

UNITS AND DIMENSIONS

- UNITS

Standard to measure a physical quantity

- Physical Quantities : Quantities

Law of physics which are expressed by using certain measurable Quantities are called as physical Quantities.

- Types (i) Fundamental Quantities :-

Ex:- length

(ii) Derived Quantities :-

Ex:- Area

* Physical quantities is categorised into two types:-

(i) Fundamental Quantities :-

(ii) Derived Quantities

- Fundamental Quantities :

Fundamental quantities are those quantities which do not requires any other physical quantities for their measurement are called Fundamental

quantities.

Ex: Length, mass, time etc.

- Derived Quantities:

Derived Quantities are those quantities which requires other physical Quantities for their expression.

Ex: Area, volume, force, velocity etc.

- UNIT:-

It is a standard which is used to measured a physical quantity.

- Types of Units:

(i) Fundamental Unit

(ii) Derived Unit.

* Fundamental Units:

Fundamental units are those units which are independent and not related to each other. The units of Fundamental quantities are called Fundamental units.

Ex: Meter, second etc.

* Derived Units:

Derived units are those units which are expressed in form of fundamental units.

Ex: Unit of area is m^2 ,

Unit of volume is m^3 ,

Unit of velocity is m/s ,

Unit of acceleration m/s^2 etc.

* SYSTEM OF UNITS:

Types:- ① C.G.S (French):

Centimeter, Gram, Second.

② F.P.S (British):

Foot, Pound, second.

③ M.K.S (Metric system):

Meter, Kilogram, second

④ S.I :

International system of units.

- C.G.S system of Units :-

This system is based on centimeter, gram, second as the fundamental unit of length, mass and time respectively. This system is also known as French system.

- F.P.S System of Units:

This system is based on foot, pound, and second as the fundamental units of length, mass and time respectively. This system is also known as British system.

- M.K.S system of Units:

This system is based on meter, kilogram and second as the fundamental units of length, mass and time respectively. This system is also known as Metric method.

- S.I system of Units

S.I system

It is based on seven fundamental units
and two supplementary units

Imp.

a) Write the basic Fundamental Units? 12 marks

Fundamental physical quantity	Name of Unit	Symbol of Unit
(i) Length	Meter	m
(ii) Mass	Kilogram	kg
(iii) Time	Second	s
(iv) Temperature	Kelvin	K
(v) Electric current	Ampere	A
(vi) Amount of substance	Mole	Mol.
(vii) Luminosity	Candela	cd

Supplementary physical Quantity	Name of Unit	Symbol
(i) Angle	Radian	Rad
(ii) Solid Angle	Steradian	sr.

21st March 2022

* Dimension:

Defn: Dimension are the powers to which the fundamental quantities are raised in order to represent a physical quantity.

Ex. Length = $[M^0 L^1 T^0]$

Here 0,1,0 are called the dimension of length with respect to mass length time.

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

Here 0,0,1 are called the dimension of time with respect to mass, length and time

1. M.D

Dimensional Formula:

Defn: Dimensional Formula of a physical quantity is the expression showing powers to which different fundamental units are raised.

Ex (i) Dimensional Formula of volume.

$$\text{Volume} = [M^0 L^3 T^0] \quad (0, 3, 0)$$

This is the dimensional formula of volume.

(ii) Dimensional Formula of acceleration

$$\text{Acceleration} = \frac{\cancel{\text{Mass}}}{\cancel{\text{Time}}^2} \frac{\text{Displacement}}{\text{Time}^2}$$

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

(iii) Dimensional Formula of Force.

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$= [M^0 L^0 T^0] \times [M^0 L^1 T^{-2}]$$

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

* (i) Momentum = Mass \times velocity

$$= [M^1 L^0 T^0] \times [M^0 L^1 T^{-1}]$$

$$= [M^1 L^1 T^{-1}]$$

H.W
⇒ Dimensional formulas of work, kinetic energy, potential energy, Electric current, charge.

(ii) Work = Force \times Displacement

$$= \text{Mass} \times \frac{D^2}{T^2}$$

$$= [M^1 L^0 T^0] \times [M^0 L^2 T^{-2}]$$

$$= [M^1 L^2 T^{-2}] \quad (\text{Ans})$$

(iii) Kinetic energy = $\frac{1}{2} m v^2$

$$= \text{mass} \times (\text{velocity})^2 \left(\because \frac{1}{2} \text{ dimension less} \right)$$

$$= [M^1 L^0 T^0] \times [M^0 L^2 T^{-2}]$$

$$= [M^1 L^2 T^{-2}] \quad (\text{Ans})$$

(iii) Potential Energy = mgh

= mass \times Acceleration due to gravity \times height

$$= [M' L^0 T^0] \times [M^0 L' T^{-2}] \times [M^0 L' T^0]$$

$$= [M' L^2 T^{-2}]$$

(iv) Electric current (I)

= Ampere

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

(v) Charge = Electric current \times time

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

* Dimensional Equation:

Def: When the dimensional formula of physical quantity is expressed in the form of an equation by writing the physical quantity on the left hand side and the dimensional formula on the right hand side, then the resultant equation is called the dimensional equation.

$$\text{Ex: (i) } F = [m^1 l^1 t^{-2}]$$

This eqn is called the dimensional eqn.

* Principle of homogeneity:

It states that the dimensional formula of every term on both side of a connecting relation must be same.

* Checking the dimensional correctness of a physical relation.

$$\text{Example: (i) } s = ut + \frac{1}{2}at^2$$

L.H.S:

$$\text{Dimensional formula of } s = [M^0 L^1 T^0]$$

R.H.S

Dimensional formula of vt = velocity \times time
 $= [M^0 L^1 T^0]$

Dimensional formula of at^2 = Acceleration \times (time) 2
 $= \frac{\text{Displacement} \times (\text{time})^3}{(\text{time})^2}$
 $= [M^0 L^1 T^0]$

From the above we get the dimensional formula of every term are same.

Therefore according to principle of homogeneity the given relation is said dimensionally correct.

$$(ii) t = 2\pi \sqrt{\frac{g}{l}}$$

L.H.S
 Dimensional formula of $t = [M^0 L^0 T^1]$

RHS

Dimensional formula of $\sqrt{\frac{g}{L}}$

Acceleration due to
gravity
length

$$= \sqrt{\frac{[M^0 L^1 T^{-2}]}{[M^0 L^1 T^0]}}$$

$$= \sqrt{[M^0 L^0 T^{-2}]}$$
$$= [M^0 L^0 T^{-2}]^{\frac{1}{2}}$$

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

LHS \neq RHS

From the above eqn we get the

Dimensional formula of every term on both the side are not same.

