GOVT. POLYTECHNIC KANDHAMAL , PHULBANI

(State Council for technical education and vocational training, Odisha)

Th-2A Engg. Physics

Lecture Notes

(For 1st & 2nd Semester Diploma students)

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INDEX

NAME: STD.: SEC.: ROLL NO.: SUB.:

UNITS & DIMENSIONS

MEASUREMENT

A measurement is said to be Completely, only, if we have the following two informations.

(i) Name of the unit (x)

(ii) How many times the unit is contained in that measurement.

This part of the measurement is also known as it's "numerical Value".

UNIT

In order to make the measurement of a physical quantity we have, first of all to evolve a standard for that measurement so that different measurement of Some physical quantity can be expressed relative to each other. that standard is called a unit of that physical quantity.

CHARACTERISTICS OF A UNIT

A unit must be possess following characteristics.

(i) It should be acceptable to all.

(ii) It should be invariable. The value of the unit should remain the same under all circumstances i.e no external factor should be able to affect its magnitude.

(iii) It should be easily transportable or reproduceable.

(iv) It should be easily available for Comparison with Various measurement.

(v) It should be non-perishable.

(vi) It should be Convenient in size.

PHYSICAL QUANTITY

A qualitative description of any physical phenomena always involve certain measurable quantities in terms of which the laws of physics are invariably expressed such quantities like force, velocity, time, density, charge, temperature etc. others are called observable or physical quantity.

physical quantities can be classified into following two categories.

(i) Fundamental quantities
(ii) Derived quantities.

(i) FUNDAMENTAL QUANTITY

physical quantities are a set of suitably chosen independent observables which are defind operationally.

For convinies it was agreed to choose a set of length, mass, time temprature, electric current, luminous intensity + amount of substance to constitute a set known as fundamental quantities.

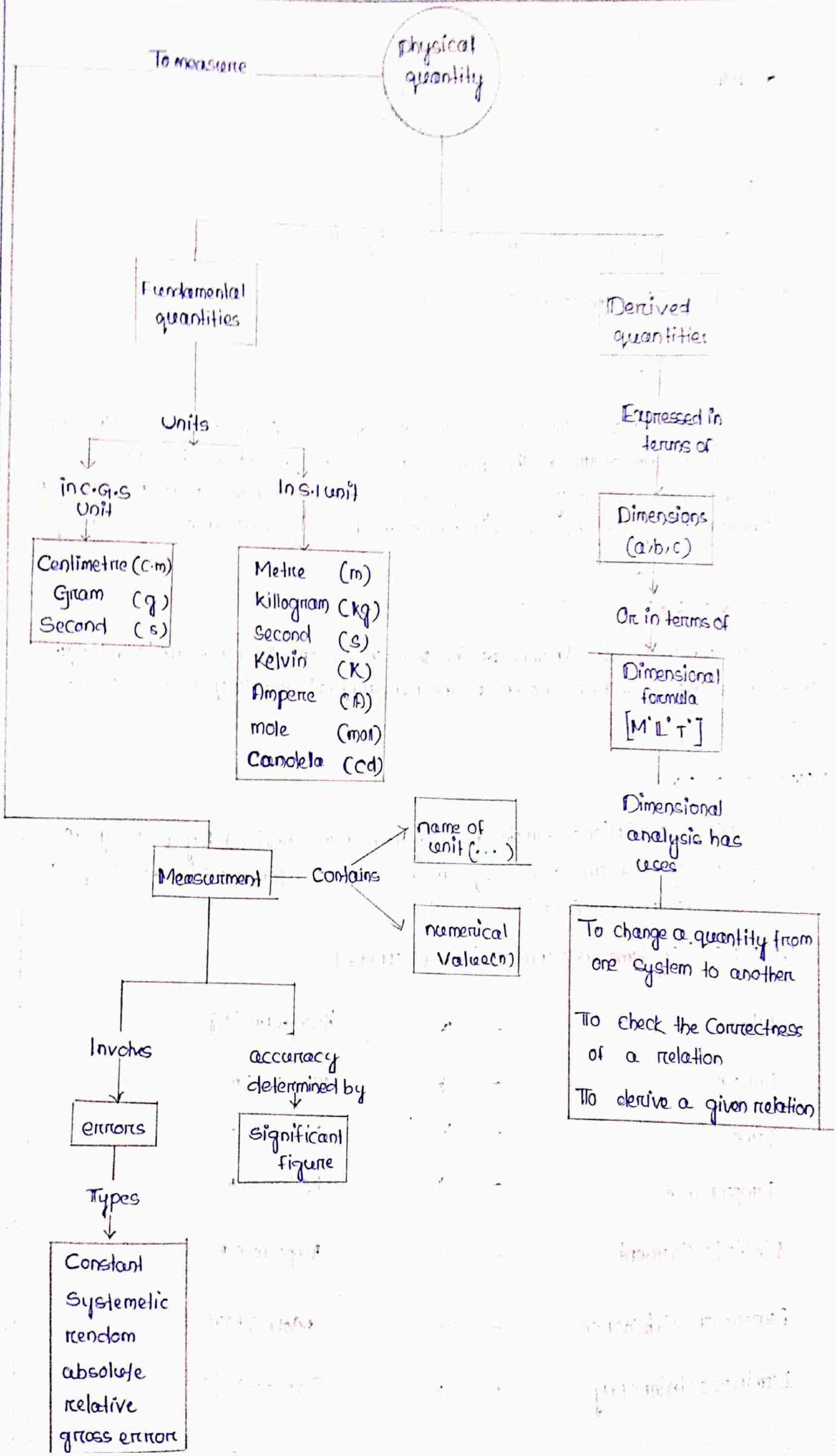
(ii) DERIVED QUANTITY

Quantities which are defind in terms of fundamental quantities are known as derived quantities.

EX:- Velocity, Accelenation, Force, Momentum etc.

CGPM :- Conference Generale despoids et measures.
(French name)

General Conference on weights + measures.



physical quantity
To measure
Fundamental quantities
Units
in C.G.S Unit
Centimetre (c.m)
Gram (g)
Second (s)
In S.I unit
Metre (m)
killogram (kg)
second (s)
Kelvin (K)
Ampere (A)
mole (mol)
Candela (cd)
Derived quantities
Expressed in terms of
Dimensions (a,b,c)
Or in terms of
Dimensional formula [M'L'T']
Dimensional analysis has uses
To change a quantity from one system to another
To check the Correctness of a relation
To derive a given relation
Measurement
Contains
name of unit (...)
numerical Value(n)
Involves
errors
Types
Constant
Systemetic
random
absolute
relative
gross error
accuracy determined by
significant figure

SYSTEM OF UNITS

Following system of measurement are commonly in use :-

(a) C.G.S (Centimetre - Gram - Second) system

(b) F.P.S (Foot - pound - Second) system

(c) M.K.S (Metre - Kilogram - Second) system

(d) S.I (International system of unit)

(a) C.G.S SYSTEM

The C.G.S system (also called french system) of units is based on Centimetre as the unit of length the gram as the unit of mass & the second as the unit time. This system of units, Formerly widely used in science. is also known as Gaussian system. However, many of the derived units in this systems are inconviently small.

(b) F.P.S SYSTEM

In this system which is also known as the British system. the basic units of length, force (Instead of mass) & time chosen as the fundamental quantity are foot, pound & second respectively.

(C) MKS SYSTEM

In order to make calculations, simple this system was devised by a Giorgi in 1901. This system grew from C.G.S system & is based upon a metre, a kilogram & a second as its fundamentations units.

(d) SI UNITS (Systeme internationale 'd' units)

Mass	$\longrightarrow$	Kilogram (kg)
Length	$\longrightarrow$	metre (m)
Time	$\longrightarrow$	Second (s)
Temprature	$\longrightarrow$	Kelvin (K)
Electric Current	$\longrightarrow$	Ampere (A)
Amount of Substance	$\longrightarrow$	Mole (Mol)
Luminous Intensity	$\longrightarrow$	Candela (cd)

DIMENSIONLESS UNITS (suplimentary units)

Two more fundamental units for the measurments, of angle & solid angle had to be defind. These units are called " dimensionless units."

1. plane angle (radian, rd)

Radian is the angle subtended, at the Centre of a circle by an arc whose length is equal to the radious of the Circle.

2. Solid angle (steradian, sr)

Steradian in the solid angle subtended, at the Centre of a sphere, by a surface area of the sphere whose magnitude is equal to the square of the radious of the sphere.

PREFIXES FOR POWER OF TEN

Deca	10^{1}	Deci	10^{-1}
Hecto	10^{2}	Centi	10^{-2}
Killo	10^{3}	Milli	10^{-3}
Mega	10^{6}	Micro	10^{-6}
Giga	10^{9}	Nano	10^{-9}
Tera	10^{12}	Pico	10^{-12}
peta	10^{15}	Femto	10^{-15}
Exa	10^{18}	Atto	10^{-18}

1 Fermi $= 10^{-15}$

$1 Å = 10^{-10}$ m (Angstorm)

1 Light year $= 3\times10^{8}\,m/s \times 86400 \times 365 \times 25$

$= 9.46 \times 10^{15}\,m$

1 day $= 24\,hrs = 24 \times 3600 - 86400$ Sec

1 astronomical units $= 5 \times 3\times10^{8} = 15 \times 10^{10}\,m$

DIMENSIONS

A dimension deal with the qualitative part of measurment.

Dimension of a physical quantity

Dimension of a physical quantity are the powers to which the fundamental units be raised in order to represent that quantity.

Dimensional formula of a physical quantity is the formula which tells us how & which of the fundamental units have been used for the measurment of that quantity.

physical quantity	Formula	Dimensional Formula	SI unit
Area	Length x breadth	$[M^0 L^2 T^0]$	m^2
Volume	Length x breadth x height	$[M^0 L^3 T^0]$	m^3
Density	$\frac{\text{Mass}}{\text{Volume}}$	$[M^1 L^{-3} T^0]$	$kg\ m^{-3}$
Speed/Velocity	$\frac{\text{Distance}}{\text{Time}}$	$[M^0 L^1 T^{-1}]$	ms^{-1}
Acceleration	$\frac{\text{Velocity}}{\text{Time}}$	$[M^0 L^1 T^{-2}]$	m/s^2
Momentum	Mass x Velocity	$[M^1 L^1 T^{-1}]$	$kg\ m/s$
Force	Mass x Acceleration	$[M^1 L^1 T^{-2}]$	$kg\ m/s^2 = N$
Work	Force x displacement	$[M^1 L^2 T^{-2}]$	$kg\ m^2/s^2 = J$
Impulse	Force x Time	$[M^1 L^1 T^{-1}]$	$kg\ m/s = Ns$
Energy	$mgh / \frac{1}{2}mv^2$	$[M^1 L^2 T^{-2}]$	$kg\ m^2/s^2 = J$
Power	$\frac{\text{Work}}{\text{Time}}$	$[M^1 L^2 T^{-3}]$	$m^2/s^2\ kg = W$
Pressure	$\frac{\text{Force}}{\text{Area}}$	$[M^1 L^{-1} T^{-2}]$	$kg/m^{-2}/s^2$ $N/m^2 = (pa)$

Physical quantity	Formula	Dimensional Formula	SI unit
Temprature		$[M^0L^0T^0K]$	K
Entropy	$\frac{\text{heat energy}}{\text{absolute temp}}$	$[M^1L^2T^{-2}K^{-1}]$	$kg\,m^2/s^2/K = J/K$
Intensity of illumination	$\frac{\text{luminous intensity}}{\text{distance}^2}$	$[M^0L^{-2}T^0cd]$	m^{-2} cd
Current		$[M^0L^0T^0A^1]$	A
Charge	Current x Time	$[M^0L^0T^1A^1]$	As = C (Coulumb)
Electric field intensity	$\frac{\text{Force}}{\text{Charge}}$	$[M^1L^1T^{-3}A^{-1}]$	$kg\,m/s^3/A = N/C$
Electric potential	$\frac{\text{Work done}}{\text{charge}}$	$[M^1L^2T^{-3}A^{-1}]$	$kg\,m^2/s^3/A = V$
Registance	$\frac{\text{potential different}}{\text{Current}}$	$[M^1L^2T^{-3}A^{-2}]$	$kg\,m^2/s^2/A^2 = \Omega$
Capacitance	$\frac{\text{charge}}{\text{potential}}$	$[M^{-1}L^{-2}T^4A^2]$	$kg^{-1}/m/s^4A^2 = F$
Surface tension	$\frac{\text{Force}}{\text{Length}}$	$[M^1L^0T^{-2}]$	$kg\,s^{-2} = Nm^{-1}$
Angular momentum	moment of Inertia x angular	$[M^1L^2T^{-1}]$	$kg\,m^2/s$
Gravitational Constant (G)	$F = \frac{Gm_1m_2}{r^2}$ $G = \frac{Fr^2}{m_1m_2}$	$[M^{-1}L^3T^{-2}]$	$kg^{-1}m^3/s$ $= N\,m^2\,kg^{-2}$
Torque	Force x distance	$[M^1L^2T^{-2}]$	$kg\,m^2/s^2$ $= Nm$

PRINCIPLE OF HOMOGENEITY

An equation written in the following manner is called Dimensional Equation

$$Area = [M^0 L^2 T^0]$$

It states that " the dimensional formula of every term on the two side of a Current relation must be Same.

$$\text{if } A = B + C$$

$$[A] = [B] = [C]$$

only homogeneity

Only homogenious physical quantity can be added or Subtracted.

(i) Testing the Correctness of a given relation.

To check the Correctness of a given relation we find the dimensional formula of every term on either side of the dimensional are Identical, the relation is Said to be Correct.

$$S = ut + \frac{1}{2}at^2$$

L.h.s

$$S = [L] = [M^0 L^1 T^0]$$

R.h.s

(i) $ut = [LT^{-1}] \times [T] = [L] = [M^0 L^1 T^0]$

(ii) $at^2 = [LT^{-2}] \times [T]^2 = [L] = [M^0 L^1 T^0]$

Since According to principle of homogeneity the above relation is Correct.

(ii) Derive a relation between Various physical quantity.

Relation of one physical quantity with others can be derived provided the factors on which the quantity depends are known to us.

The Centripetal force acting on a body may depend on

(i) Mass

(ii) Velocity of a body

(iii) Radious of the circular path

Then derive Centripetal force.

$$F \propto m^a$$

$$F \propto r^b$$

$$F \propto v^c$$

$F \propto m^a r^b v^c$

Combinely $F \propto m^a r^b v^c$

$\Rightarrow F = K m^a r^b v^c$

where k is the dimensionless propertionality Constant writing the dimensional formula of physical quantities on both side of equation we get.

$$[MLT^{-2}] = M^a L^b [LT^{-1}]^c$$

$$\Rightarrow [MLT^{-2}] = M^a L^b L^c T^{-c} = M^a L^{b+c} T^{-c}$$

equating the respective powers of mass, length, time we get

$a = 1$, $b + c = 1$

$-c = -2$

$c = 2$

$b + c = 1$

$c = 1 - 2 = -1$ $F = m^1 r^{-1} v^2 = \frac{Kmv^2}{r}$

which is the required expression.

SCALAR & VECTORS

SCALAR QUANTITY

Scalar quantity is that quantity which requires only the magnitude for their Complete Specification.

Ex :- Mass, length, Vollume, density, Temprature, charge (electric) etc.

VECTOR QUANTITY

Vector quantity is the quantity which requires magnitude as well as direction for their Complete Specification.

Ex :- Displacement, Velocity, accelaration, Force etc.

Vector quantity Can't, in general, be added gradually.

SCALAR	VECTOR
Scalars have only magnitude.	Vectors have both magnitude + direction.
They change if their magnitudes changes	They changes if either their magnitude, direction or both change.
They can be added according to ordinary Algebra	They can be added using vectors law of addition.

REPRESENTATION OF A VECTOR

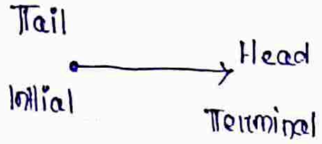
A Vector Can be represented by observing the following steps.

(i) Draw a line parallel to the direction of Vector.

(ii) Cut a length of the line so that it represents the magnitude of the vector on a Certain Convenient Scale.

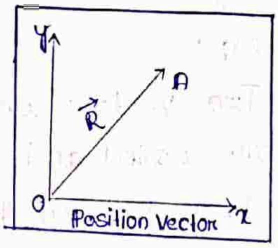
(iii) put an arrowhead, represents the given Vector.

A Vector is written with an arrowhead over its symbol like '$\vec{x}$'.



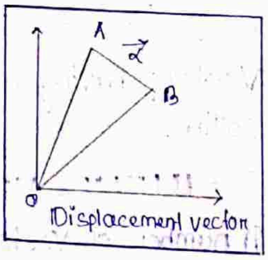
TYPES OF VECTOR

POSITION VECTOR



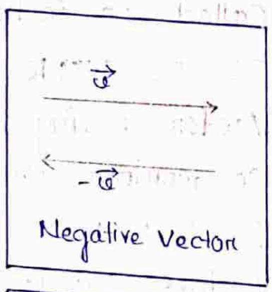
A Vector which gives position of an object with respect to the origin of a co-ordinate system is Called position Vector.

DISPLACEMENT VECTOR



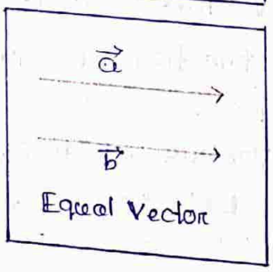
Displacement vector may be defined as the shortest distance from the initial to the final position and directed from the initial point to the final point.

NEGATIVE VECTOR



Two Vectors are said to be a negative vector of another one, if it is represented by a line having Same length as that of the Second & is directed in opposite direction.

EQUAL VECTOR



Two Vectors are Said to be equal if they passes the Same magnitude & direction.

MODULUS VECTOR

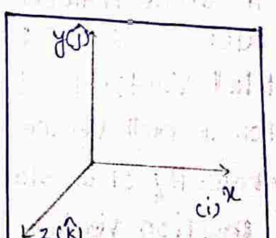
$|\vec{a}| = a$

The modulus of a Vector is the length or magnitude of that Vector.

mod $\vec{a} = |\vec{a}| = a$

UNIT VECTOR

$\vec{a} = a \times 1 \times \hat{a} \Rightarrow \hat{a} = \frac{\vec{a}}{a}$



A unit Vector is a Vector of unit magnitude drawn in the direction of the given Vector.

The unit Vector along x axis = $\hat{i}$

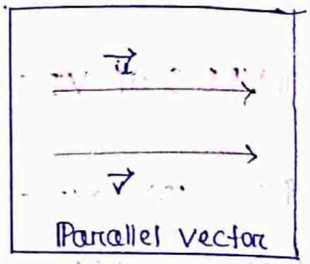
The unit Vector along y axis = $\hat{j}$

The unit Vector along z axis = $\hat{k}$

PARALLEL VECTOR ($\theta = 0°$)

Two vectors (which may have different magnitude) acting along same direction are Called parallel vectors.

Angle between them Zero.

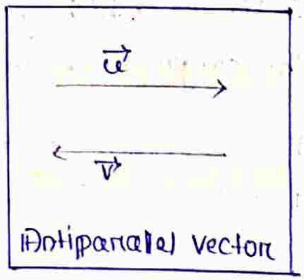


Parallel vector

ANTIPARALLEL VECTOR ($\theta = 180°$)

Two Vectors which are directed in opposite direction are called anti-parallel vectors.

Angle between them 180°.



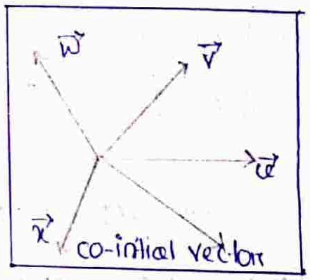
Antiparallel vector

COLLINEAR VECTOR

Vectors having a Common line of action are Called Collinear Vectors.

CO-INITIAL VECTOR

A number of Vectors having a Common initial point are Called co-initial Vectors.



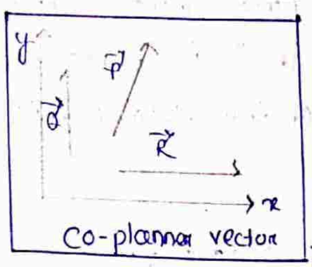
co-initial vector

CO-TERMINOUS VECTOR

Vectors having Common terminal point are Called Co-terminous Vector.

CO-PLANNER VECTOR

Vectors Situated in one plane, irrespective of their directions are known as co-planner vectors.



Co-plannar vector

LOCALISED VECTOR

Vectors which initial point is fixed are called fixed or localised Vectors.

Ex:- Position Vector

NON LOCALISED VECTOR

Vectors whose initial point (tail) is not fixed said to be a non-localised vector or a free vector.

Ex:- Vectors representing force, momentum, impulse etc.

ORTHOGONAL VECTOR

If angle between 2 Vectors is 90° then they are called orthogonal vectors.

NULL VECTOR

Null Vector is defined as a Vector having Zero magnitude & arbitrary direction.

For a null Vector the initial & the terminal points are Considerd it is represented by $\vec{0}$.

Ex- Velocity of a Stationary body

Position Vector of a particle lying at the origin.

PROPERTIES OF A NULL VECTOR

(a) It has zero magnitude

(b) It has arbitrary direction.

(c) It is represented by a point

(d) When a null Vector is added or Subtracted from a given Vector, the resultant Vector is same as the given Vector.

(e) Dot product of a null vector with any vector is always zero ($A \cdot \vec{0} = \vec{0}$)

(f) Cross product of a null Vector with any other Vector is also a null Vector.

RESULTANT VECTOR

The resultant of 2 or more Vectors is the Vector Sum of all the given Vector.

ADDITION OF VECTOR

The process of adding two or more Vectors is Called Composition of Vector or addition of Vector.

The minimum Condition for Vector addition is that the quantities should be of same nature.

Types of Vector addition

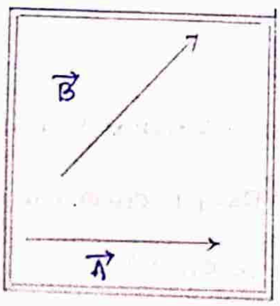
(i) Triangle law of Vector addition.

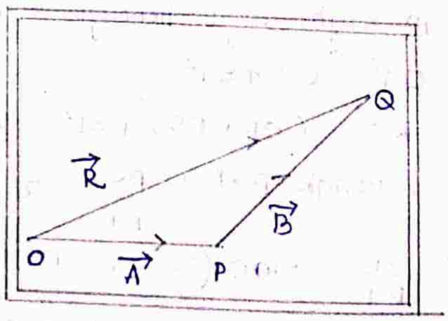
(ii) parallelogram law of Vector addition.

(iii) polygon law of Vector addition.

TRIANGLES LAW OF VECTOR ADDITION

" If two Vectors are represented (in magnitude & direction) by the two sides of a triangle, taken in the Same order, then their resultant in represented (in magnitude & direction) by the third side of the triangle in opposite order.

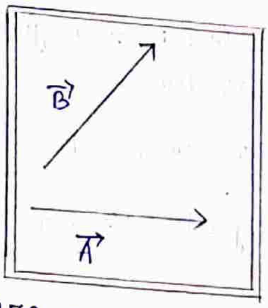


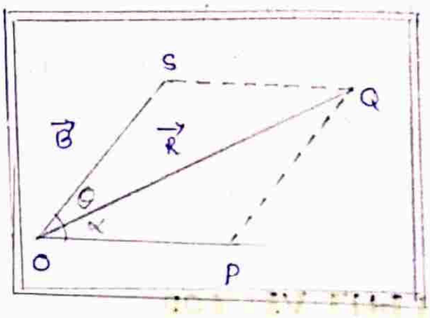


Let the two Vectors $\vec{A}$ & $\vec{B}$ acting at a point, be represented by the two Sides $\overrightarrow{OP}$ & $\overrightarrow{PQ}$ of triangle OPQ taken in Same order. According to the triangle's law, the third side $\overrightarrow{OQ}$, of the triangle, taken in opposite order gives the resultant.

PARALLELOGRAM LAW OF VECTOR ADDITION

It states that "If two vectors acting simultaniously at a point are represented in magnitude & direction by the two sides of a parallelogram drawn from a point, their resultant is given in magnitude & direction by the concurrent diagonal.





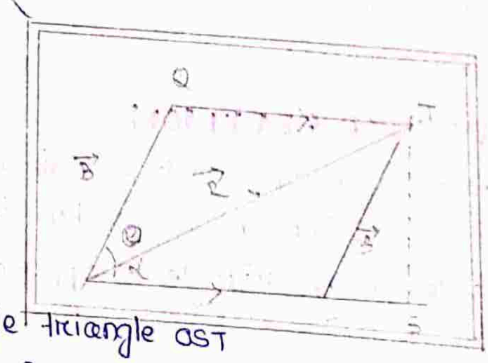
Let $\vec{A}$ & $\vec{B}$ are represented by $\vec{OP}$ & $\vec{OS}$ respectively then the resultant vector is represented by the concurrent diagonal $\vec{OQ}$.

