New Insights to the Weak Interaction and Quark Model

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I. Fundamental Elements and Interactions

The nature consists of four fundamental elements, which are radiation γ, mass M, electric charge Q, and color charge C [1-2]. Any known matter or particle is a combination of one or more of these four fundamental elements (Table 1). Radiation and mass are forms of real energy, while electric and color charges are forms of imaginary energy. Interactions between real energies are gravitational, including radiation-radiation, radiation-mass, and mass-mass interactions; while interactions between imaginary energies are gauged, including the electric-electric charge (or electromagnetic), electric-color charge (or weak), and color-color charge (or strong) interactions (Table 2). In addition, interactions between real and imaginary energies are imaginary forces, including the radiation-electric charge, radiation-color charge, mass-electric charge, and mass-color charge interactions. All these interactions can be classically unified as a single interaction between complex energies as shown in Figure 1 or by Eq. (1).

Table 1

	Real Energy		Imaginary Energy	
Particles	Radiation (γ)	Mass (M)	Electric Charge (Q)	Color Charge (C)
Photon	✓			
Neutron		✓		
Weyl Fermion			✓	
Proton		✓	✓	
Quark		✓	✓	✓

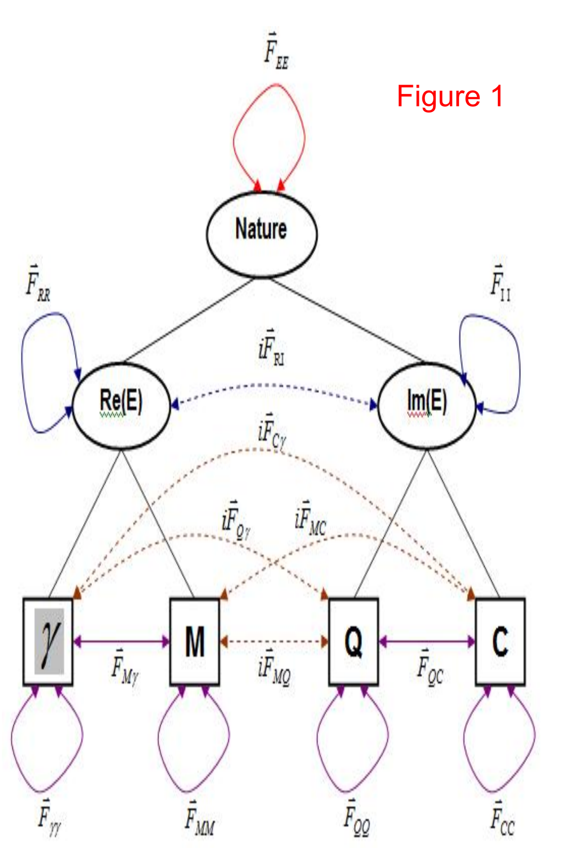

Figure 1

Table 2

Forces	M	γ	iQ	iC
M	$\vec{F}_{MM}$	$\vec{F}_{M\gamma}$	$i\vec{F}_{MQ}$	$i\vec{F}_{MC}$
γ		$\vec{F}_{\gamma\gamma}$	$i\vec{F}_{\gamma Q}$	$i\vec{F}_{\gamma C}$
iQ			$\vec{F}_{QQ}$	$\vec{F}_{QC}$
iC				$\vec{F}_{CC}$

$$\vec{F}_{EE} = -G\frac{E_1E_2}{c^4r^2}\hat{r} = \vec{F}_{MM} + \vec{F}_{M\gamma} + \vec{F}_{\gamma\gamma} + \vec{F}_{QQ} + \vec{F}_{QC} + \vec{F}_{CC} + i\vec{F}_{MQ} + i\vec{F}_{MC} + i\vec{F}_{\gamma Q} + i\vec{F}_{\gamma C} \quad \text{Eq. (1)}$$

II. Electric-Color Charge (or Weak) Interaction and *β*-Decay

The thought that the weak interaction is a force between electric and color charges is innovative. As an extremely short range interaction (~ 10^{-18} m), the weak force is effective within quarks (Figure 2a) and plays the role in excitations/ activations of quarks. Conventionally, a beta decay of a radioactive nucleus or a particle is resulted from an exchange of a W boson between a quark in the nucleus and leptons emitted during the decay as shown in the Feynman diagrams given by Figure 2b or 2c. However, it is unclear how quarks transmute their flavors, how bosons come out, and how leptons are formed and participate in the weak interactions during the quark transmutations via exchanging the bosons.

