

**Weakton Model of Elementary
Particles and Decay Mechanisms**

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ABSTRACT. Sub-atomic decays and electron radiations indicate that there must be interior structures for charged leptons, quarks and mediators. The main objectives of this article are 1) to propose a sub-leptons and sub-quark model, which we call weakton model, and 2) to derive a mechanism for all sub-atomic decays and bremsstrahlung. The theory is based on 1) a theory on weak and strong charges, 2) different levels of weak and strong interaction potentials, 3) a new mass generation mechanism, and 4) an angular momentum rule. The weakton model postulates that all matter particles (leptons, quarks) and mediators are made up of massless weaktons. The weakton model offers a perfect explanation for all sub-atomic decays and all generation/annihilation processes of matter-antimatter. In particular, the precise constituents of particles involved in all decays both *before* and *after* the reaction can now be precisely derived. In addition, the bremsstrahlung phenomena can be understood using the weakton model. Also, the weakton model offers an explanation to the baryon asymmetry problem.

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1. INTRODUCTION

The matter in the universe is made up of a number of fundamental constituents. The current knowledge of elementary particles shows that all forms of matter are made up of 6 leptons and 6 quarks, and their antiparticles. The basic laws governing the dynamical behavior of these elementary particles are the laws for the four interactions/forces: the electromagnetism, the gravity, the weak and strong interactions. Great achievements and insights have been made for last 100 years or so on the understanding of the structure of subatomic particles and on the fundamental laws for the four interactions; see among many others [3, 2, 5, 12, 10].

However, there are still many longstanding open questions and challenges. Here are a few fundamental questions which are certainly related to the deepest secret of our universe:

- Q₁** What is the origin of four forces?
- Q₂** Why do leptons not participate in strong interactions?
- Q₃** What is the origin of mass?
- Q₄** What is the mechanism of subatomic decays and reactions?
- Q₅** Why can massless photons produce massive particles? Or in general, why can lepton and anti-lepton pairs produce hadron pairs?
- Q₆** Are leptons and quarks true elementary particles? Do leptons and quarks have interior structure?
- Q₇** Why are there more matters than anti-matters? This is the classical baryon asymmetry problem.
- Q₈** What are the strong and weak force formulas?
- Q₉** Why, in the same spatial scale, do strong and weak interactions exhibit both repelling and attraction?
- Q₁₀** Why are the weak and strong interactions short-ranged, and what are the ranges of the four interactions?
- Q₁₁** What is the mechanism of quark confinement?
- Q₁₂** What is the mechanism of bremsstrahlung?

The main objectives of this article are 1) to study the mechanism of subatomic decays, 2) to propose a weakton model of elementary particles, and 2) to explain the above questions \mathbf{Q}_1 – \mathbf{Q}_{12} . We proceed as follows.

1. The starting point of the study is the puzzling decay and reaction behavior of subatomic particles. For example, the electron radiations and the electron-positron annihilation into photons or quark-antiquark pair clearly shows that there must be interior structure of electrons, and the constituents of an electron contribute to the making of photon or the quark in the hadrons formed in the process. In fact, all sub-atomic decays and reactions show clearly the following conclusion:

(1.1) *There must be interior structure of charged leptons, quarks and mediators.*

2. The above conclusion motivates us to propose a model for sub-lepton, sub-quark, and sub-mediators. It is clear that any such model should obey four basic requirements.

The first is the mass generation mechanism. Namely, the model should lead to consistency of masses for both elementary particles, which we call weaktons to be introduced below, and composite particles (the quarks, leptons and mediators). Since the mediators, the photon γ and the eight gluons g^k ($k = 1, \dots, 8$), are all massless, a natural requirement is that

(1.2) *the proposed elementary particles—weaktons— are massless.*

Namely, these proposed elementary particles must have zero rest mass.

The second requirement for the model is the consistency of quantum numbers for both elementary and composite particles. The third requirement is the exclusion of nonrealistic compositions of the elementary particles, and the fourth requirement is the weakton confinement.

3. Careful examinations of these requirements and subatomic decays/reactions lead us to propose six elementary particles, which we call weaktons, and their anti-particles:

$$(1.3) \quad \begin{array}{cccccc} w^*, & w_1, & w_2, & \nu_e, & \nu_\mu, & \nu_\tau, \\ \bar{w}^*, & \bar{w}_1, & \bar{w}_2, & \bar{\nu}_e, & \bar{\nu}_\mu, & \bar{\nu}_\tau, \end{array}$$

where ν_e, ν_μ, ν_τ are the three generation neutrinos, and w^*, w_1, w_2 are three new particles, which we call w -weaktons. These are massless, spin- $\frac{1}{2}$ particles with one unit of weak charge g_w . Both w^* and \bar{w}^* are the only weaktons carrying strong charge g_s .

With these weaktons at our disposal, the weakton constituents of charged leptons and quarks are then given as follows:

$$(1.4) \quad \begin{array}{lll} e = \nu_e w_1 w_2, & \mu = \nu_\mu w_1 w_2, & \tau = \nu_\tau w_1 w_2, \\ u = w^* w_1 \bar{w}_1, & c = w^* w_2 \bar{w}_2, & t = w^* w_2 \bar{w}_2, \\ d = w^* w_1 w_2, & s = w^* w_1 w_2, & b = w^* w_1 w_2, \end{array}$$

where c, t and d, s, b are distinguished by the spin arrangements; see (4.6) and (4.7).

4. Using the duality given in the unified field theory for four interactions, the mediators of strong, weak and electromagnetic interactions include the photon γ ,

the vector bosons W^\pm and Z , and the gluons g^k , together with their dual fields ϕ_γ , ϕ_W^\pm , ϕ_Z^0 , and ϕ_g^k . The constituents of these mediators are given by

$$(1.5) \quad \begin{aligned} \gamma &= \cos \theta_w w_1 \bar{w}_1 - \sin \theta_w w_2 \bar{w}_2 \ (\uparrow\uparrow, \downarrow\downarrow), \\ Z^0 &= \cos \theta_w w_2 \bar{w}_2 + \sin \theta_w w_1 \bar{w}_1 \ (\uparrow\uparrow, \downarrow\downarrow), \\ W^- &= w_1 w_2 (\uparrow\uparrow, \downarrow\downarrow), \\ W^+ &= \bar{w}_1 \bar{w}_2 (\uparrow\uparrow, \downarrow\downarrow), \\ g^k &= w^* \bar{w}^* (\uparrow\uparrow, \downarrow\downarrow), \quad k = \text{color index}, \end{aligned}$$

and the dual bosons:

$$(1.6) \quad \begin{aligned} \phi_\gamma &= \cos \theta_w w_1 \bar{w}_1 - \sin \theta_w w_2 \bar{w}_2 \ (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_Z^0 &= \cos \theta_w w_2 \bar{w}_2 + \sin \theta_w w_1 \bar{w}_1 \ (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_W^- &= w_1 w_2 (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_W^+ &= \bar{w}_1 \bar{w}_2 (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_g^k &= w^* \bar{w}^* (\uparrow\downarrow, \downarrow\uparrow), \end{aligned}$$

where $\theta_w \cong 28.76^\circ$ is the Weinberg angle.

Remarkably, both the spin-1 mediators in (1.5) and the spin-0 dual mediators in (1.6) have the *same* weakton constituents, differing only by their spin arrangements. The spin arrangements clearly demonstrate that there must be spin-0 particles with the same weakton constituents as the mediators in (1.5). Consequently, there must be dual mediators with spin-0. This observation clearly supports the unified field model presented in [7, 8]. Conversely, the existence of the dual mediators makes the weakton constituents perfectly fit.

5. Also, a careful examination of weakton constituents predicts the existence of an additional mediator, which we call the ν -mediator:

$$(1.7) \quad \phi_\nu^0 = \sum_l \alpha_l \nu_l \bar{\nu}_l (\downarrow\uparrow), \quad \sum_l \alpha_l^2 = 1,$$

taking into consideration of neutrino oscillations. When examining decays and reactions of sub-atomic particles, it is apparent for us to predict the existence of this mediator.

6. One important conclusion of the aforementioned weakton model is that all particles—both matter particles and mediators—are made up of massless weaktons. A fundamental question is how the mass of a massive composite particle is generated. In fact, based on the Einstein formulas:

$$(1.8) \quad \frac{d}{dt} \vec{P} = \sqrt{1 - \frac{v^2}{c^2}} \vec{F}, \quad m = \sqrt{1 - \frac{v^2}{c^2}} \frac{E}{c^2},$$

we observe that a particle with an intrinsic energy E has zero mass $m = 0$ if it moves in the speed of light $v = c$, and possess nonzero mass if it moves with a velocity $v < c$. Hence by this mass generation mechanism, for a composite particle, the constituent massless weaktons can decelerate by the weak force, yielding a massive particle.

In principle, when calculating the mass of the composite particle, one should also consider the bounding and repelling energies of the weaktons, each of which can be

very large. Fortunately, the constituent weaktons are moving in the “asymptotically-free” shell region of weak interactions as indicated by the weak interaction potential/force formulas, so that the bounding and repelling contributions to the mass are mostly canceled out. Namely, the mass of a composite particle is due mainly to the dynamic behavior of the constituent weaktons.

7. As we mentioned earlier, one requirement for the weakton model is the consistency of quantum numbers for both elementary particles and composite particles. In fact, the weakton model obeys a number of quantum rules, which can be used to exclude unrealistic combinations of weaktons. The following rules are introduced for this purpose:

- a) Weak color neutral rule: each weakton is endowed with a weak color quantum number, and all weakton composite particles must be weak color neutral,
- b) $BL = 0, L_i L_j = 0$ ($i \neq j$), where B is the baryon number and L is the lepton number.
- c) $L + Q_e = 0$ if $L \neq 0$ and $|B + Q_e| \leq 1$ if $B \neq 0$.
- d) Angular Momentum Rule: *Only the fermions with spin $s = \frac{1}{2}$ can rotate around a center with zero moment of force. The particles with $s \neq \frac{1}{2}$ will move in a straight line unless there is a nonzero moment of force present.*

The angular momentum is a consequence of the Dirac equations, and it is due to this rule that there are no spin-3/2 quarks.

8. Remarkably, the weakton model offers a perfect explanation for all sub-atomic decays. In particular, all decays are achieved by 1) exchanging weaktons and consequently exchanging newly formed quarks, producing new composite particles, and 2) separating the new composite particles by weak and/or strong forces.

One aspect of this decay mechanism is that we know now the precise constituents of particles involved in all decays/reactions both before and after the reaction. It is therefore believed that the new decay mechanism provides clear new insights for both experimental and theoretical studies.

9. The weakton theory, together with the unified field theory developed in [7, 8], provides sound explanations and new viewpoints for the twelve fundamental questions given at the beginning of the Introduction.

We end this Introduction by mentioning that there have been numerous studies on sub-quark and sub-lepton models; see among others [9, 1, 11, 4]

The paper is organized as follows. A brief introduction to the current understanding of elementary particles is given in Section 2, focusing on 1) the constituents of subatomic particles, and 2) decays. Section 3 addresses a few theoretical foundations needed for introducing the weakton model, which is then introduced in Section 4. All decays are then perfectly explained using the weakton model in Section 5. An application of the weakton model to bremsstrahlung is given in Section 6. Section 7 summarizes conclusions of this article, focusing on answers and explanations to the 12 open questions.