The magnitude of the $\vec{R}$ is $\vec{R} = \sqrt{a^2 + b^2 + 2ab\cos\theta}$

The direction of the $\vec{R}$ with respect to $\vec{A}$ is

$$\tan\alpha = \frac{b\sin\theta}{a + b\cos\theta}$$

$$\Rightarrow \alpha = \tan^{-1}\frac{b\sin\theta}{a + b\cos\theta}$$



In right angle triangle OST

$OT^2 = OS^2 + ST^2$

$R^2 = (OP + PS)^2 + ST^2 = OP^2 + PS^2 + 2 \times OP \times PS + ST^2$

In triangle PST, $\frac{PS}{PT} = \cos\theta$ ($\because PS = PT.\cos\theta$ or $PS = B\cos\theta$)

Also $\frac{ST}{PT} = \sin\theta$ ($\because ST = PT\sin\theta = B\sin\theta$)

$R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta = A^2 + B^2(\cos^2\theta + \sin^2\theta) + 2AB\cos\theta$

$R^2 = A^2 + B^2 + 2AB\cos\theta$ ($\because \sin^2\theta + \cos^2\theta = 1$)

$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

In triangle OST $\tan\alpha = \frac{ST}{OS} = \frac{b\sin\theta}{a + b\cos\theta}$ $\quad \alpha = \tan^{-1}\frac{b\sin\theta}{a + b\cos\theta}$

SPECIAL CASES

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

(i) if $\theta = 0 \Rightarrow \cos\theta = 1$

$\sin\theta = 0$

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta} = \sqrt{(A+B)^2} = A+B$$

$$\alpha = \tan^{-1}\left(\frac{B\times 0}{A+B\times 1}\right) = \tan^{-1} 0 = 0^\circ$$

(ii) If $\theta = 90^\circ$ $\cos\theta = 0$

$\sin\theta = 1$

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta} = \sqrt{A^2 + B^2}$$

$$\alpha = \frac{\tan^{-1}(B\times 1)}{A+B\cos\theta} = \tan^{-1}\left(\frac{B}{A}\right)$$

(iii) If $\theta = 180^\circ$ $\cos\theta = -1$

$\sin\theta = 0$

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta} = \sqrt{(A-B)^2} = A-B$$

$$\alpha = \tan^{-1}\frac{B\times 0}{A+B(-1)} = \tan^{-1} 0 = 0$$

PROPERTIES OF VECTOR ADDITION

1. Commutative property

$$\vec{a} + \vec{b} = \vec{b} + \vec{a}$$

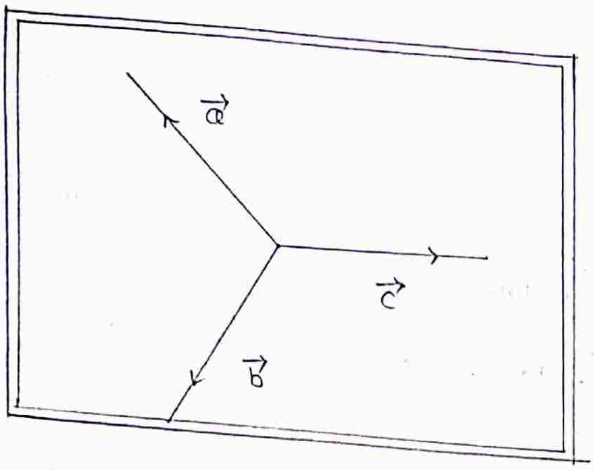
2. Associative property

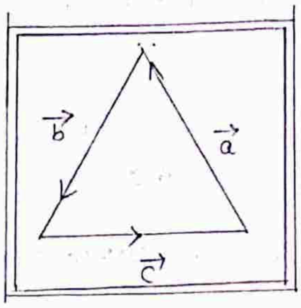
$$\vec{a} + (\vec{b} + \vec{c}) = (\vec{a} + \vec{b}) + \vec{c}$$

3. Distributive property

$$m(\vec{a} + \vec{b}) = m\vec{a} + m\vec{b}$$

CONDITION OF EQUILIBRIUM





if 3 vectors acting simultaniously (at the same time) on a body are represented both in magnitude & direction by 3 sides of a triangle taken in same order, then their resultant is a null vector. i.e they are in equilibrium.

RESOLUTION OF VECTOR

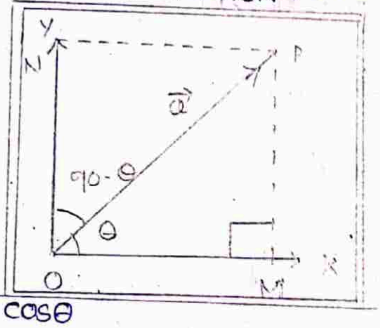
Resolution of vector is the process of obtaining the component vectors which when combined, according to laws of vector addition, produce the given vector.

Simply,

it is the process of spliting a vector into it's component.

* Resolution is exactly the, opposite of addition of vectors.

Rectangular component of vector



$OM = OP \cos\theta$

$OM = a \cos\theta$

$ON = OP \sin\theta$

$ON = a \sin\theta$

$\vec{OM} + \vec{ON} = \vec{OP}$

$$\boxed{\vec{a} = a\cos\theta\,\hat{i} + a\sin\theta\,\hat{j}}$$

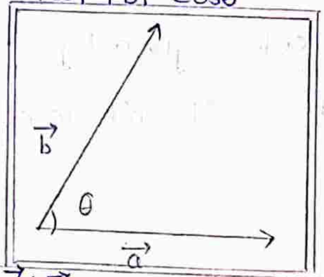
SCALAR OR DOT PRODUCT

Dot product of two vectors is defined as the product of their magnitude & the cosine of the smaller angle between the two.

* It is written by putting a dot (·) between two vectors.
* The result of this product doesn't possess any direction. So it is a scalar quantity. Hence it is called a scalar product.

Let $\vec{a}$ & $\vec{b}$ be 2 non-zero vectors inclined at an angle θ then the scalar product of $\vec{a}$ with $\vec{b}$ is defined as a scalar.

$$\vec{a}\cdot\vec{b} = |\vec{a}|\,|\vec{b}|\cos\theta$$



$$\Rightarrow \cos\theta = \frac{\vec{a}\cdot\vec{b}}{|\vec{a}|\,|\vec{b}|}$$

$$\Rightarrow \theta = \cos^{-1}\frac{\vec{a}\cdot\vec{b}}{|\vec{a}|\,|\vec{b}|}$$

$\vec{a}\cdot\vec{b} = a\,(b\cos\theta)$ $\qquad$ $\vec{b}\cdot\vec{a} = b\,(a\cos\theta)$

$= a \times$ Component $\vec{b}$ along $\vec{a}$ $\qquad$ $= b \times$ Component $\vec{a}$ along $\vec{b}$

PROPERTIES OF DOT PRODUCT

1. $\vec{a}\cdot\vec{b} = \vec{b}\cdot\vec{a}$ (Commutative)
2. Dot product of 2 vectors can be +(ve), -(ve) or Zero.
3. Distributive

$$\vec{a}\cdot(\vec{b}+\vec{c}) = \vec{a}\cdot\vec{b} + \vec{a}\cdot\vec{c}$$

4. If 2 vectors $\vec{a}$ & $\vec{b}$ are $\perp^r$ to each other then their scalar product is 0.

$$\vec{a}\cdot\vec{b} = 0$$

$$\Rightarrow \theta = 90^\circ$$

$$\hat{i}\cdot\hat{j} = 0$$

5. if $\vec{a}$ & $\vec{b}$ are ∥ to each other, then the scalar product is

$$\vec{a}\cdot\vec{b} = ab\cos\theta = ab$$

$$\hat{j}\cdot\hat{j} = 1, \quad \hat{i}\cdot\hat{k} = 0, \quad \hat{j}\cdot\hat{k} = 0$$

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$

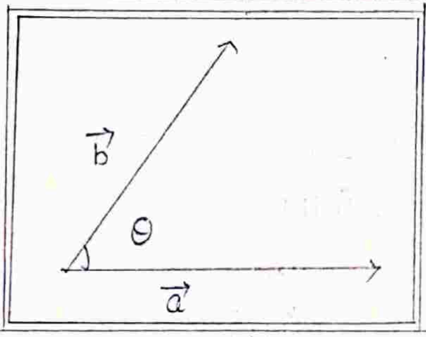
$\vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$

$$\vec{a}\cdot\vec{b} = a_x\hat{i}\cdot b_x\hat{i} + a_x\hat{i}\cdot b_y\hat{j} + a_x\hat{i}\cdot b_z\hat{k}$$
$$+ a_y\hat{j}\cdot b_x\hat{i} + a_y\hat{j}\cdot b_y\hat{j} + a_y\hat{j}\, b_z\hat{k}$$
$$+ a_z\hat{k}\cdot b_x\hat{i} + a_z\hat{k}\cdot b_y\hat{j} + a_z\hat{k}\cdot b_z\hat{k}$$
$$= a_x b_x + a_y b_y + a_z b_z$$

VECTOR OR CROSS PRODUCT

Let $\vec{a}$ & $\vec{b}$ be two non zero vectors inclined at an angle θ then there cross product is defined as a vector given by

$$\boxed{\vec{a}\times\vec{b} = |\vec{a}|\,|\vec{b}|\sin\theta\,\hat{n}}$$

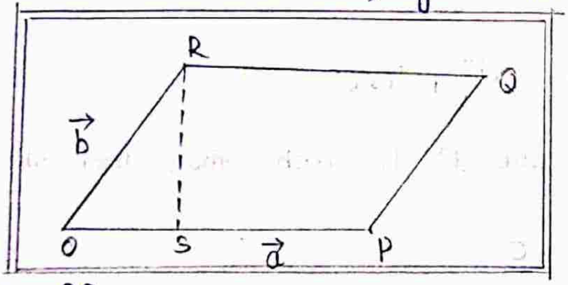


RIGHT HAND THUMB RULE

Curl the fingers of the right hand from $\vec{a}$ to $\vec{b}$ the direction in which the thumb points gives the direction of $\vec{a}\times\vec{b}$.

RIGHT HAND SCREW RULE

If a right handed screw is placed with it's axis perpendicular ($\perp^r$) to the plane containing both $\vec{a}$ & $\vec{b}$ is rotated from $\vec{a}$ to $\vec{b}$ then the direction in which the screw advances (moves) gives the direction of $\vec{a}\times\vec{b}$.



$\sin\theta = \frac{RS}{OR}$

$\Rightarrow RS = OR\sin\theta$

$\Rightarrow RS = b\sin\theta$

$|\vec{a}\times\vec{b}| = ab\sin\theta\,K = OP\times RS$ = Area of the parallelogram

PROPERTIES OF CROSS PRODUCT

1. $\vec{a} \times \vec{b} = -(\vec{b} \times \vec{a})$

   ∴ Cross product is anti- Commutative

2. $\vec{a} \times (\vec{b}+\vec{c}) = \vec{a} \times \vec{b} + \vec{a} \times \vec{c}$

   Cross product is distributive over addition.

3. Cross product of 2 vector (parallel or antiparallel) is zero.

$$\vec{a} \times \vec{b} = \vec{0}$$
$$|\hat{i} \times \hat{i}| = 0$$
$$|\hat{j} \times \hat{j}| = 0$$
$$|\hat{k} \times \hat{k}| = 0$$

4. Cross product of 2 perpendicular vector is $\vec{a} \times \vec{b} = ab \sin 90° \hat{n}$

$$\hat{i} \times \hat{j} = \hat{k}$$
$$\hat{j} \times \hat{k} = \hat{i}$$
$$\hat{k} \times \hat{i} = \hat{j}$$
$$\hat{i} \times \hat{k} = -\hat{j}$$
$$\hat{k} \times \hat{j} = -\hat{i}$$
$$\hat{j} \times \hat{i} = -\hat{k}$$

Cyclic permutation or Cyclic rotation

Anticlock wise (+) ve

clock wise (-) ve

$$|\vec{a} \times \vec{b}| = ab \sin\theta$$

$$\Rightarrow \sin\theta = \frac{|\vec{a} \times \vec{b}|}{ab}$$

$$\Rightarrow \theta = \sin^{-1} \frac{|\vec{a} \times \vec{b}|}{ab}$$

5. $\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$
   $\vec{b} = b_x \hat{i} + b_y \hat{j} + b_z \hat{k}$

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

Q-1

The magnitude of the resultant of two vectors of equal magnitude is equal to the magnitude of either vector, Find the angle between them? (A-120°)

Q-2

Three vectors $\vec{a}, \vec{b}, \vec{c}$ are such that

$\vec{a} = \vec{b} + \vec{c}$ & their magnitudes are 5, 4 & 3 respectively

Find the angle between $\vec{a}$ & $\vec{c}$.

Q-3

Determine the unit vector which is $\perp^{r}$ to both

$$\vec{a} = 2\hat{i} + \hat{j} + \hat{k}$$
$$\vec{b} = \hat{i} - \hat{j} + 2\hat{k}$$

Q-4

On a certain day rain was falling vertically with a speed of 35 m/s, A wind started blowing with a speed 12 m/s from east to west in which direction should a boy waiting at bus stop hold his umbrella? (A = 19°)

Q-5

If $|\vec{a} + \vec{b}| = |\vec{a} - \vec{b}|$

Find the angle between 2 vectors.

Q-6

If magnitude of 2 vectors are 2 & 3 & magnitude of their dot product is $3\sqrt{2}$ then find the angle between the vectors.

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KINEMATICS

REST

If a body does not change its position with respect to its surroundings & time, the body is said to be at "rest" for that time.

MOTION

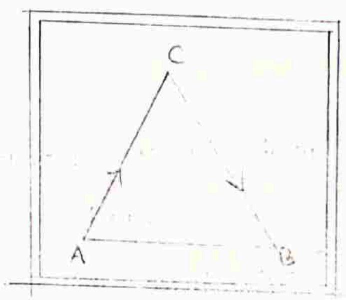
If a body changes its position with respect to its surroundings & time, the body is said to be in motion for that interval of time.

Ex :- Car moving on a road.

* Absolute rest & Absolute motion doesn't exist.

DISTANCE

It is the length of the actual path travelled by a body between it's initial & final position.



Distance Covered = AC+CB

* Distance is a Scalar quantity because it has only magnitude; no direction.
* Distance Covered is always (+ve) or Zero.

unit :- m

Dimension :- $[M^0 L^1 T^0]$

DISPLACEMENT

The displacement of an object is the difference in initial position & Final position in a fixed direction.

* It is the shortest distance measured in the direction from initial position to final position.
* Displacement is a vector quantity because it has both magnitude & direction.
* Displacement may be +(ve), -(ve), or Zero.

DISTANCE	DISPLACEMENT
Length of actual path travelled by a body is known as distance.	The straightline distance between the two positions is called displacement.
Distance is a scalar quantity	Displacement is a vector quantity.
Distance is path dependent.	Displacement is path independent.
Distance is always +(ve)	Displacement is +(ve), -(ve) or zero.
A body may cover distance without having any displacement	But displacement between 2 point is always unique.
Slope of distance vs timegraph gives speed.	Slope of displacement vs timegraph gives velocity.

SPEED

Speed of a body is defind as the distance covered by the body in 1 second.

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}}, \quad V = \frac{S}{t}$$

unit :- m/s , cm/s

Dimension :- $[M^0L^1T^{-1}]$

$$\boxed{\begin{aligned} 1\,km/h &= \frac{5}{18}\,m/s \\ 1\,m/s &= \frac{18}{5}\,km/s \end{aligned}}$$

UNIFORM SPEED

If the body covers equal distance in equal intervals of time then it's motion is called uniform motion or speed.

EX :- A ball moving on a friction less surface.

VARIABLE / NON UNIFORM SPEED

If a body covers equal distance in unequal time intervals or unequal distance in equal time intervals then the speed in non uniform / variable speed.

AVERAGE SPEED

Average Speed is defined as total distance covered per total time taken.

$$V_{avg} = \frac{\text{total distance}}{\text{total time}}$$

INSTANTANEOUS SPEED

$$V_{int} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

* The speed of an object at any particular constant of time is called the instanstaneous speed of objects.

Special case for Vavg

$$V_{avg} = \frac{2v_1 v_2}{v_1 + v_2}$$

* If a body covers equal distance with difference speed.
* If a body travels with speeds $v_1, v_2, v_3 \ldots$ in time intervals. $t_1, t_2, t_3 \ldots$ respectively the $V_{avg} = \frac{d}{t} = \frac{v_1 t_1 + v_2 t_2 + v_3 t_3 \ldots}{t_1 + t_2 + t_3 \ldots}$

VELOCITY

The rate of change of position of an object with time in a given direction is called velocity.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

* Velocity is a vector quantity

unit :- m/s

Dimension :- $[M^0 L^1 T^{-1}]$

* velocity can be (+ve), (-ve), 0 because displacement can be (+ve), (-ve) 0.

UNIFORM VELOCITY

If the body covers equal displacements in equal Intervals of time then it's velocity is called uniform velocity.

NON UNIFORM VELOCITY

A body is said to be moving with non uniform/variable velocity if either it's speed changes or direction changes or both change with time.

AVERAGE VELOCITY

For a body moving with non-uniform velocity, Average velocity is defined as the ratio of it's total displacement to the total time interval.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

INSTANTANEOUS VELOCITY

The Velocity of an object at a particular instant of time is Called its instantaneous velocity.

$$\vec{V}_{int} = \lim_{\Delta t \to 0} \frac{\Delta \vec{s}}{\Delta t} = \frac{d\vec{s}}{dt}$$

ACCELERATION

* The rate of Change of Velocity of an object with time is Called its acceleration.
* Its tells how fast the velocity of an object changes with time.
* It is a vector quantity whose direction depends on change in Velocity.

unit :- m/s^2

Dimension :- $[M^0L^1T^{-2}]$

$$\text{Acceleration} :- \frac{\text{Change in Velocity}}{\text{Time}} = \frac{\Delta \vec{V}}{\Delta t} = \frac{\vec{V_2} - \vec{V_1}}{t_2 - t_1}$$

(+ve) Acceleration

if the Velocity of an object increases with time, then its acceleration is (+ve).

(−ve) Acceleration

if the Velocity of an object decreases with time then it's acceleration is (−ve) : it is also known as retardation or deceleration.

$$a_{int} = \lim_{\Delta t \to 0} \frac{\Delta \vec{V}}{\Delta t} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{s}}{dt^2}$$

KINEMATIC EQUATION

(1) $V = u + at$

(2) $S = ut + \frac{1}{2}at^2$

(3) $v^2 = u^2 + 2as$

(4) $S_{nth} = u + \frac{a}{2}(2n-1)$

FREE FALL

In the absense of air resistance all bodies fall with the same acceleration near the surface of the earth. This motion of body falling towards the earth from a small height is called free fall.

The acceleration with which the body falls is called acceleration due to gravity.

EQUATION OF MOTION UNDER GRAVITY

Upward Motion	Downword Motion
$V = u - gt$	$V = u + gt$
$S = ut - \frac{1}{2}gt^2$	$S = ut + \frac{1}{2}gt^2$
$v^2 = u^2 - 2gs$	$v^2 = u^2 + 2gs$

PROJECTILE MOTION

When a particle is thrown obliquely into space with some Initial velocity near the earth's surface under the influence of gravity alone without the help of any engine or fuel, that motion is called projectile motion.

it is an example of motion in a plane with Constant acceleration.

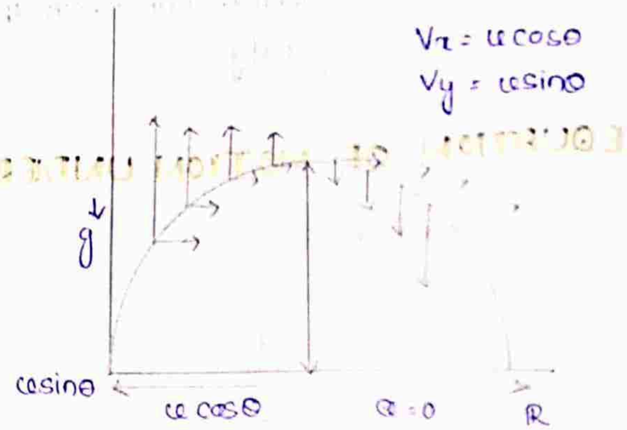
A body projected into the space & is no longer being propelled by fuel is called projectile.

* Some energy is given to the projectile at the initial stage. As it moves through space, there is no supply of energy to it & it moves freely under the action of gravity.

Ex:- A stone threw at a tree,

$u_x = u\cos\theta$ along ox

$u_y = u\sin\theta$, along oy



Motion along Horizontal

Neglating air friction the horizontal component of velocity $u_x = u\cos\theta$ constant because $a = 0$.

$$x = u_x t - \frac{1}{2} a_x t^2$$

$$\Rightarrow x = u_x t$$

$$\Rightarrow x = (u\cos\theta)t \quad \text{---- (i)}$$

$$\Rightarrow t = \frac{x}{u\cos\theta} \quad \text{---- (ii)}$$

Motion along Vertical

Because of g the velocity along vertical direction goes on decreasing initial velocity along vertical

$$u_y = u \sin\theta \quad \text{acceleration along vertical}$$

$$a_y = -g$$

position along vertical after time (t)

$$y = u_y + \frac{1}{2} a_y t^2$$

$$\Rightarrow y = (u \sin\theta) t - \frac{1}{2} g t^2 \quad \text{- - - (ii)}$$

TRAJECTORY

The path along which the particle moves in a projectile motion is Called trajectory of the projectile.

The motion along vertical is given by

$$y = (u \sin\theta) t - \frac{1}{2} g t^2$$

putting the value of t

$$\Rightarrow y = (u \sin\theta) \frac{x}{u \cos\theta} - \frac{1}{2} g \left(\frac{x}{u \cos\theta}\right)^2$$

$$\Rightarrow y = x \tan\theta - \frac{1}{2} \frac{g x^2}{u^2 \cos^2\theta}$$

$$\Rightarrow y = px - qx^2 \text{ (parabola)}$$

when p & q are Constants

Thus, y is a quadratic Function of x.

Hence, this is an equation of parabola. It shows that a projectile projected at same angle with horizontal moves along " parabollic path."

MAXIMUM HEIGHT (H)

* It is the maximum height to which a projectile rises above the point of projection.
* H is the maximum distance travelled by the projectile in the vertical direction.

We know that

$$v^2 = u^2 + 2as$$

At the ~~height~~ highest point the vertical component of the velocity is 0.
The vertical component of the initial velocity is $u_y = u \sin\theta$ & Acceleration at the highest point is $a_y = -g$

Using the relation

$$v_y^2 = u_y^2 + 2a_y H$$

$$\Rightarrow 0 = (u \sin\theta)^2 + 2(-g)H$$

$$\Rightarrow u^2 \sin^2\theta - 2gH = 0$$

$$\Rightarrow H = \frac{u^2 \sin^2\theta}{2g}$$

Time of Flight.

it is the time taken by the projectile to return the ground.

Time of Ascent

it is the time taken by the projectile to rise to the highest point of the trajectory.

$$V = u + at$$

$$\Rightarrow v_y = u_y + a_y t_a$$

$$\Rightarrow 0 = u \sin\theta - g t_a$$

$$\Rightarrow g t_a = u \sin\theta$$

$$\Rightarrow \boxed{t_a = \frac{u \sin\theta}{g}}$$

Time of Descent

it is the time taken by the projectile to come down from the highest point to the point of projection.

$$u_y = 0 \quad , \quad a_y = g$$

$$S = ut + \frac{1}{2}at^2$$

$$\Rightarrow H = u_y t_d - \frac{1}{2}g t_d^2$$

$$\Rightarrow H = \frac{1}{2}g t_d^2$$

$$\Rightarrow \frac{u^2 \sin^2\theta}{2g} = \frac{1}{2}g t_d^2$$

$$\Rightarrow t_d^2 = \frac{u^2 \sin^2\theta}{g^2}$$

$$\Rightarrow t_d = \sqrt{\frac{u^2 \sin^2\theta}{g^2}} = \frac{u \sin\theta}{g}$$

Time of Flight = Time of Ascent + Time of Descent

$$\boxed{T = \frac{2u \sin\theta}{g}}$$

Another Method

$$t_a = \frac{T}{2}$$

The velocity of projectile of any time along vertical is

$$V_y = u_y + a_y t$$

$$U_y = u \sin\theta \, , \, a_y = -g$$

$$t = \frac{T}{2} , \quad V_y = 0$$

$$0 = u \sin\theta - g \times \frac{T}{2}$$

$$g\frac{T}{2} = u \sin\theta$$

$$\Rightarrow \boxed{T = \frac{2u \sin\theta}{g}}$$

HORIZONTAL RANGE

It is the distance travelled by the projectile in the horizontal direction between the point of projection to the point on ground.

$$S = ut + \frac{1}{2}at^2$$

$$R = u_x T + \frac{1}{2} a_x T^2$$

$$\Rightarrow R = u\cos\theta \times \frac{2u\sin\theta}{g}$$

$$\Rightarrow R = \frac{u^2 \cdot 2 (\sin\theta \cdot \cos\theta)}{g}$$

$$\Rightarrow \boxed{R = \frac{u^2 \sin 2\theta}{g}}$$

$\sin 2\theta = \max = 1 = \sin 90°$

$\Rightarrow 2\theta = 90°$

$\Rightarrow \theta = 45°$ (Angle of projection for maximum range)

$R_{max} = \frac{u^2}{g}$

$\downarrow$

Maximum horizontal range.

CIRCULAR MOTION

The motion of a body is said to be Circular if it moves in such a way that its distance from a certain fixed point always remains the same.

Direction of motion of body at any instant

If the breaks suddenly, the stone shall fly tangentially to the path of motion, So, Instataneous direction of motion of the body is always along the tangent to the curve at that point.

UNIFORM CIRCULAR MOTION

The motion of a body about a circular track is said to be uniform if it travels of time. In such a way the radious of the circle shall traverse equal angle in equal intervals of time.

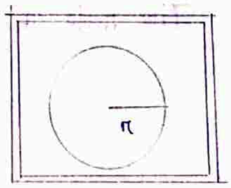
Simply,

If a body moves in such a way that its distance from a fixed point always remains constant then, the motion is called uniform circular motion.

Ex

* Motion of the second hand of a clock.
* Motion of a point on the rim of a cycle wheel.

Note - Uniform Circular motion is an accelerated motion.



(direction of velocity changes)

1) Angular displacement

The angular displacement of a particle moving along a circular path is defined as the angle made by the radious vector in a given time interval.