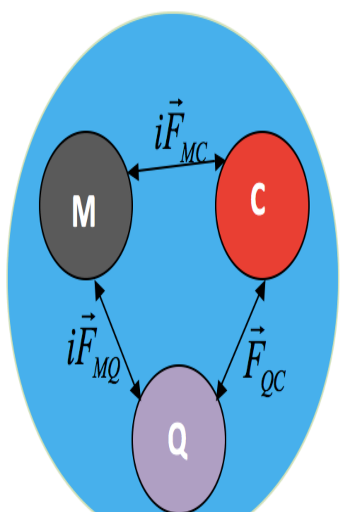

Figure 2a

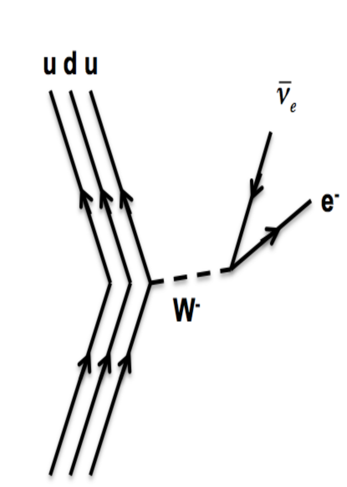

Figure 2b

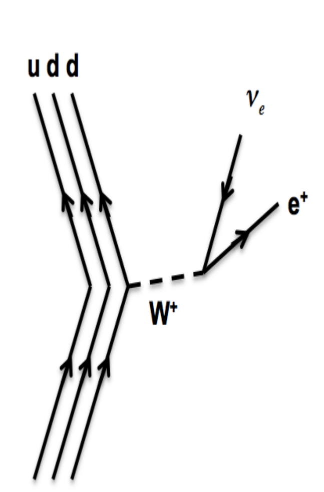

Figure 2c

To sufficiently understand how leptons are formed and emitted during the decays of quarks, the author has developed fine structures of the beta-decay Feynman diagrams (Figure 3) [3]. A neutron has an excited down quark, which emits an excited up-antiup quark pair and becomes a ground down quark. The excited up quark combines with the original two quarks and forms a proton, while the excited antiup quark combines with the ground down to form a W^- boson. The excited antiup quark in W^- boson further emits a ground up-antiup quark pair. Then, the ground down and antiup quarks annihilate into electron and the ground up and antiup quarks annihilate into an antineutrino (Figure 3a). It is similar for the positron emission from a proton (Figure 3b). Therefore, a beta-decay involves two quark-antiquark pair-productions and two quark-antiquark annihilations. Bosons and leptons are products rather than participants of the weak interactions.

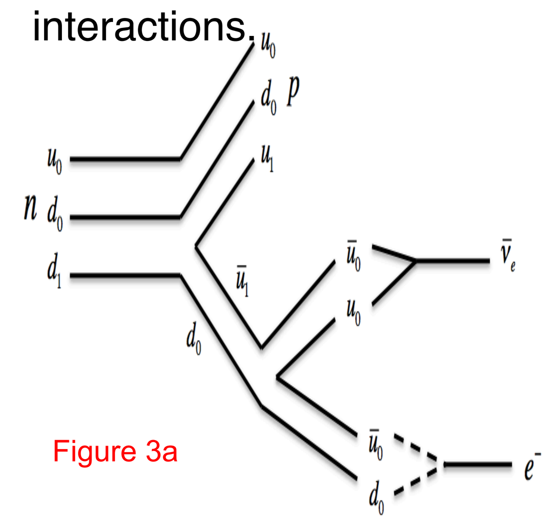

Figure 3a

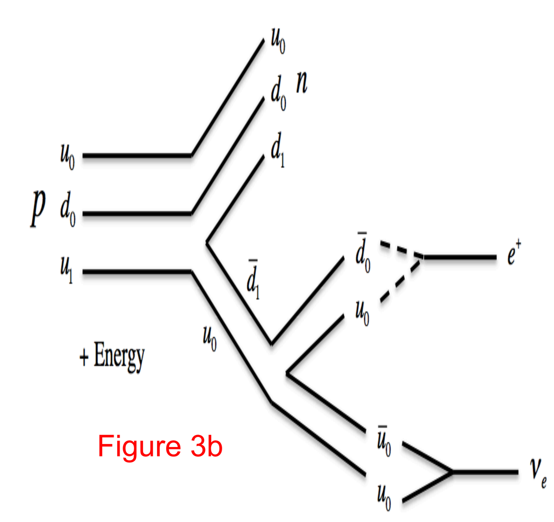

Figure 3b

III. Quark Excitation, Pair Production, Annihilation, and Lepton Formation

A quark and an antiquark combine to form a meson when no annihilation occurs, a charged lepton when color charges annihilate, a neutrino when both electric and color charges annihilate, and a photon when all mass, electric, and color charges annihilate (Figure 4a).