2. CURRENT KNOWLEDGE OF ELEMENTARY PARTICLES

The current view on subatomic particles classifies all particles into two basic classes, bosons and fermions:

$$\begin{aligned} \text{bosons} &= \text{integral spin particles,} \\ \text{fermions} &= \text{fractional spin particles.} \end{aligned}$$

However, based on their properties and laws in Nature, all particles are currently classified into four types:

$$\text{leptons, quarks, mediators, hadrons.}$$

Hereafter we recapitulate the definitions and the quantum characterizations of these particles.

2.1. Leptons. Leptons are fermions which do not participate in strong interaction, and have three generations with two in each generation:

$$\begin{pmatrix} e \\ \nu_e \end{pmatrix}, \quad \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}, \quad \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix},$$

where e, μ, τ are the electron, the muon, the tau, and ν_e, ν_μ, ν_τ are the e neutrino, the μ neutrino, the τ neutrino. Together with antiparticles, there are total 12 leptons:

$$\begin{aligned} \text{particles:} & \quad (e^-, \nu_e), (\mu^-, \nu_\mu), (\tau^-, \nu_\tau), \\ \text{antiparticles:} & \quad (e^+, \bar{\nu}_e), (\mu^+, \bar{\nu}_\mu), (\tau^+, \bar{\nu}_\tau). \end{aligned}$$

The quantum numbers of leptons include the mass m , the charge Q , the lifetime τ , the spin J , the e -lepton number L_e , the μ -lepton number L_μ , and the τ -lepton number L_τ . Table 2.1 lists typical values of these quantum numbers, where the mass is in MeV/c^2 , lifetime is in seconds, and the charge is in the unit of proton charge. Also, we remark that the left-hand property of neutrinos is represented by $J = -\frac{1}{2}$ for ν , and $J = +\frac{1}{2}$ for $\bar{\nu}$.

2.2. Quarks. Based on the Standard Model, there are three generations of quarks containing 12 particles, which participate in all interactions:

$$\begin{aligned} \text{quarks:} & \quad (u, d), (c, s), (t, b), \\ \text{antiquarks:} & \quad (\bar{u}, \bar{d}), (\bar{c}, \bar{s}), (\bar{t}, \bar{b}). \end{aligned}$$

The celebrated quark model asserts that three quarks are bounded together to form a baryon, and a pair of quark and antiquark are bounded to form a meson. Quarks are confined in hadrons, and no free quarks have been found in Nature. This phenomena is called quark confinement, which can be very well explained using the three levels of strong interaction potentials derived using a unified field theory developed recently in [7, 8]; see discussions in Section 3.4.

The quantum numbers of quarks include the mass m , the charge Q , the baryon number B , the spin J , the strange number S , the isospin I and its third component I_3 , the supercharge Y , and the parity P . These quantum numbers are listed in Table 2.2.

TABLE 2.1. Leptons

lepton	M	Q	J	L_e	L_μ	L_τ	τ
e^-	0.51	-1	$\pm 1/2$	1	0	0	∞
ν_e	0	0	$-1/2$	1	0	0	∞
e^+	0.51	+1	$\pm 1/2$	-1	0	0	
$\bar{\nu}_e$	0	0	$+1/2$	-1	0	0	∞
μ^-	105.7	-1	$\pm 1/2$	0	1	0	2.2×10^{-6}
ν_μ	0	0	$-1/2$	0	1	0	∞
μ^+	105.7	+1	$\pm 1/2$	0	-1	0	
$\bar{\nu}_\mu$	0	0	$+1/2$	0	-1	0	∞
τ^-	1777	-1	$\pm 1/2$	0	0	1	3×10^{-13}
ν_τ	0	0	$-1/2$	0	0	1	∞
τ^+	1777	+1	$\pm 1/2$	0	0	-1	
$\bar{\nu}_\tau$	0	0	$+1/2$	0	0	-1	∞

2.3. Mediators. The standard model shows that associated with each interaction is a class of mediators. Namely, there are four classes of mediators:

Gravitation:	graviton g_G ,
Electromagnetism:	photon γ ,
Weak interaction:	vector meson W^\pm, Z^0 ,
Strong interaction:	gluons g^k ($1 \leq k \leq 8$).

The quantum numbers of these mediators include the mass m , the charge Q , the spin J , and the lifetime τ , listed in Table 2.3.

With the unified field theory developed in [7, 8], we have obtained a natural duality between the interacting fields $\{g_{\mu\nu}, A_\mu, W_\mu^a, S_\mu^k\}$ and their dual field $\{\Phi_\mu^G, \phi_E, \phi_w^a, \phi_s^k\}$:

$$\begin{aligned}
 \{g_{\mu\nu}\} &\longleftrightarrow \Phi_\mu^G, \\
 A_\mu &\longleftrightarrow \phi_E, \\
 \{W_\mu^a\} &\longleftrightarrow \{\phi_w^a\}, \\
 \{S_\mu^k\} &\longleftrightarrow \{\phi_s^k\}.
 \end{aligned}$$

TABLE 2.2. Quarks

Quarks	m	Q	J	B	S	Y	I	I_3	P
u	3	2/3	$\pm 1/2$	1/3	0	1/3	1/2	+1/2	+1
d	7	-1/3	$\pm 1/2$	1/3	0	1/3	1/2	-1/2	+1
c	1200	2/3	$\pm 1/2$	1/3	0	1/3	0	0	+1
s	120	-1/3	$\pm 1/2$	1/3	-1	-2/3	0	0	+1
t	1.7×10^5	2/3	$\pm 1/2$	1/3	0	1/3	0	0	+1
b	4300	-1/3	$\pm 1/2$	1/3	0	1/3	0	0	+1
\bar{u}	3	-2/3	$\pm 1/2$	-1/3	0	-1/3	1/2	-1/2	-1
\bar{d}	7	1/3	$\pm 1/2$	-1/3	0	-1/3	1/2	+1/2	-1
\bar{c}	1200	-2/3	$\pm 1/2$	-1/3	0	-1/3	0	0	-1
\bar{s}	120	1/3	$\pm 1/2$	-1/3	+1	2/3	0	0	-1
\bar{t}	1.7×10^5	-2/3	$\pm 1/2$	-1/3	0	-1/3	0	0	-1
\bar{b}	4300	1/3	$\pm 1/2$	-1/3	0	-1/3	0	0	-1

TABLE 2.3. Interaction Mediators

Interaction	Mediator	m	Q	J	τ
Gravitation	g_G	0	0	2	∞
Electromagnetic	γ	0	0	1	∞
Weak	W^+	8×10^4	+1	1	3×10^{-25}
	W^-	8×10^4	-1	1	3×10^{-25}
	Z^0	9×10^4	0	1	2.6×10^{-25}
Strong	$g^k (1 \leq k \leq 8)$	0	0	1	∞

This duality leads to four classes of new dual bosonic mediators:

$$(2.1) \quad \begin{array}{ll} \text{graviton } g_G & \longleftrightarrow \text{ vector boson } \Phi^G, \\ \text{photon } \gamma & \longleftrightarrow \text{ scalar boson } \phi_\gamma, \\ \text{vector bosons } W^\pm, Z & \longleftrightarrow \text{ scalar bosons } \phi_W^\pm, \phi_Z^0, \\ \text{gluons } g^k (1 \leq k \leq 8) & \longleftrightarrow \text{ scalar bosons } \phi_g^k (1 \leq k \leq 8) \end{array}$$

These dual mediators are crucial not only for the weak and strong potential/force formulas given in the next section, but also for the weakton model introduced in this article. In addition, the dual vector field Φ^G gives rise to a unified theory for dark matter and dark energy [6].

The quantum numbers of these dual mediators are given as follows:

$$(2.2) \quad \begin{array}{llll} \Phi^G : & m = 0, & J = 1, & Q = 0, \quad \tau = \infty, \\ \phi_e : & m = 0, & J = 0, & Q = 0, \quad \tau = \infty, \\ \phi_W^\pm (\text{Higgs}) : & m \sim 10^5, & J = 0, & Q = \pm 1, \quad \tau \sim 10^{-21} s, \\ \phi_Z^0 (\text{Higgs}) : & m \sim 1.25 \times 10^5, & J = 0, & Q = 0, \quad \tau \sim 10^{-21} s, \\ \phi_g^k : & m = ?, & J = 0, & Q = 0, \quad \tau = ?. \end{array}$$

2.4. Hadrons. Hadrons are classified into two types: baryons and mesons. Baryons are fermions and mesons are bosons, which are all made up of quarks:

$$\text{Baryons} = q_i q_j q_k, \quad \text{mesons} = q_i \bar{q}_j,$$

where $q_k = \{u, d, c, s, t, b\}$. The quark constituents of main hadrons are listed as follows:

- BARYONS ($J = \frac{1}{2}$) : $p, n, \Lambda, \Sigma^\pm, \Sigma^0, \Xi^0, \Xi^-$.

$$(2.3) \quad \begin{array}{llll} p(ud), & n(udd), & \Lambda(s(du - ud)/\sqrt{2}), \\ \Sigma^+(uus), & \Sigma^-(dds), & \Sigma^0(s(du + ud)/\sqrt{2}), \\ \Xi^-(uss), & \Xi^0(dss). \end{array}$$

- BARYONS ($J = \frac{3}{2}$) : $\Delta^{++}, \Delta^\pm, \Delta^0, \Sigma^{*\pm}, \Sigma^{*0}, \Xi^{*0}, \Xi^{*-}, \Omega^-$.

$$(2.4) \quad \begin{array}{llll} \Delta^{++}(uuu), & \Delta^+(uud), & \Delta^-(ddd), & \Delta^0(udd), \\ \Sigma^{*+}(uus), & \Sigma^{*-}(dds), & \Sigma^{*0}(uds), \\ \Xi^{*0}(uss), & \Xi^{*-}(dss), & \Omega^-(sss). \end{array}$$

- MESONS ($J = 0$) : $\pi^\pm, \pi^0, K^\pm, K^0, \bar{K}^0, \eta$,

$$(2.5) \quad \begin{array}{llll} \pi^+(u\bar{d}), & \pi^-(\bar{u}d), & \pi^0((u\bar{u} - d\bar{d})/\sqrt{2}), \\ K^+(u\bar{s}), & K^-(\bar{u}s), & K^0((d\bar{s}), & \bar{K}^0(\bar{d}s), \\ \eta((u\bar{u} + d\bar{d} - 2s\bar{s})/\sqrt{6}). \end{array}$$

- MESONS ($J = 1$) : $\rho^\pm, \rho^0, K^{*\pm}, K^{*0}, \bar{K}^{*0}, \omega, \psi, \Upsilon$,

$$(2.6) \quad \begin{array}{llll} \rho^+(u\bar{d}), & \rho^-(\bar{u}d), & \rho^0((u\bar{u} - d\bar{d})/\sqrt{2}), \\ K^{*+}(u\bar{s}), & K^{*-}(\bar{u}s), & K^{*0}(\bar{d}s), & \bar{K}^{*0}(\bar{d}s), \\ \omega((u\bar{u} + d\bar{d})/\sqrt{2}), & \psi(c\bar{c}), & \Upsilon(b\bar{b}). \end{array}$$

2.5. Principal decays. Decays are the main dynamic behavior for sub-atomic particles, and reveal the interior structure of particles. We now list some principal decay forms.