Therefore according to principle of homogeneity the given relation is dimensionally incorrect.

$$(iii) v = u + at$$

LHS

Dimensional formula of $v = [M^0 L^1 T^{-1}]$

RHS

(i) Dimensional formula of $v = \frac{\text{Displacement}}{\text{time}}$

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

(ii) Dimensional formula of $ad = \text{acceleration} \times \text{time}$

$$= \frac{\text{velocity} \times \text{time}}{\text{time}}$$

= velocity

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

$$\therefore L.H.S = R.H.S$$

From the above equation we get the dimensional formula of every term on both side are same

Therefore according to principle of homogeneity the given relation is dimensionally correct (Proved)

$$(IV) v^2 - u^2 = 2as$$

L.H.S

Dimensional formula of v^2 = $(\text{Final velocity})^2$

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

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

R.H.S

Dimensional formula of u^2 = $(\text{Initial velocity})^2$

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

R.H.S

Dimensional formula of $2as$ = acceleration \times displacement

$$= \frac{(\text{Displacement})^2}{(\text{Time})^2}$$

$$= \frac{[M^0 L^1 T^0]^2}{[M^0 L^0 T^1]^2}$$

$$= \frac{[M^0 L^2 T^0]}{[M^0 L^0 T^2]}$$

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

L.H.S = R.H.S

From the above equation we get
the dimensional formula of every term on
both side are same.

Therefore, according to principle of homogeneity the given relation is dimensionally correct.
 (Proved)

$$(v) F = \frac{mv^2}{r}$$

L.H.S

Dimensional formula of F

$F = \text{mass} \times \text{Acceleration}$

$$= \text{mass} \times \frac{\text{Displacement}}{(\text{Time})^2}$$

$$= [M'L^0T^0] \times \frac{[M^0L^1T^0]}{[M^0L^0T^2]}$$

$$= [M'L^0T^0] \times [M^0L^1T^{-2}]$$

$$= [M'L^1T^{-2}]$$

R.H.S Dimensional formula of $\frac{mv^2}{r}$

$$\frac{mv^2}{r} = \frac{\text{mass} \times (\text{velocity})^2}{\text{radius}}$$

$$= \frac{\text{mass} \times (\text{Displacement})^2}{\text{radius} \times (\text{Time})^2}$$

$$\begin{aligned}
 &= \frac{[M' L^0 T^0]}{[M^0 L^1 T^0]} \times \left(\frac{[M^0 L^2 T^0]}{[M^0 L^0 T^2]} \right) \\
 &= [M' L^1 T^0] \times [M^0 L^2 T^{-2}] \\
 &= [M' L^1 T^{-2}]
 \end{aligned}$$

$$\therefore LHS = RHS$$

From the above equation we get
 the dimensional formula of every term on
 both side are same.

Therefore, according to principle
 of homogeneity the given relation is dimensionally
 correct (proved).

SCALARS AND VECTORSScalors

- Scalars quantities: 12 marks

The physical quantities which requires only magnitude for their complete specification are called scalars quantities.

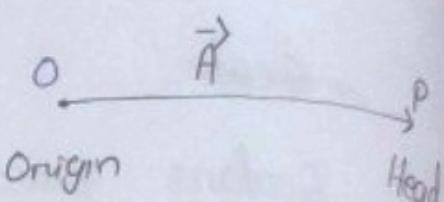
Ex: Mass, length, volume, time, distance, speed, density, temperature, charge etc.

- Vector quantities: 12 marks

The physical quantities which requires magnitude as well as direction for their complete specification and satisfies the law of vector addition are called vector quantities.

Ex: Displacement, velocity, acceleration, force, momentum, electric field, magnetic field etc.

- Representation of a Vector :

- (i) A vector ' \vec{A} ' is represented by an arrow 
- ~~(B)~~ is of finite length directed from initial point 'O' to the terminal point 'P'.
- (ii) The length of the arrow represent the magnitude of the vector and the arrow head denotes the direction of vector.
- (iii) A vector is written with an arrow head over its symbol like ' \vec{A} '.
- (iv) The magnitude of ~~the~~ the vector is represented by modulus of vector i.e $|\vec{A}|$ or simply ' A '.

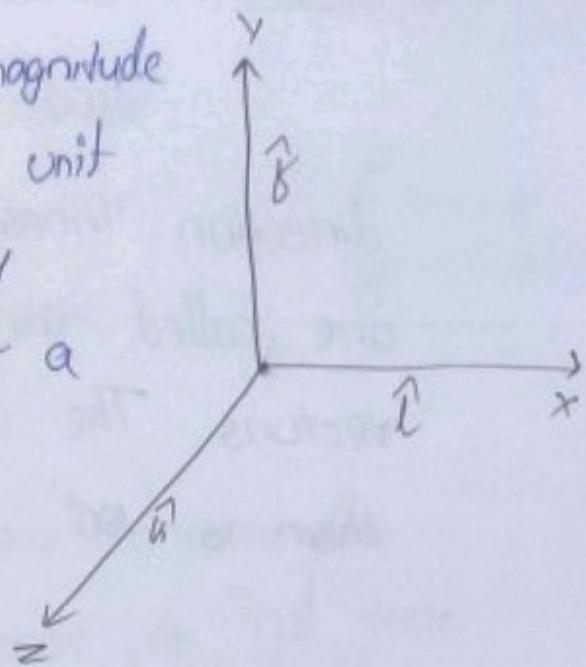
* TYPES OF VECTORS

(1) Null Vector :-

It is a vector having zero magnitude and an arbitrary direction.

(ii) Unit Vectors:

Any vector whose magnitude is 1 unit is called as a unit vector. A unit vector only specifies the direction of a given vector.



(iii) Collinear Vectors:

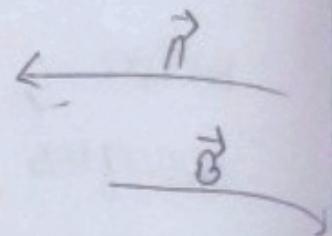
Vectors having common line of action are called collinear vectors. It is of two types:

(a) Parallel vectors ($\theta=0^\circ$)

Two vectors acting along same direction irrespective of their magnitude are called parallel vectors. The angle between them is '0°'.

b) Antiparallel Vectors ($\theta = 180^\circ$)

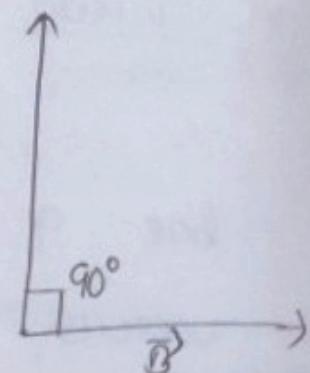
Two vectors acting along opposite direction irrespective of their magnitude are called as antiparallel vectors. The angle between them is 180° .