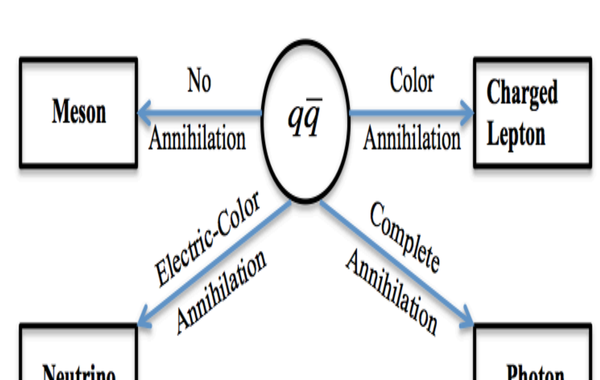

Figure 4a

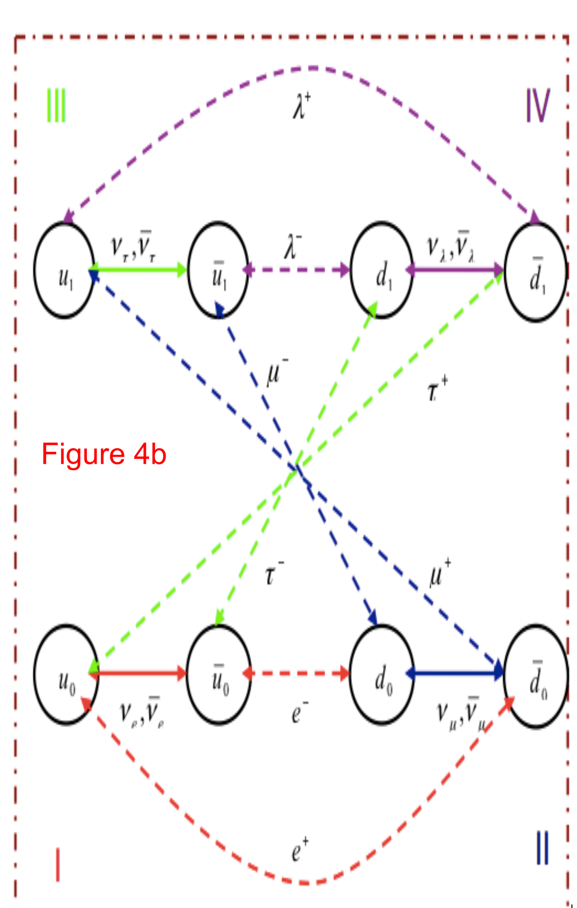

Figure 4b

Table 3

	u_0	d_0	u_1	d_1
$\bar{u}_0$	$\nu_e,\bar{\nu}_e$	e^-	?	τ^-
$\bar{d}_0$	e^+	$\nu_\mu,\bar{\nu}_\mu$	μ^+	?
$\bar{u}_1$	?	μ^-	$\nu_\tau,\bar{\nu}_\tau$	λ^-
$\bar{d}_1$	τ^+	?	λ^+	$\nu_\lambda,\bar{\nu}_\lambda$

Table 3 and Figure 4b shows the leptons that are formed from the annihilations of up and down quarks and antiquarks from the ground states to the first excited states. The electron is formed from the color charge annihilation between the ground antiup and down quark; the electron-type neutrino is formed from both the electric and color charge annihilations between the ground up and antiup quarks; and so on. Here, it predicts the formation of the fourth generation leptons from the charge annihilations between the excited up and down quarks and antiquarks.

IV. Electron-Positron Collision and Particles of Two-Flavor Quark Model

Electron and positron, when collide, are disintegrated into quarks and antiquarks, which are excited from the collision to different energy levels. The annihilations or combinations of these excited quark and antiquarks form other-type leptons or various mesons and their antiparticles (Figure 5c). Similarly, a neutrino, when it collides with a nucleus, is disintegrated into a quark and an antiquark, which are excited and annihilated into another type of neutrino (Figure 5a and 5b). This may explain the oscillation of neutrinos between different flavors. Table 4 lists many possible leptons and mesons probably formed from the annihilations and combinations of various highly excited up and down quarks and antiquarks according to two-flavor quark model..