- Lepton decays:

$$\begin{aligned}\mu^- &\rightarrow e^- + \bar{\nu}_e + \nu_\mu, \\ \mu^+ &\rightarrow e^+ + \nu_e + \bar{\nu}_\mu, \\ \tau^- &\rightarrow e^- + \bar{\nu}_e + \nu_\tau, \\ \tau^- &\rightarrow \mu^- + \bar{\nu}_\mu + \nu_\tau, \\ \tau^- &\rightarrow \pi^- + \nu_\tau, \\ \tau^- &\rightarrow \rho^- + \nu_\tau, \\ \tau^- &\rightarrow K^- + \nu_\tau.\end{aligned}$$

- Quark decays:

$$\begin{aligned}d &\rightarrow u + e^- + \bar{\nu}_e, \\ s &\rightarrow u + e^- + \bar{\nu}_e, \\ s &\rightarrow d + g + \gamma && (g \text{ the gluons}), \\ c &\rightarrow d + \bar{s} + u,\end{aligned}$$

- Mediator decays:

$$\begin{aligned}2\gamma &\rightarrow e^+ + e^-, q\bar{q}, \\ W^+ &\rightarrow e^+ + \nu_e, \mu^+ + \nu_\mu, \tau^+ + \nu_\tau, \\ W^- &\rightarrow e^- + \bar{\nu}_e, \mu^- + \bar{\nu}_\mu, \tau^- + \bar{\nu}_\tau, \\ Z^0 &\rightarrow e^+ + e^-, \mu^+ + \mu^-, \tau^+ + \tau^-, q\bar{q}.\end{aligned}$$

- Baryon decays:

$$\begin{aligned}n &\rightarrow p + e^- + \bar{\nu}_e, \\ \Lambda &\rightarrow p + \pi^-, n + \pi^0, \\ \Sigma^+ &\rightarrow p + \pi^0, n + \pi^+, \\ \Sigma^0 &\rightarrow \Lambda + \gamma, \Sigma^- \rightarrow n + \pi^-, \\ \Xi^0 &\rightarrow \Lambda + \pi^0, \Xi^- \rightarrow \Lambda + \pi^-, \\ \Delta^{++} &\rightarrow p + \pi^+, \Delta^+ \rightarrow p + \pi^0, \\ \Delta^0 &\rightarrow n + \pi^0, \Delta^- \rightarrow n + \pi^-, \\ \Sigma^{*\pm} &\rightarrow \Sigma^\pm + \pi^0, \Xi^{*0} \rightarrow \Sigma^0 + \pi^0, \\ \Xi^{*0} &\rightarrow \Xi^0 + \pi^0, \Xi^{*-} \rightarrow \Xi^- + \pi^0.\end{aligned}$$

- Meson decays:

$$\begin{aligned}
\pi^+ &\rightarrow \mu^+ + \nu_\mu, & \pi^0 &\rightarrow 2\gamma, \\
\pi^- &\rightarrow \mu^- + \bar{\nu}_\mu, \\
K^+ &\rightarrow \mu^+ + \nu_\mu, & \pi^+ + \pi^0, & \pi^+ + \pi^+ + \pi^-, \\
K^- &\rightarrow \mu^- + \bar{\nu}_\mu, & \pi^- + \pi^0, & \pi^- + \pi^+ + \pi^-, \\
K^0 &\rightarrow \pi^+ + e^- + \bar{\nu}_e, & \pi^+ + \pi^-, & \pi^+ + \pi^- + \pi^0, \\
\eta &\rightarrow 2\gamma, & \pi^+ + \pi^- + \pi^0, \\
\rho^\pm &\rightarrow \pi^0, & \rho^0 &\rightarrow \pi^+ + \pi^-, \\
K^{*\pm} &\rightarrow K^\pm + \pi^0, & K^{*0} &\rightarrow K^0 + \pi^0, \\
\omega &\rightarrow \pi^0 + \gamma, & \pi^+ + \pi^- + \pi^0, \\
\psi &\rightarrow e^+ + e^-, & \mu^+ + \mu^-, \\
\Upsilon &\rightarrow e^+ + e^-, & \mu^+ + \mu^-, & \tau^+ + \tau^-.
\end{aligned}$$

3. THEORETICAL FOUNDATIONS FOR THE WEAKTON MODEL

3.1. Angular momentum rule. It is known that the dynamic behavior of a particle is described by the Dirac equations:

$$(3.1) \quad i\hbar \frac{\partial \psi}{\partial t} = H\psi, \quad \psi = (\psi_1, \psi_2, \psi_3, \psi_4)^T$$

where H is the Hamiltonian

$$(3.2) \quad H = -i\hbar c(\alpha^k \partial_k) + mc^2 \alpha^0 + V(x),$$

V is the potential energy, and α^0, α^k ($1 \leq k \leq 3$) are the Dirac matrices

$$\begin{aligned}
\alpha^0 &= \begin{pmatrix} 1 & & & 0 \\ & 1 & & \\ & & -1 & \\ 0 & & & -1 \end{pmatrix}, & \alpha^1 &= \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}, \\
\alpha^2 &= \begin{pmatrix} 0 & 0 & 0 & -i \\ 0 & 0 & i & 0 \\ 0 & -i & 0 & 0 \\ i & 0 & 0 & 0 \end{pmatrix}, & \alpha^3 &= \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix}.
\end{aligned}$$

By the conservation laws in relativistic quantum mechanics, if a Hermitian operator L commutes with H in (3.2):

$$LH = HL,$$

then the physical quantity L is conservative.

Consider the total angular momentum \vec{J} of a particle given by

$$\vec{J} = \vec{L} + s\hbar\vec{S},$$

where L is the orbital angular momentum

$$\vec{L} = \vec{r} \times \vec{p}, \quad \vec{p} = -i\hbar\nabla,$$

\vec{S} is the spin

$$\vec{S} = (S_1, S_2, S_3), \quad S_k = \begin{pmatrix} \sigma_k & 0 \\ 0 & \sigma_k \end{pmatrix},$$

and σ_k ($1 \leq k \leq 3$) are the Pauli matrices.

We know that for H in (3.2)

$$(3.3) \quad \begin{aligned} \vec{J}_{1/2} = \vec{L} + \frac{1}{2}\hbar\vec{S} & \text{ commutes with } H, \\ \vec{J}_s = \vec{L} + s\hbar\vec{S} & \text{ does not commute with } H \text{ for } s \neq 1/2 \text{ in general.} \end{aligned}$$

Also, we know that

$$(3.4) \quad s\hbar\vec{S} \text{ commutes with } H \text{ with straight line motion for any } s.$$

The properties in (3.3) imply that only particles with spin $s = \frac{1}{2}$ can make a rotational motion in a center field with free moment of force. However, (3.4) implies that the particles with $s \neq \frac{1}{2}$ will move in a straight line, i.e. $\vec{L} = 0$, unless they are in a field with nonzero moment of force.

In summary, we have derived the following angular momentum rule for subatomic particle motion, which is important for our weakton model established in the next section.

Angular Momentum Rule: *Only the fermions with spin $s = \frac{1}{2}$ can rotate around a center with zero moment of force. The particles with $s \neq \frac{1}{2}$ will move on a straight line unless there is a nonzero moment of force present.*

For example, the particles bounded in a ball rotating around the center, as shown in Figure 3.1, must be fermions with $s = \frac{1}{2}$.

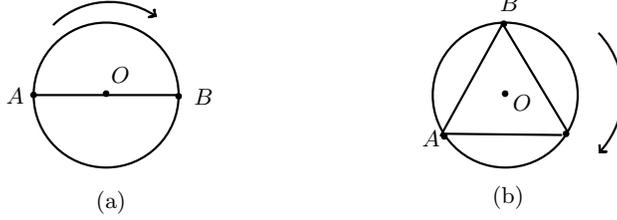


FIGURE 3.1. (a) Two particles A, B rotate around the center O ;
(b) three particle A, B, C rotate around the center O .

3.2. Mass generation mechanism. For a particle moving with velocity v , its mass and energy E obey the Einstein relation

$$(3.5) \quad E = mc^2 / \sqrt{1 - \frac{v^2}{c^2}}.$$

Usually, we regard m as a static mass which is fixed, and energy E is a function of velocity v .

Now, taking an opposite viewpoint, we regard energy E as fixed, and mass m is a function of velocity v , i.e. the relation (3.5) is rewritten as

$$(3.6) \quad m = \sqrt{1 - \frac{v^2}{c^2}} \frac{E}{c^2}.$$

Thus, (3.6) means that a particle with an intrinsic energy E has zero mass $m = 0$ if it moves at the speed of light $v = c$, and will possess nonzero mass if it moves with a velocity $v < c$. All particles including photons can only travel at the speed sufficiently close to the speed of light. Based on this viewpoint, we can think that

if a particle moving at the speed of light (approximately) is decelerated by an interaction field, obeying

$$\frac{d\vec{P}}{dt} = \sqrt{1 - \frac{v^2}{c^2}} \vec{F},$$

then this massless particle will generate mass at the instant. In particular, by this mass generation mechanism, several massless particles can yield a massive particle if they are bounded in a small ball, and rotate at velocities less than the speed of light.

From this mass generation mechanism, we can also understand the neutrino oscillation phenomena. Experiments show that each of the three neutrinos ν_e, ν_τ, ν_μ can transform from one to another, although the experiments illustrate that neutrinos propagate at the speed of light. This oscillation means that they generate masses at the instant of transformation. This can be viewed as the neutrinos decelerate at the instant when they undergo the transformation/oscillation, generating instantaneous masses, and after the transformation, they return to the usual dynamic behavior—moving at the speed of light with zero masses. In other words, by the mass generation mechanism, we can assert that neutrinos have no static masses, and their oscillations give rise to instantaneous masses.

3.3. Interaction charges. In the unified field model developed in [7, 8], we derived that both weak and strong interactions possess charges, as for gravity and electromagnetism:

$$(3.7) \quad \begin{array}{ll} \text{gravitation:} & \text{mass charge } m \\ \text{electromagnetism:} & \text{electric charge } e, \\ \text{weak interaction:} & \text{weak charge } g_w, \\ \text{strong interaction:} & \text{strong charge } g_s. \end{array}$$

If Φ is a charge potential corresponding to an interaction, then the interacting force generated by its charge \mathfrak{C} is given by

$$(3.8) \quad F = -\mathfrak{C}\nabla\Phi,$$

where ∇ is the spatial gradient operator.

The charges in (3.7) possess the physical properties:

- 1) Electric charges Q_e , weak charges Q_w , strong charges Q_s are conservative. The energy is a conserved quantity, but the mass M is not a conserved quantity due to the mass generation mechanism as mentioned earlier.
- 2) There is no interacting force between two particles without common charges. For example, if a particle A possesses no strong charge, then there is no strong interacting force between A and any other particles.
- 3) Only the electric charge Q_e can take both positive and negative values, and other charges can take only nonnegative values.
- 4) Only the mass charge is continuous, and the others are discrete, taking discrete values.
- 5) We emphasize that the continuity of mass is the main obstruction for quantizing the gravitational field, and it might be essential that gravity cannot be quantized.