(iii) Perpendicular Vectors ($\theta = 90^\circ$):

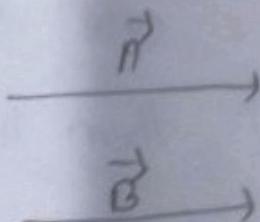
Two vectors are called perpendicular when they are normal to each other.

The angle between two vectors is 90° .



(iv) Equal Vectors:

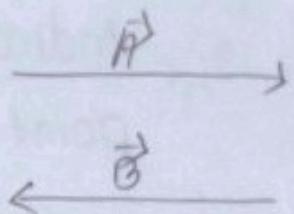
Two vectors are said to be equal if they have same magnitude and direction.



- * All equal vectors are parallel vectors but the reverse is not true.

(v) Negative Vectors:

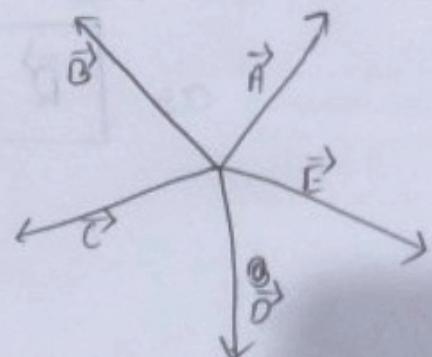
A vector is said to be negative vector of another one if they have same magnitude but opposite direction.



- * All negative vectors are antiparallel vectors but the reverse is not true.

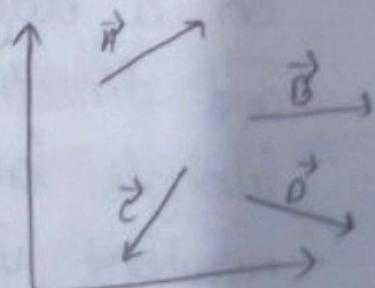
(vi) Co-initial Vectors:

A number of vectors are called co-initial when they have common initial point.



(vii) Co-planer Vectors

A number of vectors are said to be coplaner when they are lying in the same plane.



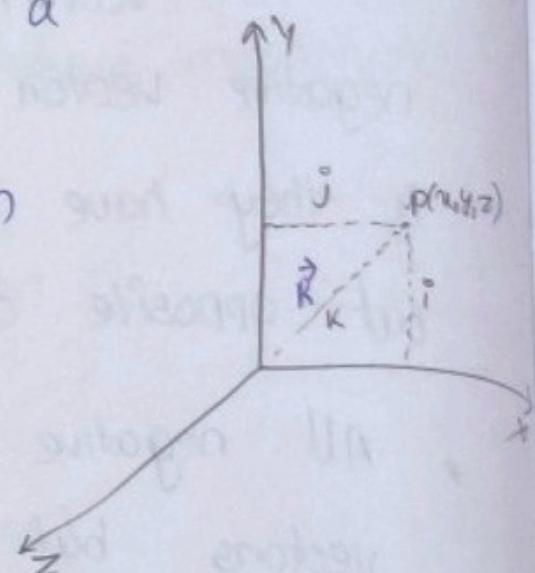
1.M.P

(VIII) Position Vectors:

The vectors that indicates the position of a point in a co-ordinate system is called position vector. ' \vec{R} ' is called position vector of position point ' P ' from the origin.

Position vector can be written

$$\text{as } \vec{R} = xi + yj + zk$$



25th MARCH 2022

* ADDITION OF VECTORS:

1) Triangle law of vector addition:

If two vectors are acting simultaneously on a body one represented in magnitude and direction by two adjacent side of a triangle taken in same order, then the resultant vector is represented in magnitude and direction by the third side of the triangle taken in opposite order.

If two vectors \vec{A} & \vec{B} acting at a point are represented by two sides OP & PQ of the triangle OPQ , taken in same order. The third of the OQ represents the resultant vector \vec{R} taken in opposite order.

$$\text{So, } \vec{R} = \vec{A} + \vec{B}$$

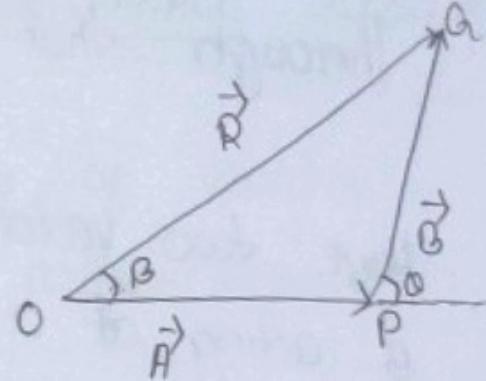
Mathematically it is proved that

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

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

2) Parallelogram law of vector addition:

If two vectors acting simultaneously are represented in magnitude and direction by two adjacent side of a parallelogram drawn from a point, then the resultant vector is represented in magnitude and direction by the diagonal of the parallelogram passing



through that point.

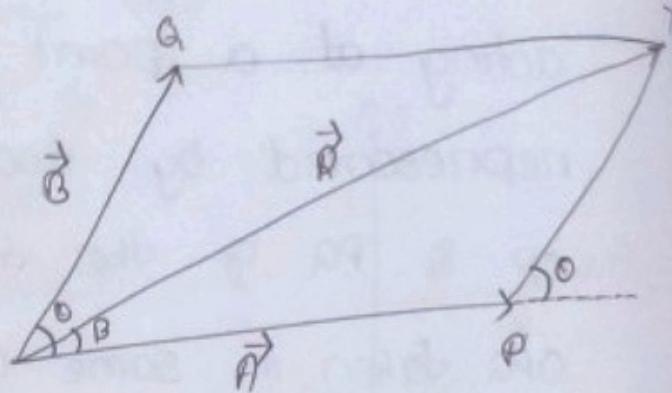
Hence two vectors \vec{A} & \vec{B} acting at a point is represented by two adjacent sides OP &

OQ of the parallelogram $OPTQ$ drawn from a point. The diagonal OP represent the resultant vector \vec{R} passing through the said point.