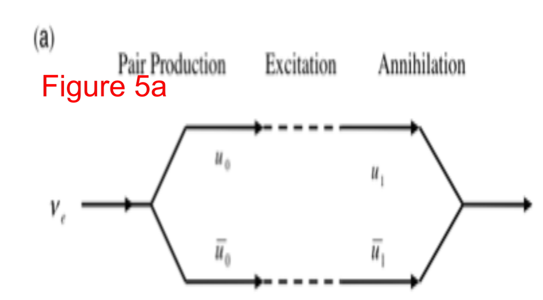

Figure 5a

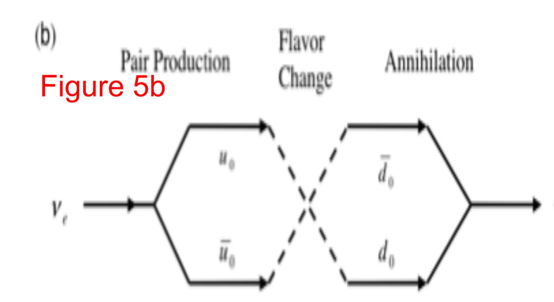

Figure 5b

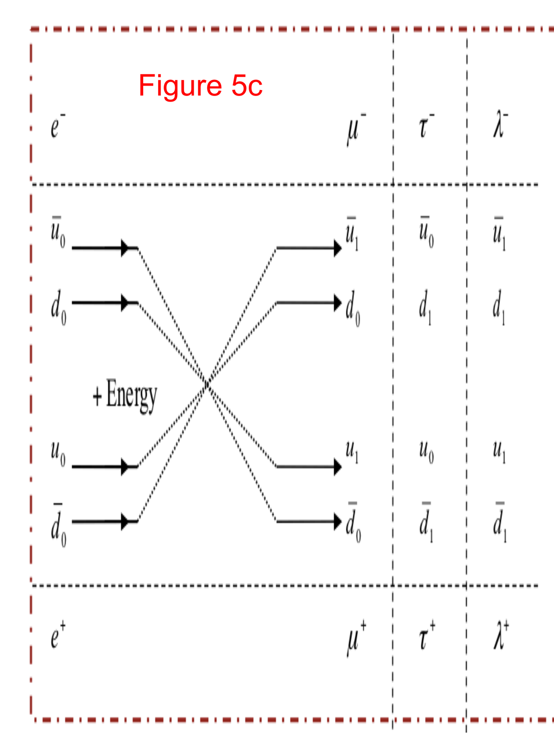

Figure 5c

Table 4

$q/\bar{q}$	u_0	d_0	u_1	d_1	u_2 (c)	d_2 (s)	u_3 (t)	d_3 (b)
$\bar{u}_0$	$\nu_e\,\bar{\nu}_e$	e^-		τ^-				
$\bar{d}_0$	e^+	$\nu_\mu\,\bar{\nu}_\mu$	$\mu^+\,W^+$	Z^0				
$\bar{u}_1$		$\mu^-\,W^-$	$\nu_\tau\,\bar{\nu}_\tau$ π^0	λ^- π^-	H^0 D^0	K^-	T^0	B^-
$\bar{d}_1$	τ^+	Z^0	λ^+ π^+	$\nu_\lambda\,\bar{\nu}_\lambda$ π^0	D^+	K^0	T^+ DsJ+	$\bar{B}^0$
$\bar{u}_2$			H^0 $\bar{D}^0$	D^-	$\nu_c\,\bar{\nu}_c$ J/ψ	D_s^-	T_c^0 X	B_c^-
$\bar{d}_2$			K^+	K^0	D_s^+	$\nu_s\,\bar{\nu}_s$ ϕ	T_s^+	$\bar{B}_s^0$
$\bar{u}_3$			$\bar{T}^0$	T^- DsJ-	$\bar{T}_c^0$	T_s^- Z	$\nu_t\,\bar{\nu}_t$ Y	T_b^-
$\bar{d}_3$			B^+	B^0	B_c^+	B_s^0	T_b^+	$\nu_b\,\bar{\nu}_b$ Υ

V. Summary

The weak force is an interaction between electric and color charges, occurs inside quarks, and causes quarks to excite, decay, and produce quark-antiquark pairs. Annihilations or combinations of quarks and antiquarks form leptons or mesons. Decay of a quark with formation of leptons involves quark-antiquark pair-productions and annihilations. The fine structures of Feynman diagrams show W bosons and leptons to be products rather than exchangers and participants of the weak interaction. The two-flavor (up and down) quark model predicts many more mesons and leptons to be formed when highly excited quarks and antiquarks annihilate or simply are coupled via the strong or color-color charge interaction. Leptons, when collide, disintegrate into quarks and antiquarks and excite them to form others.

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VI. References

1. T.X. Zhang, Electric charge as a form of imaginary energy, Prog. Phys., 2, 79-83 (2008).
2. T.X. Zhang, Fundamental elements and interactions of nature: a classical unification theory, Prog. Phys., 2, 36-42 (2010).
3. T.X. Zhang, Quark annihilation and lepton formation versus pair production and neutrino oscillation: The fourth generation of leptons, Prog. Phys., 2, 20-26 (2011).

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