CHAPTER 26

RECENTS TRENDS IN PHYSICS

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Particle physics:-

↳ Elementary particles are those particles whose internal structures are unknown. Leptons, quarks and mediator particles are considered as the elementary particles.

Particles and Antiparticles:-

↳ A particle is said to be antiparticle of a particle if that has equal mass and magnitude of electric charge, but nature of charge is opposite.
Some examples of particle-antiparticle pair:-

i) Electron and positron:-

↳ They having equal mass and equal magnitude of charge (i.e., 1.6×10^{-19} C). When an electron combines with positon, they disappear.

ii) proton and antiproton:-

↳ Antiprton is the antiparticle of a proton.

iii) Neutron and antineutron:-

↳ Antineutron is the antiparticle of neutron. Neutron & antineutron have zero electric charge.

iv) Neutrino and anti-neutrino:-

↳ Pauli purposed, in 1931, that β-decay is always accompanied by another particle of almost zero rest mass and zero-charge, called neutrino. Antineutrino is the antiparticle of neutrino.

v) Matter and antimatter:-

↳ Antielements (i.e., positron, antiproton, antineutron) are responsible to form antimatter.

Annihilation:-

↳ When a particle interacts with its antiparticle, whose masses of both particle and antiparticle rise completely converted into energy (photons), usually, a pair of γ-rays (sometimes x-rays). This process of conversion of matter into energy is called annihilation.

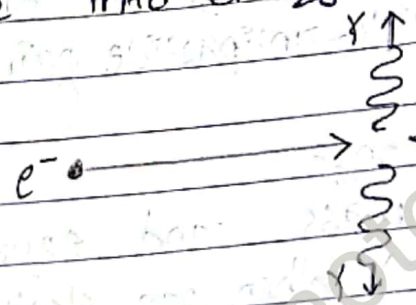

fig: Electron position annihilation.

pair production:-

↳ An x-ray or γ-ray, may interact with the matter while traversing nearer from the nucleus. When a photon of x-ray or γ-ray passes through the nuclear field, a electron-positron pair (+ve & -ve) appears in place of photon. This materialization process of energy is known as pair production.

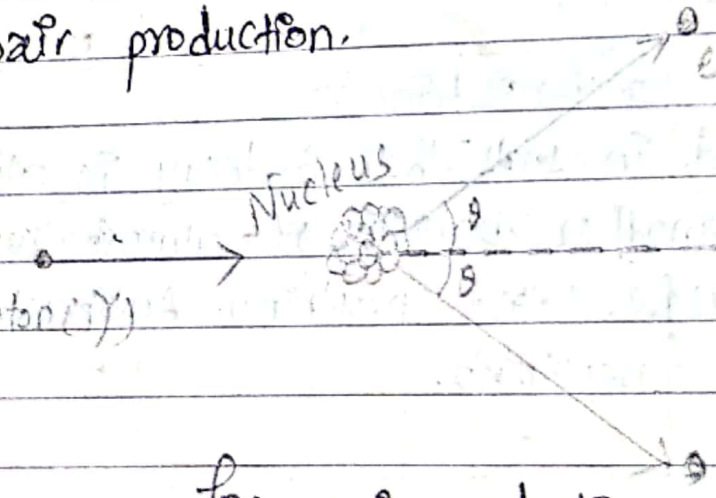

fig:- pair production.

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Concept of Spin:-

↳ Rotation of an object along its axis is called spin. It is quite different than classical physics in the context of elementary particles.

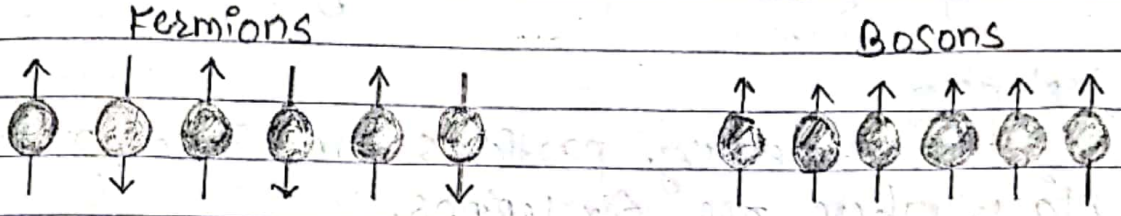


fig:- Spin of particles

i) Half Spin:-

↳ In this spin, particle reverse their direction in 2π rotation (i.e. upside turns down) and after another 2π rotation, come to their original position. or, such particles can recover their original position after 4π rotation. Fermions are half-spin particles.

ii) Integer Spin:-

↳ The particles having integer spin, recover their original position after 2π rotation. Bosons are integer spin particles.

