Physics
MSH Sir

Modern Physics

Relativity

* Process of relative measurement

Relativity is the process of measurement of a body or object with respect to a reference frame.

Reference Frame

A reference frame is a space in which we are making observations and measuring physical quantities.

A body or object of point selected by 3D characteristics

There are two types of reference frame.

i. Inertial reference frame

ii. Non-inertial reference frame

Inertial Reference Frame: Inertial reference frames are reference frame in which Newton's first law of motion holds that is an object at rest and an object in motion remains in motion unless acted by a net force. An inertial reference frame is either at rest or moves with a constant velocity.

Non-inertial reference frame: A non-inertial reference reference frame is a reference frame that is accelerating, either in linear fashion or rotating around some axis.

* Variable velocity

Some examples of Reference frames:

1. A train moving with constant velocity (Inertial)
2. A rotating merry-go-round (Non-inertial)
3. A turning car with constant speed (Non inertial)
4. The rotating earth (Non inertial)

Theories of Relativity :

1. Special theory of relativity

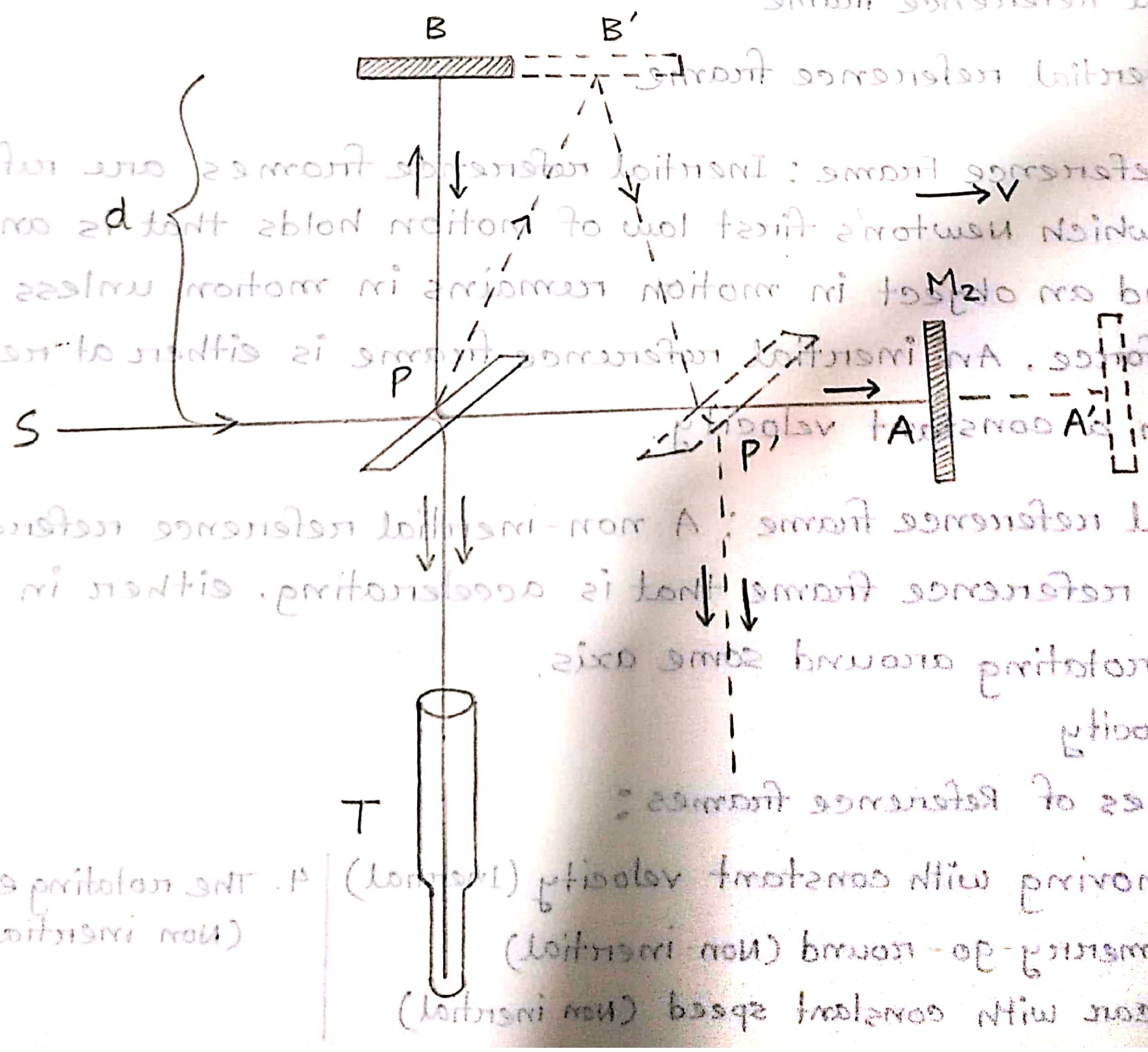
2. General theory of relativity

Postulates of Special Theory of relativity :

a) The laws of physics may be expressed in equations having the same form in all inertial frames of reference i.e. frames of reference moving at constant velocity with respect to one another.

b) The velocity of light in free space (vacuum) is a constant (same for all obsercvercs), independent not only of the direction of propagation but also of the relative velocity of the source and the observer.