3.4. Strong interaction potentials. Three levels of strong interacting potentials are derived in [8] using the field equations, and they are called the quark potential S_q , the hadron potential S_h , and the atom/molecule potential S_a :

$$(3.9) \quad S_q = g_s \left[\frac{1}{r} - \frac{Bk_0^2}{\rho_0} e^{-k_0 r} \varphi(r) \right],$$

$$(3.10) \quad S_h = N_0 \left(\frac{\rho_0}{\rho_1} \right)^3 g_s \left[\frac{1}{r} - \frac{B_1 k_1^2}{\rho_1} e^{-k_1 r} \varphi(r) \right],$$

$$(3.11) \quad S_a = 3N_1 \left(\frac{\rho_0}{\rho_1} \right)^3 \left(\frac{\rho_1}{\rho_2} \right)^3 g_s \left[\frac{1}{r} - \frac{B_1 k_1^2}{\rho_2} e^{-k_1 r} \varphi(r) \right],$$

where N_0 is the number of quarks in hadrons, N_1 is the number of nucleons in an atom/molecule, g_s is the strong charge, B and B_1 are constants, ρ_0 is the effective quark radius, ρ_1 is the radius of a hadron, ρ_2 is the radius of an atom/molecule, and

$$k_0 \cong 10^{13} \text{cm}^{-1}, \quad k_1 \cong 10^{16} \text{cm}^{-1}.$$

It is natural to approximately take

$$(3.12) \quad \rho_0 \cong 10^{-21} \text{cm}, \quad \rho_1 \cong 10^{-16} \text{cm}, \quad \rho_2 \cong 10^{-8} \text{cm}.$$

The function $\varphi(r)$ in (3.9)-(3.11) is a power series, approximately given by

$$\varphi(r) = \frac{r}{2} + o(r).$$

Formula (3.9) and (3.10) lead to the following conclusions for quarks and hadrons:

- 1) Based on (3.7), it follows from (3.9) that the quark interacting force F has the properties

$$(3.13) \quad F = \begin{cases} > 0 & \text{for } 0 < r < R_0 \\ = 0 & \text{for } r = R_0, \\ < 0 & \text{for } R_0 < r < \rho_1, \end{cases}$$

where R_0 is the quark repelling radius, ρ_1 is the radius of a hadron as in (3.12). Namely, in the region $r < R_0$ the strong interacting force between quarks is repelling, and in the annulus $R_0 < r < \rho_1$, the quarks are attracting, as shown in Figure 3.2.

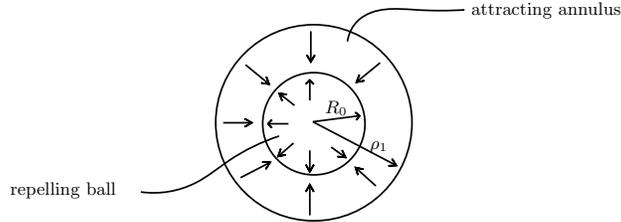


FIGURE 3.2. In the ball $r < R_0$ quark strong force is repelling, and in the annulus $R_0 < r < \rho_1$ quark strong force is attracting.

- 2) In the attracting annulus $R_0 < r < \rho_1$ as shown in Figure 3.2, the binding energy of quarks is in the Planck level, which explains the quark confinement; see [8] for details.

- 3) For hadrons, the strong interacting force is determined by (3.10), which implies that

$$(3.14) \quad F = \begin{cases} > 0 & \text{for } r < R_1, \\ < 0 & \text{for } R_1 < r < R_2, \end{cases}$$

where R_1 is the hadron repelling radius, R_2 is the attracting radius, with values given by

$$(3.15) \quad R_1 = \frac{1}{2} \times 10^{-13} \text{ cm}, \quad R_2 = 4 \times 10^{-12} \text{ cm}.$$

Namely the strong interacting force between hadrons is repelling in the ball $r < R_1$, and attracting in the annulus $R_1 < r < R_2$. In particular the repelling force tends infinite as $r \rightarrow 0$:

$$(3.16) \quad F = +\infty \quad \text{as} \quad r \rightarrow 0,$$

which means that there is a large repelling force acting on two very close hadrons.

These properties will be used to explain the strong interacting decays as well.

3.5. Weak interaction potentials. Two weak interaction potential formulas can also be derived by the unified field equations in [8]. The weakton potential Φ_w^0 and the weak interacting potentials Φ_w^1 for any particle with weak charge, including leptons, quarks and mediators, as well as the weaktons introduced in the next section, are written as

$$(3.17) \quad \Phi_w^0 = \left(\frac{\rho_0}{\rho_w} \right)^3 g_w e^{-k_1 r} \left(\frac{1}{r} - \psi_1(r) e^{-k_0 r} \right),$$

$$(3.18) \quad \Phi_w^1 = g_w e^{-k_1 r} \left(\frac{1}{r} - \psi_2(r) e^{-k_0 r} \right),$$

where g_w is the weak charge, ρ_0 is the radius of the charged leptons, the quarks and the mediators, ρ_w is the weakton radius,

$$k_0 \cong 10^{16} \text{ cm}^{-1}, \quad k_1 \cong 2 \times 10^{16} \text{ cm}^{-1},$$

and ψ_1, ψ_2 are two power series:

$$\psi_1(r) = \alpha_1 + \beta_1(r - \rho_0) + o(|r - \rho_0|),$$

$$\psi_2(r) = \alpha_2 + \beta_2(r - \rho_0) + o(|r - \rho_0|).$$

Here $\alpha_1, \beta_1, \alpha_2, \beta_2$ are the initial values of a system of second order ordinary differential equations satisfied by ψ_1 and ψ_2 , and they are determined by the physical conditions or experiments.

We remark that (3.18) was derived in [8], and (3.17) can be derived in the same fashion as the three level of strong interaction potentials (3.9)–(3.11) in [8].

Based on physical facts, phenomenologically we take $\rho_0, \rho_w, \alpha_1, \alpha_2, \beta_1, \beta_2$ as

$$(3.19) \quad \begin{aligned} \rho_w &\cong 10^{-26} \text{ cm}, & \rho_0 &\cong 10^{-21} \text{ cm}, & \rho_1 &\cong 10^{-16} \text{ cm}, \\ \alpha_1 &\cong \frac{2}{\rho_0}, & \alpha_2 &= \frac{1}{\rho_1}, & \beta_1 &= 0, & \beta_2 &> 0. \end{aligned}$$

The potentials (3.17) and (3.18) imply following assertions:

- 1) Weaktons are confined in the interior of charged leptons, quarks and mediators. In fact, the bound energy of the weaktons has the level

$$E = g_w \Phi_w^0(\rho_0) \cong -\frac{1}{\rho_0} \left(\frac{\rho_0}{\rho_w} \right)^3 g_w^2 = -10^{36} g_w^2 / \text{cm}.$$

By the Standard Model,

$$(3.20) \quad g_w^2 = \frac{8}{\sqrt{2}} G_f \left(\frac{m_w c}{\hbar} \right)^2 = 10^{-1} \hbar c.$$

Hence the bound energy is

$$E = -10^{35} \hbar c / \text{cm} = -10^{21} \text{GeV}.$$

This is the Planck level, to sufficiently confine the weaktons in their composite particles.

- 2) By (3.17) and (3.19), for the weak interacting force F_0 between weaktons, we have

$$(3.21) \quad F_0 = \begin{cases} > 0 & \text{for } 0 < r < \frac{1}{2}\rho_0, \\ < 0 & \text{for } \frac{1}{2}\rho_0 < r < \rho_1, \end{cases}$$

where ρ_0, ρ_1 are as in (3.12).

- 3) By (3.18) and (3.19), for the weak interacting force F_1 of a composite particle, we have

$$(3.22) \quad F_1 \begin{cases} > 0 & \text{for } 0 < r < \rho_1, \\ < 0 & \text{for } \rho_1 < r < \rho_2. \end{cases}$$

Hence the weak force is repelling if the particles are in the ρ_1 -ball, and is attracting if they are in the annulus $\rho_1 < r < 2\rho_1$.

- 4) F_0 and F_1 tend to infinite as $r \rightarrow 0$:

$$F_0, F_1 \rightarrow +\infty \quad \text{as } r \rightarrow 0.$$

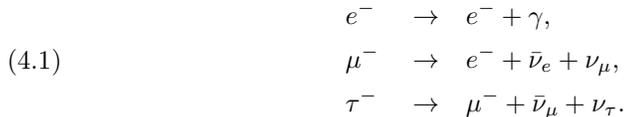
Namely, the weak interacting force between two very close particles is large and repelling.

We shall see that these properties of the weak interacting force are crucial for the weakton model presented in the next few sections.

4. WEAKTON MODEL OF ELEMENTARY PARTICLES

4.1. **Decay means the interior structure.** From Section 2.5, it is clear that all charged leptons, quarks and mediators can undergo decay as follows:

- Charged lepton decay:



- Quark decay:



- Mediator decay:

$$(4.3) \quad \begin{aligned} 2\gamma &\rightarrow e^+ + e^-, \\ W^\pm &\rightarrow l^\pm + \bar{\nu}_{l^\pm}, \\ Z^0 &\rightarrow l^+ + l^-. \end{aligned}$$

All leptons, quarks and mediators are currently regarded as elementary particles. However, the decays in (4.1)-(4.3) show that these particles must have interior structure, and consequently they should be considered as composite particles rather than elementary particles:

Decay Means Interior Structure.

4.2. Weaktons and their quantum numbers. The above observation on the interior structure of quarks, charged leptons and mediators leads us to propose a set of elementary particles, which we call weaktons. These are massless, spin- $\frac{1}{2}$ particles with one unit of weak charge g_w .

The introduction of weaktons is based on the following theories and observational facts:

- (a) the interior structure of charged leptons, quarks and mediators demonstrated by the decays of these particles as shown in (4.1)-(4.3),
- (b) the new quantum numbers of weak charge g_w and strong charge g_s introduced in (3.7),
- (c) the mass generating mechanism presented in Section 3.2, and
- (d) the weakton confinement theory given by the weak interacting potentials (3.17).

The weaktons consist of 6 elementary particles and their antiparticles, total 12 particles:

$$(4.4) \quad \begin{aligned} w^*, w_1, w_2, \nu_e, \nu_\mu, \nu_\tau, \\ \bar{w}^*, \bar{w}_1, \bar{w}_2, \bar{\nu}_e, \bar{\nu}_\mu, \bar{\nu}_\tau, \end{aligned}$$

where ν_e, ν_μ, ν_τ are the three generation neutrinos, and w^*, w_1, w_2 are three new elementary particles, which we call w -weaktons.

These weaktons are endowed with the quantum numbers: electric charge Q_e , weak charge g_w , strong charge g_s , weak color charge Q_c , baryon number B , lepton numbers L_e, L_μ, L_τ , spin J , and mass m . The quantum numbers of weaktons are listed in Table 4.1.

A few remarks are now in order.

Remark 4.1. The quantum numbers $Q_e, Q_c, B, L_e, L_\mu, L_\tau$ have opposite signs and g_w, g_s, m have the same values for the weaktons and antiweaktons. The neutrinos ν_e, ν_μ, ν_τ possess left-hand helicity with spin $J = -\frac{1}{2}$, and the antineutrinos possess right-hand helicity with spin $J = \frac{1}{2}$.

Remark 4.2. The weak color charge Q_c is a new quantum number introduced for the weaktons only, which will be used to rule out some unrealistic combinations of weaktons.

Remark 4.3. Since each composite particle contains at most one w^* particle, there is no strong interaction between the constituent weaktons of a composite particle. Therefore, for the weaktons (4.4), there is no need to introduce the classical strong interaction quantum numbers as strange number S , isospin (I, I_3) and parity P .

