that:

$$n_1 = n_{11} + n_{12} + n_{13} + n_{14}$$

Moreover, this photon with frequency ν' and energy $h\nu'$ is formed of n_2 elements, so that:

$$n_2 = n_{21} + n_{22} + n_{23} + n_{24}$$

²¹ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " Sub Quantum electrodynamics, page 40
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics , [http://gsjournal.net/Science-Journals/%7B\\$cat_name%7D/View/649](http://gsjournal.net/Science-Journals/%7B$cat_name%7D/View/649)

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For two levels of energy $h\nu'$, $h\nu$, we form the below matrices:

$$h\nu = \begin{bmatrix} n_{11} & n_{12} \\ n_{13} & n_{14} \end{bmatrix} \quad (30)$$

$$h\nu' = \begin{bmatrix} n_{21} & n_{22} \\ n_{23} & n_{24} \end{bmatrix} \quad (31)$$

Now, we consider the matrix of changing energy of photon $\Delta E = h\nu' - h\nu$ as follow:

$$\Delta E = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad (32)$$

Matrices (12, 13 and 14) must satisfy the following equation:

$$h\nu' = \begin{bmatrix} A & B \\ C & D \end{bmatrix} + \begin{bmatrix} n_{11} & n_{12} \\ n_{13} & n_{14} \end{bmatrix} = \begin{bmatrix} n_{21} & n_{22} \\ n_{23} & n_{24} \end{bmatrix} \quad (33)$$

Now we should determine elements A, B, C, D. We consider the first row of the matrix 32, the elements of A, B for negative and positive color-charges. Element A represents positive color-charges and element B represents negative color-charges. In interaction between gravitons and photons, photon falls at specified distance dy and its energy increases (gravitational blue-shift) that due to equation ($F = -\frac{dU}{dx}$) the identity of a number of gravitons change by carrying gravitational force to color-charges and enter to the structure of photon. We use the symbol of graviton G, for the both negative color-charge as G^- and positive color-charge as G^+ , so that:

$$A = \kappa G^+, \quad B = \kappa G^-$$

Where κ is a natural number. In other words, when gravity does the work on photon, a number of gravitons enter into the structure of photon and photon's intensity of electric field increases, without any electrically effect and it is not created electric charge, because the photon is electrically neutral.

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So A , B must carry electric effect and their numbers must be equal (photon is a packet of electromagnetic energy)²². Also according to the relative intensity electric fields and magnetic of electromagnetic waves $\mathbf{E} = c\mathbf{B}$, since color-charges and magnetic-colors are carrying electric and magnetic fields that they are countable, therefore, this relative can be replacement by a natural number such as κ , so we have $\mathbf{E} = \kappa \mathbf{B}$. When a number G^+ enter into photon structure, intensity of positive electric field of photon increases. Therefore, according to Maxwell's electromagnetic equations, the intensity of magnetic field increases, too. Therefore, the element C (equation 32) must increases the intensity of magnetic effect around the positive color-charges. Similarly, the element D must increases the intensity of magnetic field around the negative color-charges. The effect of these two elements are the same, but in terms of direction (which is proportional to the electric field) are different. Thus, according to the electric and magnetic field intensity we can be written:

$$C = G_m^+, \quad D = G_m^-$$

The negative sign in relation $D = G_m^-$, only determines the direction of magnetic colors around the negative color-charges. Therefore, matrix (32) that is called the CPH matrix will be defined as follows:

$$CPH = \begin{bmatrix} \kappa G^+ & \kappa G^- \\ G_m^+ & G_m^- \end{bmatrix} \quad (34)$$

According to the above expression, we are now able to define the least magnitude of a photon. A photon of minute energy contains some positive color-charges G^+ , negative color-charges G^- , right rotation color-magnetic G_m^+ and left rotation color-magnetic G_m^- as shown in the CPH matrix (equation 34). This very small energy can be express as the following²³;

$$\text{Minute electromagnetic energy: } E_{Minute} = (2\kappa + 2)E_G \quad (35)$$

According to definition of $E_{minimum}$ (relation 23), it is clear that:

$$E_{Minute} = E_{minimum} \quad (36)$$

²² - In 1905, Albert Einstein suggested that electromagnetic waves could only exist as discrete wave-packets. German article "Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt" http://myweb.rz.uni-augsburg.de/~eckern/adp/history/einstein-papers/1905_17_132-148.pdf