Michelson - Morley Experiment :



Light from an extended source (monochromatic) S falls on a glass plate P. P is half silvered and this surface reflects half of the light towards M_1 while the other half is transmitted and goes towards M_2. The reflected portion falls normally at B on M_1. The transmitted portion falls at A on M_2. Both M_1 & M_2 are full-silvered front surface mirrors that reflect their beams back towards P. The beam from M_1 is partly reflected at P and the remainder goes on through to the telescope T. A portion of the beam from M_2 is reflected at the telescope T and the rest goes through the glass plate P to the telescope T and the

and is lost.

Let, d_1 be the distance from M_2 to P and d_2 be the distance of M_1 from P.

Here, $d_1 = d_2 = d$

$$v^2 + d^2 = c^2$$

$$\Rightarrow c^2 - v^2 = d^2$$

$$\therefore d = \sqrt{c^2 - v^2}$$

Now,

$$t_1 = \frac{d}{c+v} + \frac{d}{c-v}$$

$$= d\left(\frac{c-v+c+v}{c^2-v^2}\right)$$

$$= d \cdot \frac{2c}{c^2-v^2}$$

$$= \frac{2dc}{c^2-v^2}$$

$$= \frac{2dc}{c^2\left(1-\frac{v^2}{c^2}\right)}$$

$$\therefore t_1 = \frac{2d}{c}\left(1-\frac{v^2}{c^2}\right)^{-1} \quad \text{......(i)}$$

$$t_2 = \frac{2d}{\sqrt{c^2-v^2}}$$

$$= \frac{2d}{c\sqrt{1-\frac{v^2}{c^2}}}$$

$$\therefore t_2 = \frac{2d}{c}\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} \quad \text{......(ii)}$$

Time difference, $\Delta t = t_1 \sim t_2$

$$= \frac{2d}{c}\left[\left(1-\frac{v^2}{c^2}\right)^{-1} - \left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}\right]$$

$$= \frac{2d}{c}\left[\left\{1+1.1!\left(\frac{v^2}{c^2}\right)+\cdots\cdots\right\} - \left\{1+\frac{1}{2}\cdot 1!\left(\frac{v^2}{c^2}\right)+\cdots\cdots\right\}\right]$$

$$= \frac{2d}{c}\cdot\frac{1}{2}\cdot\frac{v^2}{c^2}$$

$$\therefore \Delta t = \frac{dv^2}{c^3} \quad \cdots\cdots (iii)$$

Fringe shift, $\Delta N = \frac{2\Delta t}{T} = \frac{2\Delta t\cdot c}{\lambda} = 2\cdot\frac{dv^2}{c^3}\cdot\frac{c}{\lambda}$

$$= \frac{2d}{\lambda}\left(\frac{v^2}{c^2}\right)$$

Summary of Michelson-morley experiment:

1) Time difference, $\Delta t = \frac{2dv^2}{c^3}$

2) Fringe shift, $\Delta N = \frac{2d}{\lambda}\left(\frac{v^2}{c^2}\right)$

Galilean - Newtonian transformation :

These frames (S and S') are referred to as inertial frames in which the law of inertia - Newton's first law, as well as second law of motion hold good.

An event may be imagined to be a collision of two particles or the turning-on of a tiny light source.

Let us s ppose that we are in a frame of reference S. We specify an event by four measurements in a particular frame of reference, say the position numbers x, y, z and the time t.

An observer at another frame of reference S' which is moving with a constant velocity v relative to S will find that the same event occurs at the time t' and has the co-ordinates x', y' and z'.

Let us say that time in both systems is measured from the instant when the origins of S and S' coincided.

Then measurements in x direction made in S will exceed those made in S' by an amount vt, which represents the distance that S' has moved in the x direction.