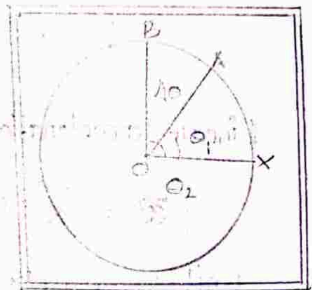
Angular displacement $= \Delta\theta = \theta_2 - \theta_1$

$\Delta\theta = \frac{\Delta l}{r}$, $\theta = \frac{l}{r}$

$\Rightarrow \Delta\theta = \theta_2 - \theta_1$

Unit = radian

Dimension :- $[M^0L^0T^0]$ i.e dimensionless



2) Angular Velocity

The rate of change of angular displacement (w.r.t) angular velocity.

* it is denoted by ω (omega).

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\Delta l}{r\Delta t} = \frac{v}{r} \Rightarrow \boxed{\omega = \frac{v}{r}}$$

$$\Rightarrow \boxed{v = r\omega}$$

Linear Velocity = Angular velocity x radious

In Vector form, $\boxed{\vec{v} = \vec{\omega} \times \vec{r}}$

unit :- rad/sec

Dimension :- $[M^0 L^0 T^{-1}]$

3) Angular Acceleration

The rate of change of angular velocity w.r.t time is called Angular Acceleration.

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} \text{ (Instataneous angular acceleration)}$$

We know that

$$v = r\omega$$

$$\Rightarrow \frac{dv}{dt} = r\frac{d\omega}{dt}$$

$$\Rightarrow \boxed{a = r\alpha}$$

Linear acceleration = radious x Angular acceleration

$$\boxed{\vec{a} = \vec{\alpha} \times \vec{r}}$$

unit :- rad/s²

Dimension :- $[M^0 L^0 T^{-2}]$

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4) Time period

The time required by a particle to complete one revolution is called as time period.

* It is denoted by T

In one revolution time taken = T

It completes 2π rad angular displacement in one revolution.

∴ Angular velocity $\boxed{\omega = \frac{2\pi}{T}}$

5) Frequency

it is defind as the no. of revolutions. Completed per second.

$$\boxed{f = \frac{1}{T}}$$

$\Rightarrow \omega = 2\pi f$

$\Rightarrow f = \frac{\omega}{2\pi}$

FORCE

Force is defined as an effect which changes the state of rest motion.

Centripetal Force.

A force require to make a body move along circular path with uniform speed is called centripetal force.

$$\text{Magnitude of } F_c = \frac{mv^2}{r}$$

$$a_c = \frac{v^2}{r}$$

$$F_c = M \cdot \frac{v}{r} \times v = M\omega \times \omega r.$$

$$\Rightarrow F_c = m\omega^2 r$$

chapter-4

GRAVITATION

GRAVITATIONAL FORCE

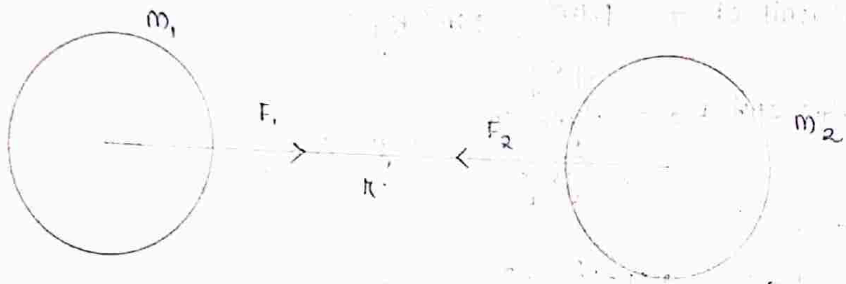
The phenomenon of mutual attraction between any 2 bodies of the universe is called gravitation & the corresponding attractive force is called gravitational force.

Ex:- The attraction between sun & earth.

Falling of raindrops from the clouds.

NEWTON'S LAW OF GRAVITATION

Statement :- Every particle of matter in this universe attracts every other particle with a force which varies directly as the product of the masses of two particle & ~~inversly~~ inversely as the square of the distance between them.



Consider two bodies of masses, m_1 & m_2 & separated by distance r.

According to the law of gravitation, the force of attraction F between them is such that

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r^2}$$

$$\therefore F \propto \frac{m_1 m_2}{r^2}$$

$$\Rightarrow F = G \frac{m_1 m_2}{r^2}$$

where G is a constant called universal gravitational constant.

Definition of G

Let $m_1 = m_2$ 1 unit

$r = 1$ unit

Then, $F = G\frac{1\times 1}{1^2} = G$

$F = G$

Thus,

The gravitational constant may be defind as the magnitude of force of attraction between two bodies each of unit mass & separated by a unit distance from each other.

Unit + Value of G

$$G = \frac{Fr^2}{m_1 m_2}$$

$\therefore$ SI unit of G $= \frac{Nm^2}{kg \cdot kg} = Nm^2\,Kg^{-2}$

C.G.S unit of G $= \frac{dyne\ cm^2}{g \times g} = dyne\ cm^2\ g^{-2}$

Dimension

$$[G] = \frac{MLT^{-2} \times L^2}{M \times M} = [M^{-1}L^3T^{-2}]$$

Value of $G = 6.67 \times 10^{-11}\ Nm^2\,Kg^{-2}$

GRAVITY

If one of the attracting bodies is earth, then gravitation is called gravity. Gravity is defind as the force of attraction between the earth + any object lying on or near its surface.

Example : A body thrown up falls back on the surface of earth, falling of raindrops from cloud.

Free Fall

The motion of a body under the influence of gravity alone is called a free fall.

Example :- A stone dropped (not throwed) from the roof of a building

ACCELERATION DUE TO GRAVITY

The acceleration produced in a freely falling object under the gravitational force at the earth is called acceleration due to gravity (g).

it is a vector quantity having direction towards the Centre of the earth. It doesn't depend upon the mass, size & shape of the object.

$$g = 9.8 \, m/s^2$$

RELATION BETWEEN g & G

Let the mass of the earth be M & radious be R. Consider an apple of mass m is falling from the tree.

Then the acceleration it gained due to gravity is g.

Hence the force on the apple is $F = mg$

This force must be equal to the gravitational force of earth on the apple.

so, $$mg = \frac{GMm}{R^2}$$

$$\Rightarrow \boxed{g = \frac{GM}{R^2}}$$

In this case it is assumed that the falling apple is almost at the Surface of the earth & mass of the entire earth is Supposed to be Concentrated at its Centre.

VARIATION OF g WITH ALTITUDE (HEIGHT)

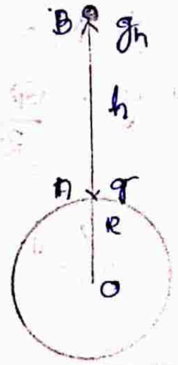
Consider the earth to be a sphere of mass, M, radious R, & Centre O.

Then the acceleration due to gravity at a point A on the surface of the earth, will be

$$g = \frac{GM}{R^2} \quad \text{- - - (i)}$$

if g_h is the acceleration due to gravity at a point B at a height h from the earth's surface, then

$$g_h = \frac{GM}{(R+h)^2} \quad \text{- - - (ii)}$$



Now deviding (ii) by (i) we get

$$\frac{g_h}{g} = \frac{GM}{(R+h)^2} \times \frac{R^2}{GM}$$

$$\Rightarrow \frac{g_h}{g} = \frac{R^2}{(R+h)^2} = \frac{R^2}{R^2\left(1+\frac{h}{R}\right)^2} = \left(1+\frac{h}{R}\right)^{-2}$$

$$\Rightarrow \frac{g_h}{g} = \left(1+\frac{h}{R}\right)^{-2}$$

Now expanding the R.H.S by using Binomial theorm & neglating the higher order terms, we get

$$\frac{g_h}{g} = \left(1 - \frac{2h}{R}\right) \qquad \left(\because h << R \Rightarrow \frac{h}{R} << 1, \text{so higher order terms can be neglected} \right)$$

$$\Rightarrow g_h = g\left(1 - \frac{2h}{R}\right)$$

Hence from above equation, it is clear that as the height (altitude) of the place increases the value of 'g' decreases.

VARIATION OF g WITH DEPTH

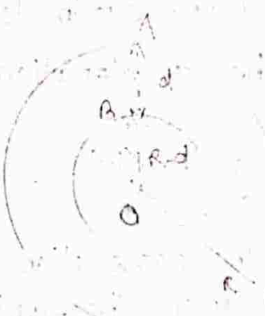
Consider the earth to be a sphere of mass M, radious R & Centre O.
The acceleration due to gravity at any point A on the surface of the earth will be

$$g = \frac{GM}{R^2}$$

Assuming the earth to be a homogeneous sphere of average density ρ (rho), then its total mass will be

$$M = \text{Volume} \times \text{density}$$

$$\Rightarrow M = \frac{4}{3}\pi R^3 \rho$$



Now $g = \frac{GM}{R^2} = \frac{G \times \frac{4}{3}\pi R^3 \rho}{R^2}$

$$\Rightarrow g = \frac{4}{3}\pi G R \rho \quad \text{---- (i)}$$

Let g_d be the acceleration due to gravity at point B at depth 'd' below the surface of the earth.

Let a body at B is situated at the surface of inner solid sphere & lies inside the spherical shell of thickness d.

The gravitational force of attraction on a body inside a spherical shell is always zero.

Therefore, a body at B experiences gravitational force due to inner sphere of radious (R-d) + mass M, where.

$$M = \frac{4}{3}\pi (R-d)^2 \rho$$

Hence $$g_d = \frac{GM}{(R-d)^2} = \frac{G}{(R-d)^2} \times \frac{4}{3}\pi (R-d)^2 \rho$$

$$\Rightarrow g_d = \frac{4}{3}\pi G (R-d)\rho \quad \text{---(ii)}$$

Now deviding (ii) by (i)

$$\frac{g_d}{g} = \frac{\frac{4}{3}\pi G (R-d)\rho}{\frac{4}{3}\pi G R \rho}$$

$$\Rightarrow \frac{g_d}{g} = \frac{R-d}{R} = 1 - \frac{d}{R}$$

$$\Rightarrow g_d = g\left(1 - \frac{d}{R}\right)$$

clearly, the acceleration due to gravity decrease with the increase in depth d. That is why the acceleration due to gravity is less in mines than that on earth's surface.

MASS

Mass is a measure of the amount of matter in an object Mass is usually measured in kg or grams. Mass measures the quantity of matter irrespective of the location in the universe & the gravitational force applied to it.
An object's mass is constant in all situations.

WEIGHT

The weight of a body is the force with which a body is pulled towards the centre of the earth.

$$W = mg$$

The value of g changes from place to place, so the weight of a body is different places. The SI unit of weight is newton (N).

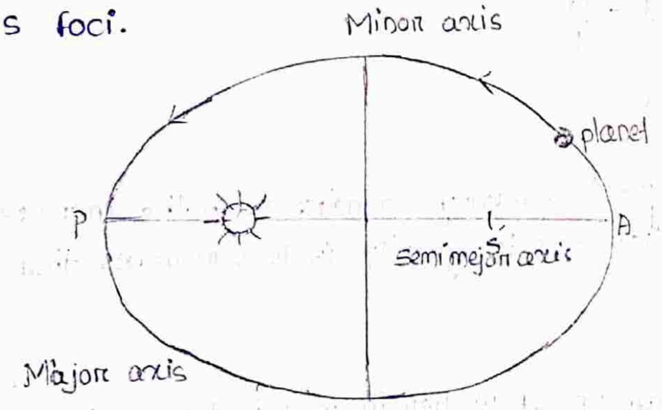
MASS	WEIGHT
1. Mass is a measure of inertia.	1. Weight is a measure of gravity.
2. It is a scalar quantity.	2. It is a vector quantity.
3. It is a constant quantity.	3. It varies from place to place.
4. It can't be zero for a body.	4. weight of a body is zero.
5. Its units are kg, gram etc.	5. Its units are dyne, newton etc.

KEPLER'S LAWS OF PLANETARY MOTION

It was Copernicus who, first of all, introduced the idea that the central body of our planetary system was sun rather than earth. Galileo's construction of telescope enabled him to discover direct visual evidence supporting 'Copernicus theory' Kepler later on confirmed by putting it on a solid mathematical background. Kepler annouced two of his laws in 1609 & the 3rd one 10 years later the laws can be stated as below.

(i) KEPLER'S FIRST LAW - LAW OF ELLIPTICAL ORBIT

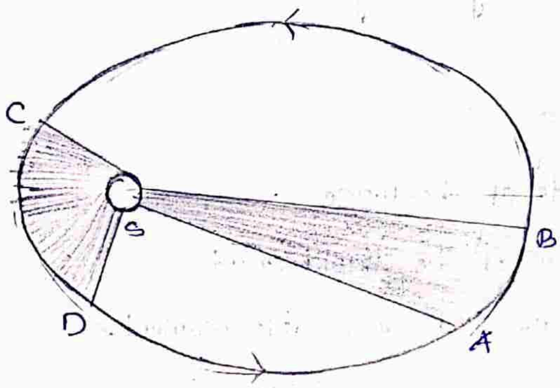
A planet moves round the sun in an elliptical orbit with sun situated at one of its foci.



Since the focus of an ellipse is not equidistant from the point on the orbit the distance of planet from sun varies between a certain minimum & a maximum value. Rotation is the reason for a change of seasons from winter to summer & repetition of the seasons after 1 year.

(ii) KEPLER's SECOND LAW - LAW OF AREAL VELOCITY

A planet moves round the sun in such a way that its areal velocity is constant (i.e the line joining the planet with the sun sweeps equal areas in equal interval of time)



(iii) KEPLER's THIRD LAW - LAW OF TIMEPERIOD: HARMONIC LAW

A planet moves round the sun in such a way that the square of its period is proportional to the cube of semi major axis of its elliptical orbit.

If T is the time period of revolution of a planet & 'a' is the length of the semi-major axis of its elliptical orbit, then

$$T^2 \propto a^3 / R^3$$

$$\Rightarrow \frac{T_1^2}{T_2^2} = \frac{a_1^3}{a_2^3} \Big/ \frac{R_1^3}{R_2^3} = \left(\frac{a_1}{a_2}\right)^3 \Big/ \left(\frac{R_1}{R_2}\right)^3$$

Thus larger the distance of a planet from the sun, the larger will be its period of revolution around the sun.

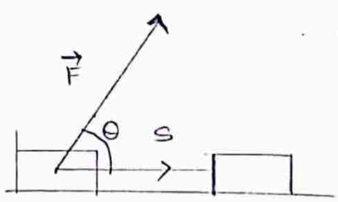
The period of revolution of the 1st planet of our solar system mercury is 81 days where as that of earth is 365 days.

WORK & FRICTION

Work

Work is said to be done if a force acting on a body produces displacement + if the force has a component in the direction of displacement.

Then work done is given by



$$W = \vec{F}\cdot\vec{S}$$

$$\boxed{W = FS\cos\theta}$$

Where F = Magnitude of the force

S = Magnitude of the displacement

θ = Angle between force & displacement.

⇒ Here $F\cos\theta$ is the magnitude of component of the force in the direction of displacement

⇒ Work done is dot product of two vectors $\vec{F}$ & $\vec{S}$ hence work is a scalar quantity.

Unit :- Joule (J) - SI unit

erg - CGS unit

Dimension :- $[M^1 L^2 T^{-2}]$

Joule

$$1J = 1N \times 1m$$

One joule of work is said to be done when a force of one newton produces a displacement of one metre in the direction of force on the body.

Erg

$$1\,erg = 1\,dyne \times 1\,cm$$

One erg of work is said to be done when a force of one dyne produces a displacement of one cm on the body in the direction of force.

Relation between J & erg.

$$1J = 1N \times 1m = 10^5 dyne \times 10^2 cm$$

$$\boxed{1J = 10^7\,erg}$$

Positive Work ($0° < \theta < 90°$) –

If a force acting on a body has a Component in the direction of the displacement then work done is (+)ve.

* When the force & displacement are in same direction, work done is positive. This work is said to be done upon the body.

$$0° < \theta < 90° \quad [0, 90°)$$

$$W = F s \cos\theta$$

Ex -

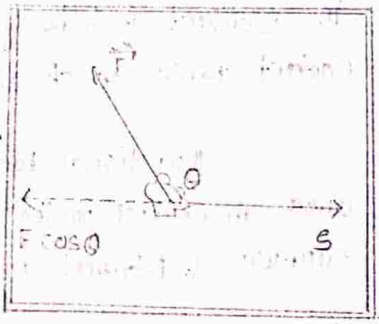
(i) Engine of a car exerts a force on the car in the direction of propagation. the work done by the engine is positive.

(ii) A block placed on the table & being pulled by a string has a positive work-done by the applied force.

(iii) A body falling freely under the action of gravity has positive work done by the gravitational force.

Negative Work ($90° < \theta < 180°$)

$\cos\theta$ is negative when $90° < \theta \leq 180°$, hence $W =$ negative i.e if a force acting on a body has a Component in the opposite direction of displacement, then the workdone is negative.



Ex -
(i) Work done by the frictional force
(ii) Work done by gravitational force on the body when it is going up.
(iii) Work done by the force of repulsion when two like charges approach each other.

Zero Work

a) $\cos\theta = 0$ when $\theta = 90°$, $W = 0$

i.e when the force has no Component in the direction of displacement, then work done is zero.

Ex - (i) Work done by Centripetal force is 0.

(ii) Work done by Coolie walking on a horizontal road with a bag on a head.

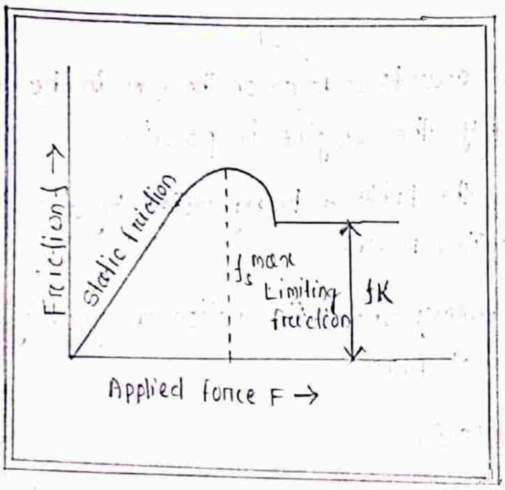
(b) Again Work done will be Zero if $\vec{F}$ or $\vec{S}$ or both are Zero.

Ex - (i) A person pushing a rigid wall

(ii) A person standing with a suit case in his hand.

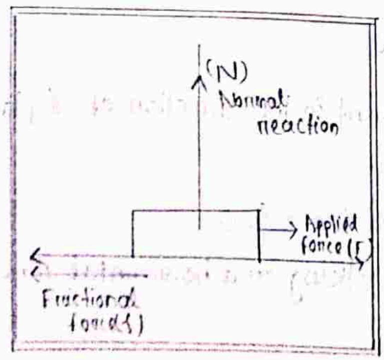
FRICTION

Whenever a body tends to slide over another's surface, an opposing force, Called force of friction, Comes into play This force acts tangentially to the interface of two bodies.



It is observed that when a body slides over another a force is generated to oppose the motion, this is called force of friction. it arises when 2 bodies are in Contact & 1 body moves relative to another thus, force of friction is a Contact force which oppose the motion a body.

Frictional force is self adjusting it doesn't depend on the amount of area in Contact on the speed of relative motion. It depends on the nature of surface & Normal force.

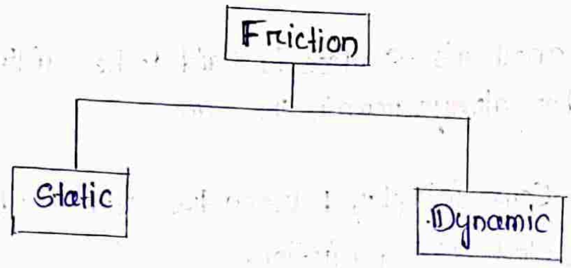


ORIGIN OF FRICTION

→ Friction originels from relative motion between 2 rough surfaces in close Contact.

→ Friction is Cause by the adhesive force of one surface to the other.

TYPES OF FRICTION



STATIC FRICTION

The frictional force which keeps the body by opposing relating motion between the 2 surfaces is Called static friction.

When a force is applied on a body but the body doesn't move the frictional force is already active & opposing the motion. As the applied force on the body is increased the static friction(f_s) also increases.

LIMITING FRICTION (f_s max)

The maximum force of static friction when the body just starts moving is Called limiting friction.

$$\boxed{f_s \leq f_s^{max}}$$

Once the motion began the force of friction decreases.

DYNAMIC/KINETIC FRICTION

The force acting between the surface in relative motion is Called force of kinetic/ Dynamic friction.

Once the body starts moving the forces of Kinetic friction remains Constant & it is less than maximum forces of static friction.

TYPES OF KINETIC FRICTION

1) Sliding Friction
2) Rolling Friction
3) Fluid Friction

SLIDING FRICTION

The motion of a body over another's surface is said to be sliding if the points of contact of first body with other always remain the same.

⇒ The force of friction which come into play between two surface when one tends to slide over the other is called sliding friction.

⇒ The force of friction that arises when a body slides over the surface of another body is called sliding friction.

Ex :- when a box is pull or push on a horizontal surface.

ROLLING FRICTION

Motion of a body over another's surface is said to be rolling if its point of contact with the other keeps on changing continously & its centre of gravity also moves forward.

⇒ Force of friction which comes into play, between two surfaces, while one is rolling over the other is called rolling friction.

⇒ The force of friction that arises when a body rolls over the surface of another body is called Rolling friction.

Note :- Rolling friction is smaller than sliding friction.

FLUID FRICTION

⇒ The friction arises when the body is inside a fluid that force of friction is called Fluid friction

⇒ Fluid friction is the opposing force which comes into play when a body moves through a fluid.

Ex :- An aeroplane is flying in the sea of Air.

LAW OF FRICTION

* The frictional force depends on the nature of the surfaces in contact & the condition of the surfaces, i.e polish, roughness & dry or wet.
* The force of friction acts tangential to both the surface in contact & in a direction opposite to the direction of motion.
* The frictional force is directly proportional to the normal reaction.

$$f_s \propto R_N$$

$$\Rightarrow f = \mu R_N$$

$$\Rightarrow \mu = \frac{f}{R_N} \quad (\mu = \text{Coefficient of friction})$$

* The frictional force is independed of the speed of sliding. (only for dynamic Friction)

Static Friction

$$f_s^{max} \propto R_N$$

$$f_s^{max} = \mu_s R_N$$

$$\mu_s = \frac{f_s}{R_N}$$

Dynamic Friction

$$f_K \propto R_N$$

$$f_K = \mu_K R_N$$

$$\mu_K = \frac{f_K}{R_N}$$

$$\mu = \frac{\text{Limiting Friction}}{\text{Normal Reaction}}$$

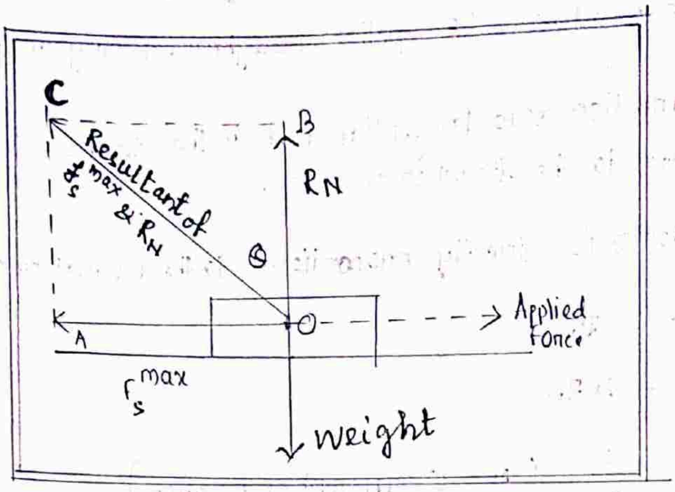
⇒ The proportionality constant μ_s is called Coefficient of friction.

$$f_K < f_s^{max}$$

$$\mu_K R_N < \mu_s R_N$$

$$\Rightarrow \mu_K < \mu_s$$

ANGLE OF FRICTION



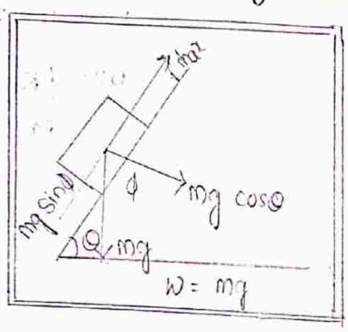
The angle of friction may be defind as the angle which the resultant of the limiting friction & the Normal reaction makes with the normal reaction.

From the diagram, ΔOCB $\tan = \frac{BC}{OB} = \frac{f_s^{max}}{R_N} = \mu_s$

$\Rightarrow \tan\theta = \mu_s$

Tanjent of the angle of friction = coeffcient of static friction.

ANGLE OF REPOSE.



it is the minimum angle that an inclined plane makes with the horizontal when a body placed on it just began to slide down.

From the diagram $R_N = mg\cos\theta$ - - - (i)

$f_s max = mg\sin\theta$ - - (ii)

Now devide Equation (ii) by Equation (i)

$\frac{f_s}{R_N} = \frac{mg\sin\phi}{mg\cos\phi} = \tan\phi$

$\Rightarrow \tan\phi = \mu_s = \tan\theta$

$\Rightarrow \phi = \theta$

Thus,

Angle of friction is equal to Angle of Repose.

METHODS OF REDUCING FRICTION

Friction can be reduced if we try to remove the cause of friction.

(i) By rubbing & polishing :- By rubbing, the irregularities of the surface are smoothened.

(ii) By lubricant :- Lubricant is an oil when spread over to surfaces fills the irregularities & forms a thin layer between them, thus avoiding their interlockings.

(iii) By converting sliding into rolling friction :- If we slide a heavy object, on the floor we require a big force. On the otherhand, if we put it on wheels we can move it easily.