TABLE 4.1. Weakton quantum numbers

Weakton	Q_e	g_w	g_s	Q_c	B	L_e	L_μ	L_τ	J	m
w^*	+2/3	1	1	0	1/3	0	0	0	$\pm 1/2$	0
w_1	-1/3	1	0	1	0	0	0	0	$\pm 1/2$	0
w_2	-2/3	1	0	-1	0	0	0	0	$\pm 1/2$	0
ν_e	0	1	0	0	0	1	0	0	-1/2	0
ν_μ	0	1	0	0	0	0	1	0	-1/2	0
ν_τ	0	1	0	0	0	0	0	1	-1/2	0

Remark 4.4. It is known that the quark model is based on the $SU(3)$ irreducible representations:

$$\text{Meson} = 3 \otimes \underline{3} = 8 \oplus 1,$$

$$\text{Baryon} = 3 \otimes 3 \otimes 3 = 10 \oplus 8 \oplus 8 \oplus 1.$$

The weakton model is based on the aforementioned theories and observational facts (a)–(d), different from the quark model.

4.3. Weakton constituents. In this section we give the weakton compositions of charged leptons, quarks and mediators as follows.

CHARGED LEPTONS AND QUARKS. The weakton constituents of charged leptons and quarks are given by

$$(4.5) \quad \begin{aligned} e &= \nu_e w_1 w_2, & \mu &= \nu_\mu w_1 w_2, & \tau &= \nu_\tau w_1 w_2, \\ u &= w^* w_1 \bar{w}_1, & c &= w^* w_2 \bar{w}_2, & t &= w^* w_2 \bar{w}_2, \\ d &= w^* w_1 w_2, & s &= w^* w_1 w_2, & b &= w^* w_1 w_2, \end{aligned}$$

where c, t and d, s, b are distinguished by the spin arrangements. We suppose that

$$(4.6) \quad \begin{aligned} u &= w^* w_1 \bar{w}_1 (\uparrow\uparrow\downarrow, \downarrow\downarrow\uparrow, \uparrow\downarrow\uparrow, \downarrow\uparrow\downarrow), \\ c &= w^* w_2 \bar{w}_2 (\uparrow\uparrow\downarrow, \downarrow\downarrow\uparrow), \\ t &= w^* w_2 \bar{w}_2 (\uparrow\downarrow\uparrow, \downarrow\uparrow\downarrow), \end{aligned}$$

and

$$(4.7) \quad \begin{aligned} d &= w^* w_1 w_2 (\uparrow\uparrow\downarrow, \downarrow\downarrow\uparrow), \\ s &= w^* w_1 w_2 (\uparrow\downarrow\uparrow, \downarrow\uparrow\downarrow), \\ b &= w^* w_1 w_2 (\uparrow\downarrow\uparrow, \downarrow\uparrow\downarrow). \end{aligned}$$

MEDIATORS. The duality between mediators given in (2.1) plays an important role in the weakton model. In fact, the mediators in the classical interaction theory have spin $J = 1$ (graviton has spin $J = 2$), and are apparently not complete. The unified field theory in [7, 8] leads to complement mediators with spin $J = 0$

(graviton dual particle is $J = 1$). Thus, the spin arrangements of weaktons in the mediators become perfectly reasonable.

For convenience, we only write the dual relation for the mediators of electromagnetism, weak interaction, and strong interaction in the following:

$$(4.8) \quad \begin{array}{ll} J = 1 & J = 0 \\ \text{photon } \gamma & \leftrightarrow \text{electro-dual boson } \phi_\gamma, \\ \text{vector bosons } W^\pm, Z & \leftrightarrow \text{weak-dual bosons } \phi_W^\pm, \phi_Z^0 \\ \text{gluons } g^k (1 \leq k \leq 8) & \leftrightarrow \text{strong-dual bosons } \phi_g^k. \end{array}$$

In view of this duality, we propose the constituents of the mediators as follows:

$$(4.9) \quad \begin{aligned} \gamma &= \cos \theta_w w_1 \bar{w}_1 - \sin \theta_w w_2 \bar{w}_2 (\uparrow\uparrow, \downarrow\downarrow), \\ Z^0 &= \cos \theta_w w_2 \bar{w}_2 + \sin \theta_w w_1 \bar{w}_1 (\uparrow\uparrow, \downarrow\downarrow), \\ W^- &= w_1 w_2 (\uparrow\uparrow, \downarrow\downarrow), \\ W^+ &= \bar{w}_1 \bar{w}_2 (\uparrow\uparrow, \downarrow\downarrow), \\ g^k &= w^* \bar{w}^* (\uparrow\uparrow, \downarrow\downarrow), \quad k = \text{color index}, \end{aligned}$$

and the dual bosons:

$$(4.10) \quad \begin{aligned} \phi_\gamma &= \cos \theta_w w_1 \bar{w}_1 - \sin \theta_w w_2 \bar{w}_2 (\uparrow\downarrow, \downarrow\uparrow) \\ \phi_Z^0 &= \cos \theta_w w_2 \bar{w}_2 + \sin \theta_w w_1 \bar{w}_1 (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_W^- &= w_1 w_2 (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_W^+ &= \bar{w}_1 \bar{w}_2 (\uparrow\downarrow, \downarrow\uparrow), \\ \phi_g^k &= w^* \bar{w}^* (\uparrow\downarrow, \downarrow\uparrow), \end{aligned}$$

where $\theta_w \cong 28.76^\circ$ is the Weinberg angle. Here ϕ_Z^0 corresponds to the Higgs particle in the standard model, found in LHC. As all the dual mediators in our theory have the same constituents as the classical mediators, distinguished by spin arrangements, each mediator and its dual should possess masses in the same level with slight difference, as evidence by the masses of Z^0 and ϕ_Z^0 .

Remark 4.5. The reason why we take γ, Z^0 and their dualities ϕ_γ, ϕ_Z^0 as the linear combinations in (4.9) and (4.10) is that by the Weinberg-Salam electroweak theory, the $U(1) \times SU(2)$ gauge potentials are

$$\begin{aligned} Z_\mu &= \cos \theta_w W_\mu^3 + \sin \theta_w B_\mu, \\ A_\mu &= -\sin \theta_w W_\mu^3 + \cos \theta_w B_\mu \\ \sin^2 \theta_w &= 0.23. \end{aligned}$$

Here A_μ, Z_μ represent γ and Z^0 .

THE ν -MEDIATOR. Now the neutrino pairs

$$(4.11) \quad \nu_e \bar{\nu}_e, \nu_\mu \bar{\nu}_\mu, \nu_\tau \bar{\nu}_\tau (\downarrow\uparrow)$$

have not been discovered, and it should be a mediator. Due to the neutrino oscillations, the three pairs in (4.11) should be indistinguishable. Hence, they will be regarded as a particle, i.e. their linear combination

$$(4.12) \quad \phi_\nu^0 = \sum_l \alpha_l \nu_l \bar{\nu}_l (\downarrow\uparrow), \quad \sum_l \alpha_l^2 = 1,$$

is an additional mediator, and we call it the ν -mediator. We believe that ϕ_ν^0 is an independent new mediator.

4.4. Weakton confinement and mass generation. Since the weaktons are assumed to be massless, we have to explain the mass generation mechanism for the massive composite particles, including the charged leptons e, τ, μ , the quarks u, d, s, c, t, b , and the vector bosons $W^\pm, Z^0, \phi_W^\pm, \phi_Z^0$.

The weakton confinement derived in Section 3.5 and the mass generation mechanism in Section 3.3 can help us to understand why no free w^*, w_1, w_2 are found and to explain the mass generation of the composite particles.

First, by the infinite bound energy (Planck level), the weaktons can form triplets confined in the interiors of charged leptons and quarks as (4.5), and doublets confined in mediators as (4.9)-(4.10) and (4.12). They cannot be opened unless the exchange of weaktons between the composite particles. Single neutrinos ν_e, ν_μ and ν_τ can be detected, because in the weakton exchange process there appear pairs of different types of neutrinos such as ν_e and $\bar{\nu}_\mu$, and between which the governing weak force is given by (3.18), and is repelling as shown in (3.22).

Second, for the mass problem, we know that the mediators

$$(4.13) \quad \gamma, \phi_\gamma, g^k, \phi_g^k, \phi_\nu^0,$$

have no masses. To explain this, we note that the particles in (4.13) consist of pairs

$$(4.14) \quad w_1 \bar{w}_1, w_2 \bar{w}_2, w^* \bar{w}^*, \nu_l \bar{\nu}_l.$$

The weakton pairs in (4.14) are bound in a circle with radius R_0 as shown in Figure 4.1. Since the interacting force on each weakton pair is in the direction of their connecting line, they rotate around the center O without resistance. As $\vec{F} = 0$, by the relativistic motion law:

$$(4.15) \quad \frac{d}{dt} \vec{P} = \sqrt{1 - \frac{v^2}{c^2}} \vec{F},$$

the massless weaktons rotate at the speed of light.¹ Hence, the composite particles formed by the weakton pairs in (4.14) have no rest mass.

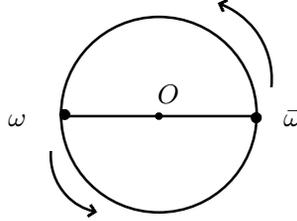


FIGURE 4.1

Third, for the massive particles

$$(4.16) \quad e, \mu, \tau, u, d, s, c, t, b,$$

by (4.5), they are made up of weakton triplets with different electric charges. Hence the weakton triplets are not arranged in an equilateral triangle as shown in Figure 3.1 (a), and in fact are arranged in an irregular triangle as shown in Figure 4.2.

¹In fact, a better way to interpret (4.15) is to take a point of view that no particles are moving at exactly the speed of light. For example, photons are moving at a speed smaller than, but sufficiently close to, the speed of light.

Consequently, the weakton triplets rotate with nonzero interacting forces $F \neq 0$ from the weak and electromagnetic interactions. By (4.15), the weaktons in the triplets move at a speed less than the speed of light. Thus, by the mass generating mechanism, the weaktons possess mass present. Hence, the particles in (4.16) are massive.

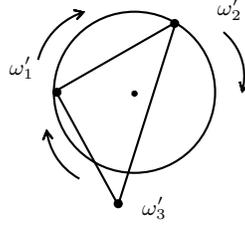


FIGURE 4.2

Finally, we need to explain the masses for the massive mediators:

$$(4.17) \quad W^\pm, \quad Z^0, \quad \phi_W^\pm, \quad \phi_Z^0.$$

Actually, in the next weakton exchange theory, we can see that the particles in (4.14) are some transition states in the weakton exchange procedure. At the moment of exchange, the weaktons in (4.17) are at a speed v ($v < c$). Hence, the particles in (4.17) are massive. Here we remark that the dual mediator ϕ_Z^0 is the Higgs particle found in LHC.

4.5. Quantum rules for weaktons. By carefully examining the quantum numbers of weaktons, the composite particles in (4.5), (4.9), (4.10) and (4.12) are well-defined.

In Section 4.4, we solved the free weakton problem and the mass problem. In this section, we propose a few rules to solve some remainder problems.

1). **WEAK COLOR NEUTRAL RULE.** *All composite particles by weaktons must be weak color neutral.*

Based on this rule, there are many combinations of weaktons are ruled out. For example, it is clear that there are no particles corresponding to the following www and $w\bar{w}$ combinations, as they all violate the weak color neutral rule:

$$\nu_e w_2 w_2, \quad w^* w_1 w_1, \quad w^* w_1 \bar{w}_2, \quad \text{etc.}, \quad \nu_e w_1, \quad w^* w_1, \quad w^* w_2, \quad \text{etc.}$$

2). $BL = 0, L_i L_j = 0$ ($i \neq j$).