²³ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " pp. 19-25 https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics

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Thus, each photon is formed of a natural number $E_{minimum}$, so we have;

$$E = n(2\kappa + 2)E_G, \text{ or } E = n \begin{bmatrix} \kappa G^+ & \kappa G^- \\ G_m^+ & G_m^- \end{bmatrix} \quad (37)$$

Sub quantum energy and Maxwell equation

When a photon falls in a gravitational field as Δr , the graviton's density in the vicinity of the photon electric field changes the value of ∂G_E , because the intensity of electric field changes as \mathbf{E}_G (\mathbf{E} is the electric field arising from graviton equations 34 to 36). In fact gravitons enter the structure of photon, and the intensity of electrical and magnetic fields which depends on photon increases. Two types of gravitons should enter the photon structure, so that they are able to increase the intensity of photon electric field without any charge effect. Thus the interaction between gravitons and photon, negative and positive \mathbf{G}^- , \mathbf{G}^+ gravitons (color-charges) are produced and enter the photon structure. The photon moves in the same direction as the increasing intensity of the gravitational field does, and the photon electric field is perpendicular to the photon movement direction that is compatible with the following equation:

$$\nabla \times \mathbf{E}_G = -\frac{\partial G_E}{\partial t} \Leftrightarrow i(\mathbf{G}^+, \mathbf{G}^-) \quad (38)$$

By changing the photon electric field, magnetic field also changes²⁴. In this case also, the gravitons are converted into magnetic carrier particles G_m^+ , G_m^- and enter the structure of photon that is given by;

$$\nabla \times \mathbf{B}_G = \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}_G}{\partial t} \Leftrightarrow j(\mathbf{G}_m^+, \mathbf{G}_m^-) \quad (39)$$

Where i , j are natural numbers, and proportion between i and j should be consistent with equation (37). According to the above relations, we can define energy and mass of graviton and photon in relation with each other.

Graviton Principle

Graviton is the most minuscule unit of energy with constant mass m_G that moves with a constant magnitude of speed so that $|V_G| > |c|$, in all inertial reference frames. Any interaction between graviton

²⁴ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " page 28
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and other existing particles represents a moment of inertia I where the magnitude of V_G remains constant and never changes²⁵. Therefore;

$$\nabla V_G = 0, \text{ in all inertial reference frame and any space} \quad (40)$$

Based on the principle of graviton, a graviton carries two types of energy generated by its movement in inertial reference frame, one is transmission energy E_{GT} and the other one is non-transmission energy E_{GS} . So that;

$$E_G = E_{GT} + E_{GS} = \text{constant} \quad (41)$$

As the graviton mass and speed is constant, its energy remains constant and can only its transmission energy changes to non-transmission energy and vice versa. Gravitons convert to electromagnetic energy and electromagnetic energy converts to matter and anti-matter. In fact, everything is formed of graviton and Graviton is the only fundamental particle in the nature that makes other particles.

Sub-Quantum Energy Principle

One SQE is a very small energy with mass m_{SQE} that moves with speed $|V_{SQE}| > |c|$ relative to inertial reference frame and in every interaction between SQE s with other particles or fields the speed value of SQE remains constant²⁶; as in every physical condition we have;

$$\nabla V_{SQE} = 0, \text{ in all inertial reference frames and any space} \quad (42)$$

SQE principle (equation 42) shows that in every condition the mass, energy and the amount speed of SQE remains constant, and only the transmission speed V_{SQET} and energy E_{SQET} of SQE convert to its non-transmission speed V_{SQES} and energy E_{SQES} , and vice versa. Therefore, we have;

²⁵ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 23
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics

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²⁶ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 25
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics

