Start

Elementry Particles → These can defined as a Particle which does not have a Substructure. or Those microscopic elementry Constituents out of which All matter in this universe is Considered to be made of.

* Fundamental Interactions →

① Gravitational Interactions →

Ⓐ It is always Attractive Ⓑ weakest interaction in nature

Ⓒ It's Carrier Particle is graviton. Ⓓ $F=\frac{GM_1M_2}{r^2}$ or $F\propto\frac{1}{r^2}$

It is obey inverse squre Law, conservative and Central force.

Ⓔ Characteristic time of the order of 10^{-16} sec.

Ⓕ It Range goes to ∞. Ⓖ Gravitons have zero mass and spin 2. also is Boson. Ⓗ magnitude (10^{-39})

② Electro-Magnetic Interaction →

Ⓐ It is Attractive and Repulsive Ⓑ It is much Stronger than gravitional and weak Interaction.

Ⓒ It's Carrier Particle is Photon. Ⓓ $F=\frac{KQ_1Q_2}{r^2}$ or $F\propto\frac{1}{r^2}$

Ⓔ It Range goes to ∞. Ⓕ Characteristic time 10^{-20} sec. Ⓗ magnitude (10^{-3})

Ⓖ Photon have mass zero and spin 1.

③ Weak Interaction →

Ⓐ Short Range interaction (10^{-17} mt) Ⓑ These are charged W^+ and W^- Bosons and neutral Z^0 Boson. have masses of W^+ & W^- are 81800 $\frac{MeV}{c^2}$ and $m(Z^0) = 92600\ \frac{MeV}{c^2}$, also β decay.

Ⓒ spins of $W^{\pm}$ and Z^0 are 1.

Ⓓ not obey inverse square Law.

Ⓔ Characteristic time is of the order of 10^{-10} sec. Hyperons, mesons, etc. also Intermediate Bosons.

Ⓕ magnitude (10^{-14})

④ Strong Interaction →

Ⓐ Short Range interactions Ⓑ Range (2×10^{-15} mt).

Ⓒ Charge independent so it is Same for p-n, p-p, and n-n interactions.

Ⓓ not obey inverse Square Law. Ⓔ Independant of Relative orientation of the nucleons.

Ⓕ Characteristic time is 10^{-23} sec.

Ⓖ It's Carrier Particles are Pion, Kaon (Glouns) of spin 1 and mass zero.

Ⓗ All carrier of interactions have higher spin.

Ⓘ Relative magnitude (1)

* Classification of Elementry Pasticles →

- Gravitons
- Photons
- Leptons
- Hadrons
  - Mesons
  - Baryons.
    - Nucleons
    - Hyperons.

① Gravitons → gravitation force of attraction between material Pasticles due to their masses is assumed to be due to exchange of a Pasticle called graviton.
It have Zero Rest mass, zero electric charge, spin 2, also called massless Boson.

② Photons → A Photon is a Quantum unit of Radiation emitted or absorbed by electrons in the outer structure of atoms or the Pasticles with in the nucleus. Each Photon have Energy $h\nu$, It's Rest mass zero, no charge and spin in unity, It is anti-pasticle of itself, massless boson, and gives by electron-Positron pair creation or Pair Anhilated. and its energy $E = mc^2$.

③ Leptons → (Weakly Interacting Fermions) (light Pasticles) → The Pasticles whose masses are smaller than the masses of Pions and Possess angular momentum of $\frac{1}{2}\left(\frac{h}{2\pi}\right)$.
Members of this groups are → Neutrino and antineutrino, ~~nucleons~~ electrons, Positron and Muons.

Ⓐ electrons → −vely charged having Rest mass 9.1×10^{-31} kg (.51 Mev) and charge 1.6×10^{-19} cb, It is stable Pasticle and angular-momentum or spin $= \frac{\hbar}{2}$, and follows Fermi-Dirac Statistics, Positron (e^+) is Anti-Pasticle of electron.