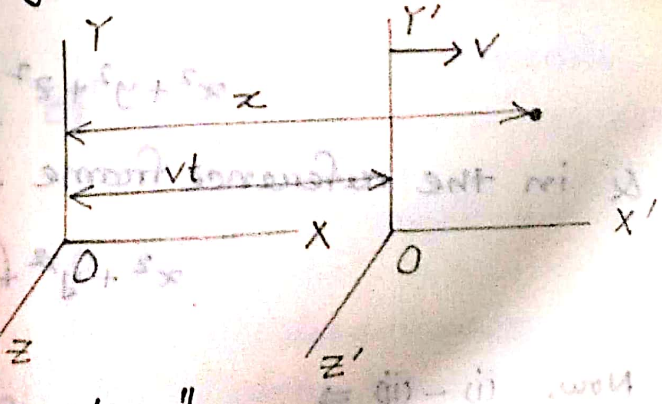
Thus, $x' = x - vt$

Since their is no relative motion in the y and z direction,

$$y' = y$$

and $z' = z$

and $t' = t$



The set of equation is known as

" Galilean or Newtonian Transformation "

Lorentz Transformation

The relation $x' = x - vt$ no longer holds good if the constancy of the value of c be assumed.

So now, Let the relationship between x and x',

$$x' = K(x - vt) \quad \dots \dots (i)$$

where K is a factor of proportionality that does not depend upon either x or t but may be a function of v.

The equations of physics must have the same form in both S and S', we need only change the sign of v (in order to take into account the difference in direction of relative motion) to write the corresponding equation for x in terms of x' and t'.

$$x = K(x' + vt') \quad \dots \dots (ii)$$

We can write,

$$y' = y \quad \dots \dots (iii)$$

$$z' = z \quad \dots \dots (iv)$$

Equation of the wavefront at O in the reference frame S,

$$x^2 + y^2 + z^2 = c^2 t^2 \quad \dots \dots (v)$$

& in the reference frame S',

$$x'^2 + y'^2 + z'^2 = c^2 t'^2 \quad \dots \dots (vi)$$

Now, (ii) $\Rightarrow$

$$x = K\left[K(x - vt) + vt'\right]$$

$$\Rightarrow x = K^2(x - vt) + Kvt'$$

$$\Rightarrow x - K^2 x + K^2 vt = Kvt'$$

$$\Rightarrow x(1 - K^2) + K^2 vt = Kvt'$$

$$\Rightarrow t' = \frac{x(1-K^2) + K^2 vt}{Kv} = \frac{x}{Kv}(1-K^2) + Kt$$

$$\Rightarrow t' = K\left[\frac{x}{v} \cdot \frac{1-K^2}{K^2} + t\right] \quad \ldots \ldots \text{(vii)}$$

Substituting equations (i) and (ii) into eqn (vi), we get

$$K^2(x-vt)^2 + y^2 + z^2 = c^2K^2\left[\frac{x}{v}\left(\frac{1}{K^2}-1\right)+t\right]^2$$

Expanding and collecting terms we have,

$$\left[K^2 - \frac{c^2K^2}{v^2}\left(\frac{1}{K^2}-1\right)\right]^2 x^2 - \left[2vK^2 + \frac{2c^2K^2}{v^2}\left(\frac{1}{K^2}-1\right)\right]xt +$$

$$y^2 + z^2 = \left[c^2K^2 - v^2K^2\right]t^2 \quad \ldots \ldots \text{(viii)}$$

Equation (viii) must be identical to equation (v). For this to be the case, the quantities in brackets in equation (viii) must be equal to 1, 0 and c^2 respectively. It can easily be seen that all three requirements are fulfilled if

$$K = \frac{1}{\sqrt{1 - v^2/c^2}}$$

For example, Let us take the case of

$$2vK^2 + \frac{2c^2K^2}{v}\left(\frac{1}{K^2}-1\right) = 0$$

$$\Rightarrow \frac{2cK^2}{v}\left(\frac{1}{K^2}-1\right) = -2vK^2$$

$$\Rightarrow \frac{1}{K^2} - 1 = -\frac{v^2}{c^2}$$

$$\therefore K = \frac{1}{\sqrt{1 - v^2/c^2}}$$

From equation (vii),

$$t' = \frac{1}{\sqrt{1-v^2/c^2}}\left[\frac{x}{v}\cdot\frac{1-}{\quad\quad} + t\right]$$

$$= \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left[\frac{x}{v}\cdot\frac{\quad}{\quad\quad} + t\right]$$

$$= \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left[\frac{\quad}{\quad\quad} + t\right]$$

$$= \frac{1}{\quad\quad}\left[\quad + \quad\right]$$

Insertion of the above values,

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$$

direction $= +x$
velocity $= +v$

$$y' = y$$

$$z' = z$$

$$t' = \frac{t - \frac{v}{c^2} \cdot x}{\sqrt{1 - \frac{v^2}{c^2}}}$$

These transformation are refered to as "Lorentz Transformation."

$$x = \frac{x' + vt'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$y = y'$$

$$z = z'$$

$$t = \frac{t' + \frac{v}{c^2} \cdot x'}{\sqrt{1 - v^2/c^2}}$$

These transformation are refered to as "Inverse Lorents Transformation"

Space/Length Contraction:

An observer in the moving reference fram S' determines the co-ordinates of the ends of the rod lying along the x' axis to be x_1' and x_2' while the observer in S frame determines x_1 & x_2.