Classification of Elementary Particles:-

- Elementary particles
  - Fermions
    - Leptons
      - Electron (e^-)
      - Electron neutrino (ν_e)
      - Muon (μ)
      - Muon neutrino (ν_μ)
      - Taun (τ)
      - Taun neutrino (ν_τ)
    - Quarks
      - Up (u)
      - Down (d)
      - Charm (c)
      - Strange (s)
      - Top (t)
      - Bottom (b)
  - Bosons
    - Gauge Boson
      - Gluons
      - Photons
      - W and z Bosons
      - Gravitons
    - Higg's Boson

Fermions:-

↳ The elementary particles with half-integer spins are called fermions. Half integer can be the odd multiples of $\frac{1}{2}$. [i.e $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$]. Leptons & quarks belongs to this family. This particles obey pauli Exclusion principle.

Leptons:-

↳ Lighter elementary particles are incorporated in this class. There are six leptons.
Some important information of lepton's are tabulated below:-

particle	Symbol	Charge	Rest mass (MeV)
Electron	e^-	$-e$	0.51
Muon	μ^-	$-e$	106
Taun	τ^-	$-e$	1784
e-neutrino	ν_e	0	0
μ-neutrino	ν_μ	0	0
τ-neutrino	ν_τ	0	0

Quarks:-

↳ Quarks are elementary particles which are the fundamental constituents of matter. They are fermions. They combine to form composite particles called hadrons. Short description of quarks are tabulated below:-

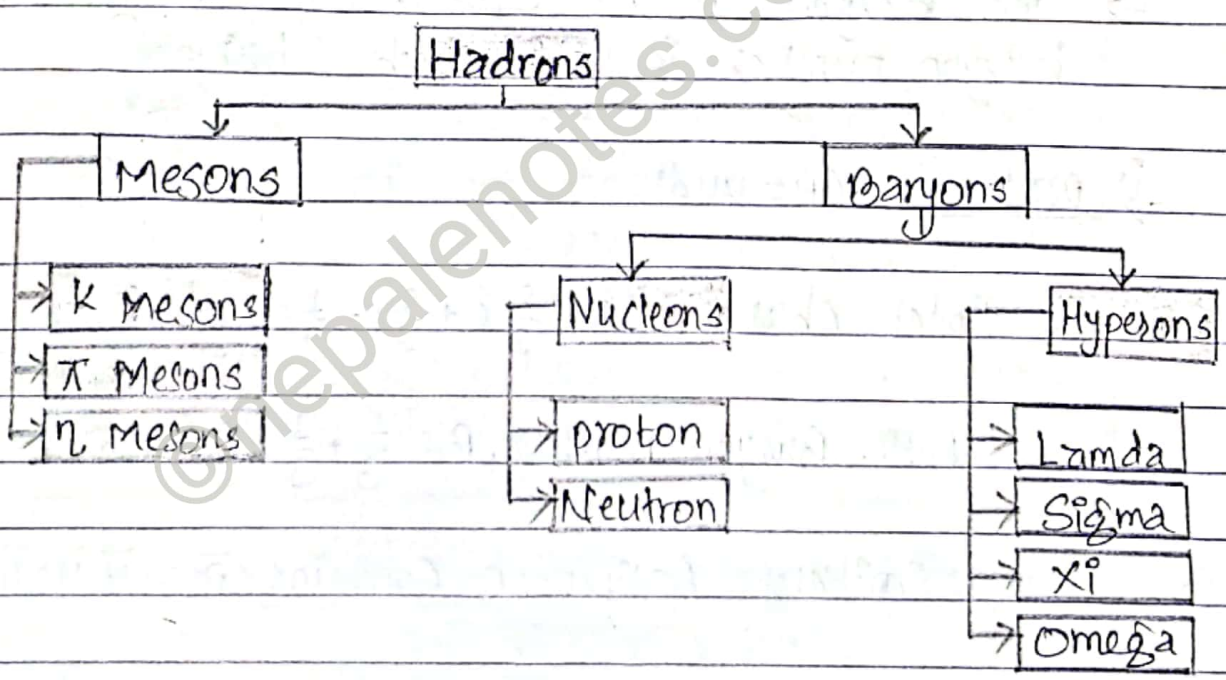
Types of quarks	Symbol	Charge	Baryon NO.	Antiquarks
Up	u	$+\frac{2}{3}e$	$\frac{1}{3}$	$\bar{u}$
Down	d	$-\frac{1}{3}e$	$\frac{1}{3}$	$\bar{d}$
Charm	c	$+\frac{2}{3}e$	$\frac{1}{3}$	$\bar{c}$
Strange	s	$-\frac{1}{3}e$	$\frac{1}{3}$	$\bar{s}$
Top	t	$+\frac{2}{3}e$	$\frac{1}{3}$	$\bar{t}$
Bottom	b	$-\frac{1}{3}e$	$\frac{1}{3}$	$\bar{b}$