→ Positron → $e^- + e^+ \rightarrow \gamma + \gamma$

Ⓑ Muons (μ^-) → Muons are heavier than electrons with Rest mass equal to '$207 m_e$', and spin angular momentum $\frac{\hbar}{2}$, it is unstable (Half life $= 2.2 \times 10^{-6}$ sec) are unstable Pasticles, μ^+ is its anti-Pasticle and there is no neutral Muon. its charge 1.6×10^{-19} cb,
Muons decay to → $\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$
$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$

© neutrinos → These particles have zero Rest mass and no charge. It moves with velocity of light, its spin $\frac{\hbar}{2}$ and stable particle, These are Three type → ν_e (electron neutrino), ν_μ (muon neutrino), and tau neutrino (ν_τ) have +1 Lepton, these anti particles are $\bar{\nu}_e, \bar{\nu}_\mu, \vec{\nu}_\tau$ have −1 Leptons.

④ Hadrons →

Ⓐ Mesons (Strong interacting Bosons) → These particle posses Rest mass between 250me and 1000me or leptons and nucleons, It have zero or integral spins 0, 1, 2 etc. and obey Bose-Einstein statistics. These exist from cosmic Rays. Members of this group are ① π-meson or Pions, K-meson or kaons and η-mesons.

Ⓘ π- mesons (Pions) → (π^+, π^-, π^0)

$$p + \gamma \Rightarrow \pi^+ + n$$
$$p + \gamma \rightarrow \pi^0 + p$$
$$d + \gamma \rightarrow \pi^- + 2p$$

Particle	Mass	Charge	spin	magnetic Moment	Parity	Mean life
π^0	264me	0	0	0	odd	7×10^{-17}sec
π^+	273me	+e	0	0	odd	1.8×10^{-8}sec
π^-	273 me	−e	0	0	odd	1.8×10^{-8}sec

→ π^0 is Anti particle of itself and π^- is antiparticle of π^+.

→ Decay Modes →
$$\pi^0 \rightarrow \gamma + \gamma$$
$$\pi^+ \rightarrow \mu^+ + \nu$$
$$\pi^- \rightarrow \mu^- + \nu$$

Ⓘ K- Mesons (kaons) → These are four type. K^+, K^- (antiparticle of K^+) They are K^0 and $\bar{K}^0$ (antiparticle of K_0), no angular momentum, These are unstable, Heavy Mesons, mass of K^+ and K^- is equal to 966me and K^0 and $\bar{K}^0$ is 974me.

Charge of K^+ is (+e), K^- is (−e), K^0 and $\bar{K}^0$ is (zero).

Mean life: K^+ → 1.2×10^{-8}sec, K^- → 1.2×10^{-8}sec, K^0 → 9×10^{-11}sec. $\bar{K}^0$ → 10^{-10}sec.

Decay modes →
$$K^+ \rightarrow \pi^+ + \pi^0$$
$$K^+ \rightarrow \mu^+ + \nu$$
$$K^- \rightarrow \pi^- + \pi^0$$
$$K^0 \rightarrow \pi^+ + \pi^-$$
$$\bar{K}^0 \rightarrow \mu^+ + \pi^- + \nu$$

(iii) η Mesons (η^0) → It is neutral particle have Rest mass 1073 me and ~~unstable~~ unstable having mean life 7×10^{-19} sec, spin zero. η^0 is anti-particle of itself.

Decay modes →
$$\eta^0 \rightarrow 2\gamma$$
$$\eta^0 \rightarrow \pi^0+\pi^0+\pi^0$$
$$\eta^0 \rightarrow \pi^+ + \pi^- + \pi^0$$

(B) Baryons → (Strongly Interacting fermions) → They obey Fermi-Dirac Statistics of Half integral spins $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ etc. These are two types – (I) Nucleons (II) Hyperons.

→ They are subjected to strong, weak and electromagnetic interactions.

→ Nucleons → Protons, Antiproton, neutron, antineutron are member of this class.

→ Hyperons → Particles whose masses are greater than nucleons, Lambda particle (Λ^0), Sigma particle ($\Sigma^+, \Sigma^0, \Sigma^-$), Xi (Cascade) Particle (Ξ) and omega particle (Ω).