(iv) By streamlining :- As a body is driven through fluid, fluid friction is depends on the body. It is minimum for a shape known as streamlined shape.

OSCILLATIONS & WAVES

PERIODIC MOTION

⇒ The motion of a body is said to be periodic it passes through similar Conditions after equal intervals of time.

⇒ A motion that repeats itself identically after an equal interval of time is called periodic motion.

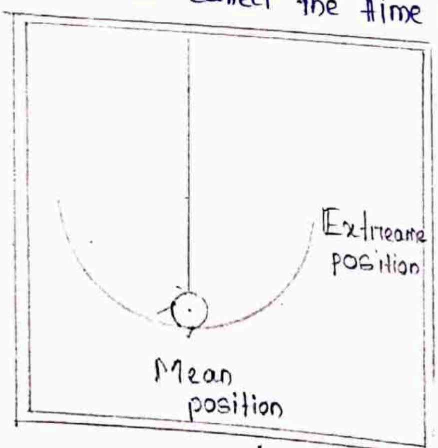
EX :-

(i) Rotation of earth around the sun.
(ii) Rotation of an electron around the nucleous.
(iii) Vibrations of the prongs of a tuning fork.
(iv) Vibrations of a streached string.

⇒ The fixed interval of time after which the motion is repeated is called the time period of the motion.

OSCILLATORY MOTION

Oscilatory motion is that motion in which the body moves to & Fro or Back & forth repeatedly about a fixed point called the mean position in a definite interval of time called the time period of motion.



⇒ The motion is confined within 2 fixed points known as the extreme points.

EX :- (i) pendulum of a clock.
(ii) Motion of a swing.
(iii) oscillation of spring.

Note :- All periodic motion are not oscillatory all oscillatory motions are periodic.

⇒ Essential requirement for a periodic motion to be oscillatory is the presence of mean position or equilibrium position.

HARMONIC MOTION

Harmonic motion is that oscillation or vibration which can be expressed in terms of harmonic functions like sin or cosine function of an angle that depends on time.

$$\omega = \frac{\theta}{t}$$

$$\Rightarrow \theta = \omega t$$

SIMPLE HARMONIC MOTION

⇒ Simple harmonic motion is the motion in which in which the restoring force is proportional to displacement from the mean position & oppose its increase.

⇒ The oscillation in which the displacement from the mean position can be expressed as a single harmonic function like sin or cosin Function is called simple harmonic motion (SHM).

⇒ It is that to & Fro motion in which the acceleration of the body is directly proportional to the displacement of the body from the mean position.

$$F \propto x$$

$$F = -Kx$$

where F = Restoring Force

& K = Force constant, Spring Constant.

Equation of SHM

$$F = -Kx$$

$$\Rightarrow ma = -Kx$$

$$\Rightarrow m\frac{d^2x}{dt^2} = -Kx$$

$$\Rightarrow \frac{d^2x}{dt^2} = -\frac{K}{m}x$$

$$\Rightarrow \frac{d^2x}{dt^2} + \frac{K}{m}x = 0$$

$$\Rightarrow \frac{d^2x}{dt^2} + \omega^2 x = 0$$

$$\omega^2 = \frac{K}{m} \quad \therefore \omega = \sqrt{\frac{K}{m}}$$

The solution of the different equation.

$$x = A\cos(\omega t + \phi_0)$$

$$x = A\sin(\omega t + \phi_0)$$

where ϕ_0 is called the ~~interval~~ initial phase.

Velocity of SHM

$$V = \frac{dx}{dt} = -A\omega\sin(\omega t + \phi_0)$$

$$= -A\omega\sqrt{A^2 - x^2}$$

$$V = -\omega\sqrt{A^2 - x^2}$$

$$\Rightarrow \cos(\omega t + \phi_0) = \frac{x}{a}$$

$$\sin(\omega t + \phi_0) = \sqrt{1 - \frac{x^2}{A^2}} = \sqrt{\frac{A^2 - x^2}{A^2}}$$

At mean position, $x = 0$

$$V_{max} = -\omega A \cdot V_{min} = 0$$

Direction of velocity is either towards or away from the mean position.

Acceleration

$$a = \frac{dv}{dt}$$

$$a = -A\omega^2\cos(\omega t + \phi_0)$$

$$\boxed{a = -\omega^2 x}$$

Mean position

$$a_{min} = 0$$

Extreame

$$\boxed{a_{max} = \omega^2 A} \quad x = A$$

WAVES

⇒ The disturbance that moves through a medium because of which energy transmission between different part of the medium takes place without the actual physical transfer or flow of matter of the medium are called waves.

⇒ Wavemotion is the disturbance that travels through the medium & is due to repeated periodic motion of the particles of the medium, the motion being handed over from particle to particle.

⇒ The motion of a wave in a medium is due to transfer of energy between adjacent particles of the medium.

Note :- The medium should be Elastic must posses inertia & offer minimum resistance to wave motion.

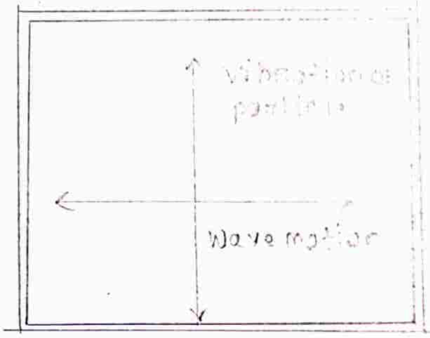
Ex :- Sound, waves, waves on string, waves on water surface.

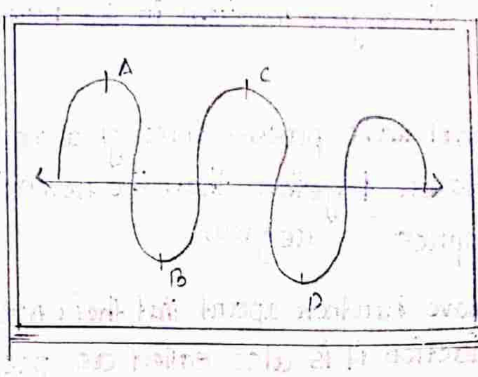
PROPAGATION OF WAVE MOTION

(i) TRANSVERSE WAVES

It is the type of wavemotion in which the particles of the medium are vibrating in a direction at right angles to the direction of propagation.

⇒ When the particles of the medium vibrate $\perp^{r}$ to the direction of propagation of the wave, that wave is called transverse wave.





Ex :- Waves on strings, waves on water surface.
Electromagnetic waves, Movement of guitar string.

Crest :- A crest the portion of the medium which is raised above the normal level of the surface when a transverse wave passes through it.

⇒ The centre of the crest is maximum +(ve) Displacement (A, C)

Trough :- A trough is the portion of medium which is depressed below level of the surface when a transverse wave passes through it.

⇒ The centre of the trough is maximum -(ve) Displacement (B, D)

⇒ Transverse wave can pass through solid & surface of the liquid medium.

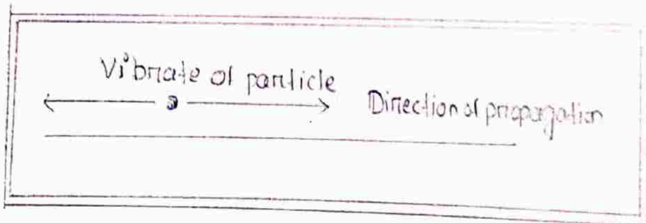
⇒ Mechanical transverse wave can't pass through gaseous medium.

(ii) LONGITUDINAL WAVES

It is the type of wavemotion in which the particles of the medium vibrate in the direction of propagation of wave.

⇒ When the particle of the medium vibrate parallel to the direction of propagation of wave. that wave is called longitudinal wave.

Ex :- Sound wave



⇒ Longitudinal travel through a medium in the form of alternate compression & rarefraction.

⇒ When a longitudinal wave passes through a medium particles of some layers come closer together than the normal separation that region is called compression region.

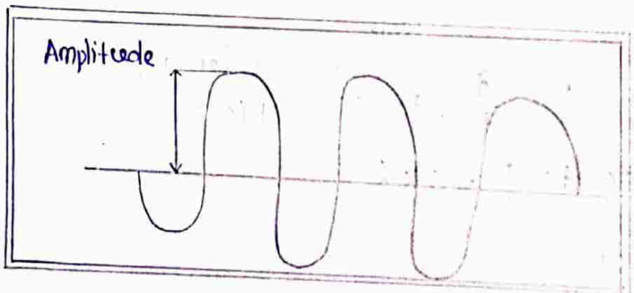
⇒ when the particles move further apart that their normal separation that region is called rarefraction it is also called as pressure waves.

TRANSVERSE WAVE	LONGITUDINAL WAVE
1) It is perpendicular to the medium	1) It is parallel to the medium.
2) Transverse wave consist of alternate crest & trough moving forward.	2) It is consist of alternate Compression & rarefraction moving forward.
3) The propagation of transverse wave through a medium Causes a temporary change in the shape of medium.	3) The propagation of longitudinal wave through a medium causes temporary change in the size of medium.
4) It travel through solid & over the liquid surface of the medium.	4) It passes through all medium, solid liquid, & gaseous.
5) It can be poralised.	5) It can't be poralised

WAVE PARAMETERS

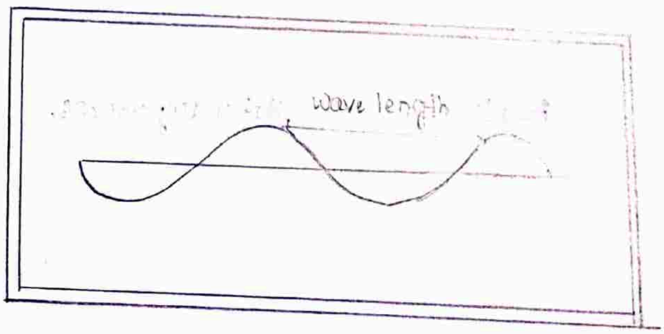
Amplitude

The maximum displacement of a particle in the medium from its mean position when a wave passes through it (medium) is called as the amplitude of the wave.



Wave length

Wavelength is defind as the distance travelled by a wave okerring the time particle executing SHM Completes 1 vibration it is denoted as λ (lambda).



⇒ It is the distance between two Consecutive particles executing SHM in same phase

⇒ It is the distance between two Consecutive crests/trough.

Frequency

It is the number of complete vibrations performed by a particle in 1 sec.

unit :- Hz

Time period

It is the time taken by a particle to complete one vibration.

$$f = \frac{1}{T}$$

Wave velocity

It is the distance travelled by a wave through a medium in one second.

Wave number

It is the resiprocal of wavelength & is defind as the number of waves in unit distance. $\left(\frac{1}{\lambda}\right)$.

Relation between Velocity, Frequency & wave length

We know that wave velocity $(v) = \frac{\text{distance}}{\text{Time}}$

$$v = \frac{\lambda}{t} = \frac{\text{wave length}}{\text{time}}$$

$$\Rightarrow \lambda \times \frac{1}{T} = \lambda \times f$$

$$\therefore \boxed{v = \lambda f}$$

Super position of wave

- Interferance
- Beats
- Stationary waves.

PROGRESSIVE WAVE	STATIONARY WAVE
1) Each particle of the medium communicate disturbance to the next particle.	1) Disturbance is not communicated from one particle to the next it remains Fixed.
2) Amplitude of each particle is same.	2) Amplitude of different particles is different. It is maximum at antinodes & is zero at nodes.
3) Consecutive particles reach the maximum displacement position at different times.	3) At the particle in between consecutive nodes reach the position of maximum displacement simultaneously.
4) There is a gradual change of phase from one particle to the next.	4) phase of all particles, in one segment, is same & is opposite to those in the next segment.
5) No particle is permanently at rest Every particle comes to rest momentarily twice during each revolution.	5) particle at nodes are permanently at rest.
6) which passing through the mean position every particle acquires same maximum velocity.	6) Maximum velocity while they pass through their mean position, is different for different particles. it is greatest for particles at anti-nodes since they posses the biggest amplitude.
7) Every region passes, successively through crests & through compression & rarefraction.	7) Crests & through or compression & rarefraction remain fixed in their position.
8) There is a flow of energy across any cross - section of the medium.	8) There is no flow of energy across any cross-section of the medium.

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ULTRASONIC

Having a frequency above the human ears audibility limit of about 20000Hz - used of waves & vibrations.

PROPERTIES OF ULTRASONIC

(i) Ultrasonic waves are longitudinal in nature.

(ii) propagation of ultrasonic through a medium results in the formation of Compression & rarefraction.

(iii) These are waves of very high frequency having a range of 2×10^4 to 10^8Hz.

(iv) They travel with the speed of sound.

(v) Since the energy of sound is proportional to the square of their frequency.

(vi) Ultrasonics are highly energetic waves.

(vii) Due to their much smaller wavelength, ultrasonics do not spread that much as audiable sound wave do, so ultrasonics can constitute narrow beams.

(viii) passage of ultrasonic through a liquid results in a variation of density. (greater at nodes & lesser at anti-nodes. such a liquid can be used as different gratting to produce diffraction of light.

APPLICATION OF ULTRASONIC

1. High powered ultrasonic pulses are radiated & received back after reflection from the obstacle. This method is known as Echo sounding. Depth of sea is generally determined by this method.

2. Thickness gauging :- The process of echo sounding can also be used to measure the thickness of rolled sheets in rolling mills.

3. Flaw detection :- Ultrasonics can be used for detection of internal defects, laminations & other defects inside a material.

4. Fuel gauging :- Ultrasonic are used to make an idea about the fuel present in rockets.

5. Velocity of ultrasonics :- $V = \sqrt{\frac{Y}{\rho}}$, Y is the Young's modulus of elasticity & ρ is the density of the material. knowing the velocity, the value of Y can be determined.

6. Ultrasonic waves can be used for welding. If two surfaces slide at ultrasonic frequencies, the amount of heat produced is large enough to weld the two materials.

7. Ultrasonic drilling is used for machining materials like aluminium & titanium alloys, glass, mica, quartz etc.

8. Ultrasonics are capable of destroying bacteria & small insects.

9. Ultrasonics, in some cases, act as catalytic agent.

10. Using the echo technique, ultrasonic waves are used in detecting tumors, abnormal growth in the body.

HEAT & THERMODYNAMICS

HOT & COLD BODIES

When we rub our hands some time, they become warm when a block sides on a rough surface it becomes warm when a vehicle collide with each other during an accident; they became very hot when an aeroplane crashes. It becomes so hot that it catches fire.

In each of these examples mechanical energy is lost & the bodies become hot the mechanical energy converts into the internal energy of the bodies. Thus we conclude that cold bodies absorb energy to become hot in other words, a hot body has more internal energy than a cold body.

CONCEPT OF HEAT

When a hot body is kept in contact with a cold body the cold body warms up & the hot body cools down. The internal energy of the hot body decreases & the internal energy of the cold body increases. Thus, energy is transformed from the hot body to the cold body when they are placed in contact but no mechanical work is done during this transfer of energy.

The transfer of energy from a hot body to cold body is a non-mechanical process. The energy, that is transformed from one body to the other, without any mechanical work, involved, is called heat.

" Thus we can define heat as something which flows from a body at higher temprature to another body at lower temprature. The two bodies may or may not be in contact with each other.

Heat produces the sensation of hotness or coldness in a body when a hot copper ball is droped into a beaker containing water, the water become hot & the copper ball, cools down till the temprature of the two becomes equal.

UNIT OF HEAT

As heat is just energy in transit its SI unit is Joule. Another unit of heat is calorie.

The amount of heat needed to raise the temprature of 1 gm of water from 14.5°C to 15.5°C at a pressure of 1 atm is called 1 calorie.

$\boxed{1 \text{ cal} = 4.186 \text{ Joule}}$ $\boxed{\text{Dimension of heat} = [M^1 L^2 T^{-2}]}$

THERMAL EQUILIBRIUM

Two bodies in thermal contact are said to be in thermal equilibrium when there is no flow of heat energy. between them. when two bodies at different tempratures are kept in contact with each other heat flows from the body at higher temprature to the body at lower temprature. till their tempratures become equal, though the heat contact of the hot body is different from the heat content of the cold body (May be less greater or equal).

The direction of heat flow is determined by the temprature difference, but not by the amount of heat of inside a body.

ZEROTH LAW OF THERMODYNAMICS

If two systems are in thermal equilibrium with a 3rd system separated then they are in thermal equilibrium with each other.

According to this law, when two systems 'A' & 'B' are separately in thermal equilibrium with a 3rd system 'C' then system 'A' & 'B' are in thermal equilibrium with each other.

The Zeroth law allows us to introduce the concept of temprature to measure the hotness or coldness of a body when 'A' & 'B' are in thermal equilibrium.

$$T_A = T_B$$

when B & C are in thermal equilibrium.

$$T_B = T_C$$

Thus $T_A = T_C$

where T indicates the temprature of the system.

CONCEPT OF TEMPRATURE

The degree of hotness or coldness of a body is called the temprature of the body.
Temprature difference determine the direction of flow heat energy.
Temprature is a scalar quantity the instrument that it used to measure the temprature of a body is called a thermometer.
A thermometer uses the property of a substance that changes with temprature to measure the unknown temprature.

SI unit of temprature Kelvin (K).

SCALES OF TEMPRATURE

Generally 4 scales of temprature are used.

(i) The Centigrade or celcious scale. (°C)
(ii) Farehhite Scale (°F)
(iii) Reumer Scale (°R)
(iv) Kelvin Scale (K)

Comparision of the temprature s

Comparision of the temprature scales:-

	Celcious	Kelvin	Farehnite	Reumer
Lower fixed point (LFP) or melting point of ice.	0	273	32	0
Upper fixed point (UFP) or Boiling point of water	100	373	212	80

The general convension equation is

$$\left(\frac{\text{Reading} - \text{LFP}}{\text{U.F.P} - \text{L.F.P}}\right)_{\text{Scale-1}} = \left(\frac{\text{Reading} - \text{L.F.P}}{\text{U.F.P} - \text{L.F.P}}\right)_{\text{Scale-2}}$$

$$\Rightarrow \frac{C-0}{100-0} = \frac{K-273}{373-273} = \frac{F-32}{212-32} = \frac{R-0}{80-0}$$

$$\Rightarrow \frac{C}{100} = \frac{K-273}{100} = \frac{F-32}{180} = \frac{R}{80}$$

$$\Rightarrow \frac{F-32}{9} = \frac{C}{5} = \frac{R}{4}$$

THERMAL EXPANSION OF SOLID

The change of size of a body due to the change in the temprature is called thermal expansion.

Solids are made up of atoms & molecules which are located at some equilibrium distances from each other at a given temprature when a solid is heated this equilibrium distance increases to elastic vibrations thus effective in atomic separation increases. This is how thermal expansion occurs.

when a solid is heated its length, breadth & height will increases so thermal expansion of solid can be treated in 3 ways.

1. Linear or Longitudinal expansion,
2. superficial or Area expansion.
3. Cubical or Vollume expansion.

1. LINEAR EXPANSION

This is known as expansion along one dimension when a solid is heated its length increases.

Let L_0 be the length at $0^\circ C$

If it is heated to $T^\circ C$, its length becomes L_T.

This increase in length $\Delta_L = L_T - L_0$ is directly proportional to

(i) Original length L_0 at 0°

(ii) Rise in temprature Δ_T

Hense $\Delta_L \propto L_0$

$\Delta_L \propto \Delta_T$

So Combinely - $\Delta_L \propto L_0 \Delta_T$

$\Rightarrow \Delta_L = \alpha L_0 \Delta_T$ - - - (i)

Here $\Delta_L = \alpha . L_0 (T-0)$

$\Rightarrow L_T - L_0 = \alpha L_0 T$

$\Rightarrow L_T = L_0 + \alpha L_0 T$

$\Rightarrow L_T = L_0 (1 + \alpha T)$ - - - (ii)

This is the final length of the body at temprature

From equation (i) $\alpha = \dfrac{\Delta_L}{L_0 \Delta_T}$

where α is called the co-efficient of linear expansion The linear expansion co-efficient can be defind as the rate of unit length per unit degree change in temprature.

unit of α = $^\circ C^{-1}$, K^{-1}, per $^\circ c$, per $^\circ K$

$\left(\dfrac{1}{^\circ C}, \dfrac{1}{Kelvin}\right)$

Dimension of α = $[M^0 L^0 T^0 K^{-1}]$

2 SUPERFICIAL OR AREA EXPANSION

This is known as expansion along two dimensions when a is heated its surfaces area or cross sectional area increases.

Let A° be the area at $0^\circ c$

if it is heated to $T^\circ c$, its Area becomes A_T

The increase in area $\Delta_A = A_T - A_0$ is directly propertional to

(i) Original area A_0 at 0°

(ii) Rise in temprature Δ_T

Hence $\Delta_A \propto \Delta_0$

$\Delta_A \propto \Delta_T$

So $\Delta_A \propto A_0 \Delta_T$

$\Rightarrow \Delta_A = \beta A_0 \Delta_T$ - - - -(i)

Here $A_T - A_0 = \beta A_0 (T-0)$

$\Rightarrow A_T = A_0 + \beta A_0 T$

$\Rightarrow A_T = A_0 (1 + \beta T)$ - - -(ii)

This is the final area of the body at temprature T.

From equation (i)

$$\beta = \frac{1}{A^\circ} \left(\frac{\Delta A}{\Delta T} \right)$$

where β is called co-efficient of superficial expansion.

The co-efficient of superficial expansion (β) can be defind as the increase in area per unit degree rise of temprature it has same unit & dimension as α.

3. CUBICAL OR VOLUME EXPANSION

This is known as expansion along three dimensions. When a solid is heated its volume increases.

Let V_0 be the volume at $0°C$.

If it is heated to $T°C$, its volume becomes V_T.

The increase in volume $\Delta V = (V_T - V_0)$ is directly proportional to

(i) Original volume at $0°C$

(ii) Rise in temprature ΔT.

Hence $\Delta V \propto V_0$

& $\Delta V \propto \Delta T$

so $\Delta V \propto V_0 \Delta T$

$\Rightarrow \Delta V = \gamma V_0 \Delta T$ - - - (i)

Here $V_T - V_0 = \gamma V_0 (T - 0)$

$\Rightarrow V_T = V_0 + \gamma V_0 T$

$\Rightarrow V_T = V_0 (1 + \gamma T)$

This is the final volume of the body at temprature T.

From equation (i)

$$\gamma = \frac{1}{V_0}\left(\frac{\Delta V}{\Delta T}\right)$$

where γ is called the coefficient of cubical expansion. The coefficient of cubical expansion (γ) can be defind as the increase in volume per unit volume per unit rise of temprature it has same dimension as α & β.

RELATION BETWEEN EXPANSION COEFFICIENTS.

We know that $\alpha = \frac{1}{L}\left(\frac{dL}{dT}\right)$

$$\beta = \frac{1}{A}\left(\frac{dA}{dT}\right)$$

$$\gamma = \frac{1}{V}\left(\frac{dV}{dT}\right)$$

(i) RELATION BETWEEN α & β :-

$$\beta = \frac{1}{A}\left(\frac{dA}{dT}\right)$$

We can write $A = L^2$

$$\text{so } \beta = \frac{1}{L^2} \cdot \frac{dL^2}{dT}$$

$$= \frac{2L}{L^2} \frac{dL}{dT}$$

$$= 2 \times \frac{1}{L}\left(\frac{dL}{dT}\right)$$

$$\Rightarrow \boxed{\beta = 2\alpha}$$

Thus the coefficient of superficial expansion of a solid is twice the value of the co-efficient of linear expansion.

(ii) RELATION BETWEEN α & γ

$$\gamma = \frac{1}{V}\left(\frac{dV}{dT}\right)$$

We can write $V = L^3$

$$\text{so } \gamma = \frac{1}{L^3} \cdot \frac{dL^3}{dT}$$

$$= \frac{3L^2}{L^3} \cdot \frac{dL}{dT}$$

$$\Rightarrow \gamma = 3 \times \frac{1}{L}\left(\frac{dL}{dT}\right)$$

$$\Rightarrow \boxed{\gamma = 3\alpha}$$

Thus the coefficient of cubical expansion of a solid is thrice than the coefficient of linear expansion.

Hence we have $\beta = 2\alpha$ & $\gamma = 3\alpha$

$$\Rightarrow \alpha = \frac{\beta}{2} \text{ \& } \alpha = \frac{\gamma}{3}$$

$$\therefore \boxed{\alpha = \frac{\beta}{2} = \frac{\gamma}{3}}$$

WORK & HEAT

It is observed that heat is produced when mechanical work is done on a system. For example when we rub our hands, work is done to overcome the force of friction which is converted into heat energy & we feel the hotness. so heat & work are related to each other.

According to the 'dynamical theory of heat' heat is contained in the body in the form of molecular motion. Thus heat ~~can be~~ is said to be a form of 'mechanical energy.'

Joule after doing a series of experiments found that the molecular motion due to mechanical work done on a system, results in production of heat. so he included that there is an equivalence between work & heat.

According to Joule "Whenever a work is converted into heat or vice versa, the quantity of work dissapearing in the system is equivalent to quantity of heat appearing in that system."

Thus work (W) & heat (Q) are found to be directly proportional to each other.

$W \propto Q$

$\Rightarrow W = JQ$

This constant of proportionality J is called mechanical equivalent of heat.

$$J = \frac{W}{Q}$$

when $Q = 1$, $J = W$

Hence the mechanical equivalent of heat is defind as the amount of mechanical work done to produce unit quantity of heat.

If W is measured in Joule & heat is measured in calorie, then

$J = 4.186$ Joule/cal (M.K.S system)

$J = 1$ (S.I system)

$J = 4.186 \times 10^7$ erg/cal (C.G.S unit)

Thus J is constant for a system of unit & has no dimension.

THERMODYNAMICS

Thermodynamics → Thermo + dynamic

= Heat + mechanical motion.

Thermodynamics is that branch of physical in which we study the processes involving heat & its conversion into work.