The following combinations of weaktons

$$(4.18) \quad w^* \nu, \quad \nu_i \nu_j, \quad \nu_i \bar{\nu}_k \quad (i \neq k), \quad \nu_k = \nu_e, \nu_\mu, \nu_\tau.$$

are not observed in Nature, and to rule out these combinations, we postulate the following rule:

$$(4.19) \quad BL = 0, \quad L_i L_j = 0 \quad (i \neq j), \quad L_i = L_e, L_\mu, L_\tau,$$

where B, L are the baryon number and the lepton number.

3). $L + Q_e = 0$ if $L \neq 0$ and $|B + Q_e| \leq 1$ if $B \neq 0$.

The following combinations of weaktons

$$(4.20) \quad \nu w_1 \bar{w}_1, \nu w_2 \bar{w}_2, \bar{\nu} w_1 w_2, w^* w^* \text{ etc}$$

cannot be found in Nature. It means the lepton number L , baryon number B , and electric charge Q_e obey

$$(4.21) \quad L + Q_e = 0 \quad \text{if } L \neq 0 \quad \text{and} \quad |B + Q_e| \leq 1 \quad \text{if } B \neq 0.$$

Thus (4.20) are ruled out by (4.21).

4). SPIN SELECTION.

In reality, there are no weakton composites with spin $J = \frac{3}{2}$ as

$$(4.22) \quad w^* w_1 \bar{w}_1 (\uparrow\uparrow\uparrow, \downarrow\downarrow\downarrow), w^* w_2 \bar{w}_2 (\uparrow\uparrow\uparrow, \downarrow\downarrow\downarrow), w^* w_1 w_2 (\uparrow\uparrow\uparrow, \downarrow\downarrow\downarrow)$$

and as

$$(4.23) \quad \nu w_1 w_2 (\uparrow\uparrow\uparrow, \downarrow\downarrow\downarrow).$$

The cases (4.22) are excluded by the Angular Momentum Rule in Section 3.1. The reasons for this exclusion are two-fold. First, the composite particles in (4.22) carries one strong charge, and consequently, will be confined in a small ball by the strong interaction potential (3.9), as shown in Figure 3.1 (b). Second, due to the uncertainty principle, the bounding particles will rotate, at high speed with almost zero moment of force, which must be excluded for composite particles with $J \neq \frac{1}{2}$ based on the angular momentum rule.

The exclusion for (4.23) is based on the observation that by the left-hand helicity of neutrinos with spin $J = -\frac{1}{2}$, one of w_1 and w_2 must be in the state with $J = +\frac{1}{2}$ to combine with ν , i.e. in the manner as

$$\nu w w (\downarrow\uparrow\uparrow, \downarrow\uparrow\downarrow).$$

In summary, under the above rules 1)-4), only the weakton constitutions in (4.5), (4.9), (4.10) and (4.12) are allowed.

5). EIGHT QUANTUM STATES OF GLUONS.

It is known that the gluons have eight quantum states

$$g^k : g^1, \dots, g^8.$$

In (4.9), g^k have the form

$$w^* \bar{w}^* (\uparrow\uparrow, \downarrow\downarrow).$$

According to *QCD*, quarks have three colors

$$\text{red } (r), \text{ green } (g), \text{ blue } (b),$$

and anti-colors $\bar{r}, \bar{g}, \bar{b}$. They obey the following rules

$$(4.24) \quad \begin{aligned} \bar{b}\bar{b} &= r\bar{r} = g\bar{g} = w(\text{white}), \\ \bar{b}\bar{r} &= g, & r\bar{b} &= \bar{g}, \\ \bar{b}\bar{g} &= r, & g\bar{b} &= \bar{r}, \\ \bar{r}\bar{g} &= b, & g\bar{r} &= \bar{b}, \\ r\bar{r} &= \bar{r}, & b\bar{b} &= \bar{b}, & g\bar{g} &= \bar{g}, \\ r\bar{b} &= g, & r\bar{g} &= b, & g\bar{b} &= r. \end{aligned}$$

Based on (4.5), w^* is endowed with three colors

$$w_b^*, w_r^*, w_g^*.$$

Thus, by (4.24) we give the eight gluons as

$$(4.25) \quad g^1 = (w^* \bar{w}^*)_w, \quad g^2 = w_b^* \bar{w}_r^*, \quad g^3 = w_b^* \bar{w}_g^*, \quad g^4 = w_r^* \bar{w}_g^*,$$

$$(4.26) \quad g^5 = (w^* \bar{w}^*)_{\bar{w}}, \quad g^6 = w_r^* \bar{w}_b^*, \quad g^7 = w_g^* \bar{w}_b^*, \quad g^8 = w_g^* \bar{w}_r^*,$$

where $(w^* \bar{w}^*)_w$ is a linear combination of $w_b^* \bar{w}_b^*, w_r^* \bar{w}_r^*, w_g^* \bar{w}_g^*$. Namely, the gluons in (4.26) are the antiparticles of those in (4.25).

In summary, all of the most basic problems in the weakton model have a reasonable explanation.

5. MECHANISM OF SUB-ATOMIC DECAYS

5.1. Weakton exchanges. We conclude that all particle decays are caused by exchanging weaktons. The exchanges occur between composite particles as mediators, charged leptons, and quarks.

5.1.1. Weakton exchange in mediators. First we consider one of the most important decay processes in particle physics, the electron-positron pair creation and annihilation:

$$(5.1) \quad \begin{aligned} 2\gamma &\rightarrow e^+ + e^-, \\ e^+ + e^- &\rightarrow 2\gamma. \end{aligned}$$

In fact, the reaction formulas in (5.1) are not complete, and the correct formulas should be as follows

$$(5.2) \quad 2\gamma + \phi_\nu^0 \rightleftharpoons e^+ + e^-.$$

Note that the weakton component of γ is as

$$(5.3) \quad \gamma = \cos \theta_w w_1 \bar{w}_1 - \sin \theta_w w_2 \bar{w}_2,$$

which means that the probability of the photon γ at the state $w_1 \bar{w}_1$ is $\cos^2 \theta_w$, and its probability at the state $-w_2 \bar{w}_2$ is $\sin^2 \theta_w$. Namely, for photons, the densities of the $w_1 \bar{w}_1 (\uparrow\uparrow)$ and $-w_2 \bar{w}_2 (\downarrow\downarrow)$ particle states are $\cos^2 \theta_w$ and $\sin^2 \theta_w$. Hence, the formula (5.2) can be written as

$$(5.4) \quad w_1 \bar{w}_1 (\uparrow\uparrow) + w_2 \bar{w}_2 (\downarrow\downarrow) + \nu_e \bar{\nu}_e (\downarrow\uparrow) \rightleftharpoons \nu_e w_1 w_2 (\downarrow\uparrow\downarrow) + \bar{\nu}_e \bar{w}_1 \bar{w}_2 (\uparrow\downarrow).$$

It is then clear to see from (5.4) that the weakton constituents $w_1, \bar{w}_1, w_2, \bar{w}_2, \nu_e, \bar{\nu}_e$ can regroup due to the weak interaction, and we call this process weakton exchange. The mechanism of this exchanging process can be explained using the weak interacting potentials (3.17) and (3.18).

The potential formula (3.17) means that each composite particle has an exchange radius R , which satisfies

$$(5.5) \quad r_0 < R < \rho_1,$$

where r_0 is the radius of this particle and ρ_1 is the radius as in (3.21). As two composite particles A and B are in a distance less than their common exchange radius, there is a probability for the weaktons in A and B to recombine and form new particles. Then, after the new particles have been formed, in the exchange radius R , the weak interacting forces between them are governed by (3.22) which are repelling, and then drive them apart.

For example, to see how the weaktons in (5.4) undergo the exchange process in Figure 5.1. When the randomly moving photons and ν -mediators, i.e. $w_1\bar{w}_1, w_2\bar{w}_2$ and $\nu_e\bar{\nu}_e$, come into their exchange balls, they recombine to form an electron $\nu_e w_1\bar{w}_1$ and a positron $\bar{\nu}_e\bar{w}_1\bar{w}_2$, and then the weak repelling force pushes them apart, leading to the decay process (5.2). We remark here that in this range the weak repelling force is stronger than the Coulomb force. In fact, by (3.20), $g_w^2 = 10^{-1}\hbar c$ and the electric charge square $e^2 = 1/137\hbar c$. Hence, the weak repelling force between e^- and e^+ in Figure 5.1 is $(3g_w)^2/r^2$, stronger than e^2/r^2 .

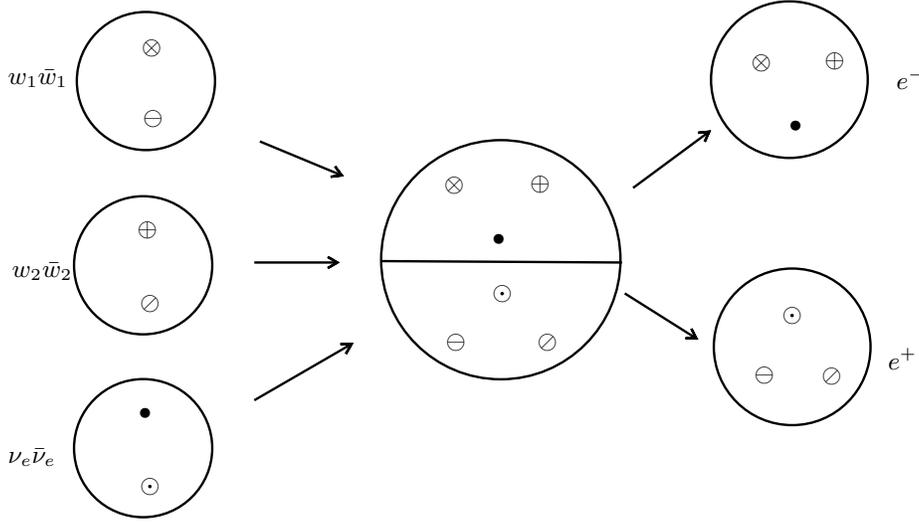


FIGURE 5.1. $\otimes, \ominus, \oplus, \otimes, \bullet, \odot$ represent $w_1, \bar{w}_1, w_2, \bar{w}_2, \nu_e, \bar{\nu}_e$.

5.1.2. *Weakton exchanges between leptons and mediators.* The μ -decay reaction formula is given by

$$(5.6) \quad \mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu.$$

The complete formula for (5.6) is

$$\mu^- + \phi_\nu \rightarrow e^- + \bar{\nu}_e + \nu_\mu,$$

which is expressed in the weakton components as

$$(5.7) \quad \nu_\mu w_1 w_2 + \nu_e \bar{\nu}_e \longrightarrow \nu_e w_1 w_2 + \bar{\nu}_e + \nu_\mu.$$

By the rule $L_e L_\mu = 0$, the μ neutrino ν_μ and the e antineutrino $\bar{\nu}_e$ can not be combined to form a particle. Hence, $\bar{\nu}_e$ and ν_μ appear as independent particles, leading to the exchange of ν_μ and ν_e as shown in (5.7).