Mathematically it is proved that

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

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



* RESOLUTION OF VECTORS:

The process of splitting of vectors into various components is called resolution of vectors.

Let, \vec{R} be the position vector of point $P(x,y)$ in my plane.

From point P , two perpendiculars are drawn that is PA on x axis and PB on y axis.

Let, \hat{i} and \hat{j} be the unit vectors along \vec{x} and \vec{y} axis respectively. The vector \vec{R} is resolved into two component \vec{R}_x and \vec{R}_y .

Now According to triangle law of vectors addition,

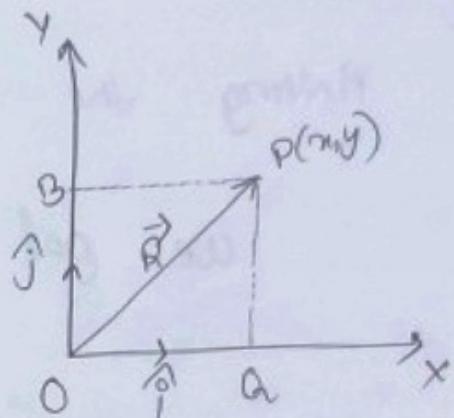
$$\vec{R} = \vec{R}_x + \vec{R}_y$$

$$\Rightarrow \vec{R} = \hat{i} R_x + \hat{j} R_y \quad \text{--- (1)}$$

$$\text{In } \triangle OPQ, \cos \theta = \frac{b}{h} = \frac{OQ}{OP}$$

$$\Rightarrow \cos \theta = \frac{R_x}{R}$$

$$\Rightarrow R \cos \theta = R_x \quad \text{--- (II)}$$



$$\text{similarly } \sin \theta = \frac{PQ}{OP}$$

$$\therefore \sin \theta = \frac{Ry}{R}$$

$$\Rightarrow R \sin \theta = Ry \quad \text{---(iii)}$$

Putting the value of (ii) and (iii)

$$\text{we get } R = \sqrt{R \cos^2 \theta + R \sin^2 \theta}$$

* VECTOR MULTIPLICATION:

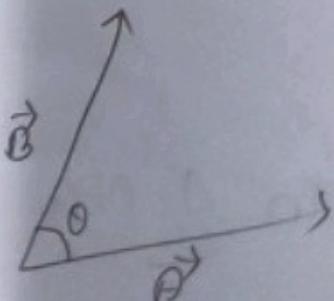
It is of two types.

(i) Scalar product (Dot product)

(ii) Vector product (Cross product)

1) Scalar product on Dot product:

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



Mathematically

$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

(i) If $\theta = 90^\circ$

$$\begin{aligned}\vec{A} \cdot \vec{B} &= AB \cos 90^\circ \\ &= AB \times 0 \\ &= 0\end{aligned}$$

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

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

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

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

$$\begin{aligned}\vec{A} \cdot \vec{B} &= AB \cos 0^\circ \\ &= AB \times 1 \\ &= AB\end{aligned}$$

So $\hat{i} \cdot \hat{i} = 1$

$$\hat{j} \cdot \hat{j} = 1$$

$$\hat{k} \cdot \hat{k} = 1$$

Problem -1

Find the dot products of the given vectors are $\vec{A} = 3\hat{i} + 2\hat{j} + 5\hat{k}$
 $\vec{B} = 4\hat{i} + 3\hat{j} + 7\hat{k}$

Sol?

* Dot product in term of Rectangular components:

$$\text{If } \vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$$

$$\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$$

$$\text{so, } \vec{A} \cdot \vec{B} = (A_x\hat{i} + A_y\hat{j} + A_z\hat{k}) \cdot (B_x\hat{i} + B_y\hat{j} + B_z\hat{k})$$

$$\Rightarrow \vec{A} \cdot \vec{B} = A_x\hat{i} \cdot B_x\hat{i} + A_x\hat{i} \cdot B_y\hat{j} + A_x\hat{i} \cdot B_z\hat{k} +$$

$$A_y\hat{j} \cdot B_x\hat{i} + A_y\hat{j} \cdot B_y\hat{j} + A_y\hat{j} \cdot B_z\hat{k} +$$

$$A_z\hat{k} \cdot B_x\hat{i} + A_z\hat{k} \cdot B_y\hat{j} + A_z\hat{k} \cdot B_z\hat{k}$$

$$\Rightarrow \vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$$

Q. Find the dot products of the given vectors of $\vec{A} = 3\hat{i} + 2\hat{j} + 5\hat{k}$
 $\vec{B} = 4\hat{i} + 3\hat{j} + 7\hat{k}$

Soln

Given $\vec{A} = 3\hat{i} + 2\hat{j} + 5\hat{k}$

$$\vec{B} = 4\hat{i} + 3\hat{j} + 7\hat{k}$$

Here $A_x = 3, A_y = 2, A_z = 5$

$$B_x = 4, B_y = 3, B_z = 7$$

\therefore We know $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$

$$= (3+4) + (2+3)$$

$$= (3 \cdot 4) + (2 \cdot 3) + (5 \cdot 7)$$

$$= 12 + 6 + 35$$

$$= 53 \text{ (Ans)}$$

2) $\vec{A} = 2\hat{i} + 5\hat{j} + 6\hat{k}$

$$\vec{B} = 3\hat{i} - 6\hat{j} + \hat{k}$$

Here $A_x = 2, A_y = 5, A_z = 6$

$$B_x = 3, B_y = -6, B_z = 1$$

$\therefore \vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$

$$= (2 \cdot 3) + 5 \cdot (-6) + 6 \cdot 1$$

$$= 6 - 30 + 6$$

$$= -18 \text{ (Ans)}$$



$$(iii) \vec{A} = 5\hat{i} + 2\hat{j} + 3\hat{k}$$

$$\vec{B} = 2\hat{i} - 3\hat{j}$$

$$\text{Hence } A_x = 5, A_y = 2, A_z = 3$$

$$B_x = 2, B_y = (-3), B_z = 0$$

$$\vec{A} \cdot \vec{B} = (5 \cdot 2) + 2 \cdot (-3) + 3 \cdot 0$$

$$= 10 - 6$$

$$= 4 \text{ J} \text{ (Ans)}$$

$$(iv) \vec{A} = 6\hat{i} + 2\hat{k}$$

$$\vec{B} = 3\hat{i} + 4\hat{j} + 6\hat{k}$$

$$\text{Hence } A_x = 6, A_y = 0, A_z = 2$$

$$B_x = 3, B_y = 4, B_z = 6$$

$$\vec{A} \cdot \vec{B} = (6 \cdot 3) + (0 \cdot 4) + 2 \cdot 6$$

$$= 18 + 12$$

$$= 30 \text{ (Ans)}$$

$$(v) \vec{A} = 3\hat{i} + 2\hat{j} \quad \text{Hence } A_x = 3, B_Ay = 2, A_z = 0$$