(I) Nucleons →

① Proton (P) → Stable particle, having Rest mass 1836 me, Charge 1.6×10^{-19} cb, $\bar{P}$ is anti-particle of P. its spin is $\frac{1}{2}$.

② Neutron (n) → No charge, unstable, 1839 me mass, spin $=\frac{1}{2}$, $\bar{n}$ anti-particle of n. mean life 932 sec.

(II) Hyperons →

① Lambda Hyperons (Λ^0) → Λ^0 and $\bar{\Lambda}^0$, neutral particle, 2182 me, spin $\frac{1}{2}$, unstable, mean life 2.5×10^{-10} sec.

~~Deat~~ Decay modes
$$(\Lambda^0) \rightarrow P+\pi^-$$
$$\rightarrow n+\pi^0$$

② Sigma Hyperons (Σ) → These are $\Sigma^+, \Sigma^0, \Sigma^-$, These antiparticle are $\bar{\Sigma}^+$, $\bar{\Sigma}^0$ and $\bar{\Sigma}^-$ Charge (+e, 0, −e) spin $(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$. mass (2328 me, 2334 me, 3241 me)

Decay modes →
$$\Sigma^+ \rightarrow P+\pi^0$$
$$\rightarrow n+\pi^+ \quad (\text{mean life} = 8\times10^{-11}\text{ sec})$$
$$\Sigma^0 \rightarrow \Lambda^0+\gamma \quad (10^{-14}\text{ sec})$$
$$\Sigma^- \rightarrow n+\pi^- \quad (10^{-10}\text{ sec})$$

(iii) Xi (Cascade) Particle → There are two type

Ⓐ Ξ^0 → neutral, 2570 me, spin $\frac{1}{2}$, unstable, 3×10^{-10} sec, is antiparticle of itself.

Ⓑ Ξ^- → −e, 2580 me, spin $\frac{1}{2}$, unstable, 1.7×10^{-10} sec, Ξ^+ antiparticle of Ξ^-.

Decay mode → $\Xi^- \rightarrow \Lambda^0 + \pi^-$

$\Xi^0 \rightarrow \Lambda^0 + \pi^0$

(IV) omega-particle (Ω^-) → −e, 3290 me, Spin = $\frac{3}{2}$, unstable, 1.3×10^{-10} sec, Ω^+ is antiparticle of Ω^-.

Decay mode → $\Omega^- \rightarrow \Xi^0 + \pi^-$

$\rightarrow \Xi^- + \pi^+$

$\rightarrow \Lambda^0 + K^-$

* PARAMETERS →

① Quantum Numbers →

Ⓐ Nucleon Number (N) = number of nucleon, stable, mean life 10^{21} yr.

Ⓑ Lepton Number → (e^-, e^+) and (ν_e, $\bar{\nu}_e$) are e- leptons.

$L_e = +1$ for e^- and ν_e (L → Lepton number)

$L_e = -1$ for e^+ and $\bar{\nu}_e$

Similarly (μ^-, μ^+) and (ν_μ, $\bar{\nu}_\mu$) are μ- leptons.

$L_\mu = +1$ for μ^- and ν_μ

$L_\mu = -1$ for μ^+ and $\bar{\nu}_\mu$

Thus $L = +1$ for leptons

$L = -1$ for antileptons

$L = 0$ for other Particles.

Ⓒ Baryon- number → $B = +1$ for nucleons and Hyperons (Baryons)

$B = -1$ for anti-nucleons and anti-Hyperons (anti-Baryons)

$B = 0$ for all other Particles (like Photons, mesons etc.)

Ⓓ Spin- Quantum Number → (S)

Spin angular momentum $L_S = \sqrt{S(S+1)}\,\hbar$.

S = odd Half integral values for fermions.

(E) Iso-Spin (I) → A Phenomenon in which many Particles have Same masses but different charges called Iso Spin.

EX: → (1) (Neutron, Proton) (2) Hadrons family like Pions, muons etc.