THERMODYNAMICAL TERMS

1) System :- A mechanical system is any fixed quantity of matter contained in a definite region in space.

2) Surrounding or environment :- Everything outside the system which has a direct effect on the behaviour of the system is known as the surrounding or environment.

3) open system :- when a system exchanges matter & energy with its surroundings, it is called an open system.

4) Closed system :- when a system exchanges only energy but not matter with its surroundings, it is called closed system.

5) Isolated system :- when a system neither exchanges energy nor matter with its surroundings, it is called isolated system.

6) Isobaric system :- The thermodynamic process in which pressure remains constant. (P is constant)

7) Isochoric system :- Thermodynamic process in which volume remains constant (V is constant)

8) Isothermal process :- The thermodynamic process in which temprature remains constant. (T is constant).

9) Adiabatic process :- Heat energy of the system is constant.

(Q is constant)

WORKDONE IN A THERMODYNAMIC PROCESS

Workdone in a thermodynamic process is given by

$$dW = p.dV = \text{pressure} \times \text{change in volume}$$

Workdone by the system is always positive.
Workdone on the system is always negative.

$$dW = p(V_2 - V_1)$$

FIRST LAW OF THERMODYNAMICS

The amount of heat supplied to a system is equal to the sum of the increase of its internal energy & external work done by it.

Consider some gas enclosed in a container having insulating walls & conducting buttons.

Let Q amount of heat is supplied to the system through the button. If U_1 is the initial energy of the system, total energy of the system in the beginning $= U_1 + Q$ After gaining heat the gas tends to expand, pushing the piston from A to B,

As a result of this, some work 'W' is done by the gas.

If U_2 is the final internal energy of the system, then total energy at the end $= U_2 + W$

If the supplied heat (dQ) is very small in quantity then there is a very small increase in internal energy (du) & very small work done (dw).

then $dQ = du + dw$

$$\Rightarrow dQ = du + pdv$$

This equation is known as mathematical formulation of 1st law of thermodynamics.

The first law is an example of principle of Conservation of energy.

This law applies equally to all the 3 states of matter again 1st law indicates that it is impossible to get work from any machine without giving an equivalent amount energy to it.

SPECIFIC HEAT

Specific heat of a substance is defined as the amount of heat required to raise the temprature of unit mass of the substance through one degree.

If ΔQ is the amount of heat energy required to raise/increase the temprature of a body of mass m through a small change in temprature ΔT, then it is observed that

$$\Delta Q \propto m, \text{ when } \Delta T \text{ is Constant}$$

$$\Delta Q \propto \Delta T, \text{ when m is Constant}$$

$$\Delta Q \propto m\Delta T, \text{ when both vary}$$

$$\Rightarrow \boxed{\Delta Q = ms\Delta T}$$

where s is called the specific heat of the body.

$$\boxed{s = \frac{\Delta Q}{m\Delta T}}$$

In other words, $\boxed{Q = ms(T_2 - T_1)}$

UNIT

C.G.S System :- $cal\, gm^{-1}\, {}^\circ c^{-1}$

S.I unit :- $J\, kg^{-1}\, K^{-1}$

1 cal : 4.186 J

so $1 \text{ cal } gm^{-1}\, {}^\circ c^{-1} = 4.186 J \times 1000\, kg^{-1}\, K^{-1}$

$\Rightarrow 1 \text{ cal } gm^{-1}\, {}^\circ c^{-1} = 4186\, J\, kg^{-1}\, K^{-1}$

DIMENSION

$$[s] = [M^0 L^2 T^{-2} K^{-1}]$$

Imp

specific heat of water = $1 \text{ cal } gm^{-1}\, {}^\circ c^{-1}$

ice = $0.5 \text{ cal } gm^{-1}\, {}^\circ c^{-1}$

steam = $0.47 \text{ cal } gm^{-1}\, {}^\circ c^{-1}$

MOLAR SPECIFIC HEAT

Molar specific heat of a substance is defind as the amount of heat required to raise the temprature of one mole of the substance through one degree.

If a body contains n mode of the substance is required ΔQ amount of a heat to raise the temprature through ΔT, then

$$\boxed{\Delta Q = nc\Delta T}$$

where c is called molar specific heat.

$$\boxed{C = \frac{\Delta Q}{n\Delta T}}$$

UNIT

C.G.S :- Cal mol^{-1} $°C^{-1}$

S.I :- J mol^{-1} K^{-1}

Dimension :- $[M^1L^2T^{-2}K^{-1}]$

LATENT HEAT

The heat i.e supplied during change of phase is not used to increase the temprature but to change the internal structure of the substance, this heat is called latent heat.

OPTICS

⇒ optics is the branch of physics that studies the behaviour & properties of light, including the interactions with matter & the construction of instruments that use or detect it.

⇒ optics usually describes the behaviour of visible, ultraviolet & infrared light.

Optics

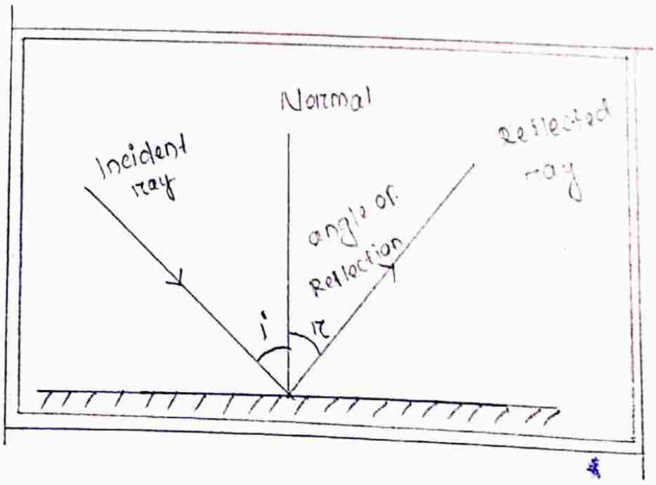
- physical optics (wave optics)
- Geometrical optics (Ray optics)

Source :- self Luminous
non- Luminous

Medium :- (i) Transparent
(ii) Transluscent
(iii) opaque.

REFLECTION

The phenomenon of returning back of light from the boundary of a medium/ The interface between 2 media into the 1st medium is called reflection of light.



LAWS OF REFLECTION

There are 2 laws of reflection which are given below.

(i) The incident ray the reflected + the normal to the reflecting surface at the point of incidence, all lie in one plane + that plane is $\perp^r$ to the reflecting surface.

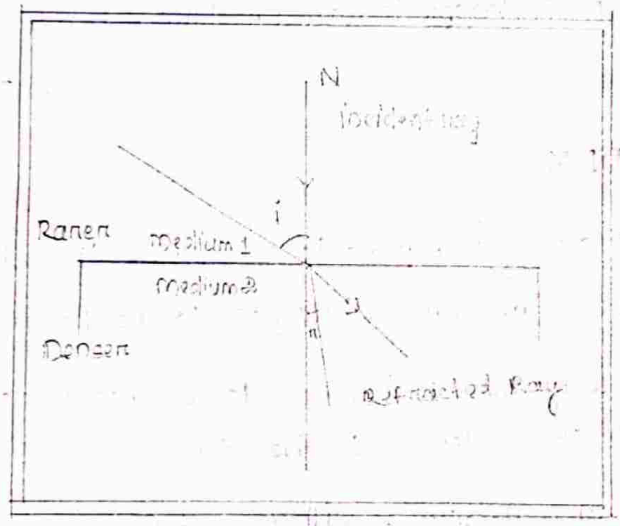
(ii) The angle of incidence is equal to the angle of reflection.

i.e $\angle i = \angle r$

REFRACTION

Snell's law

$$\frac{\sin i}{\sin r} = \text{Constant} = {}^1\mu_2$$



DEFINITION

⇒ Refraction is the phenomenon in which a ray of light going from one medium to the other undergoes a change in it's direction due to a change in it's velocity.

⇒ The ray which approaches the interface/Boundary is called incident ray & the ray which goes 2nd medium is called Refracted Ray.

⇒ Velocity of Light is different in different medium.

LAWS OF REFRACTION

(1) The incident ray, the refracted ray & the normal to the interance at the point of incident all lie in one plane & that plane is perpendicular to the interface separating the two lines.

(2) The sine of the angle of incidence bears a constant ratio with the sine of the angle of refraction for the two same pair of media & same colour of light.

$$\frac{\sin i}{\sin r} = \text{Constant}$$, this law is known as Snell's law

Notes

(i) From a beam of light incident perpendicular to the surface there is no change of path. For beam going from rarer to denser medium bends towards the normal.

(ii) For a beam going from denser to rarer medium it bends away from the normal.

REFRACTIVE INDEX

According to snell's law $\frac{\sin i}{\sin r}$ equals to constant = ${}^1\mu_2$ where ${}^1\mu_2$ is called the refractive index of 2nd medium withrespect to the 1st medium.

Refractive index of a medium withrespect to another is defind as the ratio between sin i (Angle of incidence) to the sin r.

⇒ Refractive index of a medium 2 withrespect to 1 is defind as the ratio between velocity of light in medium to the velocity of light medium 2.

i.e $$\boxed{{}^1\mu_2 = \frac{V_1}{V_2}}$$

If the first medium is air or Vacuum then the refractive index is known as Absolute refractive index (μ) it is the ratio of velocity of light in air 'c' to the velocity of light in a medium 'v',

$$\boxed{\mu = \frac{c}{V}}$$

$${}^1\mu_2 = \frac{V_1}{V_2} = \frac{V_1/C}{V_2 C}$$

We know that

$$\mu = \frac{c}{v}$$

$$\mu_1 = \frac{c}{v_1}$$

$$\Rightarrow \frac{1}{\mu_1} = \frac{v_1}{c}$$

$$\mu_2 = \frac{c}{v_2}$$

$$\Rightarrow \frac{1}{\mu_2} = \frac{v_2}{c}$$

So $\frac{1}{\mu_2} = \frac{\frac{1}{\mu_1}}{\frac{1}{\mu_2}} = \frac{\mu_2}{\mu_1}$

$$\boxed{{}^1\mu_2 = \frac{\mu_2}{\mu_1}}$$

From Snell's law $\frac{\sin i}{\sin r} = {}^1\mu_2 = \frac{\mu_2}{\mu_1}$

$$\boxed{\mu_1 \sin i = \mu_2 \sin r}$$

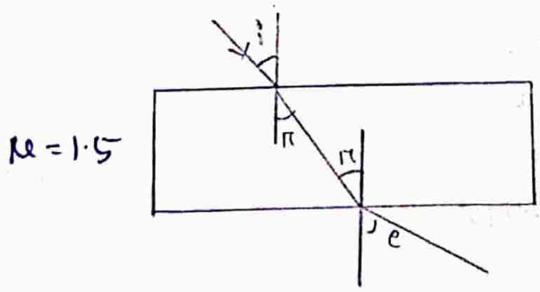
Refractive index (μ)

$$v = \lambda f$$

$$\frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = \frac{\lambda_1 f}{\lambda_2 f} = \frac{\lambda_1}{\lambda_2}$$

$$\boxed{\frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2}}$$

Prove that the angle of emergence is = the angle of incidence for a glass slab in air.



$\mu_1 \times \sin i = \mu_2 \sin r$

$\Rightarrow 1 \times \sin i = 1.5 \times \sin r$

$\Rightarrow \frac{\sin i}{\sin r} = 1.5$

$\mu_1 \sin r = \mu_2 \sin e$

$\Rightarrow 1.5 \sin r = 1 \times \sin e$

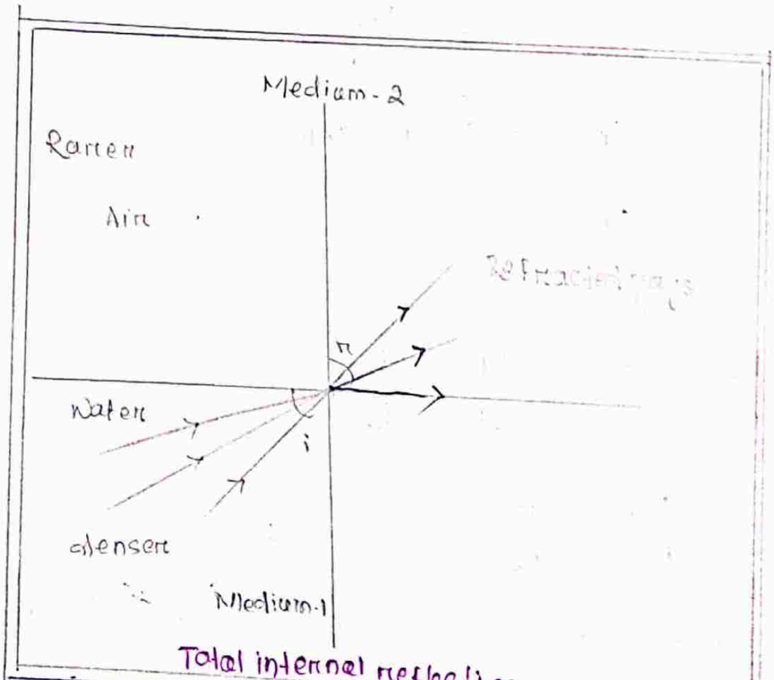
$\Rightarrow \sin e = 1.5 \sin r$

$\Rightarrow \sin e = \sin i$

$\Rightarrow e = i$ (prove)

TOTAL INTERNAL REFLECTION

CRITICAL ANGLE



Total internal reflection

$\mu_1 \sin i = \mu_2 \sin r$

$\Rightarrow \mu_1 \sin i = \mu_2 \sin r$

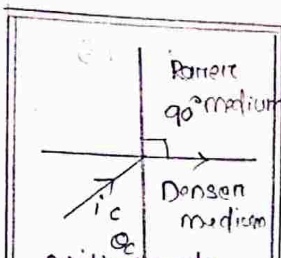
$\Rightarrow \mu_1 \sin i = \mu_2 \times \sin$

$\Rightarrow \mu_2 \sin c = \mu_2 \times \sin 90^\circ$

$\Rightarrow \mu_1 \sin i_c = \mu_2$

$\Rightarrow \sin i_c = \frac{\mu_2}{\mu_1}$

$\Rightarrow \sin i_c = \frac{1}{\mu_2} \quad \Rightarrow \mu = \frac{1}{\sin i_c}$



critical angle

The angle of incidence for which the angle of refraction is 90° is known as critical angle.

DEFINITION OF TOTAL INTERNAL REFLECTION

when a ray of light travels from denser medium to rarer medium it moves away from the normal so as the angle of incidence increases in the denser medium, the angle of refraction also increases. For a particular angle of incidence, the angle of refraction is 90°. This angle of incidence is known as critical angle.

Critical angle is the angle of incidence of a ray of light in denser medium such that its angle of refraction in the rarer medium is 90°.

If the angle of incidence of the ray is increased further, it is reflected back into the same medium. This phenomenon is called total internal reflection.

Total internal reflection is the phenomenon by virtue of which a ray of light travelling from a denser to a rarer medium is sent back in the same medium provided, it is incident on the interface at an angle greater than critical angle.

The rays, while suffering total internal reflection obey the laws of reflection.

MIRAGE

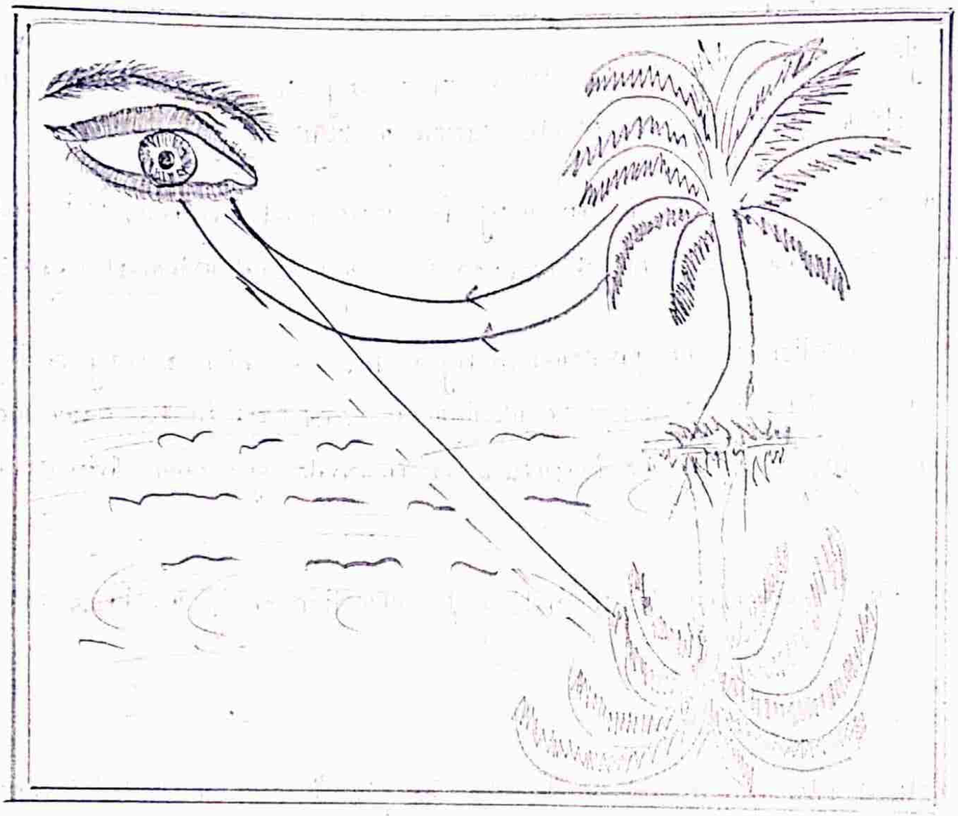
It is an optical illusion created due to the phenomenon of total internal reflection. There are two types of mirage, one observed in hot regions & the other observed in highly cold region.

a) HOT MIRAGE/INFERIOR MIRAGE

person travelling through hot deserts, sometimes, sees the presence of water at a distant place which is actually an optical illusion. The phenomenon is termed as inferior mirage surface of the earth in deserts is very hot. So air in the lower region of the atmosphere is hot as compared to that in higher regions. so the lower region of the atmosphere acts as a rarer medium & the higher region of the atmosphere acts as a denser medium.

As the atmosphere consists of layers of air, a beam starting from a tree & travelling downward finds it self going from a denser to rarer medium.

Therefore its angle of incidence at consecutive layers goes on increasing gradually till it surpasses the critical value & is reflected back due to total internal reflection. A virtual image of the object (tree) is formed. Due to the disturbance of air, the mirage is wavy in nature, thus giving an illusion for the pressure of water.

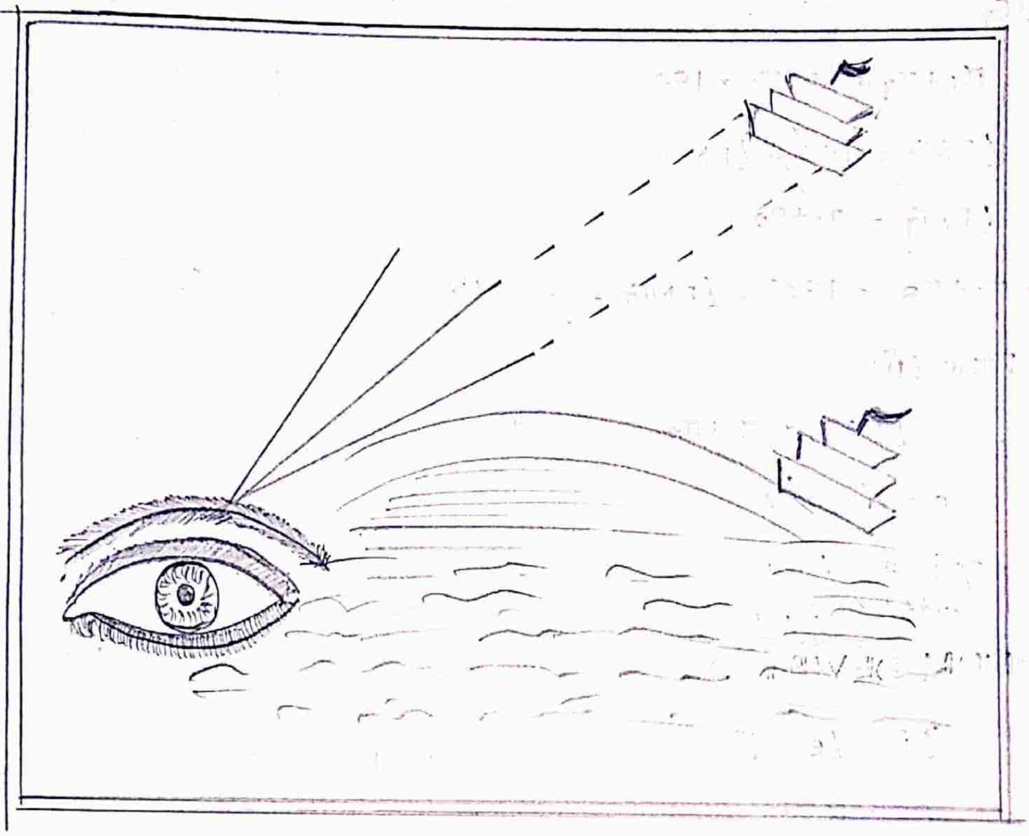


b) COLD MIRAGE / LOOMING / SUPERIOR MIRAGE

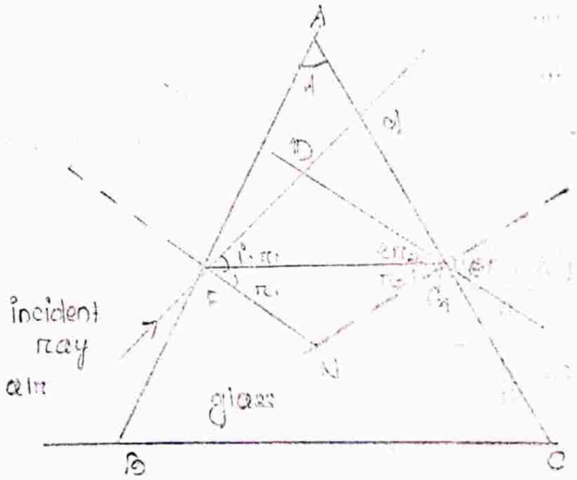
it is an optical illusion, seen, at seashore in winter evening, due to which an image of a ship is seen formed in air in sea-sky The actual ship is nowhere visible

It is due to total internal reflection. In cold evening, over sea-bed sea water becomes too cold. Air layer in its contact is cold & denser. As we go up, air layers becomes less & less colder & hence rarer.

Rays from invisible ship going upward go from denser to rarer air layers They are totally reflected downwards & received by an observer at sea-shore. The observer sees an image of the ship hanging in the sky.



REFRACTION THROUGH PRISM



$d = i - r_1 + e - r_2$

$d = i + e - (r_1 + r_2)$ - - -(i)

ΔFNG

$\angle FAG + \angle FNG = 180$ - - (ii)

$\angle AFN + \angle AGN = 180$ - - -(iii)

$\Rightarrow i + e = 180$ - - -(i)

ΔFNG

$$r_1 + r_2 + \angle FNG = 180^\circ$$

$$\angle FAG = 180^\circ - \angle FNG$$

$$\angle FAG = r_1 + r_2$$

$$\Rightarrow r_1 + r_2 = 180^\circ - \angle FNG \quad \text{---} (iv)$$

From (ii)

$$\angle FAG = r_1 + r_2 \quad \text{---} (v)$$

$$d = i + e - A$$

$$\Rightarrow i + e = A + d$$

MINIMUM DEVIATION

$$\angle i = \angle e$$

$$A = r + r$$

$$\Rightarrow r = \frac{A}{2}$$

$$(i + e)$$

$$i = e$$

$$\text{So } 2i = A + d_m$$

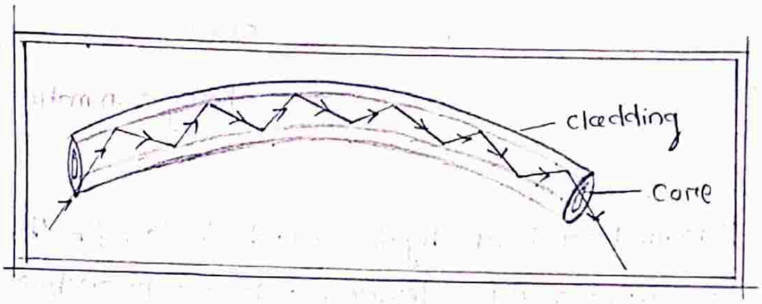
$$\Rightarrow i = \frac{A + d_m}{2}$$

$$\mu_1 = \frac{\sin i}{\sin r}$$

$$\mu = \frac{\sin\left(\frac{A + d_m}{2}\right)}{\sin \frac{A}{2}}$$

OPTICAL FIBRE

Glass fibre of diameter of 2 microns (2×10^{-6}m) are bundled together to prepare an optical fibre, also called as Light pipe.



Light energy propagates through the fibers by multiple total internal reflection. The core of the glass fibers are denser than the cladding (or surrounding) which is rarer. Hence the ray pass from denser to rarer media suffering multiple total internal reflection as shown in Figure.

In optical fibre, the information is transmitted in the form of light.

APPLICATIONS

1) Fiber optic cables transmit large amounts of data at very high speeds. This technology is therefore widely used in internet cable.
2) The optical fiber cables are used for transmitting signals for high defination (HD) televisions.
3) With the use of fiber optic communication, telephone calling can be faster & have clear conversation.
4) Networking between computers in a single building or across nearby structures is made easier & faster with the use of fiber optic cables.
5) optical fibers are also used in Medical Science to see internal sites of the human body for accurate location of the unwanted growths & their removal.
6) optical fibers are widely used in lighting decorations.
7) With high level of data security required in millitary & aerospace applications, fibre optic cables offer the ideal sollution for data transmission in these areas.