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$$|V_{SQE}| = |V_{SQET}| + |V_{SQES}| = \text{constant} \quad (43)$$

$$|E_{SQE}| = |E_{SQET}| + |E_{SQES}| = \text{constant} \quad (44)$$

Speed of light principle

According to the principle of Special Relativity, the speed of light in vacuum is constant and it is equal to c for all inertia observers, and it is independent of the light source. How we can conclude this principle by using sub quantum energy principle? First, according to principle of SQE (which is also the result of the graviton principle) the amount of the linear speed of SQE depends to the interaction between $SQEs$ and the other particles (or fields) in the medium. So, in a vacuum, photon (light) has not any interaction with other particles or fields outside of the photon structure, (assume gravitational effect of vacuum is negligible), thus, the linear speed of $SQEs$ in the structure of photons are constant and equal to $V_{SQET} = c$. Also, the linear speed of virtual photons in a vacuum is the same amount of c . Let's in generally, show the speed of photons as v_{light} , it changes from one environment to another that in a vacuum is c , it means the speed of light in vacuum also is $v_{light} = c$. So that is called "speed of light principle"²⁷ in CPH Theory which is given by:

$$\nabla v_{light} = 0 \quad (45)$$

Thus, the linear speed of photon depends to environmental conditions, the same as gravitons and sub quantum energy. But the total amount of transmission speed v_{lightT} and non-transmission speed v_{lightS} of photon is constant and it is equal to $|v_{light}|$, so that:

$$|v_{light}| = |v_{lightT}| + |v_{lightS}| = \text{constant} \quad (46)$$

Sub quantum fields

According to above descriptions, electric and magnetic fields of particles are formed and moreover, photon is formed of two perpendicular electric and magnetic fields. Energy and momentum of photon is equal to summation of energy and momentum of its formed particles. If we indicate summation of

²⁷ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 30
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics
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transmission and non- transmission energy of particles with H , then we will have for graviton, color charge and magnetic color:

$$H_G = E_G = E_{GT} + E_{GS} = constant \quad (47)$$

$$E_G = E_{G^+} = E_{G^-} = E_{G_m^+} = E_{G_m^-} = constant$$

For sub quantum energy:

$$H_{SQE} = E_{SQET} + E_{SQES} = constant \quad (48)$$

For photon, according to relation (37), we can write:

$$H_{photon} = 2nH_{SQE} = n(H_{SQE^+} + H_{SQE^-}) \quad (49)$$

Also electric and magnetic energy of photon is obtained as follows:

$$E_{electric} = n(\kappa G^+ + \kappa G^-), E_{magnetic} = n(G_m^+ + G_m^-) \quad (50)$$

$$H_{photon} = 2n(\kappa + 1)E_G = 2n(\kappa + 1)H_G \quad (51)$$

Sub quantum energy and Dirac Sea

If in the Dirac Sea, we use electric charge (in fact it is color-charge) instead of negative energy, then Dirac Sea is extensible to all physical phenomena including quantum vacuum, structure of quantum particles, materials and even stars and galaxies. Because, energy is formed of color-charges and magnetic-colors and by dense of color-charges and magnetic-colors, charged particles and neutral particles are produced. By combining relations (38, 39)²⁸, we have:

$$\nabla \times E + \nabla \times B \Leftrightarrow i(\mathbf{G}^+, \mathbf{G}^-) + j(G_m^+, G_m^-) \quad (52)$$

For Zero point energy in vacuum²⁹, we can write:

$$^{28} - \nabla \times \mathbf{E}_G = -\frac{\partial \mathbf{G}_E}{\partial t} \Leftrightarrow i(\mathbf{G}^+, \mathbf{G}^-) \quad (38) \quad \nabla \times \mathbf{B}_G = \mu_0 \epsilon_0 \frac{\partial \mathbf{E}_G}{\partial t} \Leftrightarrow j(G_m^+, G_m^-) \quad (39)$$

²⁹ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 32

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$$(n_{\kappa}G^+, n_{\kappa}G^-) + (n_{G_m^+}, n_{G_m^-}) \Leftrightarrow (n_{\kappa}G^+, n_{G_m^+}) + (n_{\kappa}G^+, n_{G_m^-})$$

$$\Leftrightarrow (n_{\triangleright}, n_{\triangleleft}) \Leftrightarrow (\gamma^+, \gamma^-) \Leftrightarrow \gamma$$

It shows that combining electric and magnetic field (even in vacuum) makes real photon.