Bosons:-

↳ The elementary particles with zero or integer spin(0,1,2---) are bosons. Gauge bosons and Higgs bosons are examples of bosons. They do not obey pauli Exclusion principle.

Hadrons:-

↳ Hadrons are strongly interacting heavy composite particles. They are composed of quarks. They are basically two types: mesons & Baryons. Mesons contain one quark and an antiquark. Baryons contain three quarks. The hadrons are classified as below:-



Mesons:-

↳ Mesons are made up of a quark and an antiquark. They possess mass intermediate between electron and proton.

Baryons:-

↳ Baryons are composite particles including nucleons & hypersons. They have half-integer spins. They have equal or greater mass of that the mass of a proton. Every baryon has an antiparticle.

Nucleons:-

↳ These are the lightest baryons. This group includes protons, neutrons & their antiparticles.

Hyperons:-

↳ Hyperons have mass value intermediate between those of neutron and deuteron. Examples:- Lamda(Λ), Sigma(Σ), Xi(Ξ) and Omega(Ω). Actually, hyperons contain strange quarks.

Quarks & Baryons:-

↳ Each baryon is combination of three quarks and baryon number is 1 for each baryon.

i) **proton:-** (P = uud)

Total Charge, $Q = +\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +e$

Also, Baryon number, $B = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

Similary, Antiproton contains, $\bar{p} = \bar{u}\,\bar{u}\,\bar{d}$.

ii) **Neutron:-** (n = udd)

Total Charge, $Q = +\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

Also, Baryon number, $B = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

Similarly, Antineutron, $\bar{n} = \bar{u}\,\bar{d}\,\bar{d}$.

(ii) Sigma :- ($\Sigma^+ = uus$)

Total Charge, $Q = +\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +e$

Also, Baryon no., $B = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

Similarly, $\Sigma^0 = uds$ & $\Sigma^- = dds$

Baryon	Q-combination	Charge
P	uud	+e
n	udd	0
Λ^0	uds	0
Σ^+	uus	+e
Σ^0	uds	0
Σ^-	dds	-e
Ξ^0	uss	0
Ξ^+	dss	-e
Ω^-	sss	-e

Three Generations of Quarks and Leptons:-

Type	Generations of matter: First	Second	Third
Quarks			
up-type	up (u)	Charm (c)	top (t)
down-type	down (d)	Strange (s)	bottom (b)
Leptones			
Charged	electron (e)	Muon (μ)	tauon (τ)
neutral	electron neutrino (ν_e)	Muon neutrino (ν_μ)	tauon neutrino (ν_τ)

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Universe:-

↳ The universe is all around us, in our vision and beyond our vison. The size of universe is still unknown. Many constituents of universe are invisible and are called **dark matter and dark energy.**
The branch of science, which deals with the study of the origin, evolution & nature of the universe, is called Cosmology.

Big-Bang:-

↳ Big bang theory is the most widely accepted and popular theory. It explains not only the origin of all known matter, the laws of physics and the large scale structure of the universe, it also accounts for the expansion of universe and broad range of other phenomena.

Red Shift:-

↳ According to Doppler effect, there is apperent change in wavelength of waves emitted by source when it is in motion with respect of observer. The wavelength is increased if the source is moving away from observer and is decreased if source is moving towards observer.
If the star is moving towards the earth wavelength of light emitted by star will be decreases and it's colour shifted toward violet and the visible spectrum formed by such process is called **blue shift.**
As, the star in the galaxy moves away from earth and wavelength of light emitted by star

will increases and shifts towards red and such a visible spectrum toward red end is called **red shift**.