$$\vec{B} = 4\hat{i} + 3\hat{j}$$

$$\vec{A} \cdot \vec{B} = (3 \cdot 4) + 2 \cdot 3 + (0 \cdot 0)$$

$$= 12 + 6$$

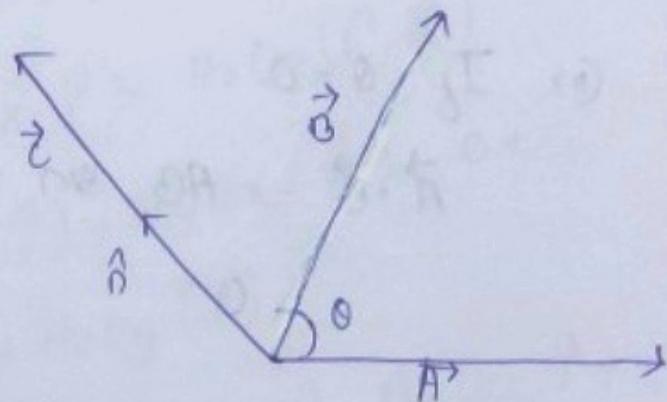
$$= 18 \text{ (Ans)}$$

* CROSS PRODUCT / VECTOR PRODUCT :-

Cross product of two vectors \vec{A} & \vec{B} defined as a single vector \vec{C} whose magnitude is equal to the product of their individual magnitude and the sine of smaller angle along the normal to the plane containing vector \vec{A} & \vec{B} .

$$\vec{A} \cdot \vec{B} = AB \sin \theta \hat{n}$$

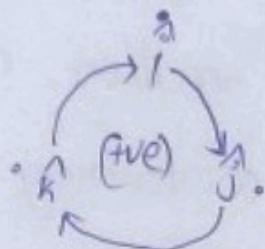
When, \hat{n} is the unit vector \vec{C} directed perpendicular to the plane containing vector \vec{A} & \vec{B} .



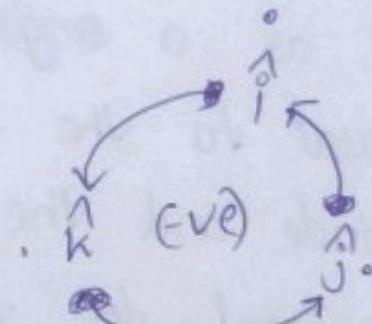
(ii) If $\theta = 90^\circ$

$$\begin{aligned}\vec{A} \cdot \vec{B} &= AB \sin 90^\circ \hat{n} \\ &= AB \times 1 \times \hat{n} \\ &= AB \hat{n} \\ &= AB\end{aligned}$$

$$\text{So, } \begin{array}{l} \hat{i} \times \hat{j} = \hat{k} \\ \hat{j} \times \hat{k} = \hat{i} \\ \hat{k} \times \hat{i} = \hat{j} \end{array} \quad \left| \begin{array}{l} \hat{j} \times \hat{i} = -\hat{k} \\ \hat{k} \times \hat{j} = -\hat{i} \\ \hat{i} \times \hat{k} = -\hat{j} \end{array} \right.$$



(clockwise direction)



(Anticlockwise direction)

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

$$\vec{A} \cdot \vec{B} = AB \sin 0^\circ$$

$$= 0$$

$$\text{So } \hat{i} \times \hat{j} = 0$$

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

$$\hat{k} \times \hat{k} = 0$$

* Cross product in term of Rectangular component.

$$J_f \vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$$

$$\vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$$

So,

$$\vec{A} \times \vec{B} = (A_x \hat{i} + A_y \hat{j} + A_z \hat{k}) \times (B_x \hat{i} + B_y \hat{j} + B_z \hat{k})$$

$$= A_x B_x (\cancel{\hat{i} \times \hat{i}}) + A_x B_y (\hat{i} \cdot \hat{j}) + A_x B_z (\hat{i} \cdot \hat{k}) +$$

$$A_y B_x (\cancel{\hat{j} \times \hat{i}}) + A_y B_y (\hat{j} \cdot \hat{j}) + A_y B_z (\hat{j} \cdot \hat{k}) +$$

$$A_z B_x (\cancel{\hat{k} \times \hat{i}}) + A_z B_y (\hat{k} \cdot \hat{j}) + A_z B_z (\hat{k} \cdot \hat{k}) +$$

$$= 0 + A_x B_y \hat{k} + A_x B_z (-\hat{j}) + A_y B_x (-\hat{k}) + 0 +$$

$$A_y B_z \hat{i} + A_z B_x \hat{j} + A_z B_y (-\hat{i})$$

$$= A_x B_y \hat{k} - A_x B_z \hat{j} - A_y B_x \hat{k} + A_y B_z \hat{i} +$$

$$A_z B_x \hat{j} - A_z B_y \hat{i}$$

$$= (A_y B_z - A_z B_y) \hat{i} + (A_z B_x - A_x B_z) \hat{j} +$$

$$(A_x B_y - A_y B_x) \hat{k}$$

$$\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

Problem

1) Find the cross product between

$$\vec{A} = 3\hat{i} + 2\hat{j} + 5\hat{k}$$

$$\vec{B} = 4\hat{i} + 3\hat{j} + 7\hat{k}$$

Here $A_x = 3, A_y = 2, A_z = 5$

$$B_x = 4, B_y = 3, B_z = 7$$

$$\vec{A} \cdot \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 2 & 5 \\ 4 & 3 & 7 \end{vmatrix}$$

$$= (14 - 15)\hat{i} + (20 - 21)\hat{j} + (9 - 8)\hat{k}$$

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

Ans

2) Find the cross product between

$$\vec{A} = 2\hat{i} + 5\hat{j} + 6\hat{k}$$

$$\vec{B} = 3\hat{i} - 6\hat{j} + \hat{k}$$

Soln: Here $A_x = 2, A_y = 5, A_z = 6$

$B_x = 3, B_y = -6, B_z = 1$

∴ The cross product,

$$\vec{A} \cdot \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 5 & 6 \\ 3 & -6 & 1 \end{vmatrix}$$

$$\begin{aligned} &= (5+36)\hat{i} + (18-2)\hat{j} + (-12-15)\hat{k} \\ &= 41\hat{i} + 16\hat{j} - 27\hat{k} \quad (\text{Ans}) \end{aligned}$$

3) Two forces of 5N and 20N are at an angle of 60° between them. Find the resultant force in magnitude and direction?