$\therefore$ The length of the rod, $L = x_2' - x_1'$

The length of the rod measured by an observer in S, $= x_2 - x_1$

We know,

$$x = \frac{x' + vt'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$L_0 = x_2 - x_1$$

$$= \frac{x_2' + vt'}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{x_1' + vt'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{x_2' + vt' - x_1' - vt'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{x_2' - x_1'}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{L}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\therefore L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

Definition of space/Length contraction: Length contraction is the phenomenon of a decrease in length of an object as measured by an observer who is travelling at any non-zero velocity relative to the object.

Time Dilation: Let the frame of reference s' be moving with a velocity v relative to the stationary frame of reference s along the positive x-direction. Let us further suppose that their origin O and O' just coincide.

Imagine a gun fires two shots at times t_1' and t_2' as noted on the clock carried by the frame S'. Let t_1 & t_2 be the corresponding times as noted on the clock carried by the frame S. Then the time interval between the two events in the moving frame S' is given by,

$$\Delta t' = t_2' - t_1' = t_0$$

& time interval in the stationary frame S is given by,

$$\Delta t = t_2 - t_1 = t$$

According to Lorentz transformation equations,

$$t_1 = \frac{t_1' + \frac{v}{c^2}x'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

and $$t_2 = \frac{t_2' + \frac{v}{c^2}x'}{\sqrt{1 - v^2/c^2}}$$

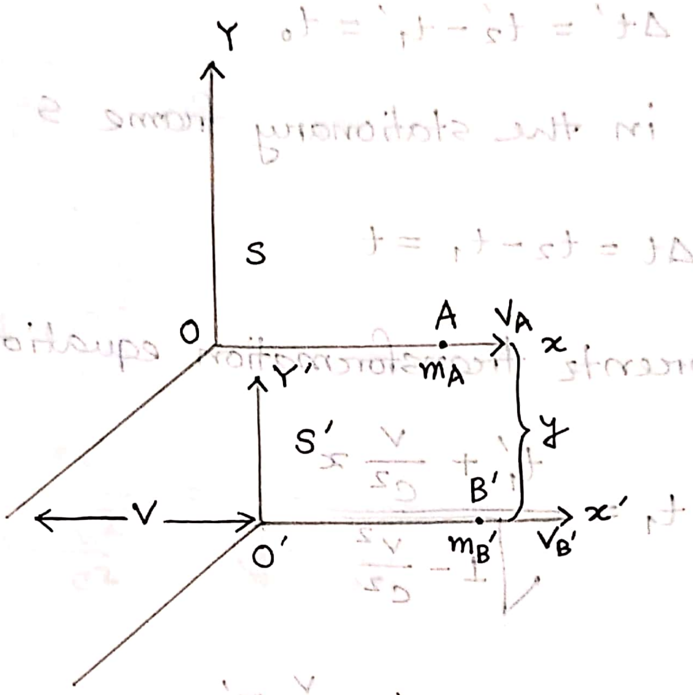
$$\Delta t = \frac{t_2' + \frac{v}{c^2}x'}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{t_1' + \frac{v}{c^2}x'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{t_2' - t_1'}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\therefore \quad t = \frac{t'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Definition of Time dilation : Time dilation, in the theory of special relativity, is the slowing down of a clock as determined by an observer who is in relative motion with respect to that clock.

Relativity of mass :



$m_A = m_B'$

$V_A = V_B'$

For S structure, $T_0 = \dfrac{y}{V_A}$ ...... (i)

For S' structure, $T = \dfrac{y}{V_{B'}}$ ...... (ii)

Again,

$m_A V_A = m_{B'} V_{B'}$ ...... (iii)

$\Rightarrow m_A \cdot \dfrac{y}{T_0} = m_{B'} \cdot \dfrac{y}{T}$

$\Rightarrow m_A \cdot \dfrac{y}{T_0} = m_{B'} \cdot \dfrac{y}{T_0} \cdot \sqrt{1 - \dfrac{v^2}{c^2}}$; As $T = \dfrac{T_0}{\sqrt{1 - v^2/c^2}}$

$\Rightarrow m_A = m_{B'} \sqrt{1 - v^2/c^2}$

$\Rightarrow m_B' = \dfrac{m_A}{\sqrt{1 - v^2/c^2}}$

$m_A = m_o$ (rest mass)