→ An Isospin space can be defined just like the Intrinsic spin in which strong interactions will be invarient under a Rotation, so its multiplicity of Iso-Spin is $(2I+1)$

in Isospin space its component in particular direction is z-axis

So $I_Z (I_3) = I, I-1, I-2 ---- (I-2)(I-1)(I)$

$$I_Z = Q_P - \bar{Q}$$

where Q_P is the electric charge number of the Particle and $\bar{Q}$ is the average number of its group.

$Q_P = +1,\ Q_n = 0$ and $\bar{Q} = \frac{Q_P + Q_n}{2} = \frac{1+0}{2} = \frac{1}{2}$

$I_Z(\text{Proton}) = Q_P - \bar{Q} = 1 - \frac{1}{2} = +\frac{1}{2}$

$I_Z(\text{neutron}) = Q_n - \bar{Q} = 0 - \frac{1}{2} = +\frac{1}{2}$ ✓

Table →

Class	Type	Particle	Antiparticle	Spin	IsoSpin I	
Mesons	π-Meson	π^+			+1	
		π^0		0	0	
			π^-		-1	
	K-Meson	K^+			+1/2	
		K^0		0	-1/2	
			$\bar{K}^0$		+1/2	
			$\bar{K}^-$		-1/2	
	η-Meson	η^0		0	0	
	Nucleons	p^+			+1/2	
		n^0		$\frac{1}{2}$	-1/2	
			$\bar{P}$		+1/2	
			$\bar{n}^0$		-1/2	

...ss	Type	Particle	Anti particle	Spin	Isospin
Baryons	Λ-Hyperons	Λ^0		$\frac{1}{2}$	0
			$\bar{\Lambda}^0$		0
	Σ-Hyperons	Σ^+			1
		Σ^0			0
		Σ^-		$\frac{1}{2}$	−1
			$\overline{\Sigma^+}$		−1
			$\overline{\Sigma^0}$		0
			$\overline{\Sigma^-}$		+1
	Cascade Hyperons	Ξ^0			$+\frac{1}{2}$
		Ξ^-		$\frac{1}{2}$	$-\frac{1}{2}$
			Ξ^+		$+\frac{1}{2}$
			Ξ^0		$-\frac{1}{2}$
	Ω-Hyperons	Ω^-			0
			Ω^+	$\frac{3}{2}$	0.

(F) Hyper- Charge (Y) →

$$Y = 2\bar{Q} \quad \text{—(1)} \quad \bar{Q} = \text{average charge of each particle group.}$$

we know $I_z = Q - \bar{Q}$

$\bar{Q} = Q - I_z$

So $Y = 2(Q - I_z)$ —(2)

Ex → (1) For Triplet π^+, π^0, π^- , average charge $= \bar{Q} = \frac{1+0-1}{3} = 0.$

So $Y = 0.$

(2) for pair K^+, K^0 , $\bar{Q} = \frac{1+0}{2} = \frac{1}{2}$

$Y = 2 \times \frac{1}{2} = 1$

for antiparticles $K^-, \bar{K}_0$ $\bar{Q} = \frac{-1+0}{2} = \frac{-1}{2}$

$Y = 2 \times -\frac{1}{2} = -1$

(3) for Nucleon (P, n) $\bar{Q} = \frac{1+0}{2} = \frac{1}{2}$

$Y = 2 \times \frac{1}{2} = 1$

(G) Strangeness → Gell-Mann and Nishijima was observed the K-Mesons and Hyperons are Produced by strong interactions (10^{-} But decay by means of weak interactions (10^{-10} sec) and these Particles are Produced in Pairs and are never Produced separately. Due to this strange Behaviour these Particles are called Strange Particles.