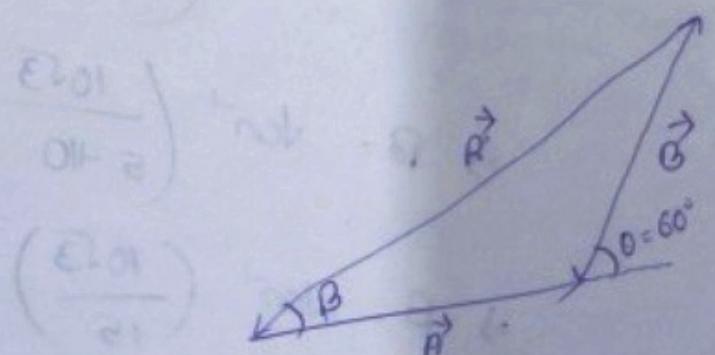
Soln: Given, $A = 50 \text{ N}$

$$B = 20 \text{ N}$$

$$\theta = 60^\circ$$

$$R = ?$$

$$B = ?$$



\therefore Magnitude of Resultant force.

$$\begin{aligned} R &= \sqrt{A^2 + B^2 + 2AB \cos \theta} \\ &= \sqrt{(5)^2 + (20)^2 + 2 \cdot 5 \cdot 20 \cdot \cos 60^\circ} \\ &= \sqrt{25 + 400 + 200 \times \frac{1}{2}} \\ &= \sqrt{425 + 100} \\ &= \sqrt{525} \\ &= 5\sqrt{21} \text{ N} \\ &= 22.912 \text{ N} \end{aligned}$$

\therefore Direction of Resultant force

$$\tan \beta = \frac{B \sin \theta}{A + B \cos \theta}$$

$$\Rightarrow \beta = \tan^{-1} \left(\frac{20 \sin 60^\circ}{5 + 20 \cos 60^\circ} \right)$$

$$\Rightarrow \beta = \tan^{-1} \left(\frac{20 \times \frac{\sqrt{3}}{2}}{5 + 20 \times \frac{1}{2}} \right)$$

$$\Rightarrow \beta = \tan^{-1} \left(\frac{10\sqrt{3}}{5 + 10} \right)$$

$$\Rightarrow \beta = \tan^{-1} \left(\frac{10\sqrt{3}}{15} \right)$$

$$\Rightarrow \beta = \tan^{-1} \theta \left(\frac{2\sqrt{3}}{3} \right)$$

$$\Rightarrow \beta = 49.10^\circ$$

\therefore Magnitude is 22.912 N and direction is
 49.10° of resultant force.

KINEMATICS:-

* The branch of physics which deals with the study of the motion of a body is called kinematics.

* Concept of Rest and motion:-

Rest:- A body is said to be in Rest if it does not change its position with respect to surrounding or a specified reference frame.

Motion:- A body is said to be in motion if it changes its position with respect to surrounding or a specified reference frame.

① * Displacement:- The shortest distance between the initial and the final position of the body is called the displacement.

It is a vector quantity and it is represented by 'S'.

Dimension formula = $[M^0 L^1 T^0]$.

SI unit :- meter (m)

② * Speed:- It is defined as the distance traveled by the body per unit time.

It is given by speed = $\frac{\text{Distance}}{\text{Time}}$

It is a scalar quantity

SI unit = m/s

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

③ * Velocity:- It is defined as the rate of change of displacement per unit time.

It is given by velocity = $\frac{\text{Displacement}}{\text{Time}}$

It is a vector quantity

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

SI unit = m/s

4 Acceleration: $\rightarrow (\ddot{a})$

It is defined as the rate of change of velocity per unit time.

$$\text{It is given by } \ddot{a} = \frac{\text{Change in velocity}}{\text{Change in time}} = \frac{dv}{dt}$$

$$\text{Dimension} = [M^0 L^1 T^{-2}]$$

$$SI \text{ unit} = m/s^2$$

5 Force: $\rightarrow (\vec{F})$ Force is an external agent capable of changing the state of rest or motion of a body.

$$\text{If it is given by force } F = \text{mass}(m) \times \text{acceleration}(\ddot{a})$$

$$\text{Dimension} = [M^1 L^1 T^{-2}]$$

$$SI \text{ unit} = \text{kg } \frac{m}{s^2}$$

$$= N \text{ (Newton)}$$

Note:-

① Average Velocity: $\rightarrow (\vec{v}_{av})$

It is defined as the total displacement covered per total time. It is given by

$$(\vec{v}_{av}) = \frac{\text{Total Displacement}}{\text{Total time}} = \frac{\Delta \vec{s}}{\Delta t}$$

② Instantaneous Velocity: $\rightarrow (v)$

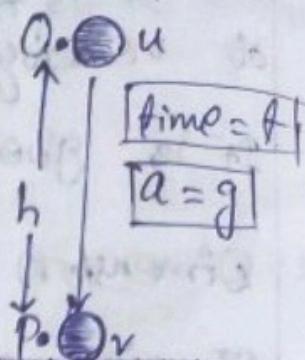
It is defined as the velocity at a particular instant of time.

$$\text{It is given by } (v) = \frac{ds}{dt}$$

Equation of motion under Gravity:

Downward motion:-

Consider a body falling freely from a point 'O' with initial velocity $\vec{u} = 0$



It reaches a point 'P' after 't' second and acquires a velocity 'v', due to the uniform acceleration which is due to the gravity 'g'

Here 'v' is called the final velocity just before the body hitting the ground.