$m_{B'} = m$ (effective mass)

$$\therefore \quad m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$$

$$T = \int F\,dS$$

$$= \int \frac{d}{dt}(mv)\,dS$$

$$= \int^{mv} \frac{d}{dt}(mv) \cdot v\,dt$$

$$= \int^{mv} v\,d(mv)$$

$$= \int^{mv} v\,(m\,dv + v\,dm)$$

$$= \int^{mv} (mv\,dv + v^2 dm) \quad \ldots \ldots (1)$$

$\frac{dS}{dt} = v$

$\therefore dS = v\,dt$

We know,

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\Rightarrow 1 - \frac{v^2}{c^2} = \frac{m_o^2}{m^2}$$

$$\Rightarrow m_o c^2 = m^2c^2 - m^2v^2$$

$$\Rightarrow m^2c^2 - m^2v^2 = m_o c^2$$

$$\Rightarrow 2m\,dm\,c^2 - 2m\,dm\,v^2 + m^2 \cdot 2v\,dv = 0$$

$$\Rightarrow dm\,c^2 - dm\,v^2 + mv\,dv = 0$$

$$\therefore c^2 dm = v^2 dm + mv\,dv \quad \ldots \ldots (2)$$

By putting the value in equation (1),

$$T = \int_{m_0}^{m} c^2 dm$$

$$= \left[mc^2\right]_{m_0}^{m}$$

$$= mc^2 - m_0c^2$$

$\therefore$ Total energy $= T + m_0c^2 = mc^2$

$$\therefore E = mc^2$$

Nuclear Physics

From alpha-decay studies, it was known that a nucleus is built up of elementary particles. Nucleus is built up of neutrons and protons.

Protons has a positive charge of the same magnitude as that of an electron but its mass is about 1837 times more than that of an electron. A neutron has almost the same mass as that of the proton but is electrically neutral. The proton and the neutron are considered to be two different charge states of the same particle which is called a nucleon.

A **nuclide** is an atomic species characterized by the specific constitution of its nucleus, i.e., by its number of protons Z, its number of neutrons N and its nuclear energy state.

A nuclide is representend by $_Z X^A$ $_Z^A X$ X_Z^A

A = mass number
Z = Number of proton = Atomic number

Number of neutron, $N = A - Z$

$$^{23}_{11}Na \quad (A \leftarrow 23,\ Z \leftarrow 11)$$

$\therefore N = A - Z = 12$

Nuclei : Nuclei is the plural form of nucleus. A nucleus is the positively charged center of the atom consisting of protons and neutrons.

Isotopes : Nuclei with the same atomic number Z but different mass numbers A are called isotopes. Since the characteristics properties of an atom is ultimately determined by its nuclear charge, the isotopes of an element have identical chemical behaviour and differ physically only in mass.

$_{28}Ni^{58}$, $_{28}Ni^{60}$, $_{28}Ni^{61}$, $_{28}Ni^{64}$ are all isotopes of Nickel.

Isobars : Nuclei having the same mass number A but different atomic number Z are called isobars. The nuclei $_{22}Ti^{50}$ and $_{20}Cr^{50}$ are isobars. The isobars are atoms of different elements and have different physical and chemical properties.

Isotones : Nuclei with the same number of neutrons N are called isotones. The nuclei $_{6}C^{14}$, $_{7}N^{15}$, $_{8}O^{16}$ are isotones.

Isomers : There are atoms, which have the same atomic number Z and same mass number A but differ from one another in their internal nuclear energy states and exhibit differences in their internal structure. One of these energy states may be an excited state with a relatively long life. Such an excited state is called an isomeric state. Thus two nuclei of the same species but capable of existing in different energy states, at least one of which is relatively stable are called isomers.

$$= \frac{A m_n}{\frac{4}{3}\pi R_0^3 A}$$

$$\therefore \rho_N = \frac{m_n}{\frac{4}{3}\pi R_0^3}$$

$m_n = 1.67 \times 10^{-27}$ Kg

$R_0 = 1.3 \times 10^{-15}$ m

$\therefore$ Nuclear density doesn't depend on atomic mass number (A).

Nuclear mass :

Nuclear mass or the mass of the nucleus should be

$$= Zm_p + Nm_N$$

m_p = mass of proton
m_N = mass of neutron

Mass defect : The mass of a nucleus containing Z protons and N neutrons is given by $Zm_p + Nm_N$.

But the real nuclear mass is less than $(Zm_p + Nm_N)$

$$\therefore (Zm_p + Nm_N) - \text{real nuclear mass} = \Delta m$$

$\therefore$ Mass defect ; $\Delta m = M - A$

M → Atomic mass

A → mass number

Binding Energy : If a nucleus is to be broken into its constituent particles, the minimum energy required is the binding energy.

Mirror nuclei : Nuclei having the same mass number, but with the proton and neutron interchanged, i.e., the number of protons in one is equal to the number of neutrons in the other, are called mirror nuclei.