Ex. → $P + P \rightarrow P + \Lambda^0 + K^+$ (Strong interaction)

and decay by in ordinary particles are

$\Lambda^0 \rightarrow P + \pi^-$ (weak interaction)

$K^+ \rightarrow \pi^0 + \pi^+$ (weak interaction)

→ Strangeness Quantum number $S = Y - B$.   B → Baryon number.

$$Y = 2(Q - I_3)$$

So $S = 2(Q - I_3) - B$.

or $Q - I_3 = \frac{S+B}{2}$.

$$\boxed{Q = I_3 + \frac{B+S}{2}}$$

Table →

class	Particle	S	Y = B+S.
Mesons B=0.	π^+	Q=+1, I=+1	0
	π^0	0 Q=0, I=0	
	π^-	Q=−1, I=−1	
	K^+	Q=+1, I=+1/2	1
	K^0	1 Q=0, I=−1/2	
	$\bar{K}^0$	Q=0 I=+1/2	−1
	K^-	−1 Q=−1 I=−1/2	
	η^0	0 Q=0, I=0.	0
Baryons B=+1	P	Q=1 I=+1/2	1
	n	0 Q=0 I=−1/2.	
	Λ^0	−1 Q=0, I=0	0
	Σ^+	Q=+1 I=1	0
	Σ^0	−1 Q=0 I=0	
	Σ^-	Q=−1 I=−1	
	Ξ^0	Q=0 I=1/2	−1
	Ξ^-	−2 Q=−1 I=−1/2	
	Ω^-	−3 Q=−1, I=0.	−2.

Parity → The wave function ψ is a function of all the Positions and spin co-ordinates of the system. If we Reflect the Position co-ordinates of the system to obtain mirror image, have two Possibilities for ψ..

if $\psi(-\vec{r}) = -\psi(\vec{r})$ odd Parity called as (−1)

$\psi(-\vec{r}) = \psi(\vec{r})$ even Parity Called as (+1)

These two Process viewed by Reflection in a Mirror would also occur with equal Probability called Conservation of Parity Law.

→ Parity is Conserve in strong and electro-magnetic interactions But it is not Conserved in weak interaction such as β-decay.

(I) CHARGE-CONJUGATION → non-Conservation of Parity in weak-Interaction explained by two closely Related Conservation laws →

① Charge Conjugation (C) → In this interactions and Processes are unchanged when every Particle is Replaced by its anti-particle. Called Charge Conjugation Invarience.

Here strong interaction, e.m interaction are invarient But weak interaction like (β-decay) is not obey Charge conjugation.

$C|\beta\rangle = -|\beta\rangle$, $C|\pi^{\pm}\rangle = |\pi^{\pm}\rangle$

$C|\pi^{0}\rangle = |\pi^{0}\rangle$

② Time-invarience (T) → Any Process can Proceed either forward or Back-ward in time without change.

T → also Conserved in weak interaction.

Special Point → P & C seperately not Conserved for weak interaction.

But PC or G Conserved for weak interactions.

→ CPT (Theorem) → Combined operation of CPT take in any order conserved weak and strong interaction.

* CONSERVATION LAWS →

Law → 1 → Total energy, including Rest mass remains Constant.

Law → 2 → Total Linear momentum Remains Constant.

Law → 3 → Total angular momentum Remains Constant.

Law → 4 → Total charge Remains Constant.

* Law → 5 →
(Law of Conservation of Leptons) →

In any Reaction total number of leptons Conserved, every leptone have Counted +1 & anti lepton -1.

$(\nu, e^-, \mu^-) \rightarrow +1$, its anti-lepton → -1.

Ex → $\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$

1   1   1   -1   so Leptons Conserved.

Point → single lepton is never Created or Annihilated

Ex $\gamma = e^+ + e^-$ alowed But $\gamma = e^- + p^+$ is forbidden as lepton number not Conserved.

* Law → 6 (Law of Conservation of Baryon) →

Protons and neutrons have +1 Baryon whereas anti-proton and anti-neutron are -1 Baryon.

$n \rightarrow p + e^- + \bar{\nu}_e$

1   1   0   0

ΣB = Constant.

→ these '6' Conservation laws that are universely valid for all four fundamental interactions.

*→ Conservation Law for Strong and electro-magnetic Interactions →

① Isospin Conservation Law → . (~~for strong~~)

$\Sigma I_z = \Sigma I_3$ = Constant.