ELECTROSTATICS & MAGNETOSTATICS

Electricity

Electrostatics (charges at rest)

Electrodynamics (charges in motion)

ELECTRICITY :- It is the branch of physics which deals with the properties of charges. It is divided into two branches.

ELECTROSTATICS :- The study of properties of charges at rest is known as electrostatics.

ELECTRODYNAMICS :- It deals with the properties of charges in motion.

ELECTRIC CHARGE

An electric charge is a fundamental properties of elementary particles of matter which can explain certain forces of interaction & some types of interaction energies. Electric charge is a scalar quantity.

FRICTIONAL ELECTRICITY

The Greek philosopher Thales observed that if amber (a yellow resinous substance) is rubbed with a woollen cloth, it acquires some special properties of attracting small piece of paper, dust etc. towards it. Same phenomenon is observed in case a glass rod is rubbed with a silk cloth. Due to this property developed on amber & glass rod, it is said to have acquired electricity on itself.

The charge that developed on amber is known as resinous & the type of charge that developed on wool is known as vitreous.

American scientist Benjamin Franklin introduced a convention. Type of charge that developed on amber is known as Negative charge & type of charge that developed on wool is known as positive charge.

Hence only two kinds of charges are there i.e. positive & Negative.

The process of charging of bodies by friction is known as frictional electricity. Here there is actual transfer of electron from one body to another. A body which gains electron is known as negatively charged. A body which loses electron is said to be positively charged. Thus the charge of electron is conventionally taken as negative.

A body is said to be neutral if total amount of positive charge = total amount of negative charge.

PROPERTIES OF ELECTRIC CHARGE

1. Charge is a derived quantity in electricity & electricity & electric current is taken as fundamental quantity. $q = it$ or $i = \frac{q}{t}$
2. Charge is a scalar quantity having S.I unit coulomb & dimension [A T].
3. There are 2 & only two kinds of charges i.e the positive kind & the negative kind.
4. The charge on electron is chosen as negative & charge on proton is taken as positive by Benjamin Franklin.
5. Mass of electron $m_e = 9.1 \times 10^{-31}$ Kg
   Mass of proton $m_p = 1.67 \times 10^{-27}$ Kg
   charge on electron $q_e = -(1.6 \times 10^{-19})C$
   charge on proton $q_p = +(1.6 \times 10^{-19})C$
6. Quantization of charge :-
   charge is quantised.

   The smallest charge that exists in nature is the charge of electron.
   Every object contains the charge in the integral multiple of the charge of the charge of electron.

   $$\boxed{q = \pm ne}$$
7. Charge is additive
   The charge of a body is the algebric sum of all the charges inside the body.
   $q = 5e - 2e = 3e$

8. Conservation of charge.

Charge can neither be created nor be destroyed. only it transfers form one body to another body. The total charge remains constant.

9. charge of a body is independent of frame of reference.

10. On charging the mass of the body changes. when a body is negatively charged, it gains mass. where as when a body is positively charged, it loses mass.

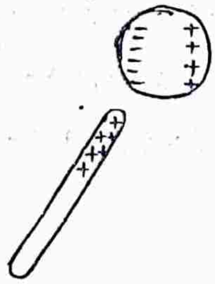
11. Like charges repel & unlike charges attract each other.

12. Charging by Conduction:-

when a charged body is electrically in contact with uncharged body, then charges are shared by both the bodies. This process of charging is known as charging by Conduction.

13. Charging by induction:-

when a charged body is placed near an uncharged body, then the separation of charge takes place on the uncharged body. one end of uncharged body is positively charged & other end is negatively charged. This process of charging is known as charging by induction.



14. Point charges:-

point charge in electrostatics means either the charges are concentrated at a point or are distributed uniformly over a body so that the charges.

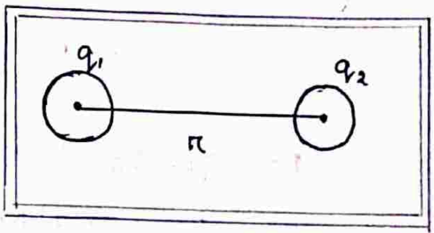
COULOMB'S LAW

Charles colulomb was the first person to investigate the force between electrostatic charges & stated the following law, now known as Coulomb's law of electrostatics.

The law states that the electrostatic force of attraction or repulsion between two point charges is directly propertional to the product of charges & inversly proportional to the square of the distance between them & acts along the line joining the two charges.

Mathematically, $F \propto q_1 q_2$ where r is Constant

$F \propto \frac{1}{r^2}$ when $q_1 q_2$ are constants.



Hence $F \propto \frac{q_1 q_2}{r^2}$ when q_1, q_2 & r changes.

so $\boxed{F = K \frac{q_1 q_2}{r^2}}$ - - (1)

where k is constant of propertionallity that depends on the system of unit & the nature of the medium.

Equation (1) gives the magnitudes of the force.

In vector form

$$\boxed{\vec{F} = \frac{K q_1 q_2}{r^2} \hat{r} = K \frac{q_1 q_2}{r^2} \cdot \frac{\vec{r}}{r} = K \frac{q_1 q_2}{r^3} \vec{r}}$$

VALUE OF K

(i) In C.G.S $K = 1$ for air or vacuum

so $\boxed{F = \frac{q_1 q_2}{r^2}}$

(ii) In S.I $K = \frac{1}{4\pi\epsilon}$ for any medium

$K = \frac{1}{4\pi\epsilon_0}$ for air or vaccum or free space

where ϵ is the permitivity of the medium

ϵ_0 is the permitivity of free space or air or vaccum

$\boxed{F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}}$ for air

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{(\text{Coulomb})^2}{Nm^2}$$

Hence $$\boxed{K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{(\text{Coulomb})^2}}$$

UNIT OF CHARGE

1. In S.I unit, the unit of charge in coulomb.

We know $F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2}$

$\Rightarrow F = 9\times10^9 \frac{q_1 q_2}{r^2}$

For $q_1 = q_2 = 1$ coulomb & $r = 1m$

$F = 9\times10^9 N$

So 1 coulomb is definded as that charge which when placed 1m apart in vaccum from a charge of equal value & similar charge shall experience a repulsive force of magnitude $9\times10^9 N$.

2. In C.G.S system, unit of charge is called stat coulomb or electrostatic unit (e.s.u).

For C.G.S system $K = 1$ in air & $q_1 = q_2 = 1$ stat coulomb $r = 1cm$.

SO $F = \frac{q_1 q_2}{r^2} = 1$ dyne

Hence 1 stat coulomb is defind as that charge which when placed 1 cm apart in vaccum from a charge of equal value & similar charge shall experience a repulsive force of magnitude 1 dyne.

RELATION BETWEEN COULOMB & STAT COULOMB

Let 1 Coulomb = x stat coulomb.

Let's consider two charges of magnitude 1 coulomb separated by a distance of 1m in air.

$q_1 = q_2 = 1$ coulomb

$r = 1m$

Then from Coulomb's law

$F = K \frac{q_1 q_2}{r^2}$

In SI unit, $F = \frac{1}{4\pi \epsilon_0} \frac{q_1 q_2}{r^2}$

$\Rightarrow F = 9\times10^9 \frac{1\times1}{1^2} N$

$\Rightarrow F = 9\times10^9 N$ - - - (1)

In C.G.S unit, $F = 1\times \frac{q_1 q_2}{r^2}$

$\Rightarrow F = \frac{x \times x}{(100)^2}$ dyne

$\Rightarrow F = \frac{x^2}{10^4}$ dyne $= \frac{x^2}{10^4} \times \frac{1}{10^5} N$. ($1 \text{ dyne} = 10^{-5} N$)

$\Rightarrow F = \frac{x^2}{10^9} N$ - - - (2)

Now Comparing equation (1) & (2), we get

$\frac{x^2}{10^9} = 9\times10^9$

$\Rightarrow x^2 = 9\times10^9 \times 10^9 = 9\times10^{18}$

$\Rightarrow x = 3\times10^9$

$$\boxed{1 \text{ Coulomb} = 3\times10^9 \text{ Stat Coulomb}}$$

ELECTRIC PERMITTIVITY

Electric permittivity is an electrical property of the medium that affects the coulomb force between the two point charges in the material.

It is denoted by ϵ (epsilon).

MKS unit or S.I unit of $\epsilon = \frac{(Coul)^2}{Nm^2}$

Dimension $[\epsilon] = [M^{-1}L^{-3}T^4A^2]$

The absolute permitivity of free space is denoted by ϵ_0.

$$\boxed{\epsilon_0 = 8.85\times10^{-12} \frac{(Coul)^2}{Nm^2}}$$

RELATIVE PERMITTIVITY

Relative permittivity or dielectric constant of a medium is defind as the ratio of the force between two point charges in vaccum to the force between two point charges in vaccum to the force between the same two charges in any other medium.

It is denoted by ϵ_r or K (Kappa)

$$\epsilon_r = \frac{F_0}{F}$$

$$\Rightarrow \epsilon_r = \frac{\frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2}}{\frac{1}{4\pi\epsilon}\frac{q^2}{r^2}}$$

$$\Rightarrow \epsilon_r = \frac{\epsilon}{\epsilon_0}$$

It is a dimensionless pure number.

PRINCIPLE OF SUPER POSITION

When two or more charges exert force on a given charge simultaneously, the total force exerted on that charge is the vector sum of the forces that the different charges exert separately.

From the above statement it is clear that the force between any two point charges is independent of the presence of all other point charges present nearby.

ELECTRIC FIELD

When an electric charge is placed at a point, the properties of space around the charge get modified space around an electric charge is called electric field.

Electric field is the region surrounding a charge in which a test charge experiences a force.

A small amount of positive charge (+q) is taken as test charge.

ELECTRIC FIELD INTENSITY

Electric field intensity or the strength of an electric field at a point in an electric field is the force experienced by a unit positive test charge placed at that point.

Mathematically, $\vec{E} = \dfrac{\vec{F}}{+q_0}$

where $\vec{E}$ is the electric field intensity & $\vec{F}$ is the force experienced by the test charge ($+q_0$) placed at the point of observation.

The direction of $\vec{E}$ is the direction of electric force. It is directed away from a positive source charge & towards a negative source charge.

UNITS OF $\vec{E}$

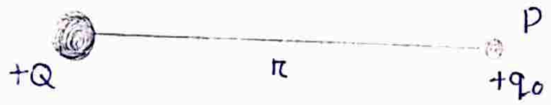
S.I unit $= \dfrac{\text{Newton}}{\text{Coulomb}} = \dfrac{N}{C}$

C.G.S unit $= \dfrac{\text{dyne}}{\text{Stat Coulomb}} =$

DIMENSION OF $\vec{E}$

$$[E] = [M^1 L^1 T^{-3} A^{-1}]$$

ELECTRIC FIELD INTENSITY DUE TO A POINT CHARGE



Let's consider a charged sphere having charge $+Q$ The charge is distributed uniformly around the sphere so that it is considered as point charge.

Let p be a point at a distance 'r' form the source charge (Q) A test charge is placed at the point p.

According to Coulomb's law, force between point charge & test charge is

$$\vec{F} = \frac{KQq_0}{r^2}\hat{r}$$

Then the electric field intensity at p is

$$\vec{E} = \frac{\vec{F}}{+q_0} = \frac{\frac{KQq_0}{r^2}}{q_0}$$

$$\Rightarrow \boxed{\vec{E} = \frac{KQ}{r^2}\hat{r} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}}$$

In S.I units for air

This is the formula for electric field intensity due to a point charge.

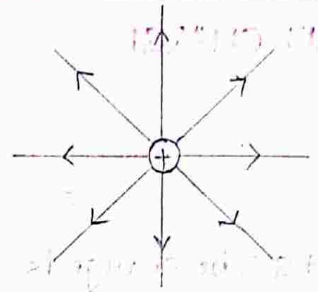
ELECTRIC LINES OF FORCE

The electric field in a region can be graphically represented by drawing certain curves known as Electric lines of force or electric field lines.

Electric lines of force may be defined as a curve, tangent to it at any point gives the direction of electric field intensity at that point.

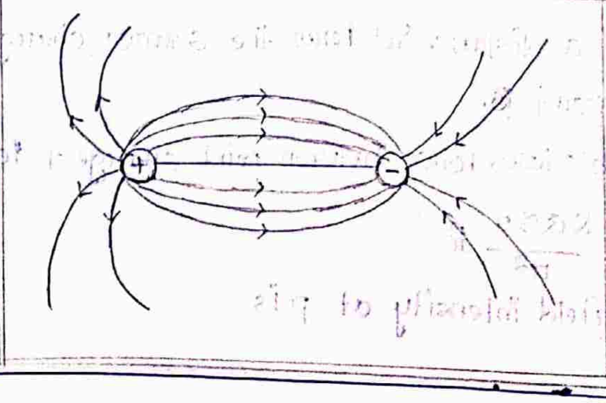
- It is the path along which a unit positive charge will move when the charge is free in an electric field. Thus, the electric field due to a positive charge is represented by straight lines originating from the charge.

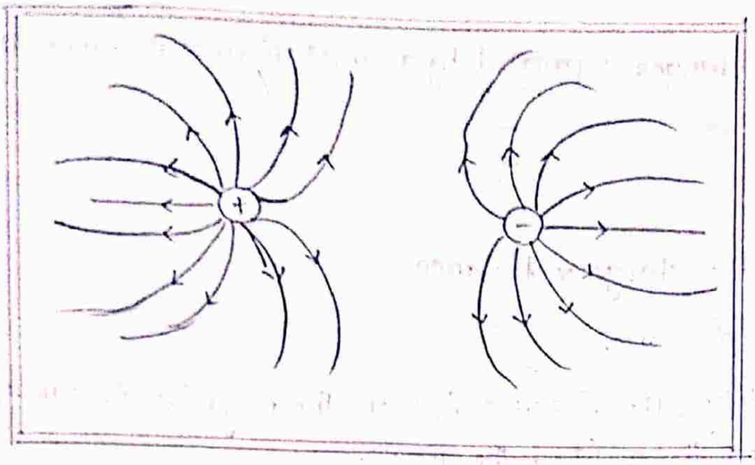
The electric field due to a negative point charge is represented by straight lines terminating (ending) at the charge.



Isolated positive charge

Isolated negative charge

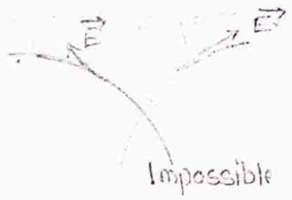




PROPERTIES OF LINES OF FORCE

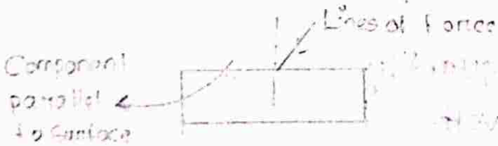
1) A line of force starts from a positive charge & ends on a negative charge.

2) Two lines of force never intersect each other, If the two lines cross, two tangents can be drawn at the point of interaction. This means that there is two directions of electric field intensity at the point of interaction which is impossible.



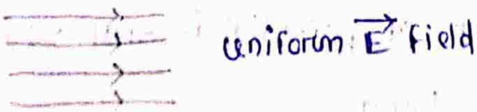
3) The number of lines of force per unit area is proportional to the magnitude of $\vec{E}$. Thus more closely spaced lines represent stronger electric Field.

4) The lines of force meet the Surface of a Conductor perpendicularly. If it were not so, the electric field $\vec{E}$ will have a Component parallel to the Surface of the Conductor.. This would mean a flow of Current which is not correct.



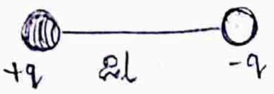
5) The lines of force never pass through the Conductor. This explain the absence of electric field within the Conductor.

6) parallel & equidistant lines of force represent uniform electric field.



ELECTRIC DIPOLE

Two equal & opposite charges separated by a small distance constitutes an electric dipole.



Then dipole moment = charge x distance

$$\vec{p} = q \times 2l$$

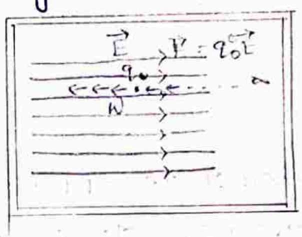
It is a vector quantity. Its direction is from the negative charge to the positive charge along the axis of the dipole.

ELECTRIC POTENTIAL ENERGY

The electric potential energy at any point in an electric field is defind as the amount of work done in moving a test charge from infinity(∞) to the point against the field direction.

The work done on the test charge is being stored on it as the electric potential energy.

The change in electric potential energy of the system is the negative of the work done by the electric forces.



$$\boxed{dU = -dW}$$

ELECTRIC POTENTIAL

The electric potential at any point in an electric field is defind as the work-done in moving a unit positive charge from infinity to that point against the direction of electric field.

$$\boxed{V = \frac{W}{+q}} \Rightarrow \boxed{V = \frac{U}{+q}}$$ ∵ U is the potential energy at that point

Electric potential is a scalar quantity.

S.I unit of potential is volt.

$$\boxed{1 \text{ volt} = \frac{1 \text{ Joule}}{1 \text{ Coulomb}}} = J/C$$

In C.G.S System unit of potential is stat volt.

$$\boxed{1 \text{ stat volt} = \frac{1 \text{ erg}}{1 \text{ stat Coul}}}$$

Dimension of potential :-

$$[V] = [M^1 L^2 T^{-3} A^{-1}] \quad (A = \text{Ampere})$$

Electric potential is the quantity which determines the direction of flow of charge between two bodies. charge always flow from higher potential to lower potential.

VOLT

Electric potential at a point is said to be one volt if 1 Joule of work is done in moving a charge of 1 Coulomb from infinite to that point against the electric field.

STAT VOLT

Electric potential at a point is said to be one stat volt if 1 erg of work is done in moving a charge of 1 stat Coul. from infinite to that point against the electric field.

RELATION BETWEEN VOLT & STAT VOLT

$$1 \text{ volt} = \frac{1\,J}{1\,\text{Coul}} = \frac{10^7 \text{ erg}}{3\times10^9 \text{ stat Coul}}$$

$$\Rightarrow 1 \text{ volt} = \frac{1}{300} \text{ stat volt}$$

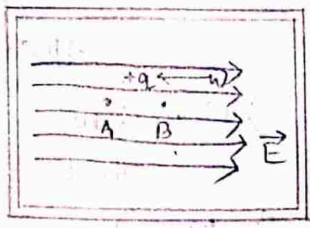
$$\Rightarrow \boxed{1 \text{ stat volt} = 300 \text{ volt}}$$

ELECTRIC POTENTIAL DIFFERENCE

The electric potential difference between any two points A & B in an electric field is defind as the work done in moving a unit positive charge from one point to other against the electric field.

Mathematically, $dV = \boxed{V_A - V_B = \frac{W_{BA}}{+q}}$

$$\Rightarrow \boxed{dV = V_A - V_B = \frac{U_A - U_B}{+q}}$$



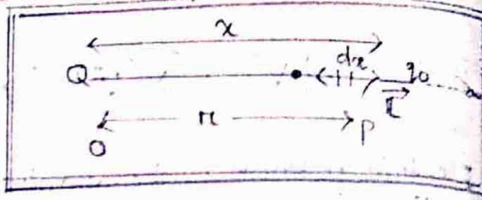
where V_A = potential of point A

V_B = potential of point B

U_A = potential energy of +q at point A

U_B = potential energy of +q at point B.

ELECTRIC POTENTIAL AT ANY POINT DUE TO A SINGLE POINT OF CHARGE



Let the source charge 'Q' be situ at point O.
Let a unit positive test charge (q_0) is being moved from infinity to point against the electric field ($\vec{E}$) of the source charge.

Then the work done in moving charge a small distance dx is given by

$$dW = \vec{F} \cdot \vec{dx}$$

$$\Rightarrow dW = F dx \cos 180^\circ$$

$$\Rightarrow dW = -F\, dx \quad \text{---} (1)$$

Using Coulomb's law of electrostatic in air

$$F = \frac{-1}{4\pi\epsilon_0} \frac{Qq_0}{x^2} \quad \text{---} (2)$$

Applying it in equation (1)

$$dW = \frac{-1}{4\pi\epsilon_0} \frac{Qq_0}{x^2} dx \quad \text{---} (3)$$

Now integrating the above equation (3) from infinity to p is

$$W = \int_0^W dW = \int_\infty^r -\frac{1}{4\pi\epsilon_0} \frac{Qq_0}{x^2} dx$$

$$\Rightarrow W = \frac{-Qq_0}{4\pi\epsilon_0} \int_\infty^r \frac{1}{x^2} dx$$

$$= \frac{-Qq_0}{4\pi\epsilon_0} \left[\frac{x^{-2+1}}{-2+1}\right]_\infty^r$$

$$= \frac{-Qq_0}{4\pi\epsilon_0} \left[-\frac{1}{x}\right]_\infty^r = \frac{Qq_0}{4\pi\epsilon_0} \left[\frac{1}{x}\right]_\infty^r$$

$$\Rightarrow W = \frac{Qq_0}{4\pi\epsilon_0} \left(\frac{1}{r} - \frac{1}{\infty}\right)$$

$$\Rightarrow \boxed{W = \frac{1}{4\pi\epsilon_0} \frac{Qq_0}{r}}$$

This is the expression for potential at a point due to a source charge.

CAPACITANCE

A combination of two conductors placed close to each other is called a capacitor. Capacitor is a device for storing charge. One of the conductors is given a positive charge & the other is given an equal negative charge. The conductor with the positive charge is called the positive plate & the other is called the negative plate.

The charge on the positive plate is called the charge on the capacitor & the potential difference, between the plates is called the potential of the capacitor.

Capacitance or capacity of a conductor is a measure of the ability to store the charge through it for a given capacitor, the charge Q on the capacitor is proportional to the potential difference V between the plates

Thus $Q \propto V$

$\Rightarrow \boxed{Q = CV}$

The propotionality constant C is called the capacitance of the capacitor. It depends on the shape, size & geometrical placing of the conductors & the medium between them.

$$\boxed{C = \frac{Q}{V}}$$

The capacity of a conductor is defind as the ratio between the charge on the conductor to its potential

If $V = 1$, then $C = Q$

The capacity of a conductor is defined as the charge required to raise it through a unit potential.

UNIT & DIMENSION

In SI unit $C = \frac{Q}{V} = \frac{\text{Coulomb}}{\text{Volt}} = \text{Farad}$

$$1 \text{ Farad} = \frac{1 \text{ Coulomb}}{1 \text{ volt}}$$

The capacity of a conductor is said to be 1 Farad (F) if a charge of 1 Coulomb is required to raise its potential through 1 volt.

In C.G.S System

$$1 \text{ stat farad} = \frac{1 \text{ stat Coulomb}}{1 \text{ stat volt}}$$

Dimension of capacitance

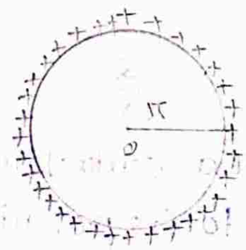
$$[C] = \frac{\text{Coulomb}}{\text{Volt}} = \frac{\text{Coulomb}}{\text{Joule/Coulomb}} = \frac{(\text{Coulomb})^2}{\text{Joule}} = \frac{C^2}{Nm}$$

$$[C] = \frac{[A^2T^2]}{[M^1L^2T^{-2}]} = [M^{-1}L^{-2}T^4A^2]$$

CAPACITANCE OF AN ISOLATED SPHERICAL CONDUCTOR

Consider a spherical conductor of radius r. Let $+q$ amount of charge given to the conductor. The charge is distributed on the outer surface, Then its potential

$$V = \frac{Kq}{r}$$



Capacitance $C = \frac{q}{V}$

$$\Rightarrow C = \frac{q}{Kq/r}$$

$$\Rightarrow \boxed{C = \frac{r}{K}}$$

$\therefore C \propto r$

In S.I unit for air, $K = \frac{1}{4\pi\epsilon_0} = 9\times10^9$

$$\boxed{C = 4\pi\epsilon_0 r}$$

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In C.G.S system of unit, $K=1$

$$\boxed{C = r}$$

⇒ Capacity of a Conductor is a Scalar quantity.

⇒ If Earth is Considered to be a spherical Conductor of radious ($R = 6.4 \times 10^6 m$), then capacitance

$$C = \frac{r}{9\times10^9} = \frac{6.4\times10^6}{9\times10^9}$$

$$\Rightarrow \boxed{C = 711 \times 10^{-6} F = 711\,\mu F}$$ Capacity of Earth.

PRINCIPLE OF A CAPACITOR

A Capacitor or a condenser is an arrangement which provides a larger capacity in a smaller space.

It is based on the principle that when, an earthed conductor is placed close to a charged conductor, the capacity of the system increases considerably.

GROUPING OR COMBINATION OF CAPACITORS

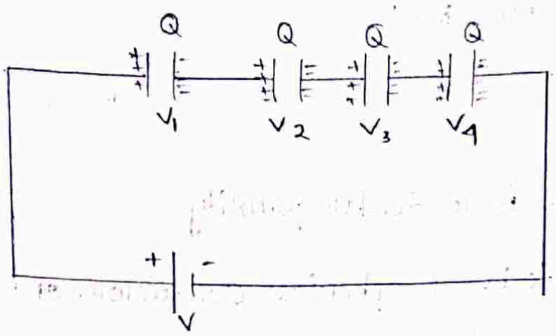
If a number of capacitors having capacitances $C_1, C_2 \ldots C_N$ are grouped together, the Combination behaves like a single capacitor of capacitance C. There are two ways of grouping of capacitors.

(1) Series Combination or Series grouping

(2) parallel Combination or parallel grouping.

(1) SERIES COMBINATION

Capacitors are said to be Connected in Series if the negative plate of one capacitor is Connected with the positive plate of the next capacitor & so on. In series combination, each capacitor has equal charge for any value of capacitance. But the potential drop across the capacitors are different in accordance with their capacites.