$_4Be^7$ and $_3Li^7$ are mirror nuclei.

$$\begin{array}{cc} _4Be^7 & _3Li^7 \\ \Downarrow & \Downarrow \\ A = 7 & A = 7 \\ Z = 4 & Z = 3 \\ N = 3 & N = 4 \end{array}$$

Properties of nucleus :

1) Nuclear Radius : R

$$R^3 \propto A$$

$$\Rightarrow R \propto A^{1/3}$$

$$\therefore R = R_0 A^{1/3}$$

Here, A = mass number

$R_0 = 1.3 \times 10^{-15} m$

$= 1.3 F$

$= 1.3$ fermi

2) Nuclear Density : ρ_N

$$\rho_N = \frac{\text{Nuclear mass}}{\text{Nuclear volume}}$$

$$= \frac{A m_n}{\frac{4}{3}\pi R^3}$$

$$= \frac{A m_n}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$

A = mass number

m_n = mass of a nucleon

Nucleare Reaction :

The reaction in which it is possible to bring about a change in the structure of nuclei by bombordened them with fast moving particle and as a result the identity or characteristics or energy or both of the structed particle is known as the nuclear reaction.

$$\underset{\text{Fast particle}}{a} + \underset{\text{Target nucleus}}{X} \Longrightarrow X + a \quad \text{(elastic)}$$

$$\left.\begin{array}{l} \text{Or, } X^* + a \\ \text{Or, } Y + \text{Energy} \\ \text{Or, } Y + b \end{array}\right\} \text{(In-elastic)}$$

$$a + X \longrightarrow Y + b$$

This reaction can be expressed as <u>X (a, b) Y</u>

example:

$$_7N^{14} + \underset{\alpha}{_2He^4} \Longrightarrow {_8O^{17}} + \underset{\beta}{_1H^1}$$

This equation can be written as,

$$_7N^{14}\,(\underset{\alpha}{_2He^4}, \underset{\beta}{_1H^1})\,{_8O^{17}}$$

Elastic Reaction: In an elastic scattering reaction between a neutron and a target nucleus, there is no energy transffered into nuclear excitation.

Inelastic reaction : In an inelastic scattering reaction between a neutron and a target nucleus, some energy of the incident neutron is absorbed to the recoiling nucleus and the nucleus remains in the excited state.

i. Exothermic reaction ↑

ii. Endothermic reaction ↓

Q value of Nuclear Reaction :

* Kinetic energy difference between the incident particle and product particle
* Total energy release or absorbed of that nuclear reaction.

$$a + X \Rightarrow Y + b$$

$K.E. = \frac{1}{2}mv^2$

$P.E. = m_0c^2$

$$(E_a + m_a c^2) + (0 + m_x c^2) \Rightarrow (E_y + m_y c^2) + (E_b + m_b c^2)$$

or, $(E_y + E_b) - E_a = [(m_a + m_x) - (m_y + m_b)]c^2$

or, $(E_y + E_b) - E_a = \Delta m c^2$

$$\therefore Q = (E_y + E_b) - E_a = \Delta m c^2$$

$$Q = K.E._{\text{Products}} - K.E._{\text{Reactants}}$$

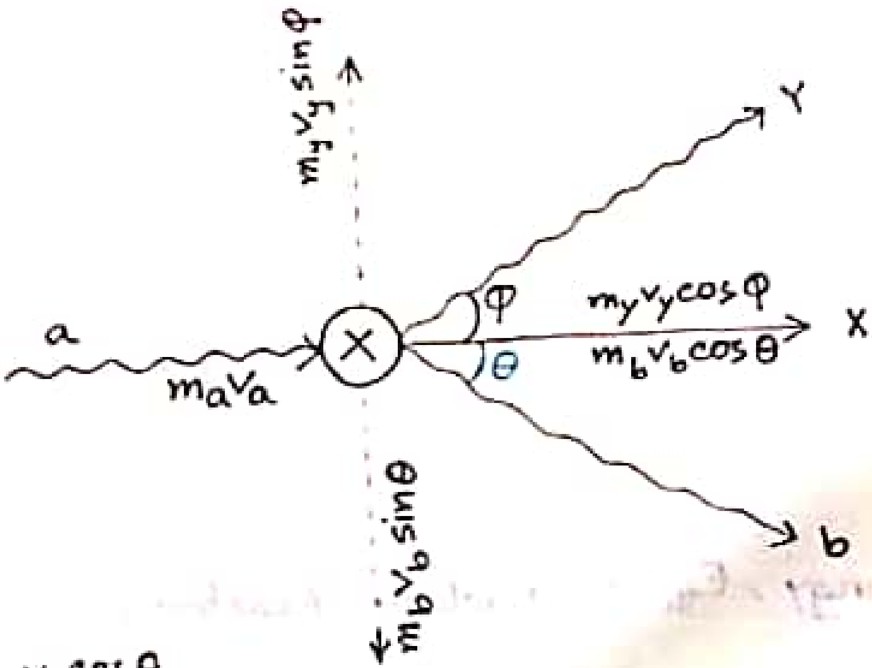
Significance of Q-value of Nuclear Reaction :

1/ If the Q value is positive $(Q>0)$, then the reaction will be termed as "Exothermic Reaction", i.e., the reaction is an inelastic nuclear reaction.