Sub quantum energy and Feynman diagrams

By using sub quantum energies and virtual photon, interactions and different physical phenomena is describable and visualized. It is noticed that in the diagrams of sub quantum energies, apparently was taken into account (considered) just one path, that's mean, it is thus shown that particles move on a special path that it is not apparently consistent with quantum mechanics. Because, in classic mechanics, just one path introduces the motion of a particle, while in quantum mechanics, all paths are considered for a particle, even paths that are similar to classic path, but it is not also true. For example, charged particles produce and propagate virtual photons such that combination of two non-homonymous virtual photons causes absorbing non-homonymous charged particles and repulsion of two homonymous virtual particles causes repulsion of homonymous charged particles³⁰. Virtual photons can move on all possible paths, if they reach to each other, interaction is done. However, since charged particles are continuously producing virtual photons with high speed, if two charged particles lie in their fields, occurrence of interaction is certain. Even in Feynman diagrams, it is important that what the result of interaction between particles is, not probability of traveled paths.

In quantum electrodynamics, charged particles (for example electron and positron) have interaction with each other through propagation and absorption of photon (particles that carry electromagnetic force) and these interactions are justified by Uncertainty Principle. Even Feynman diagrams is a representation to describe physical processes³¹. While by using sub quantum energies and positive and negative virtual photons, interaction between charged particles is explainable as physical analysis and mathematical computations³². For example, notice to repulsion of two electrons (figure 4) and absorption of positron and electron (figure 5).

³⁰ - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 40
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics

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³¹ - Feynman Diagrams are Maths not Physics

<https://protonsforbreakfast.wordpress.com/2014/04/13/feynman-diagrams-are-maths-not-physics/>

³² - Hossein Javadi, et, at. "Adaptive Review of Three Fundamental Questions in Physics " , page 42
https://www.researchgate.net/publication/302313653_Adaptive_Review_of_Three_Fundamental_Questions_in_Physics

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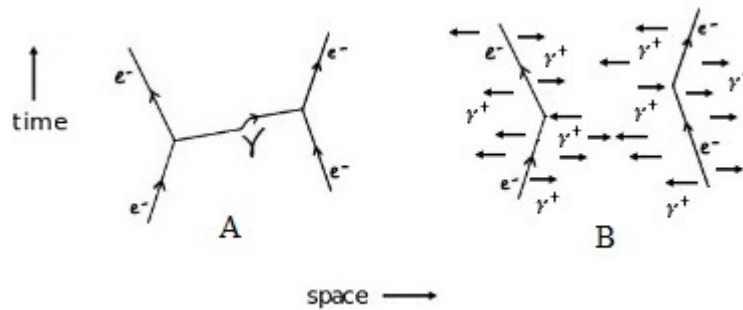


Fig.4: Feynman diagram A and virtual photons B for repulsion of two electrons

According to equations (25, 26 and 29), the number of positive color-charges and its related magnetic-colors in positive sub quantum energy \triangleright , is equal to number of negative color-charges and its related magnetic-colors in negative sub quantum energy \triangleleft . Therefore it is enough, if the number of positive and negative sub quantum energies are equal to each other before physical process and again if the number of positive and negative sub quantum energies are equal to each other after the physical process and it is consistent with conservation law in physics very well.

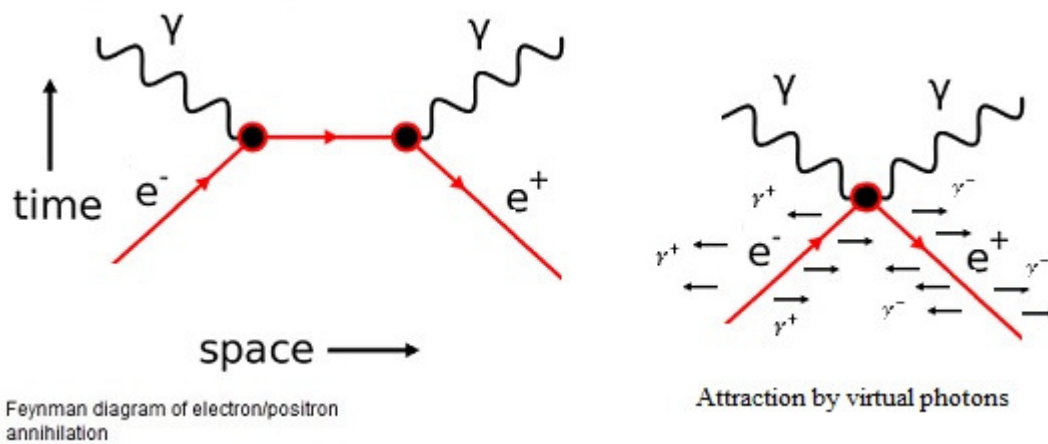


Fig.5: Feynman Diagrams and absorption of electron and positron by virtual photons

