



STUDY MATERIAL ON ELEMENTARY PARTICLE PHYSICS

VIVEKANANDA COLLEGE, THAKURPUKUR

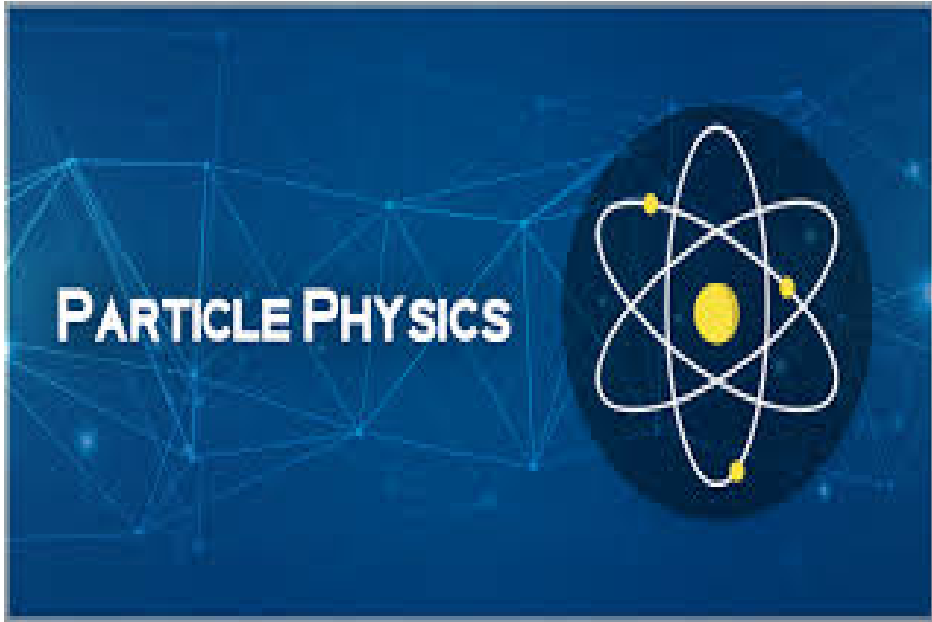
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By

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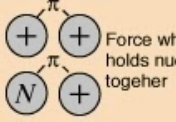
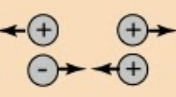
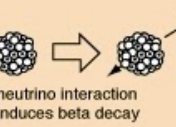
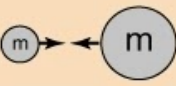
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I. FUNDAMENTAL FORCES

There are four fundamental interaction between particles namely,

- Strong
- Electromagnetic
- Weak
- Gravitational

Fundamental Forces				
<i>Strong</i>		Strength 1	Range (m) 10^{-15} (diameter of a medium sized nucleus)	Particle gluons, π (nucleons)
<i>Electro-magnetic</i>		Strength $\frac{1}{137}$	Range (m) Infinite	Particle photon mass = 0 spin = 1
<i>Weak</i>		Strength 10^{-6}	Range (m) 10^{-18} (0.1% of the diameter of a proton)	Particle Intermediate vector bosons W^+ , W^- , Z_0 , mass > 80 GeV spin = 1
<i>Gravity</i>		Strength 6×10^{-39}	Range (m) Infinite	Particle graviton ? mass = 0 spin = 2

II. ELEMENTARY PARTICLES

In particle physics, an elementary particle or fundamental particle is a particle with no substructure, thus not composed of other particles. Particles currently thought to be elementary include the fundamental fermions (quarks, leptons, antiquarks, and antileptons), which generally are "matter particles" and "antimatter particles", as well as the fundamental bosons (gauge bosons and the Higgs boson), which generally are "force particles" that mediate interactions among fermions. A particle containing two or more elementary particles is a composite particle. Elementary particles can be divided into four groups viz:

- Photons
- Leptons
- Mesons
- Baryons

A. Photons

- It only participates in EM interactions.
- Strong and weak interactions are not in photon domain of experience.
- When particle annihilate with anti-particles the end product is often photons.
- Photon is its own anti particle.
- Under some circumstances it can disappear and can create particle -anti particle pair.
- Rest mass of photon is zero.
- Photon is a boson with angular momentum equal to 1.
- Spin of photon is 1

B. Leptons

- A particle which are untouched by strong forces and which participates in weak interactions are called leptons.
- All these particles (leptons) also have their corresponding anti particles.
- Unlike baryons and mesons no heavier leptons have been detected.
- Electrons with its anti-particle positron along with its associated neutrino and anti neutrino are leptons.
- Muons with their respective neutrino and anti-particles of these are also leptons. Another pair of leptons known as tau, and its associated neutrino.

- All taus are charged and decay into electrons, muons or pions along with appropriate neutrino.
- The particles are left handed and anti-particles are right handed.

Particle	L_e	L_μ	L_τ
e^-	+1	0	0
ν_e	+1	0	0
μ^-	0	+1	0
ν_μ	0	+1	0
τ^-	0	0	+1
ν_τ	0	0	+1

C. Mesons

- Mesons are particles with zero or integral spin so they are Bosons.
- The lightest meson is pion or π^- -meson, with other meson masses ranging beyond proton mass.
- All mesons are unstable and decay in various ways.

D. Baryons

A baryon is a composite subatomic particle made up of three quarks (a triquark, as distinct from mesons, which are composed of one quark and one antiquark). Baryons and mesons belong to the hadron family of particles, which are the quark-based particles.

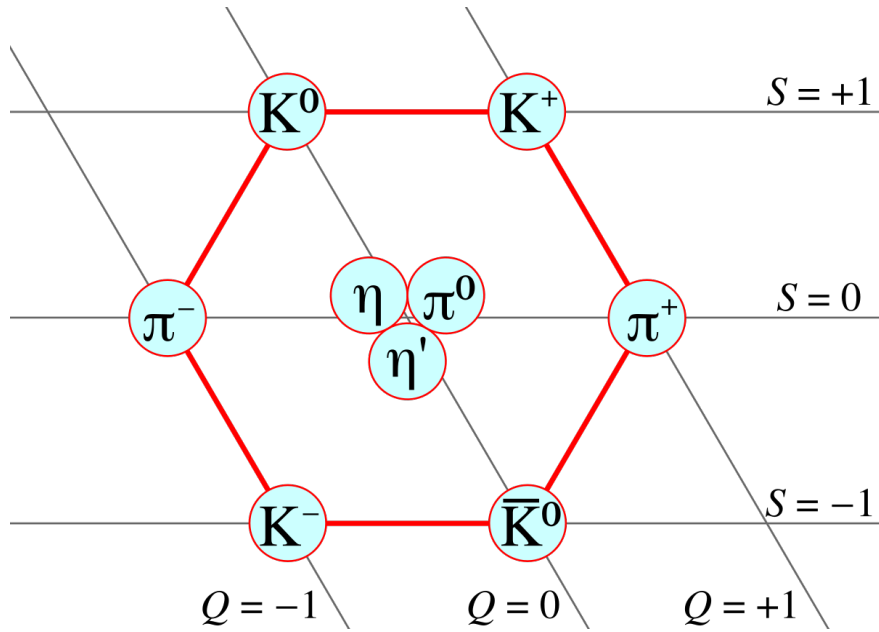


FIG. 1. Meson Nonet

Mesons $q\bar{q}$					
Mesons are bosonic hadrons					
These are a few of the many types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.776	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2.980	0

As quark-based particles, baryons participate in the strong interaction, whereas leptons, which are not quark-based, do not. The most familiar baryons are the protons and neutrons that make up most of the mass of the visible matter in the universe. Electrons (the other major component of the atom) are leptons.