(Strong) → $p^+ + p^+ \rightarrow \Lambda^0 + K^0 + p^+ + \pi^+$

$\frac{1}{2} + \frac{1}{2} \rightarrow 0 - \frac{1}{2} + \frac{1}{2} + 1$ (I_z = Conserved)

weak → $\Lambda^0 \rightarrow p^+ + \pi^-$

$0 \neq \frac{1}{2} - 1$ (I_z not Conserved).

② Conservation of Hyper-charge → ΣY = Const.

$p^+ + p^+ \rightarrow \Lambda^0 + K^0 + p^+ + \pi^+$

$1 + 1 \rightleftharpoons 0 + 1 + 1 + 0.$ (ΣY = Conserved).

Conservation of Strangeness →

$\Sigma S = \text{Const.}$

$p^+ + p^+ \rightarrow \Lambda^0 + K^0 + p^+ + \pi^+$

0 0 −1 1 0 0 (ΣS = Conserved).

→ for weak interaction (specially).

(A) $K^0 \rightarrow \pi^+ + \pi^-$

1 0 0 ($\Delta S = -1$)

(B) $\Lambda^0 \rightarrow p^+ + \pi^-$

−1 0 0 ($\Delta S = +1$)

(C) $n^0 \rightarrow p^+ + e^- + \bar{\nu}_e$

0 0 0 0 ($\Delta S = 0$)

So ~~for~~ $\Delta S = \pm 1$ or 0 known as selection Rule of weak interaction.

④ Conservation of Parity ⇒ (Symmetry).
for strong it Conserved.

* QUARKS →

① Quarks are thought to be elementary in the Same Sense as leptons, Here Point particles with no internal Structure.

② They are Supposed to Possess fractional electric charges, The six Quarks are named up (u), down (d), charm (c), Strange (s), top (t), bottom (b). The six antiquarks are labelled $\bar{u}$ ~~(anti)~~ (anti up), $\bar{d}$ (anti down), $\bar{c}$ (anti-charm), $\bar{s}$ (anti strange), antitop ($\bar{t}$) and anti bottom ($\bar{b}$). These twelve quark-anti quark particles along with their electric charges are given ~~below~~ below →

$u = +\frac{2}{3}e$	$\bar{u} = -\frac{2e}{3}$
$d = -\frac{e}{3}$	$\bar{d} = +\frac{e}{3}$
$c = +\frac{2}{3}e$	$\bar{c} = -\frac{2e}{3}$
$s = -\frac{1}{3}e$	$\bar{s} = +\frac{e}{3}$
$t = +\frac{2e}{3}$	$\bar{t} = -\frac{2e}{3}$
$b = -\frac{e}{3}$	$\bar{b} = +\frac{e}{3}$.

(3) Each Quark has a Baryon number, $B = \frac{1}{3}$ and its each anti-Quark has a Baryon number $B = -\frac{1}{3}$.

(4) Each Baryon is made up of three quarks and each anti baryon is made-up three anti-quarks. Meson is made up of one Quark and one anti-Quark.

(5) Quarks and Anti quarks have spin equal to $\frac{1}{2}$.

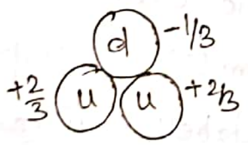
(6) Quarks have three Colours:- Red, green, Blue. Anti Quarks have three anti colours i.e antired, antigreen, antiblue (i.e cyan, Magenta, Yellow) All three Quarks in Baryon have different Colours.

(7) Meson is consist of a quark of one colour and antiquark of the anti colour, so mesons are always colourless.

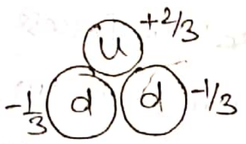
(8) The strong interaction between Hadrons is because of interaction between Quarks. The Particle exchanged during the interaction between Quarks are called gluons. These gluons are massless and move with speed of light. Each gluon carries colour and anticolour.

(9) The Theory which explains the interaction of Quarks with each other is called Quantum Chromodynamics.

(10)



= Proton,



= Neutron.

(11) No Quark has been Isolated in an experiment.

(12) Strange Quark has $S = -1$, anti Quark has $S = +1$, and other Quark have $S = 0$.

(13) Quark donot exist as an independent entity.

(14)