I. Fundamental Interactions in Nature:

There are four types of interactions between particles.

		Relative Strength	Range	Particle Exchanged (Mediators)	Lifetime for decay
a]	**Strong Interaction**	1	10^{-15}m	Gluon	10^{-23}s
b]	**Electromagnetic Interaction**	10^{-2}	∞	Photons	10^{-16}s
c]	**Weak Interaction**	10^{-13}	10^{-18}m	W^+, W^-, Z^0	10^{-8}s
d]	**Gravitational Interaction**	10^{-38}	∞	Graviton	-

i) Gravitational Interaction:

- Weakest force
- Force of mutual attraction between masses
- Long range force ($\sim \frac{1}{r^2}$)
- Mediator is **Gravition**- mass less, speed of light, interacts with all particles with mass, spin 2ħ

ii) Electromagnetic Interaction:

- Acts between charged particles
- Responsible for binding of electrons, formation of molecules, electrical and optical signals
- Responsible for all chemical and biological processes
- Tension, Friction, Drag ultimately results from EM interaction
- Responsible for almost all non gravitational forces
- Mediator is **Photon**- mass less, spin 1ħ

iii) Weak Interaction:

- Responsible for β decay by nuclei
- Range is smaller than 0.001fm
- The Electroweak theory (1960) unified EM and weak interaction, experimentally proved in 1983
- EM and Weak forces act independently except at high particle energies

- Mediators are $\mathbf{W^{\pm}}$ (80.4GeV) and $\mathbf{Z^0}$ (91.2GeV) bosons- spin 1ħ

iv) Strong Interaction:

- Responsible for binding of nucleons in a nucleus
- Strongest of all forces, 100 times stronger than EM interaction
- Keeps protons together against strong electrostatic repulsion
- Short range & non-central
- Main force of reaction and decays of elementary particles
- Charge independent, spin dependent
- Mediator is Gluon- mass less, neutral, spin 1ħ, a quark, can emit and absorb other gluons

II. Classification of Elementary Particles:

The elementary particles are broadly grouped into three families according to spin, mass and type of interaction.

		Spin	Mass	Types of Interactions
1	**Massless Bosons**	Integer	0	EM/Gravitational
2	**Leptons**	Half Integer	$<207\ m_e$	Weak, EM
3	**Hadrons-**			Strong, Weak, EM, Gravitational
	➢ **Mesons**	Integer	$<m_p$	
	➢ **Baryons**	Half Integer	$>m_p$	

Mass less Bosons:

Name	Rest mass (MeV)	Spin (×ħ)	Charge (×e)	Decay
Photon	0	1	0	stable
W^+	80.4×10^3	1	1	observed
W^-	80.4×10^3	1	-1	observed
Z^0	91.2×10^3	1	0	observed
Gluon	0	1	0	Bound in hadrons

The particles and its anti-particles in lepton and hadron groups are:

Name	Rest mass (MeV)	Mean life (Sec)	Charge Q (×e)	Spin (×ħ)	Lepton no. L	Baryon no. B	Strangeness no. S
Leptons							
ν_e ($\bar{\nu}_e$)	$<7\times10^{-6}$	∞	0 (0)	$1/2$	+1 (-1)	--	--
ν_μ ($\bar{\nu}_\mu$)	<0.17	∞	0 (0)	$1/2$	+1 (-1)	--	--
ν_τ ($\bar{\nu}_\tau$)	<18	∞	0 (0)	$1/2$	+1 (-1)	--	--
e^- (e^+)	0.51	∞	-1 (+1)	$1/2$	+1 (-1)	--	--
μ^- (μ^+)	105.7	2.2×10^{-6}	-1 (+1)	$1/2$	+1 (-1)	--	--
τ^- (τ^+)	1777	2.96×10^{-13}	-1 (+1)	$1/2$	+1 (-1)	--	--
Hadrons							
Mesons							
$\pi^+(\pi^-)$	139.6	2.6×10^{-8}	+1 (-1)	0	0	--	--
π^0 ($\bar{\pi}_0$)	135.0	0.8×10^{-16}	0	0	0	--	--
K^+ (K^-)	493.7	1.2×10^{-8}	+1 (-1)	0	0	--	+1 (-1)
K^0 ($\bar{K}^0$)	497.7	8.8×10^{-11}	0	0	0	--	+1 (-1)
η^0 ($\bar{\eta}_0$)	547.0	2.5×10^{-19}	0	0	0	--	--
ρ, ω, K^* are vector mesons, spin 1ħ, unstable							
Baryons							
p ($\bar{p}$)	938.3	∞	+1 (-1)	$1/2$	--	+1 (-1)	0 (0)
n ($\bar{n}$)	939.6	888	0 (0)	$1/2$	--	+1 (-1)	0 (0)
Λ^0 ($\bar{\Lambda}^0$)	1116	2.5×10^{-10}	0 (0)	$1/2$	--	+1 (-1)	-1 (+1)
Σ^+ ($\bar{\Sigma}^-$)	1189	8×10^{-11}	+1 (-1)	$1/2$	--	+1 (-1)	-1 (+1)
Σ^0 ($\bar{\Sigma}^0$)	1193	7.4×10^{-20}	0 (0)	$1/2$	--	+1 (-1)	-1 (+1)
Σ^-($\bar{\Sigma}^+$)	1197	1.5×10^{-10}	-1 (+1)	$1/2$	--	+1 (-1)	-1 (+1)
Ξ^- (Ξ^+)	1321	1.6×10^{-10}	-1 (+1)	$1/2$	--	+1 (-1)	-2 (+2)
Ξ^0 ($\bar{\Xi}^0$)	1315	2.9×10^{-10}	0 (0)	$1/2$	--	+1 (-1)	-2 (+2)
Ω^- (Ω^+)	1672	8.2×10^{-11}	-1 (+1)	$3/2$	--	+1 (-1)	-3 (+3)
Σ^*, Δ are spin 3/2 baryons							

Leptons:

- Interact via weak nuclear force
- Charge carrying leptons also interact via EM force
- There are six leptons plus their anti-particles
- All leptons have lepton no. 1 and antiparticles have lepton no. -1.
- All leptons have spin half
- Each charged particle has an associated neutrino similarly named
- Neutrinos are charge less, mass less and identified experimentally.
- Tau lepton, discovered in 1976 is 3000 times heavier than electron lepton
- The existence of weak interaction is necessary in order to explain how a neutrino interacts with the nuclear matter. A neutrino is mass less and charge less, thus, it can't undergo e-m & gravitational interaction. Also as it is not nuclear, it does not participate in strong interaction.
  Example: $n \rightarrow p + e^{-} + \bar{\nu}_e$
  The emission of neutrino is necessary to conserve lepton number.

Hadrons:

- Hadrons are particles that interact via strong nuclear force
- They also interact via other forces
- Hadrons are divided into two sub-groups- Mesons and Baryons
- Mesons are Bosons (integer spin), Baryons are Fermions (half integer spin)

Mesons:

- Strong interaction
- Bosons with integer spin
- Masses are greater than muon mass, fairly short lifetime

Baryons:

- Strong interaction
- Fermions with half integer spin
- All baryons have baryon no. 1 and antiparticles have baryon no. -1.
- Masses at least as large as the proton mass
- Proton and Neutrons are called Nucleons and have strangeness number 0.
- Baryons with non-zero strangeness number are called Hyperons.