Each baryon has a corresponding antiparticle (antibaryon) where quarks are replaced by

their corresponding antiquarks. For example, a proton is made of two up quarks and one down quark; and its corresponding antiparticle, the antiproton, is made of two up antiquarks and one down antiquark.

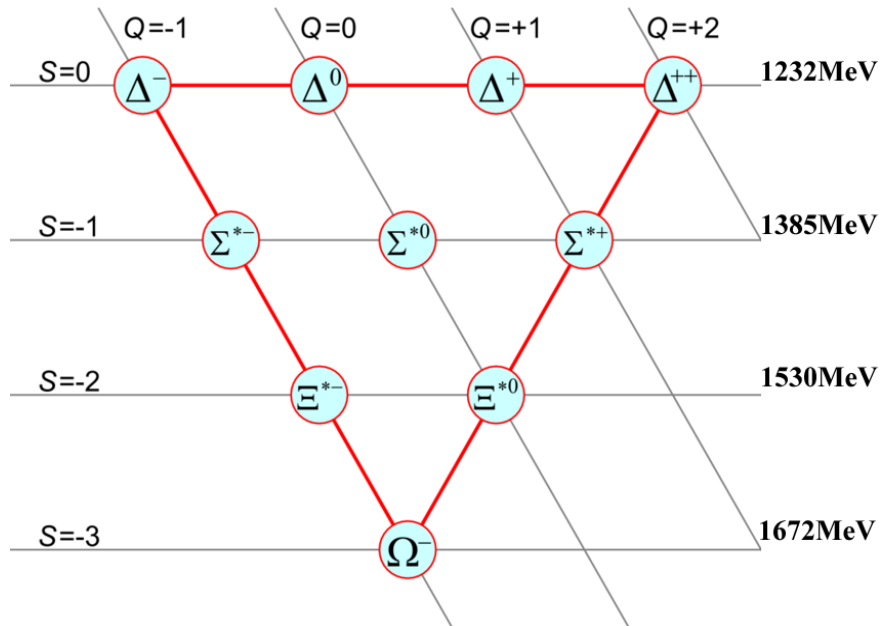


FIG. 2. Baryon Decuplet

Example Baryons (qq) and AntiBaryons ($\bar{q}\bar{q}\bar{q}$)					
Symbol	Name	Quark Content	Chg	Mass GeV/c^2	Spin
p	proton	uud	$+e$	0.938	1/2
\bar{p}	antiproton	$\bar{u}\bar{u}\bar{d}$	$-e$	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Δ^{++}	delta++	uuu	$+2e$	1.232	3/2
Ω^-	omega-	sss	$-e$	1.672	3/2

III. STANDARD MODEL

The Standard Model of particle physics is the theory describing three of the four known fundamental forces (the electromagnetic, weak, and strong interactions, and not including the gravitational force) in the universe, as well as classifying all known elementary particles.

Drei Generationen der Materie (Fermionen)

	I	II	III	
Masse	2,3 MeV	1,275 GeV	173,07 GeV	125,9 GeV
Ladung	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
Spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0
Name	u up	c charm	t top	H Higgs Boson
				q e/p-Quant
Quarks	4,8 MeV	95 MeV	4,18 GeV	0
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	d down	s strange	b bottom	g Gluon
Leptonen	<2 eV	<0,19 MeV	<18,2 MeV	91,2 GeV
	0	0	0	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	ν_e Elektron-Neutrino	ν_μ Myon-Neutrino	ν_τ Tau-Neutrino	Z⁰ Z Boson
	0,511 MeV	105,7 MeV	1,777 GeV	80,4 GeV
	-1	-1	-1	± 1
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	e Elektron	μ Myon	τ Tau	W[±] W Boson
				Eichbosonen

REFERENCE BOOKS

1. Elementary Particle Physics by Ian Kenyon
2. Modern Elementary Particle Physics: Explaining and Extending the Standard Model by Gordon Kane
3. Introduction to Nuclear and Particle Physics by V.K. Verma