2/ If the Q value is negative $(Q<0)$, then the reaction will be termed as "Endothermic Reaction", i.e., the reaction ~~ta~~ is an ~~elas~~ inelastic nuclear reaction.

5) If the Q value is zero (Q=0), then the reaction will be termed as "Elastic Nuclear Reaction."

<u>Q value with the help of mass-velocity conservative law:</u>



In X-direction,

$$m_a v_a = m_y v_y \cos\varphi + m_b v_b \cos\theta \qquad \ldots\ldots(1)$$

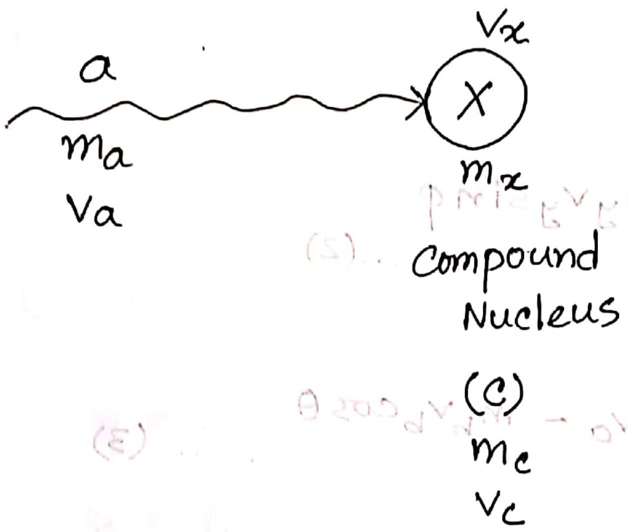
In Y-direction,

$$0 = m_b v_b \sin\theta - m_y v_y \sin\varphi \qquad \ldots\ldots(2)$$

From (1), $$m_y v_y \cos\varphi = m_a v_a - m_b v_b \cos\theta \qquad \ldots\ldots(3)$$

From (2), $$m_y v_y \sin\varphi = m_b v_b \sin\theta \qquad \ldots\ldots(4)$$

Threshold Energy, E_{Th} of Nuclear Reaction :



$$m_c = m_a + m_x$$

We know,

$$m_a v_a = m_c v_c$$

$$\Rightarrow v_c = \frac{m_a v_a}{m_c}$$

$$\Rightarrow v_c = \left(\frac{m_a}{m_a + m_x}\right) v_a$$

$$-Q = E_a - E_c$$

$$= \frac{1}{2} m_a v_a^2 - \frac{1}{2} m_c v_c^2$$

$$= \frac{1}{2} m_a v_a^2 - \frac{1}{2} (m_a + m_x) \left(\frac{m_a}{m_a + m_x}\right)^2 v_a^2$$

$$= \frac{1}{2} m_a v_a^2 - \frac{1}{2} \cdot \frac{m_a^2 v_a^2}{m_a + m_x}$$

$$= \frac{1}{2} m_a v_a^2 \left[1 - \frac{m_a}{m_a + m_x}\right]$$

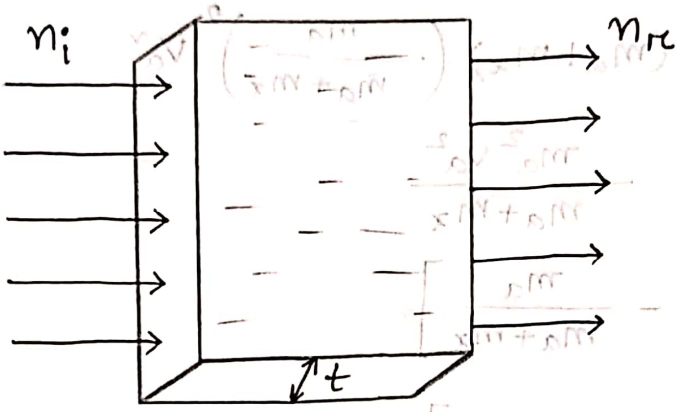
$$= \underbrace{\frac{1}{2} m_a v_a^2}_{E_{TH}} \left[\frac{m_x}{m_a + m_x}\right]$$

$$= E_{TH} \left[\frac{m_x}{m_a + m_x}\right]$$

$$\therefore E_{TH} = -Q \left[\frac{m_a + m_x}{m_x}\right] = -Q \left[1 + \frac{m_a}{m_x}\right]$$