Let N Capacitors having Capacitances $C_1, C_2, C_3 \cdots C_N$ are Connected in Series. As all the capacitors are Connected in Series, charge on each Capacitor is same. Let $V_1, V_2, \cdots V_N$ be the potential difference of the respective capacitors, then total potential difference.

$$V = V_1 + V_2 + \cdots + V_N$$

$$\Rightarrow \frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \cdots + \frac{Q}{C_N}$$

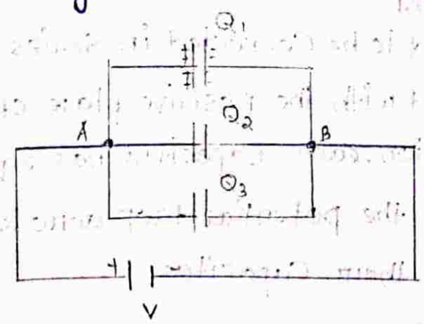
Where C_s is the total Capacitances in Series Combination.

$$\Rightarrow \boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_N}}$$

In Series Combination, the reciprocal of the resultant (net) Capacitance is equal to the algebric sum of the reciprocal of the indivisual Capacitances.

⟨2⟩ PARALLEL COMBINATION

Capacitors are said to be Connected in parallel if the positive plates of all the Capacitors are Connected together at a point A (in the figure) while the negative plates of all the capacitors are Connected together at another point B (in the figure). These two points A & B are Connected with a Battery.



Let N capacitors having capacitances $C_1, C_2, C_3 - - - C_N$ are connected parallel to each other between two points A & B, As all capacitors are connected between two points, potential difference of all capacitors remain same.

Let $Q_1, Q_2, - - - Q_N$ be the charges on the capacitors having capacitances $C_1, C_2, C_3, - - - C_N$ respectively.

Then the total charge is

$$Q = Q_1 + Q_2 + Q_3 + - - - + Q_N$$

$$\Rightarrow C_pV = C_1V + C_2V + C_3V + - - - + C_NV$$

$$\Rightarrow \boxed{C_p = C_1 + C_2 + C_3 + - - - C_N}$$

where C_p is the net capacitance in the parallel combination. The net capacitances is the algebric sum of the individual capacitances.

MAGNETOSTATICS

PROPETIIES OF A MAGNET

1. Attractive property:-

A magnet has the power of attracting iron very strongly & cobalt & nickel weakly. this attractive power is maximum at poles & decreases as move towards the centre of the magnet.

2 Directive property:-

When a magnet suspended freely by a thread it always comes to rest with its two ends pointing north & sound.

3. poles :-

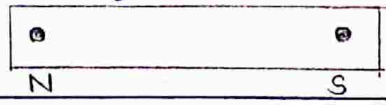
poles are the region near two ends of a magnet having maximum attracting power.

There are two & only two poles of a magnet. The pole which points towards the geographic North is known as North pole & the pole which points towards the geographic south is known south pole.

4. Magnetic Length

The distance between two poles of a magnet is known as magnetic length.

Magnetic length = 85% of total length of the magnet.



5. Magnetic axis :-

A line that passes through the two poles of a magnet is known as magnetic axis.

6. Magnetic meridian:-

An imaginary vertical plane that passes through the axis of a freely suspended magnet is known as magnetic meridian.

7. Neutral point :-

The Central region of the magnet having Zero attracting power is known as neutral point.

8. Nature of poles :-

· Like poles repel & unlike poles attract each other.

9. pole strength :-

It is a measure of the attraction power of the magnet & is denoted as 'm'. It is 'm' for South pole & 'm' for north pole.

$$S.I \text{ unit} = Amp \cdot m$$

$$\text{Dimension} = [M^0 L^1 T^0 A^1]$$

10. Magnetic moment :- (M)

It is defind as the product of the pole strength & the magnetic length.

$$\vec{M} = m \times 2\vec{l}$$

It's direction is along South pole to north pole.

$$S.I \text{ unit} = Amp \cdot m^2$$

$$\text{Dimension} = [M^0 L^2 T^0 A^1]$$

COULOMB'S LAW OF MAGNETOSTATICS

Coulomb first determined the magnitude of the force between two magnetic poles & stated the following law known as Coulomb's law.

Statement :- The force of attraction or repulsion between two poles varies directly as the product of the pole strengths & inversely as the square of the distance between them & the force acts along the line joining the two poles.

Mathematically,

$F \propto m_1 m_2$ when r = Constant

$F \propto \frac{1}{r^2}$, when m_1 & m_2 are Constants.

$\Rightarrow F \propto \frac{m_1 m_2}{r^2}$, when all vary

$$\Rightarrow F = \boxed{K \frac{m_1 m_2}{r^2}}$$

where m_1 & m_2 = pole strengths of the poles.

r = distance of separation between the poles

K is the proportionality constant whose value depends upon the properties of the medium & the system of units used.

Value of K

In S.I unit $K = \frac{\mu}{4\pi}$

μ is known as permeability of the medium for air, $K = \frac{\mu_0}{4\pi}$

$$\therefore \boxed{F = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}}$$

$\mu_0 = 4\pi \times 10^{-7} \frac{\text{weber}}{\text{amp.m}}$ = permeability of free space

In C.G.S unit $K = 1$ for air

In vector form $\boxed{\vec{F} = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2} \hat{r}}$

UNIT POLE

$F = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}$

For $m_1 = m_2 = 1$, $r = 1m$

$\frac{\mu_0}{4\pi} = \frac{4\pi \times 10^{-7}}{4\pi} = 10^{-7} \frac{wb}{amp.m}$

Unit pole in S.I unit is defined as the pole strength of that pole which when placed 1m apart in Vaccum from the pole strength of equal value will exert a force of 10^{-7} N.

MAGNETIC FIELD

The space surrounding a magnet in which the magnetic effects are experienced is called the magnetic field.

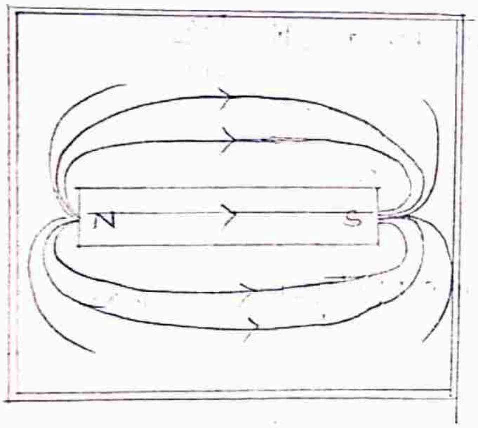
Magnetic field is a vector quantity.

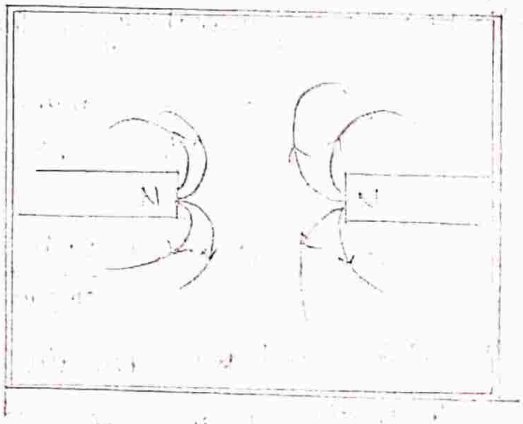
MAGNETIC LINES OF FORCE

Magnetic lines of force are the lines so drawn that tangent to it at any point gives the direction of magnetic field intensity at that point. It is also known as magnetic flux lines or magnetic lines of induction.

Suppose a unit magnetic north pole is placed at any point in a magnetic field. It experiences a force given by Coulomb's law. If the north pole were completely free to move under the action of this force. It would move along a path called lines of force.

Hence line of force is a path along which a unit north pole would move if it were free to do so.





PROPERTIES OF LINES OF FORCE

1. They start from North pole & ends at south pole. It passes inside the magnet.
2. Magnetic lines of force are closed or continuous curves.
3. Tangent at any point to the magnetic lines of force gives the direction of magnetic intensity at that point.

4. Two lines of force never cross each other. If the two lines were to cross, then two tangent could be drawn at that point which indicates two different directions of magnetic field intensity. This is impossible. Hence two lines of force never intersect each other.

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5. The no. of lines of force per unit area is proportional to magnitude of magnetic field intensity at that point crowed lines of force represents strong field & distant lines of force represents weak field.

6. The lines of force tend to contract longitudinally or lengthwise. Due to this property the two unlike poles attract each other.

7. The lines of force tend to exert lateral pressure i.e they repel each other laterally.

MAGNETIC FLUX

Magnetic flux over certain area in a magnetic field is defind as total no. of magnetic lines of force passes through that area.

$$\phi_B = \vec{B} \cdot \vec{A}$$

$$\Rightarrow \phi_B = BA \cos\theta$$

Where θ is the angle between magnetic field & the area vector.

Magnetic flux linked with a surface is the product of area & the component of B perpendicular to the area.

Case-1

when $\theta = 90°$ $\cos\theta = 0$

$\phi_{B\,min} = 0$

No magnetic flux linked with the surface when the field is parallel to the surface (or field is perpendicular to the area vector).

Let $d\phi_B$ be the magnetic flux linked with a small area $\vec{dA}$ of the surface. The area is so small that the field can be considered to be the same over that area.

$$d\phi_B = \vec{B} \cdot \vec{dA}$$

$$\Rightarrow \boxed{\phi_B = \int d\phi_B = \int \vec{B} \cdot \vec{dA}}$$

Thus magnetic flux linked with a surface in a magnetic field is defind as the surface integral of the magnetic flux density over that surface.

UNITS

S.I unit = $\phi_B = BA$

$\Rightarrow \phi_B = 1 \text{ Tesla} \times 1 m^2 = 1 \text{ weber}$

Weber :- Magnetic flux linked with an area of $1 m^2$ held normal to the direction of lines of force of a magnetic field of strength 1 tesla is called one weber.

$$\boxed{1 \text{ weber} = 1 Tm^2}$$

C.G.S UNIT

$$\phi_B = BA = 1 \text{ gauss} \times 1 cm^2$$

$$\Rightarrow \phi_B = 1 \text{ maxwell}$$

Maxwell :- Magnetic flux linked with an area of $1 cm^2$ held normal to the direction of lines of force of a magnetic field of strength 1 gauss is called one maxwell.

$$\boxed{1 \text{ maxwell} = 1 \text{ gauss } cm^2}$$

RELATION BETWEEN Wb & maxwell

$$1 \text{ weber} = 1 \text{ tesla} \times 1 m^2$$

$$= 10^4 \text{ gauss} \times 10^4 cm^2$$

$$1 \text{ weber} = 10^8 \text{ maxwell}$$

DIMENSION OF ϕ_B :-

$$[\phi_B] = [M^1 L^2 T^{-2} A^{-1}]$$

MAGNETIC FLUX DENSITY ($\vec{B}$)

Magnetic flux density at any point is defind as the number of magnetic lines of force passing through a unit area, placed at that point. If the area is held perpendicular to the direction of lines of force.

$$\boxed{B = \frac{\phi_{B\,max}}{A}}$$

The force on a moving charge placed in a uniform magnetic field is given by

$$F = qvB \sin\theta$$

For $\sin\theta = 1$, $F = qvB$

$$\Rightarrow B = \frac{F}{qv}$$

So magnetic field induction or magnetic flux density ($\vec{B}$) at any point in the field is equal to the force experienced by a unit charge moving with a unit velocity perpendicular to the direction of magnetic field :

UNIT

$$B = \frac{F}{qv} = \frac{1N}{1C \times 1m/s} = 1 \text{ Tesla} = 1T \text{ (S.I unit)}$$

C.G.S UNIT

$$B = \frac{1 \text{ dyne}}{1 \text{ ab Coul} \times 1 \text{ Cm/s}} = 1 \text{ Gauss}$$

$$1 T = 10^4 \text{ Gauss}$$

DIMENSION

$$[B] = \frac{F}{qv} = \frac{[M^1L^1T^{-2}]}{[A^1T^1][L^1T^{-1}]} = [M^1A^{-1}T^{-2}]$$

CURRENT ELECTRICITY

ELECTRIC CURRENT

Time rate of flow of charges across any crossection of conductor is known as current.

$$\boxed{I = \frac{Q}{t}}$$

Instataneous Current $I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t}$

$$\Rightarrow \boxed{I = \frac{dQ}{dt}}$$

UNITS OF ELECTRIC CURRENT

In S.I unit,

$$I = \frac{Q}{t} = \frac{\text{Coulomb}}{\text{Sec}} = \text{ampere (A)}$$

Current of a conductor is said to be one ampere if one coulomb of charge flow across any crossection of conductor in one second.

In C.G.S unit

$$\boxed{\begin{aligned} \text{Stat ampere} &= \frac{\text{stat ampere}}{\text{Sec}} \\ 1 \text{ ampere} &= 3\times10^{9} \text{ stat ampere} \end{aligned}}$$

⇒ Current is a fundamental quantity in electricity.

⇒ The conventional direction of current is the direction of flow of positive charge.

⇒ The direction of flow of electrons is known as direction of electronic current.

⇒ Current is a scalar quantity though it has magnitude & direction because it can be added algebrically.

⇒ $I = I_1 + I_2$, If $I_1 = 5A$, $I_2 = 2A$

then $I = 5+2 = 7A$

⇒ The magnitude of the current does not change if the area of crossection of the conductor changes in different section.

⇒ By convention the direction of flow of current is taken to be the direction of flow of positive charge.

OHM'S LAW & IT'S APPLICATION

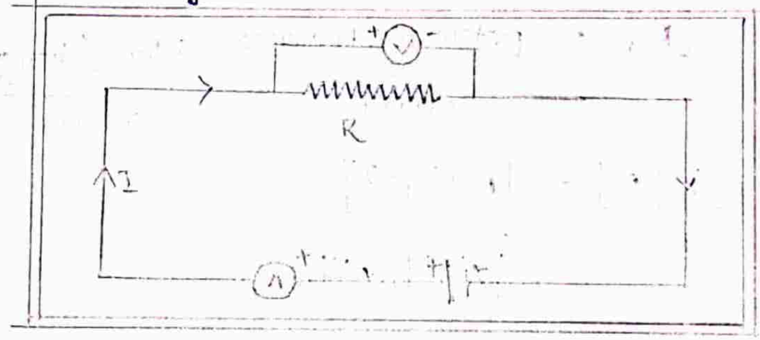
Ohm's law deals with the relationship between voltage & current in an ideal conductor.

Ohm's law states that for a particular conductor at constant temperature, the potential difference (voltage) across an ideal conductor is proportional to the current through it.

Mathematically, $V \propto I$

$$\Rightarrow V = RI$$

where the constant of proportionality 'R' is called the resistance or electric resistance.



RESISTANCE

If V be the potential difference between the two terminals of a conductor & 'I' be the current through it, then

$$R = \frac{V}{I} = \text{constant}$$

R is called the resistance of the material.

$$I = \frac{V}{R}$$

As the value of R increases, the current through the conductor decreases.

Resistance is the opposition offered by the conductor to the flow of electric current through it.

Resistance of a conductor is defined as the ratio between potential difference between the two ends of the conductor to the current flowing through it.

UNIT OF RESISTANCE

$$\boxed{R = \frac{V}{I} = \frac{\text{volt}}{\text{amperre}} = \text{ohm}}$$

$$\boxed{1 \text{ ohm} = \frac{1 \text{ volt}}{1 A}}$$

Ohm is the S.I unit of resistance.

Resistance of a conductor is said to be 1 ohm if a Current of 1ampere flows through it for a potential difference of 1 volt across its end.

C.G.S unit of resistance is stat ohm.

DIMENSION OF RESISTANCE

$$[R] = \frac{\text{potential difference}}{\text{Current}} = \frac{\text{Work/charge}}{\text{Current}}$$

$$\Rightarrow [R] = \frac{[M^1L^2T^{-2}]}{[A^1T^1][A^1]}$$

$$\Rightarrow [R] = [M^1L^2T^{-3}A^{-2}]$$

APPLICATION OF OHM'S LAW

⟨1⟩ Domestic fan regulator uses ohm's law to regulate the Current through the fan by changing the resistance of the regulator circuit.

⟨2⟩ In voltage divider circuit this law is used to divide Source voltage across the Output resistance.

⟨3⟩ ohm's law helps us in determining either voltage, Current or resistance of a linear electric circuit when the other two quantities are known to us.

⟨4⟩ ohm's law is only applicable to metalic conductor.

⟨5⟩ The electrical water heater use the Concept of ohm's law.

⟨6⟩ The electric kettle & irons have a lot of resistors in them. The size of resistors used in them is determined by using ohm's law.

⟨7⟩ Fuses the protection Components that decides the amount of Current flowing through the circuit. They are connected in the Series in the device ohm's law is used to find out which resistors are needed.

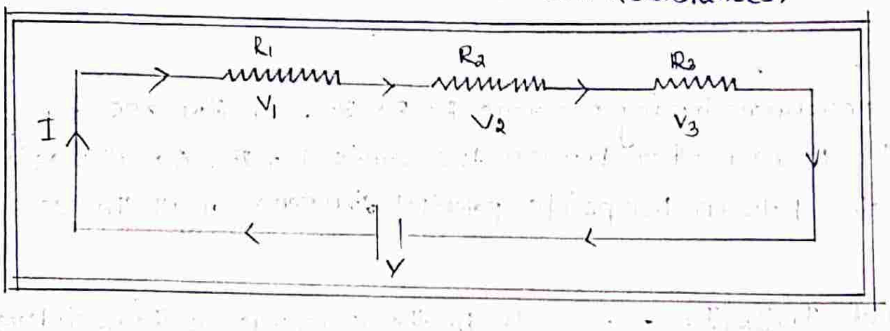
GROUPING OR COMBINATION OF RESISTORS

If a number of resistors having resistance $R_1, R_2, \dots R_N$ are Combined together, the Combination behaved like a single resistor of resistance R. There are two ways of grouping of series.

1. SERIES COMBINATION OR SERIES GROUPING
2. PARALLEL COMBINATION OR PARALLEL GROUPING

1. SERIESE COMBINATION

Two or more resistors are said to be Connected in Seriese if the same Current passes through all the resistors But the potential drop across the resistors are different in accordance with their resistances.



Let N resistors having resistances $R_1, R_2, R_3 \dots R_N$ are Connected in Series As all the resistors are Connected in Series, Current on each resistors is Same. Let $V_1, V_2, V_3 \dots V_N$ be the potential difference of the respective resistors, then the total potential difference.

$$V = V_1 + V_2 + V_3 + \dots + V_N$$

Using ohm's law,

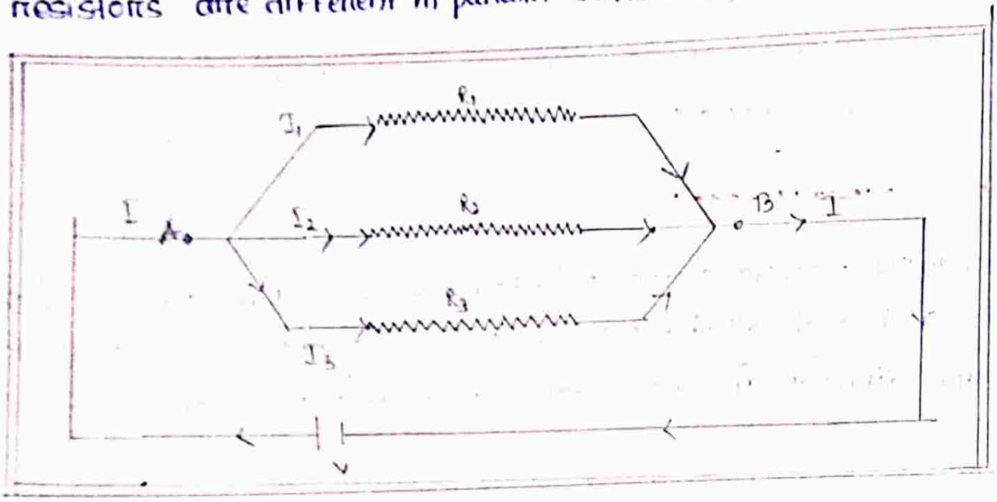
$$IR_s = IR_1 + IR_2 + IR_3 + \dots IR_N$$

$$\Rightarrow \boxed{R_s = R_1 + R_2 + R_3 + \dots R_N}$$

Where R_s is the total resistances in Series Combination. Thus in Series Connection the Combined resistance is equal to the sum of their individual resistances.

2. PARALLEL COMBINATION

Two or more resistors are said to be connected in parallel if the same potential difference exists across all the resistors. The current across the resistors are different in parallel connection.



Let N resistances having resistors $R_1, R_2, R_3 \ldots R_N$ are are connected parallel to each other between two points A & B. As all resistors are connected between two points. potential difference of all the resistors remain same.

Let $I_1, I_2, I_3 - - - I_N$ be the currents on the resistors having resistances $R_1, R_2, R_3 - - - R_N$ respectively.

Then the total current is

$$I = I_1 + I_2 + I_3 + - - - + I_N$$

$$\Rightarrow \frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + - - - \frac{V}{R_N} \quad \left(V = IR, \Rightarrow I = \frac{V}{R} \right)$$

$$\Rightarrow \boxed{\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + - - - + \frac{1}{R_N}}$$

where R_p is the net resistances in the parallel combination.

Thus in parallel combination, the reciprocal of the resultant (net) resistances is equal to the algebric sum of the reciprocal of the individual resistances.

KIRCHHOFF'S LAW

Kirchoff's give two laws which help in solving. Coplicated electrical circuits.

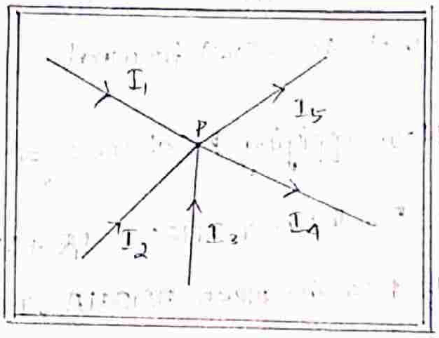
FIRST LAW

It states that the algebric sum of Currents meeting at any junctions point is zero.

Mathematically $\Sigma I = 0$

From the figure,

$I_1 + I_2 + I_3 - I_4 - I_5 = 0$



(i) The Currents approaching the junction point are taken as +(ve).

(ii) The Current leaving the junction point are taken as negative.

Here in the figure, P is the junction point I_1, I_2 & I_3 are approaching the junction & I_4 & I_5 are leaving the junction point.

This law is called Kirchoff's Current law (KCL)

This law states that Current entering a point in any that point so that there is no gatering of charge at any point on the Conductor.

SECOND LAW

In any closed mesh (circuit) of an electrical network the algebric sum of the products of Current & resistances of various branches of the mesh p equal to the net emf (Electro motive force) acting in the mesh.

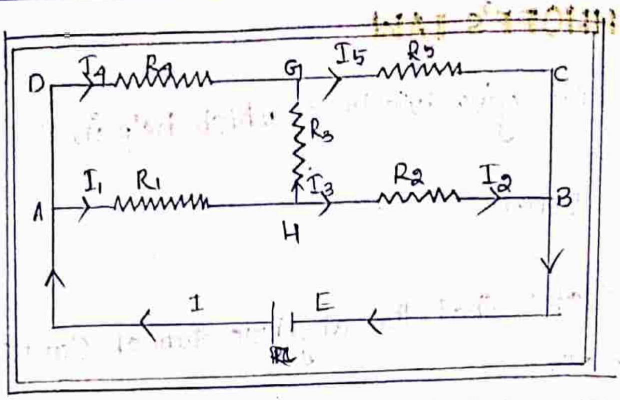
The net change in emf around any Closed mesh is zero.

Mathematically $\Sigma IR - \Sigma E = 0$

$\Rightarrow \Sigma IR = \Sigma E$

when there is no emf in the mesh, $\Sigma IR = 0$.

(i) For any mesh the product IR is taken as +(ve) when the current flowing through R is clockwise & is taken as negative if the current flowing through 'R' is anticlock wise.



(ii) EMF E is taken as positive of the direction of current is form -(ve) terminal to +(ve) terminal.

Now applying kirchoff's 2nd law to the figure.

a) For the mesh AHBEA, $I_1R_1 + I_2R_2 + Ir = E$

b) For the mesh ADGHA, $I_4R_4 - I_1R_1 - I_3R_3 = 0$

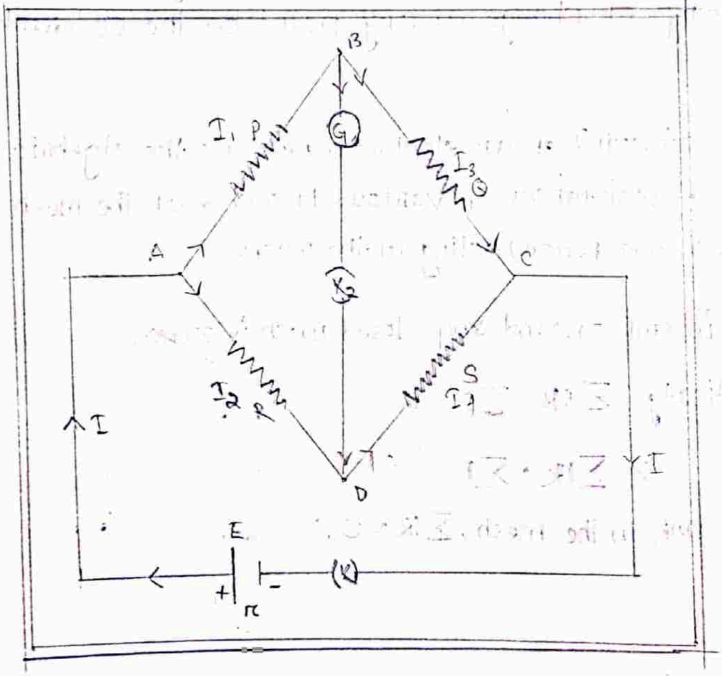
c) For the mesh GCBHG, $I_5R_5 + I_3R_3 - I_2R_2 = 0$

d) For the mesh ADCBA, $I_4R_4 + I_5R_5 - I_1R_1 - I_2R_2 = 0$

This is called kirchoff's voltage law (KVL)

APPLICATION OF KIRCHOFF'S LAW BALANCED WHEATSTONE BRIDGE

The kirchoff's laws can be applied to solve complicated networks such as wheatstone's bridge. wheat stone's bridge method is widely used for find a value of unknown resistance by using 3 known resistances.