Covers a distance 'h' from Point 'O' to 'P' under the equation of motion under gravity in downward motion can be written as follows:

Velocity time relation:

$$v = u + at$$

$$\Rightarrow v = u + gt$$

Displacement time Relation:

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

$$\Rightarrow s = ut + \frac{1}{2}gt^2$$

Velocity displacement Relation:

$$v^2 - u^2 = 2as$$

$$\Rightarrow v^2 - u^2 = 2gh$$

Displacement in nth second:

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

$$\Rightarrow S_{n\text{th}} = ut + \frac{g}{2}(2n-1)$$

⑥ For a freely falling body :- ($a = g$)

$$so \ h = at + \frac{1}{2}gt^2 \Rightarrow h = \frac{1}{2}gt^2$$

$$\Rightarrow t^2 = \frac{2h}{g}$$

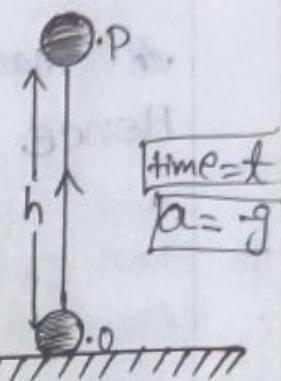
$$\Rightarrow t = \sqrt{\frac{2h}{g}}$$

This time is called the time of Descent. Time of Descent is defined as the time taken by a body to travel from a height to the surface of the Earth.

* Equation of motion under gravity:

● Downward Upward Motion:

Consider a body thrown upward from a point 'O' with initial velocity 'u' and at time $t = 0$. It reaches point 'P' after 't' seconds



it acquires a velocity v (final velocity) due to the uniform acceleration, which is due to the gravity g . It covers a distance h from Point 'O' to 'P', therefore the equation of motion under gravity in upward motion can be written as follows.

Velocity time Relation:

$$\Rightarrow v = u + at$$

$$\Rightarrow v = u + (g)t$$

$$\Rightarrow v = u - gt$$

② Displacement time Relation:

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

$$\Rightarrow s = ut + \frac{1}{2}(g)t^2$$

$$\Rightarrow s = ut - \frac{1}{2}gt^2$$

③ Velocity Displacement Relation:-

$$\Rightarrow v^2 - u^2 = 2as$$

$$\Rightarrow v^2 - u^2 = 2(g)h$$

$$\Rightarrow \boxed{v^2 - u^2 = 2gh}$$

④ Displacement in nth Second

$$\rightarrow S_{n^{th}} = u + \frac{a(2n-1)}{2}$$

$$\Rightarrow S_{n^{th}} = u - \frac{g}{2}(2n-1)$$

at maximum height $v=0$,

$$\text{Hence } v = u - gt \quad \text{or } 0 = u - gt$$

$$gt = u - v = u - 0 \Rightarrow gt = u$$

$$\Rightarrow t = \frac{u}{g}$$

$$\Rightarrow t = \frac{u}{g}$$

$$\text{and } h = ut - \frac{1}{2}gt^2 \quad (\text{Put the value of } t)$$

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

$$\Rightarrow h = \frac{u^2}{g} - \frac{u^2}{2g}$$

$$\Rightarrow h = \frac{u^2}{g} - \frac{u^2}{2g} = \frac{2u^2 - u^2}{2g}$$

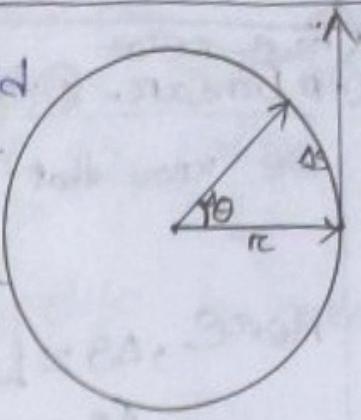
$$\therefore h = \frac{u^2}{2g}$$

Hence here the time is called the time of ascent.

Time of ascent! → It is defined as the

the time taken by a body to reach the maximum height from the surface of the earth.

* Circular Motion:- A body is said to be in circular motion if it moves in such a way that its distance from a fixed point always remains constant.



→ Angular Displacement:- It is defined as the angle turned by the a radius vector, it is denoted by $\Delta\theta$

→ It is a vector quantity.

→ It is given by $\Delta\theta = \frac{\Delta s}{r}$

→ Dimensional formula = $[M^0 L^0 T^0]$

→ SI unit = radian (rad)

→ Angular Velocity:- It is defined as the rate of change of angular displacement per unit time.

It is denoted by ω

It is a vector quantity

It is given by $\omega = \frac{\text{rate of change of angular disp}}{\text{rate of change of time}}$

$$= \frac{d\theta}{dt}$$

Dimensional formula = $[M^0 L^0 T^{-1}]$

SI unit = $\frac{\text{radian}}{\text{second}}$ ($\frac{\text{rad}}{\text{s}}$)

→ Angular Acceleration It is defined as the rate of change of angular velocity per unit time.

It is denoted by α

It is a vector quantity

It is given by $\alpha = \frac{d\omega}{dt}$

Dimensional formula = $[M^0 L^0 T^{-2}]$

SI unit = $\frac{\text{radian}}{\text{second}^2}$

The relation between Linear Displacement and Angular Displacement

We know that $\Delta\theta = \frac{\Delta s}{r}$

$$\Rightarrow \Delta s = r\Delta\theta \quad (\text{scalar form})$$

Here, Δs = Linear Displacement

$\Delta\theta$ = Angular Displacement

r = radius

$$[\vec{ds} = d\theta \times \vec{r}] \quad (\text{In vector form})$$

Linear velocity and angular velocity:-

We know that $\omega = \frac{d\theta}{dt}$

$$= \frac{1}{r} \frac{ds}{dt}$$

$$\left\{ d\theta = \frac{ds}{r} \right.$$

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

$$\rightarrow v = r\omega \quad (\text{in scalar form})$$

$$\vec{v} = \vec{\omega} \times \vec{r} \quad (\text{vector form})$$

where, v = linear velocity

ω = angular velocity, r = radius

Linear Acceleration and Angular acceleration

We know that. $\alpha = \frac{d\omega}{dt}$

$$= \frac{1}{r} \frac{dv}{dt}$$

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

a = Linear acceleration

α = angular acceleration

r = Radius

$$= \frac{a}{r}$$

$$\Rightarrow a = r\alpha \quad (\text{scalar form})$$

$$\Rightarrow \vec{a} = \vec{\omega} \times \vec{r} \quad (\text{in vector form})$$

PROJECTILE MOTION

A body projected in space and is no longer being propelled by itself is called Projectile.

The Path followed by the projectile is called Trajectory Path.

Find the expression for the equation of trajectory, time of flight, Maximum Height and Horizontal Range for a Projectile fired at an angle.

Consider a body fired at an angle ' θ ' with the horizontal having velocity 'u'. The body reaches the highest point 'P' and then falls back at Point 'Q', which is at the same level of projection.