Cross Section of Nuclear Reaction, σ

The nuclear cross section is the characteristic area of nucleus where interactions take place.
Larger the area $\rightarrow$ greater interactions
It is the probability that Nuclear reaction will take place.
It is the exposing area of the reactant



$$\frac{n_r}{n_i} = \frac{\sigma N A t}{A} = \sigma N t$$

$$\therefore \sigma = \frac{1}{Nt} = \frac{n_r}{n_i}$$

Nuclear Fission and Fusion

The process of breaking up of the nucleus of a heavy atom into two, more or less equal nuclei with the release of an enormous amount of energy is known as $\boxed{\text{fission}}$. The new nuclei that result from fission are called fission fragments.

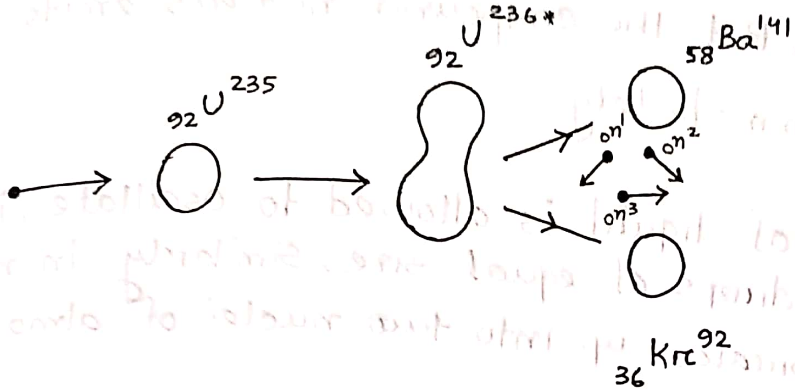
A nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy is known as nuclear $\boxed{\text{fusion}}$.

Example of typical Fission reaction:

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236*} \longrightarrow X + Y + \text{neutrons}$$

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{92}U^{236*} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q\,(\text{energy})$$

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{92}U^{236*} \rightarrow {}_{54}Xe^{140} + {}_{38}Sr^{94} + 2\,{}_{0}n^{1} + Q\,(\text{energy})$$



Example of nuclear fusion :

$${}_{2}He^{3} + {}_{1}H^{1} \longrightarrow {}_{2}He^{4} + {}_{1}e^{0}$$

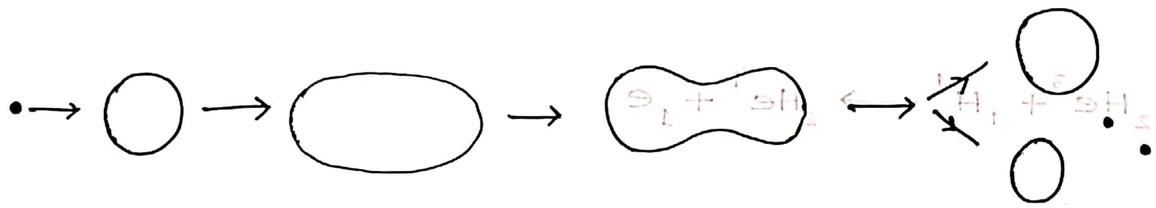
Liquid drop model :

Neils Bohr observed that there are certain marked similarities between an atomic nucleus and a liquid drops.

1. In the stable state, a nucleus is supposed to be spherical just as a liquid drop is spherical due to the symmetrical surface tension.
2. Just as the force of surface tension acts on the surface of the liquid drop, there is a potential barrier at the surface of the nucleus.
3. The density of a liquid drop is independent of its volume. Similarly the density of the nucleus is independent of its volume.
4. The molecules in a liquid drop interact only with their immediate neighbours. Similarly, the nucleons in the nucleus also interact only with their immediate neighbours. ~~These~~ This leads to the saturation of nuclear forces and a constant binding energy per nucleon.

5. When the temperature of the liquid is raised, the molecules from a liquid-drop evaporate due to their increased energy of thermal agitation. Similarly, when a nucleus is bombarded with nuclear projectiles, it gains energy and a compound nucleus is formed. But the compound nucleus emits nuclear radiations almost immediately.

6. When a small drop of liquid is allowed to oscillate, it breaks up into two smaller drops of equal size. Similarly, in nuclear fission the nucleus breaks up into two nuclei of almost equal mass numbers.



Chain Reaction :

Nuclear chain reactions are series of nuclear fissions (splitting of atomic nuclei), each initiated by a neutron produced in a preceding fission.

1. Uncontrolled chain reaction
2. Controlled chain reaction