Four resistances P, Q, R & S are connected like a bridge in 4 terminals A, B, C & D as shown in the figure P, Q & R are known & S is unknown. Two terminals A & C connected with key K_1 & source of emf E. Other two terminals B & D. Connected with key K_2 & a galvanometer. G is the resistance of galvanometer.

Wheatstone bridge is said to be balanced if there is no current in the galvanometer $\boxed{I_g = 0}$ It is known as balanced condition of wheatstone bridge.

Now applying Kirchoff's law to the terminal B. (KCL)

$$I_1 = I_3 + I_g$$

$$\Rightarrow I_1 - I_3 - I_g = 0$$

$$\Rightarrow I_1 = I_3$$

$$\boxed{\frac{I_1}{I_3} = 1} \quad \text{- - - (i)}$$

Applying 1st law to ther terminal D.

$$I_2 + I_g - I_4 = 0$$

$$I_2 = I_4$$

$$\boxed{\frac{I_2}{I_4} = 1} \quad \text{- - - - (ii)}$$

Equating equation (i) & (ii)

$$\frac{I_1}{I_3} = \frac{I_2}{I_4}$$

$$\Rightarrow \boxed{\frac{I_1}{I_2} = \frac{I_3}{I_4}} \quad \text{- - - (iii)}$$

Applying Kirchoff's voltage law to the closed mesh ABDA

$$I_1 P + I_g G - I_2 R = 0$$

$$I_1 P = I_2 R$$

$$\boxed{\frac{I_1}{I_2} = \frac{R}{P}} \quad \text{- - - (iv)}$$

Applying Kirchoff's 2nd law to the mesh BCDB

$$I_3 Q - I_1 S - I_g R_{g(G)} = 0$$

$$\Rightarrow I_3 Q = I_1 S$$

$$\Rightarrow \frac{I_3}{I_1} = \frac{S}{Q} \quad --- (iv)$$

Using

$$\frac{I_1}{I_2} = \frac{R}{P} = \frac{I_3}{I_1} = \frac{S}{Q}$$

$$\Rightarrow \frac{R}{P} = \frac{S}{Q}$$

$$\Rightarrow \boxed{\frac{P}{Q} = \frac{R}{S}}$$

It is known as balanced condition of wheatstone bridge $\boxed{S = \frac{QR}{P}}$

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ELECTROMAGNETISM & ELECTROMAGNETIC INDUCTION

MAGNET

A piece of substance which possesses the property of attracting small pieces of iron towards it is called a magnet.

A dark coloured iron are called, Magnetite was found in the city of Magnesia.

ELECTROMAGNETISM

The phenomenon of interactions of electric current & magnetic field is known as electromagnetism. The generation of magnetic field from a current carrying conductor is called electromagnetism.

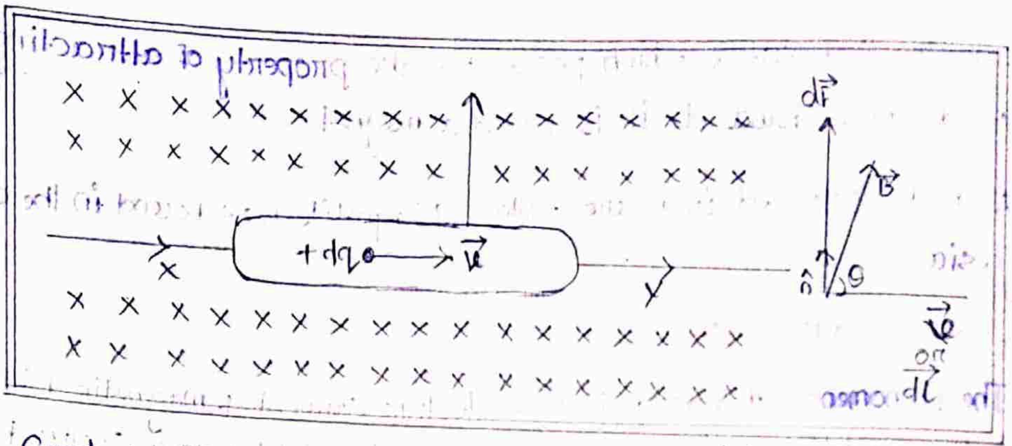
Magnetic effects of electric currents have been observed by the scientists for long periods of time. In 1820 Oersted observed that "a compass needle is deflected from its normal south-north direction when it is placed near a current carrying conductor." The deflection of the compass needle indicates that flow of current has introduced a magnetic field.

In the same year Ampere observed that two current carrying conductors placed side by side exert forces on each other, like two magnets placed close to each other.

From such observations, Ampere concluded that a current carrying conductor behaves as if it is a magnet with magnetic field surrounding it.

FORCE ACTING ON A CURRENT CARRYING CONDUCTOR PLACED IN A UNIFORM MAGNETIC FIELD

The current in a conductor is due to the motion of free electrons in a definite direction. when such a conductor is placed in a magnetic field, each electron moving in the magnetic field experiences a force. Hence we conclude that a current carrying conductor experiences a force placed in a magnetic field.



Consider a Conductor XY placed in a uniform magnetic field $\vec{B}$ acting inwards at right angle to the plane of paper. Let a Current 'I' flows through the Conductor from X to Y.

Let 'dq' be a small amount of positive charge moving from X to Y with a velocity $\vec{v}$.

The force $d\vec{F}$ experienced by this charge is given by

$$d\vec{F} = dq\,(\vec{V} \times \vec{B})$$

If the charge travels a small distance $d\vec{L}$ in time dt, then

$$\vec{V} = \frac{d\vec{L}}{dt}$$

Hence $d\vec{F} = dq \times \left(\frac{d\vec{L}}{dt} \times \vec{B}\right) = \frac{dq}{dt}\,(d\vec{L} \times \vec{B})$

$$\Rightarrow d\vec{F} = I\,(d\vec{L} \times \vec{B}) \quad \text{--- (1)}$$

Direction of the length $d\vec{l}$ is taken to be the direction of Current i.e from X to Y.
Now integrating the equation (1) to obtain the net force is given by

$$\vec{F} = \int d\vec{F} = \int d\vec{L} \times \vec{B}$$

$$\Rightarrow \vec{F} = I\,(\vec{l} \times \vec{B})$$

$$\Rightarrow \vec{F} = IlB \sin\theta\,\hat{n}$$

where $\hat{n}$ is a unit vector in a direction perpendicular to the plane containing $\vec{l}$ & $\vec{B}$, θ is the angle between $\vec{l}$ & $\vec{B}$.

Special case

(i) If $\theta = 0^\circ$ or 180° $\Rightarrow \sin\theta = 0$

$$\boxed{F = 0}$$

If the Conductor Carrying current is parallel to the direction of magnetic field, it experiences no force.

(ii) If $\theta = 90^\circ$, $\Rightarrow \sin\theta = 1$

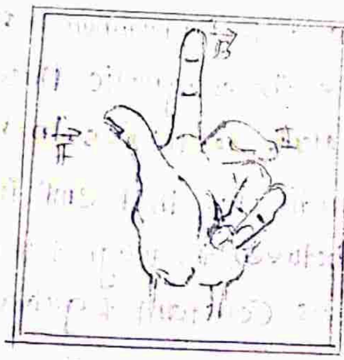
$$\boxed{F = ILB}$$

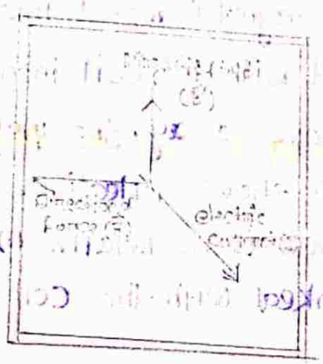
If the Conductor Carrying Current is perpendicular to the direction of magnetic field, it experiences maximum force.

The direction of force can be obtained by Right hand thumb rule or by Fleming's left hand rule.

FLEMING'S LEFT HAND RULE

- The First finger (Fore finger), the Central finger & the thumb of the left hand are stretched in mutually perpendicular direction, If the first finger represents the direction of magnetic field ($\vec{B}$) & Central finger represents the direction of the electric Current (I), then the thum represents the direction of the force ($\vec{F}$) that the Current Carrying Conductor experiences.





-This diagram represents the Fleming's Left hand rule.

Fleming's left hand rule can only be applied when the direction of motion of charged particles. i.e electric Current is perpendicular to the lines of force.

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FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

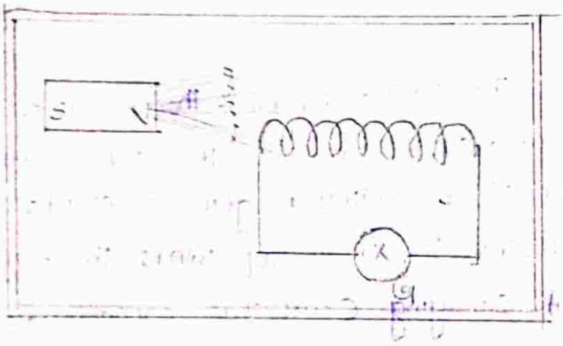
The phenomenon of generating Current or emf by changing the number of magnetic lines of force or magnetic flux associated with the Conductor is Called Electromagnetic induction.

The emf developed in the coil is Called induced emf. Thus the Current generated is Called induced Current.

The Concept of electromagnetic induction is given by Faraday.

FARADAY's FIRST LAW

Statement :- whenever magnetic flux linked with a circuit changes, an emf is induced in it. The induced emf exists in the circuit so long as the change in magnetic flux linked with it Continues.



Explanation :- when the magnet is moved towards the coil, the number of magnetic lines of force linked with the coil increase i.e the magnetic flux increases. when the magnet is moved away, the magnetic flux decreases. In both the Cases, galvanometeter shows deflection. This indicates that emf is induced in the coil. when there is no relative motion between the magnet & coil, the magnetic flux linked with the coil remains Constant & galvanometer shows no deflection.

FARADAY'S SECOND LAW

Statement :- The magnitude of the induced emf is directly proportional to the number of turns (N) of the coil & to the rate of change of magnetic flux linked through the coil.

Explanation :- when the magnet move faster towards the coil, the magnetic flux linked with the coil changes at a faster rate. Then the galvanometer deflection is more.

When the magnet moves slowly, then the rate of change of magnetic flux is smaller. Then the galvanometer deflection is small.

Hence the magnitude of the emf induced is directly proportional to the rate of change of magnetic flux linked with the coil.

Mathematically

$$E \propto N$$

$$E \propto \frac{d\phi_B}{dt}$$

Combining these two

$$E \propto N \frac{d\phi_B}{dt}$$

$$\Rightarrow \boxed{E = -N \frac{d\phi_B}{dt}}$$

Here the negative sign indicates that the induced emf always opposes the change in magnetic flux associated with the circuit.

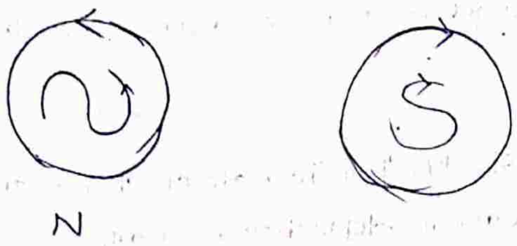
LENZ'S LAW

Lenz's law deals with the direction of emf induced in the circuit due to a change in magnetic flux linked with it.

Statement :- It states that the direction of induced emf is such that it tends to oppose the very cause which produces it.

Explanation :- Let the north pole (N) of the magnet is brought suddenly towards the closed coil, then induced current started to flow through the coil, in anticlockwise direction of induced current is such that it developed north polarity (N) as its magnetic behaviour which repels the north pole (N) of the magnet. Hence it oppose the approaching of north pole (N) of the magnet towards the closed coil. So external work has to be done against the force of repulsion to push the magnet further, This mechanical work gets converted into electrical energy which appears as induced current.

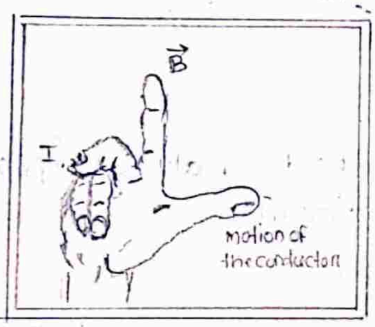
$\boxed{E = -N \frac{d\phi_B}{dt}}$ This negative sign is due to lenz's law.

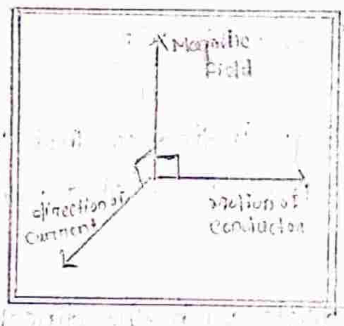


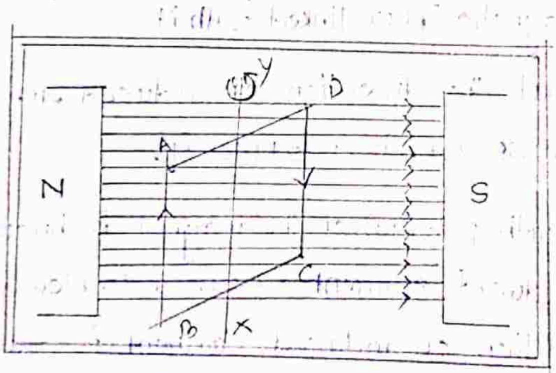
FLEMING'S RIGHT HAND RULE

Fleming's right hand rule is used to find the direction of induced Current in a Conductor.

Statement :- The first Finger, Central finger & the thumb of the right hand is stretched in three mutually perpendicular directions. If the first finger points towards the magnetic field ($\vec{B}$), thumb points towards the direction of motion of Conductor, the direction of Central finger gives the direction of induced Current set up in the Conductor.







Consider a coil ABCD turning in between the two pole pieces of a magnet. Let the direction of rotation of the coil be such that AB moves out of the plane of the paper while CD moves into the plane of paper.

Applying Fleming's right hand rule separately on AB & CD, it can be seen that direction of induced Current is form B to A & D to C.

DISTINCTION BETWEEN FLHR & FRHR

FLEMING'S LEFT HAND RULE	FLEMING'S RIGHT HAND RULE
1. The first finger, the Central finger & the thumb of the left hand are stretched in mutually perpendicular direction if the first finger represents the direction of $\vec{B}$, the Central finger represents the direction of I, then the thumb represents the direction of $\vec{F}$.	1. The first finger, central finger & the thumb of the right hand is s Stretched in three mutually perpendicular directions. If the first finger points towards the direction motion of Conductor the thumb point towards the direction of Central finger gives the direction of induced Current.
2. It is applied to d.c motor	2. It is applied to dynamo or generator.
3. permanent magnetic field & current is provided	3. permanet magnetic field & motion of the Conductor is provided.
4. FLHR gives the direction of force that the Current Carrying.	4. FRHR gives the direction of induced Current set up in the Conductor.
5. In motor, the electrical energy is Converted into mechanical energy.	5. In generator, the mechanical energy is Converted to electrical energy.

MODERN PHYSICS

LASER

The name LASER is acronym of Light amplification by Stimulated Emission of Radiation.

A laser is a device that produces an intense concentrated & highly parallel beam of monochromatic light by process involving energy states within the atoms of the materials.

The term laser has grown out of "maser", "Maser" stands for Microwave Amplification by Stimulated Emission of Radiation. The first successful maser was built by C.H Townes & his associates around 1951 & nine years later employing the same principle. T.H Maiman developed the first laser. Since then lot of research has been built & put to practical use in many fields. All lasers are either based upon principle of stimulated emission or Bersushtrahlung. We shall limit our description only to such lasers which are based upon former principle.

STIMULATED EMISSION

We know that the excited atoms. Under ordinary conditions, de excite within 10^{-5} s sending radiations in random directions. This kind of emission is known as spontaneous emission. On the other hand under special conditions the excited atoms can be made to stay on in their excited states for a comparatively longer period before they are stimulated by an external stimulating agency to get de-excited. This kind of emission is known as stimulated emission. This emission has the characteristics that the radiations emitted travel in the same direction & have same phase & frequency. Essential condition to obtain stimulated emission from ions/molecules or atoms is that they must possess at least one-stable energy level commonly referred to as meta-stable energy state. The life of this state is far longer ($\sim 10^{-3}$ s) than that of the ordinary energy state ($\sim 10^{-8}$ s). How do the existence of such states help in obtaining stimulated emission is explained below

(i) Absorption

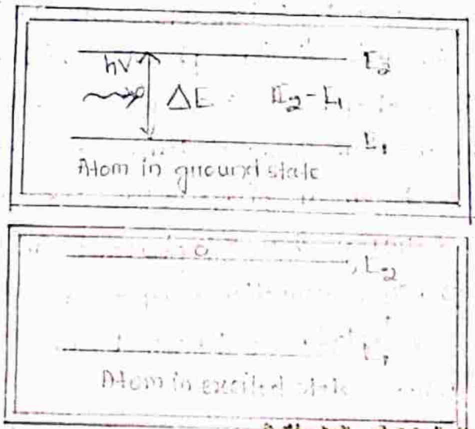
(ii) Spontaneous Emission

(iii) Stimulated Emission

ABSORPTION

when a photon, strikes an atom there is a possibility that the atom will absorb energy & be excited from the ground state to be a higher energy state.

(A photon is a small packet of light)



This process is known as Absorption.

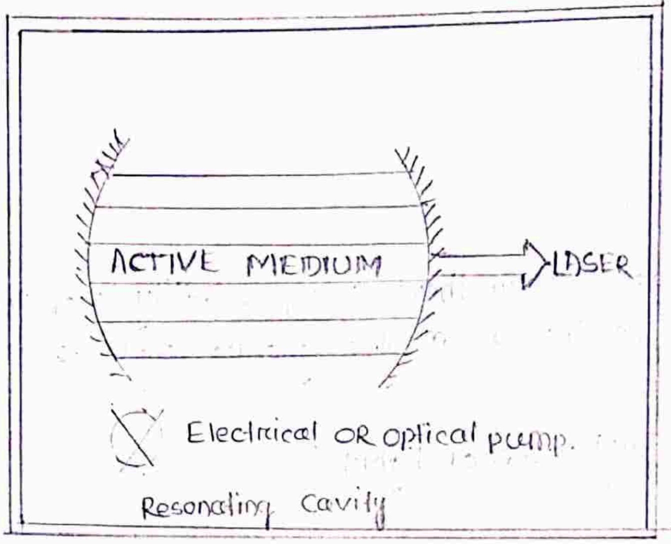
SPONTANEOUS EMISSION

An atom is an excited state has a tendency to jump back to the ground state which is a stable state.

PRINCIPLE OF A LASER SYSTEM

Every laser system consists of an active-medium (solid, liquid or a gas) having ions/molecules or atoms possesing at least one meta stable state. The active medium is placed in resonating cavity having reflectors at its ends & an electrical or optical pump to excite the atoms of the medium.

The basic principle of all lasers is to first bring about population inversion, i.e to have more atoms in the meta-stable state than that in the ground state. This is done by supplying suitable energy to the atoms of the active medium with the help of a pump. This process of bringing about population inversion is known as pumping. Out of these many atoms in the meta-stable state, one atom somewhere happens to de-excite emmitting a photon is known as fluorescent or phosphorescent photon.



As this photon happens to pass nearby other atoms, in similar metastable states, stimulates them to de-excite to emit similar photons which in turn make other atoms to de-excite. Before these photons escape from the active medium, they are made to move to & fro in the medium several times a second by relections so as to build up an intense beam of photons by de-exciting more & more atoms of the medium. It is strange that all photons emitted in this way are found to possess same frequency, direction & speed as that of primary photon or stimulating photon. This constitutes a laser beam. To obtain continous supply, the pumping is continued.

CHARACTERISTICS OF LASER BEAM

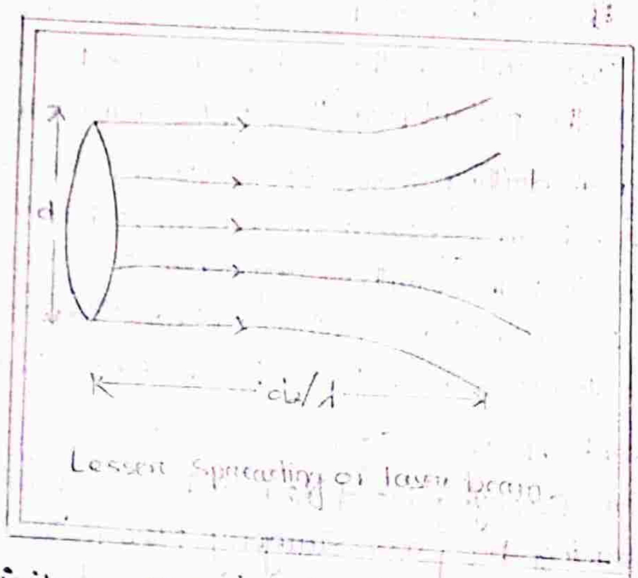
Some very important characteristics of the laser beam are:-

(i) Directionally
(ii) Intensity
(iii) Mono-chromaticity
(iv) Coherence

These properties are briefly described below.

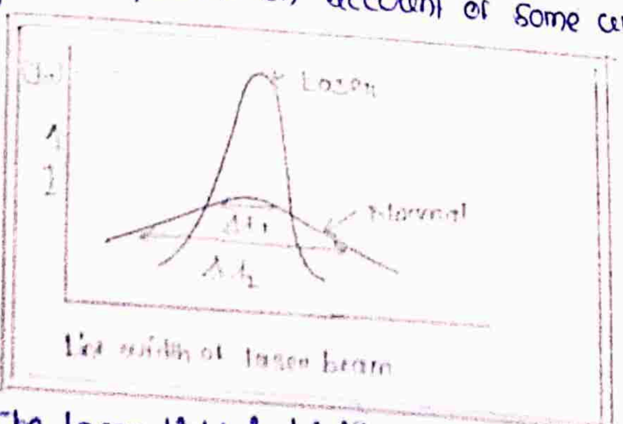
(i) Directionality Light emitted from conventional sources spread in all directions & to obtain narrow beam of light we make use of circular or rectangular apertures in front of sources. Too much spreading is due to diffraction effects of light. On the other hand, is emission only in one direction. Beam coming from an aperture of diameter 'd' continous moving parallel beam upto distance $\sim \frac{d^2}{\lambda}$ & thereafter diffraction effects make it to spread. If $d = 5\,cm$ & $\lambda = 6943\,A$, then the laser beam of this wavelength remains parallel upto distance of the order of 3.6 km from source. Thus, laser beam is highly parallel & directional.

(ii) Intensity :- As the laser beam has the ability of focus over as small an area as 10^{-6} cm^2, therefore, it is highly intense beam. For example, a 1 watt laser when focussed over an area 10^{-6} cm^2, has intensity 10^6 watt/cm^2 whereas ordinary 100 watt lamp will not have intensity even 10,000th of this. It is because the light from the lamp cannot be foccussed over an area less than a cm^2.



Lesser spreading of laser beam.

(iii) Monochromaticity :- Light emitted from a laser is a vastly more monochromatic than that emitted from a conventional mono-chromatic sources of light. Monochromaticity is determined by the spread of wavelength around the wavelength corresponding to which intensity is at the peak. It is measured in terms of line width (Δλ) - which is the width of line on λ-I graph at which the intensity becomes half the peak intensity. Line width of laser light is extreamly small in comparison to that of ordinary light. Line width of light omitted from ruby laser is ~5× course, 10^{-7} A°. This laser light is highly monochromatic. Of course, absolute mono-chromaticity even with laser light is impossible on account of some unavoidable effects.



Line width of laser beam

(iv) Coherence :- The laser light is highly coherent in space & time. This property enables us to realize a tremendous spatial concentration of light power.

APPLICATION OF LASER

(i) **Laser in Surgery** :- Laser beam can be Carried from Source using optical fibres from one place to another & can be focussed over an extreamly small area. The beam travels through optical fibres suffering total internal reflections. As the beam is very powerful Can cut flesh & seal the blood oozing cells instantly allowing the Surgery to be Carried out without wasting blood. The cut is so fine that the patient does not even feel the pain. Two ends of the cut flesh Can be instantly fused by laser beam sparing the patient from the agony of mechanical stitching.

- painless cleaning & drilling of the tooth Cavities have become possible with laser beams. Laser beam is now a days used to break & powder. Certain kinds of stones in kidneys without any major surgery. Lasers are used in eye Surgery to attach a detached retina. Glaucoma (a short of eye cancer) can be treated with laser beam. Laser beams are employed in the treatment of liver Cancer & evaporating unwanted deposits in the arteries Carrying blood to heart. freeing patient from expensive & time Consuming by-pass Surgery. New methods of surgery, using lasers, are being invented day by day. The day is not far when all kinds of Surgical operations will be performed with lasers.

(ii) **Laser in Industry** :- As laser beam is very high power beam, it is employed in melting, Cutting, drilling & welding metals. A powerful laser beam can cut a few cm thick iron sheet like a hot knife Cutting butter.

In Industrial chemistry, laser beam is very high power beam, it is employed to decompose noxious substances from industrial waste to Convert them to harmless Substances for living being.

(iii) **Laser in warfare** :- Very intent laser beams are capable of destroying enemy war plane.