Let us consider a galaxy moving away from us with a velocity 'v'. Then,

$$\text{red shift } (z) = \frac{v}{c} \quad \text{-----(i)}$$

Where, 'c' is velocity of light in vaccum.
If 'λ' be the wave length of emitted radiation by galaxy and λ₀ be the observed wave length on earth. then,

$$\text{red shift } (z) = \frac{\lambda - \lambda_0}{\lambda} \quad \text{---(ii)}$$

From eqⁿ(i) & (ii)

$$\frac{v}{c} = \frac{\lambda - \lambda_0}{\lambda} \Rightarrow \frac{v}{c} = \frac{\Delta\lambda}{\lambda} \quad [\because \Delta\lambda = \lambda - \lambda_0]$$

$$\therefore \boxed{\Delta\lambda = \frac{v\lambda}{c}}$$

Hubble's Law:-

↳ Red shift shows that galaxy are moving away from us. This gives rise the theory a universe is expanding the velocity with which galaxy moves away from us is proportional to their distance from earth. This Law is given by Hubble. Hence it is known as Hubble's Law.

According to Hubble's law the speed with which galaxy moves away from us is directly proportional to it's distance from earth.

If 'v' be the speed with which a galaxy moves away from us and 'r' be the distance of galaxy from earth. Then,

$$v \propto r$$
$$\Rightarrow v = H_0 r$$

Where, H_0 is Hubble's Constant. It's value is 2.3×10^{-18} s^{-1}.

Significance of Hubble's Constant:-

i) Age of Universe:-

↳ Suppose 'R' be the size of universe and 't' be the age of universe. If galaxy of the universe moves away from us with velocity 'v'. Then, By Hubble's law;

$$V = H_0 R$$
$$R = \frac{V}{H_0} \quad \text{---------(i)}$$

If universe is expanding to a size 'R' in time 't' then, $R = vt$ ---(ii)

From eqn (i) & (ii)

$$Vt = \frac{V}{H_0}$$
$$t = \frac{1}{H_0}$$
$$t = 14 \times 10^9 \text{ years}$$

Hence, reciprocal of Hubble's Constant estimate the age of universe.

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ii) Size of universe:-

↳ If the size of universe is R and speed of galaxy becomes speed of light. Then, by Hubble's Law,

$$v = H_0 R$$
$$c = H_0 R$$
$$R = \frac{c}{H_0}$$

$R = 6000$ Mega par secs (MpC)
$= 6000 \times 10^6$ pC
$= 6000 \times 10^6 \times 3.2$ Light year

[1 MpC = 10^6 pc
1 pc = 3.2 Light Year]

Critical density:-

↳ The density of universe which determine the expanding nature of universe is called critical density. It is denoted by ρ_c.

Let us consider, the universe as a spherical volume of radius 'R' and mass 'M'. If 'm' be the mass of radius galaxy and 'v' be it's escape velocity then from the universe then its gravitational p.E. should be equal to K.E.

$$\frac{GMm}{R} = \frac{1}{2}mv^2$$

i.e., $\Rightarrow 2GM = v^2R$ ---- (i)

According to Hubble's law;

$v = H_0 R$ ---- (i)

Also,

$M = \frac{4}{3}\pi r^3 \rho_c$ --- (iii)

Using eqn (ii) & (iii) in eqn (i)

$$2G \cdot \frac{4}{3}\pi R^3 \rho_c = H_0^2 \cdot R^3$$

$$\boxed{\rho_c = \frac{3H_0^2}{8\pi G}}$$

This gives value of critical density, i.e., 5.8×10^{-27} kg/m^3. #

Dark matter:-

↳ The average density of all the matter in the universe is about 27% of critical density but average density of visible matter is about 4% and most of matter of universe are invissible and doesn't emit any kind of radiation, the invissible matter in the universe which does not emit any kind of radiation is called **dark matter.**

The invisible form of energy which can be source of a repulsive force causing the expansion of the universe to accelerate is known as **dark energy.**

Black Hole:-

↳ If a spherical non-rotating body with mass M has a radius less than R_s, nothing, not even light can escape from the surface of the body, such body is called **blackhole.**

Gravitational wave:-

→ GTR ⟶ General Theory of Relativity of Albert Einstein.

Some properties of gravitational waves are:-

i) invisible.
ii) speed is equal to speed of light.
iii) obey the inverse square law.
iv) These could exist in any frequency, however, very low frequency waves would be impossible to detect.