5.1.3. *Weakton exchanges between quarks and mediators.* The d -quark decay in (4.3) is written as

$$(5.8) \quad d \rightarrow u + e^- + \bar{\nu}_e.$$

The correct formula for (5.8) is

$$d + \gamma + \phi_\nu \rightarrow u + e^- + \bar{\nu}_e,$$

which, in the weakton components, is given by

$$(5.9) \quad w^* w_1 w_2 + w_1 \bar{w}_1 + \nu_e \bar{\nu}_e \rightarrow w^* w_1 \bar{w}_1 + \nu_e w_1 w_2 + \bar{\nu}_e,$$

In (5.9), the weakton pair w_2 and \bar{w}_1 is exchanged, and ν_e is captured by the new doublet $w_1 w_2$ to form an electron $\nu_e w_1 w_2$.

5.2. Conservation laws. The weakton exchanges must obey some conservation laws, which are listed in the following.

5.2.1. Conservation of weakton numbers. The total weaktons given in (4.4) are elementary particles, which cannot undergo any decay. Also, the w -weaktons cannot be converted between each other. Although the neutrino oscillation converts one type of neutrino to another, at the moment of a particle decay, the neutrino number is conserved, i.e. the lepton numbers L_e, L_μ, L_τ are conserved.

Therefore, for any any particle reaction:

$$(5.10) \quad A_1 + \cdots + A_n = B_1 + \cdots + B_m,$$

the number of each weakton type is invariant. Namely, for any type of weakton \tilde{w} , its number is conserved in (5.10):

$$N_{\tilde{w}}^A = N_{\tilde{w}}^B,$$

where $N_{\tilde{w}}^A$ and $N_{\tilde{w}}^B$ are the numbers of the \tilde{w} weaktons in two sides of (5.10).

5.2.2. Spin conservation. The spin of each weakton is invariant. The conservation of weakton numbers implies that the spin is also conserved:

$$J_{A_1} + \cdots + J_{A_n} = J_{B_1} + \cdots + J_{B_m},$$

where J_A is the spin of particle A .

In classical particle theories, the spin is not considered as a conserved quantity. The reason for the non-conservation of spin is due to the incompleteness of the reaction formulas given in Section 2.5. Hence spin conservation can also be considered as an evidence for the incompleteness of those decay formulas. The incomplete decay interaction formulas can be made complete by supplementing some massless mediators, so that the spin becomes a conserved quantum number.

5.2.3. Other conservative quantum numbers. From the invariance of weakton numbers, we derive immediately the following conserved quantum numbers:

$$\begin{aligned} &\text{electric charge } Q_e, \text{ weak charge } Q_w, \text{ strong charge } Q_s, \\ &\text{baryon number } B, \text{ lepton numbers } L_e, L_\mu, L_\tau. \end{aligned}$$

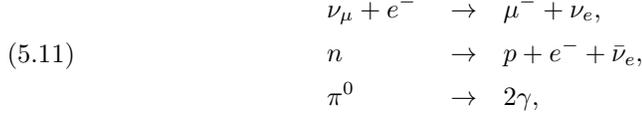
5.3. Decay types. In particle physics, the reactions as in Section 2.5 are classified into two types: the weak interacting type and the strong interacting type. However there is no clear definition to distinguish them. Usual methods are by experiments to determine reacting intensity, i.e. the transition probability Γ . In general, the classification is derived based on

Weak type:	i) presence of leptons in the reactions,
	ii) change of strange numbers,
Strong type:	otherwise.

With the weakton model, all decays are carried out by exchanging weaktons. Hence decay types can be fully classified into three types: the weak type, the

strong type, and the mixed type, based on the type of forces acting on the final particles after the weakton exchange process.

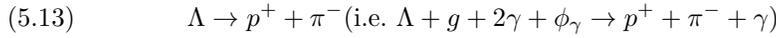
For example, the reactions



are weak decays,



is a strong decay, and



is a mixed decay.

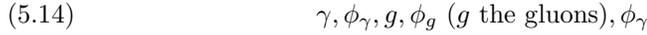
In view of (5.11)-(5.13), the final particles contain at most one hadron in a weak decay, contain no leptons and no mediators in a strong decay, and contain at least two hadrons and a lepton or a mediator in a mixed decay. Namely, we derive the criteria based on the final particle content:

Weak Decay: at most one hadron,

Strong Decay: no leptons and no mediators,

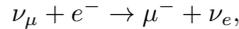
Mixed Decay: otherwise.

5.4. Weak decays. Decays and scatterings are caused by weakton exchanges. The massless mediators

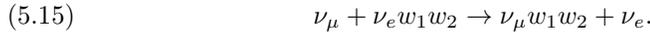


spread over the space in various energy levels, and most of them are at low energy states. It is these random mediators in (5.14) entering the exchange radius of matter particles that generate decays. In the following we shall discuss a few typical weak decays.

5.4.1. $\nu_\mu e^- \rightarrow \nu_e \mu^-$ scattering. First we consider the scattering



which is rewritten in the weakton components as



Replacing the Feynman diagram, we describe the scattering (5.15) using Figure 5.2. It is clear that the scattering (5.15) is achieved by exchanging weaktons ν_μ and ν_e .

5.4.2. β -decay. Consider the classical β -decay process

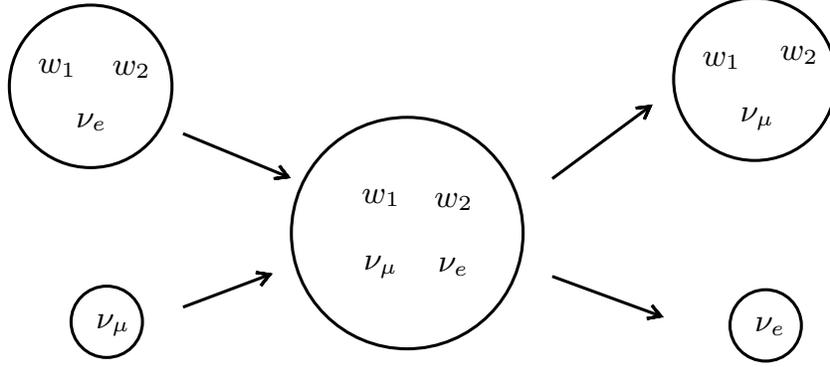


With the quark constituents of n and p



the β -decay (5.16) is equivalent to the following d -quark decay:



FIGURE 5.2. $\nu_\mu e^- \rightarrow \mu^- \nu_e$ scattering.

whose complete form should be given by

$$(5.18) \quad w^* w_1 w_2 (d) + \nu_e \bar{\nu}_e (\phi_\nu) + w_1 \bar{w}_1 (\gamma) \rightarrow w^* w_1 \bar{w}_1 (u) + w_1 w_2 (W^-) + \nu_e \bar{\nu}_e (\phi_\nu) \\ \rightarrow w^* w_1 \bar{w}_1 (u) + \nu_e w_1 w_2 (e^-) + \bar{\nu}_e.$$

In the β decay (5.18), w_2 and \bar{w}_1 in d quark and photon γ have been exchanged to form u quark and charged vector boson W^- , then W^- captures a ν_e from ϕ_ν to yield an electron e^- and a $\bar{\nu}_e$.

5.4.3. *Quark pair creations.* Consider

$$g + \phi_\gamma + \gamma \longrightarrow u + \bar{u}, \\ \phi_g + 2\phi_\gamma \longrightarrow d + \bar{d}.$$

They are rewritten in the weakton constituent forms as

$$(5.19) \quad w^* \bar{w}^* \uparrow\uparrow (g) + w_1 \bar{w}_1 \downarrow\uparrow (\phi_\gamma) + w_1 \bar{w}_1 \downarrow\downarrow (\gamma) \\ \longrightarrow w^* w_1 \bar{w}_1 \uparrow\downarrow\uparrow (u) + \bar{w}^* w_1 \bar{w}_1 \uparrow\downarrow\downarrow (\bar{u}),$$

$$(5.20) \quad w^* \bar{w}^* \uparrow\downarrow (\phi_g) + w_1 \bar{w}_1 \uparrow\downarrow (\phi_\gamma) + w_2 \bar{w}_2 \downarrow\uparrow (\phi_\gamma) \\ \longrightarrow w^* w_1 w_2 \uparrow\downarrow\downarrow (d) + \bar{w}^* \bar{w}_1 \bar{w}_2 \downarrow\downarrow\uparrow (\bar{d}).$$

In (5.19), w^* and \bar{w}^* in a gluon are captured by a γ -dual mediator ϕ_γ and a photon γ to create a pair u and \bar{u} . In (5.20), \bar{w}_1 and w_2 in two ϕ_γ are exchanged to form ϕ_W^\pm (charged Higgs), then ϕ_W^+ and ϕ_W^- capture w^* and \bar{w}^* respectively to create a pair d and \bar{d} .

5.4.4. *Lepton decays.* The lepton decays

$$\mu^- + \phi_\nu \rightarrow e^- + \bar{\nu}_e + \nu_\mu, \\ \tau^- + \phi_\nu \rightarrow \mu^- + \bar{\nu}_\mu + \nu_\tau.$$

are rewritten in the weakton constituents as

$$(5.21) \quad \nu_\mu w_1 w_2 + \nu_e \bar{\nu}_e \rightarrow \nu_e w_1 w_2 + \bar{\nu}_e + \nu_\mu, \\ \nu_\tau w_1 w_2 + \nu_\mu \bar{\nu}_\mu \rightarrow \nu_\mu w_1 w_2 + \bar{\nu}_\mu + \nu_\tau.$$

Here the neutrino exchanges form leptons in the lower energy states and a pair of neutrino and antineutrino with different lepton numbers. By the rule $L_i L_j = 0$

($i \neq j$) in Section 4.5, the generated neutrino and antineutrino cannot be combined together, and are separated by the weak repelling force in (3.22). The decay diagram is shown by Figure 5.3.

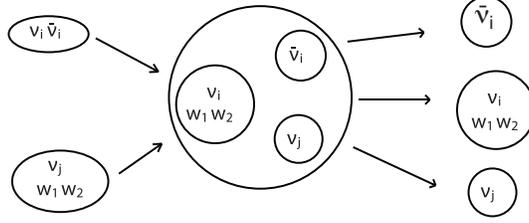


FIGURE 5.3. $\nu_i \neq \nu_j, \nu_i = \nu_e, \nu_\mu, \nu_\tau$.

5.5. Strong and mixed decays.

5.5.1. *Strong decays.* Consider the following types of decays:

$$\Delta^{++} \longrightarrow p + \pi^+.$$

The complete decay process should be

$$(5.22) \quad \Delta^{++} + \phi_g + 2\phi_\gamma \longrightarrow p + \pi^+.$$

It is clear that the final particles are the proton and charged π meson π^+ . Hence (5.22) is a strong type of decays. Recalling the weakton constituents, (5.22) is rewritten as

$$(5.23) \quad 3w^*w_1\bar{w}_1(\Delta^{++}) + w^*\bar{w}^*(\phi_g) + w_1\bar{w}_1 + w_2\bar{w}_2(\phi_\gamma) \\ \longrightarrow (2w^*w_1\bar{w}_1)(w^*w_1w_2)(p) + (w^*w_1\bar{w}_1)(\bar{w}^*\bar{w}_1\bar{w}_2)(\pi^+).$$

The reaction process in (5.23) consists of two steps:

$$(5.24) \quad \text{weakton exchanges:} \quad \phi_g + 2\phi_\gamma \longrightarrow d + \bar{d},$$

$$(5.25) \quad \text{quark exchanges:} \quad uuu + d\bar{d} \longrightarrow uud + u\bar{d}.$$

The exchange mechanism of (5.24) was discussed in (5.21), which is a weak interaction, and the quark exchange (5.25) is a strong interaction.