Example1: Pair production and decay of "electron-positron":

$$E = k(\triangleright + \triangleleft) \rightarrow e^+ + e^- = (e^+ = k \triangleright) + (e^- = k \triangleleft) = k(\triangleright + \triangleleft)$$

$$e^+ + e^- \rightarrow 2\gamma = \left(\frac{k}{2} \triangleright + \frac{k}{2} \triangleleft\right) + \left(\frac{k}{2} \triangleright + \frac{k}{2} \triangleleft\right) = k(\triangleright + \triangleleft)$$

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$$e^+ + e^- \rightarrow 3\gamma = 3\left(\frac{k}{3}\triangleright + \frac{k}{3}\triangleleft\right) = k(\triangleright + \triangleleft)$$

Example 2: Proton and anti-Proton:

Such an approach to the photon is a useful step to explain real processes of photon and quantum chromodynamics (*QCD*). Consider the combination process of proton-antiproton:

$$p\bar{p} \rightarrow \gamma + \gamma$$

Electric charge of proton and anti-proton is equal to electric charge of electron and positron respectively. Independent of proton and anti-proton mass, we have the following expressions in this process about color-charge conservation:

$$k \triangleright = e^+, \quad k \triangleleft = e^-$$

$$u = \frac{2}{3}k \triangleright, \quad d = \frac{1}{3}k \triangleleft$$

$$\bar{u} = \frac{2}{3}k \triangleleft, \quad \bar{d} = \frac{1}{3}k \triangleright$$

$$p\bar{p} = (uud)(\bar{u}\bar{u}\bar{d}) \rightarrow \gamma + \gamma$$

$$\left(\frac{2}{3}k \triangleright + \frac{2}{3}k \triangleright + \frac{1}{3}k \triangleleft\right) + \left(\frac{2}{3}k \triangleleft + \frac{2}{3}k \triangleleft + \frac{1}{3}k \triangleright\right) \Rightarrow \left(\frac{5}{3}k \triangleright + \frac{5}{3}k \triangleleft\right) = n(\triangleright + \triangleleft)$$

In the same way, all physical interactions is justifiable. Moreover, without using force, we can describe all physical processes and interactions. Even with close attention to gravitational blue-shift (and also red-shift), we can describe the mechanism of converting potential energy to kinetic energy and vice versa.

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To learn more about CPH theory, please refer to the following resources:

- 1- H. Javadi and F. Forouzbakhsh, Interactions Between Real and Virtual Spacetimes, Fundamental Journals International Journal of Fundamental Physical Sciences, 2014
http://fundamentaljournals.org/ijfps/downloads/75_IJFPS_Dec_2014_114_121.pdf
- 2- Javadi, H., et. al., "Discoveries and the necessity of Reconsidering the Perspectives on Newton's Second Law", Journal of Nuclear and Particle Physics, vol. 2(3), p.31-35, 2012
- 3- Javadi, H., et. al., "Definition of Singularity due to Newton's Second Law Counteracting Gravity", Scientific Journal of Pure and Applied Sciences, Vol 2, No 3 (2013), pp. 116-124
- 4- Javadi, H., et. al., "Sub quantum space and interactions properties from photon structure to fermions and bosons" Scientific Journal of Pure and Applied Sciences, Vol 2, No 5 (2013), pp. 235-245
- 5- H. Javadi, F. Forouzbakhsh, (2007), "Zero point Energy and Dirac Equation, SQE or Tiny Energy or Minute electromagnetic Energy", the general science journal, [Online] available:<http://www.gsjournal.net/Science-Journals/Essays/View/950>
- 6- Javadi, H., et. al., "Unification and CPH Theory", the general science journal, 2007, [online available]:
<http://gsjournal.net/Science-Journals/Essays/View/948>
- 7- Javadi, H., et. al., 2007, Unification and CPH Theory, the general science journal, online available:
<http://gsjournal.net/Science-Journals/Essays/View/948>
- 8- <http://gsjournal.net/Science-Journals-Papers/Author/67/Hossein,%20Javadi>