Let us discuss the D^0 decay, which is considered as the weak interacting type in the classical theory. But in our classification it belongs to strong type of interactions. The D^0 decay is written as

$$D^0 \longrightarrow K^- + \pi^+.$$

The complete formula is

$$(5.26) \quad D^0 + g + 2\gamma \longrightarrow K^- + \pi^+.$$

The weakton constituents of this decay is given by

$$(5.27) \quad (w^*w_2\bar{w}_2)(\bar{w}^*\bar{w}_1w_1)(c\bar{u}) + w^*\bar{w}^*(g) + 2w_1\bar{w}_1(\gamma) \\ \longrightarrow (w^*w_1w_2)(\bar{w}^*\bar{w}_1w_1)(s\bar{u}) + (w^*w_1\bar{w}_1)(\bar{w}^*\bar{w}_1\bar{w}_2)(u\bar{d}).$$

This reaction is due to the c-quark decay

$$c + g + 2\gamma \rightarrow s + u + \bar{d},$$

which is given in the weakton constituent form as

$$(5.28) \quad w^*w_2\bar{w}_2(c) + w^*\bar{w}^*(g) + 2w_1\bar{w}_1(\gamma) \\ \longrightarrow w^*w_1w_2(s) + w^*w_1\bar{w}_1(u) + \bar{w}^*\bar{w}_1\bar{w}_2(\bar{d}).$$

The reaction (5.28) consists of two exchange processes:

$$(5.29) \quad w^*w_2\bar{w}_2(c) + w_1\bar{w}_1(\gamma) \rightarrow w^*w_1w_2(s) + \bar{w}_1\bar{w}_2(W^-),$$

$$(5.30) \quad \bar{w}_1\bar{w}_2(W^-) + w_1\bar{w}_1(\gamma) + w^*\bar{w}^*(g) \rightarrow w^*w_1\bar{w}_1(u) + \bar{w}^*\bar{w}_1\bar{w}_2(\bar{d}).$$

It is clear that both exchanges here belong to weak interactions. However, the final particles of the D^0 decay are K^- and π^+ , which are separated by the strong hadron repelling force.

5.5.2. *Mixed decays.* We only consider the Λ decay:

$$(5.31) \quad \Lambda \rightarrow p + \pi^-.$$

The correct form of this decay should be

$$(5.32) \quad \Lambda + g + 2\gamma + \phi_\gamma \rightarrow p + \pi^- + \phi_\gamma.$$

There are three exchange procedures in (5.32):

$$(5.33) \quad g + \gamma + \phi_\gamma \rightarrow u + \bar{u},$$

$$(5.34) \quad s + \gamma \rightarrow d + \phi_\gamma, \quad (uds + \gamma \rightarrow udd + \phi_\gamma)$$

$$(5.35) \quad udd(n) + u\bar{u} \rightarrow uud(p) + u\bar{d}(\pi^-).$$

The procedure (5.33) was described by (5.20), the quark exchange process (5.35) is clear, and (5.34) is the conversion from s quark to d quark, described by

$$(5.36) \quad w^*w_1w_2 \uparrow\downarrow\downarrow (s) + w_1\bar{w}_1 \uparrow\uparrow (\gamma) \longrightarrow w^*w_1w_2 \uparrow\uparrow\downarrow (d) + w_1\bar{w}_1 \downarrow\uparrow (\phi_\gamma).$$

Namely, (5.36) is an exchange of two w_1 with reverse spins.

6. ELECTRON RADIATIONS

6.1. **Electron structure.** The weakton constituents of an electron are $\nu_e w_1 w_2$, which rotate as shown in Figure 4.2. Noting that

$$\begin{array}{llll} \text{electric charge:} & Q_e^\nu = 0, & Q_e^{w_1} = -\frac{1}{3}, & Q_e^{w_2} = -\frac{2}{3}, \\ \text{weak charge:} & Q_w^\nu = 1, & Q_w^{w_1} = 1, & Q_w^{w_2} = 1, \end{array}$$

we see that the distribution of weaktons ν_e , w_1 and w_2 in an electron is in an irregular triangle due to the asymptotic forces on the weaktons by the electromagnetic and weak interactions, as shown in Figure 6.1.

In addition, by the weak force formula (3.22), there is an attracting shell region of weak force:

$$(6.1) \quad \rho_1 < r < \rho_2, \quad \rho_1 = 10^{-16} \text{ cm}$$

with small weak force. Outside this region, the weak force is repelling:

$$(6.2) \quad F_w > 0 \quad \text{for } r < \rho_1 \quad \text{and } r > \rho_2.$$

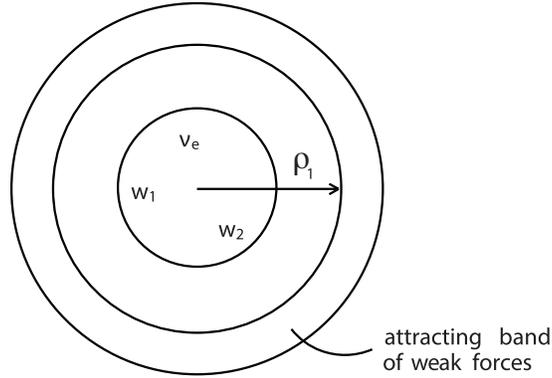


FIGURE 6.1. Electron structure.

Since the mediators γ , ϕ_γ , g , ϕ_g and ϕ_ν contain two weak charges $2g_w$, they are attached to the electron in the attracting shell region (6.1), forming a cloud of mediators. The irregular triangle distribution of the weaktons ν_2 , w_1 and w_2 generate a small moment of force on the mediators in the shell region, and there exist weak forces between them. Therefore the bosons will rotate at a speed lower than the speed of light, and generate a small mass attached to the naked electron $\nu_e w_1 w_2$.

6.2. Mechanism of Bremsstrahlung. It is known that an electron emits photons as its velocity changes. This is called bremsstrahlung, and the reasons why bremsstrahlung can occur is unknown in classical theories. We present here a mechanism of this phenomena based on the above mentioned structure of electrons.

In fact, as an electron is in an electromagnetic field, which exerts a Coulomb force on its naked electron $\nu_e w_1 w_2$, but not on the attached neutral mediators. Thus, the naked electron changes its velocity, which draws the mediator cloud to move as well, causing a perturbation to moment of force on the mediators. As the attracting weak force in the shell region (6.1) is small, under the perturbation, the centrifugal force makes some mediators in the cloud, such as photons, flying away from the attracting shell region, and further accelerated by the weak repelling force (6.2) to the speed of light, as shown in Figure 6.2.

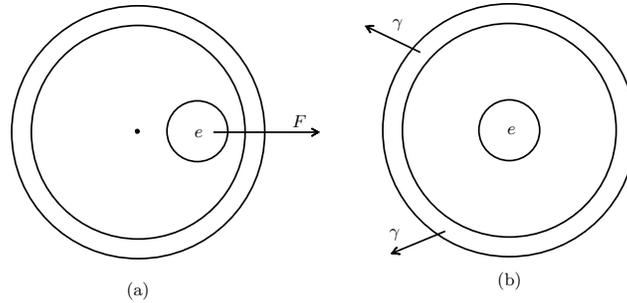


FIGURE 6.2. (a) The naked electron is accelerated in an electromagnetic field; (b) the mediators (photons) fly away from the attracting shell region under a perturbation of moment of force.

7. CONCLUSIONS

The main motivation of this article is that the sub-atomic decays amounts to saying that quarks and charged leptons must possess interior structure. With this motivation, a weakton model of elementary particles is proposed based on 1) sub-atomic particle decays, and 2) formulas for the weak and strong interaction potentials/forces. In this weakton model, the elementary particles consist of six spin- $\frac{1}{2}$ massless particles, which we call weaktons, and their antiparticles. The weakton model leads to 1) composite constituents for quarks, charged leptons and mediators, 2) a new mass generation mechanism, and 3) a perfect explanation of all sub-atomic decays and reactions.

With this weakton model and the unified field theory [7, 8], we now present our explanations and viewpoints to the twelve fundamental questions stated in the Introduction.

Q₁: Our current view on four interactions is that each interaction has its own charge, the mass charge m , the electric charge e , the weak charge g_w and the strong charge g_s , which are introduced in Section 3.3. Each weakton carries one unit of weak charge, hence the name weakton, and only w^* carries a unit of strong charge g_s . A particular interaction can only occur between two particles if they both carry charges of the corresponding interaction.

The dynamic laws for four interactions are the unified field model, which can be easily decoupled to study individual interactions. Our theory shows that each interaction has both attractive and repulsive regions, leading the stability of matter in our universe.

Q₂: With the weakton model, it is clear that leptons do not participate strong interactions, as they do not carry any strong charge—the weakton constituents of charged leptons (4.5) do not include w^* .

Q₃: The weakton model postulates that all matter particles (leptons, quarks) and mediators are made up of massless weaktons. The basic mass generation mechanism is presented in Section 3.2. Namely, for a composite particle, the constituent massless weaktons can decelerate by the weak force, yielding a massive particle, based on the Einstein mass-energy relation. Also, the constituent weaktons are moving in an “asymptotically-free” shell region of weak interactions as indicated by the weak interaction potential/force formulas, so that the bounding and repelling contributions to the mass are mostly canceled out. Hence the mass of a composite particle is due mainly to the dynamic behavior of the constituent weaktons.

Q₄ & Q₅: In Sections 5.1-5.5, the weakton model offers a perfect explanation for all sub-atomic decays and all generation/annihilation processes of matter-antimatter. In particular, all decays are achieved by 1) exchanging weaktons and consequently exchanging newly formed quarks, producing new composite particles, and 2) separating the new composite particles by weak and/or strong repelling forces. Also, we know now the precise constituents of particles involved in all decays both *before* and *after* the reaction.

Q₆: Again, the sub-atomic decays and reactions offer a clear evidence for the existence of interior structure for quarks and leptons, as well as for mediators. The consistency of the weakton model with all reactions and decays, together with

conservations of quantum numbers, demonstrates that both quarks and charged leptons are not elementary particles.

Q₇ (Baryon Asymmetry): Conventional thinking was that the Big Bang should have produced equal amounts of matter and antimatter, which will annihilate each other, resulting a sea of photons in the universe, a contradiction to reality. The weakton model offers a complete different view on the formation of matter in our universe. The weakton model says that what the Big Bang produced was a sea of massless elementary weaktons and anti-weaktons, forming all the matter, including mediators such as photon, in the universe. Hence with the weakton model, the baryon asymmetry problem is no longer a right question to ask.

Q₈–Q₁₁: The decoupled unified field model leads to three levels of strong interaction potentials and two levels of weak interaction potentials as recalled in (3.9)–(3.11), (3.17) and (3.18). These formulas give a natural explanation of both the short-range nature and confinements for both strong and weak interactions. The different levels of each interaction demonstrate that in the same spatial region, the interaction can be attracting between weaktons, and be repelling for newly formed hadrons and leptons. This special feature of weak and strong interactions plays a crucial rule for decays.

Q₁₂ (Bremsstrahlung): The weak interaction force formulas show that the attracting shell region near a naked electron can contain a cloud of neutral mediators as photon. As the naked electron changes its velocity due to the presence of an electromagnetic field, which has no effect on the neutral mediator cloud. The change of velocity of electron generates a perturbation to moment of force on the mediators causing some of the mediators flying out from the attracting shell region. This is the mechanism of bremsstrahlung; see Sections 6.1 and 6.2.

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