Equation of trajectory :-

Horizontal equation of motion \rightarrow It is uniform in nature, it is given by, displacement = Velocity \times time

$$\Rightarrow x = u \cos \theta \times t$$

$$\Rightarrow t = \frac{x}{u \cos \theta} \quad \text{--- (1)}$$

Vertical equation of motion :-

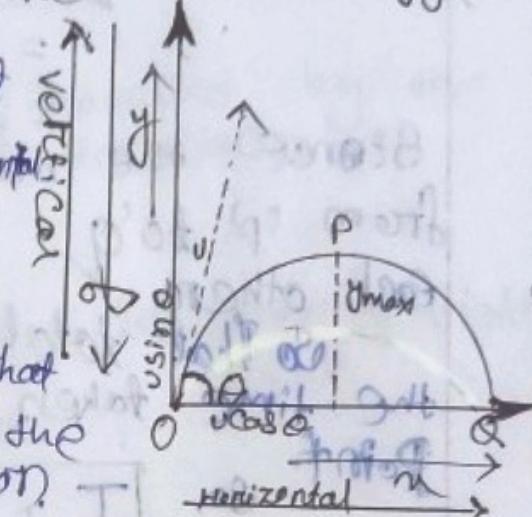
If it is non-uniform in nature, it is given by

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

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

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

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



This is the equation of parabola. Hence, the motion of the Projectile is Parabolic.

★ Time of flight \rightarrow It is the time taken by the Projectile to come back to the same level from which it was projected.

$$OP \rightarrow t$$

$$PQ \rightarrow t$$

$$T = t + t$$

$$= 2t$$

= 2x time of Ascent.

Since the motion from 'O' to 'P' and that from 'P' to 'Q' is symmetric with respect to each other.

So that total time of flight is twice the time taken to reach the highest point.

So, $T = 2t$ (3)

Now, time of ascent is given by

$$V = U + at$$

$$\Rightarrow 0 = Usin\theta + (-gt)$$

$$\Rightarrow gt = Usin\theta$$

$$\Rightarrow t = \frac{Usin\theta}{g}$$

$$+ \times 0.200 = 8$$

(4)

Putting the value of equation (4) in eqn (3)
we get $T = 2t = 2 \frac{Usin\theta}{g}$

$$T = 2t = 2 \frac{Usin\theta}{g}$$

(5)

This eqn represents the total time of flight.

Maximum Height:-

It is the maximum distance travelled by the Projectile in vertical direction.

It is given by $V^2 - U^2 = 2as$

$$\Rightarrow 0 - (U \sin \theta)^2 = 2(-g) y_m$$

$$\Rightarrow -U^2 \sin^2 \theta = -2g y_m$$

$$\Rightarrow y_m = \frac{U^2 \sin^2 \theta}{2g}$$

(6)

Horizontal Range:-

It is the distance travelled by the Projectile in Horizontal direction.

It is given by,

$$\Rightarrow x = \text{Horizontal velocity} \times \text{total time of flight}$$

$$= \frac{U \cos \theta \times 2U \sin \theta}{g}$$

$$= \frac{U^2 2 \sin \theta \cdot \cos \theta}{g}$$

$$\Rightarrow x = \frac{U^2 \sin 2\theta}{g}$$

$$(\sin 2\theta = 2 \sin \theta \cdot \cos \theta)$$

(7)

Condition for maximum horizontal range: - Horizontal range is maximum when $\sin 2\theta$ is maximum
 $\Rightarrow \sin 2\theta = 1 = \sin 90^\circ (\max)$

$$\Rightarrow 2\theta = 90^\circ$$

$$\Rightarrow \theta = 45^\circ$$

$$x_{\max} = \frac{U^2}{g}$$

(8)

UNIT-4

WORK AND FRICTION:-

WORK → work is said to be done if a force acting on a body, displaces it and the force has a component along the direction of the displacement.

It is also defined as the dot product of two vectors, force and displacement.

mathematically,

$$\Rightarrow W = \vec{F} \cdot \vec{s}$$

$$\Rightarrow W = FS \cos\theta$$

F = Magnitude of force

s = magnitude of displacement

θ = Angle between force and displacement.

* If $\theta = 0^\circ$

$$\Rightarrow W = FS \cos 0^\circ$$

$$= FS \cos 0^\circ = FS \times 1$$

$$= FS$$

Here, force and displacement are in same direction and work done is positive.

This means the work is done upon the body.
e.g., A object falling freely due to gravity.

* If $\theta = 90^\circ$

$$W = FS \cos 90^\circ$$

$$= FS \cdot 0$$

$$= 0$$

Here, force and displacement are perpendicular to each other and no work is done

e.g., A person carrying a box over his head and walking in horizontal direction.

$$* \text{If } \theta = 180^\circ$$

$$\begin{aligned}\omega &= F_S \cos 180^\circ \\ &= F_S \cdot -1 \\ &= -F_S\end{aligned}$$

Hence, force and displacement are in opposite direction and work done is negative. This means the work is done by the body
e.g. Work done by the force of friction is negative.

SI unit of work = Joules (J).

CGS unit of work = Erg

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

Dimensional formula work = force \times Displacement

= Mass \times Accn \times Displacement

$$= [M^1 L^0 T^0] \times [m^1 L^1 T^{-2}] \times [m^1 L^1 T^0]$$

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

Q1 Calculate the work done in dragging block 50m horizontally with a rope making an angle 30° with the ground with a force of 60N.

Given $\theta = 30^\circ$

$$f = 60 \text{ N}$$

$$s = 50 \text{ m}$$

$$\therefore \omega = F_S \cos \theta$$

$$= 60 \times 50 \times \cos 30^\circ = 3000 \times \frac{\sqrt{3}}{2} \text{ J}$$

$$= 1500 \times 1.732 \text{ J}$$

$$= 2598 \text{ J}$$

FRICITION

Definition: The force which opposes or tends to oppose the relative motion between two surfaces in contact is called the force of friction.

Explanation →



① When a force is applied to a box, it does not move in the beginning. This is because when the force is applied, at that time the floor is exerting equal amount of force is canceled.

② When the applied force is increased the force on the box by the floor is increasing.

③ There is a limit to the force by the floor, once it is reached the box starts moving, the floor is still applying force on the box.

The force on the box by the floor is arising between them, this force is called the frictional force.

★ Types of force →

① Static friction :-

This is the opposing force which exist between the surface and the body at rest.
e.g:- A book on a table.

② Kinetic friction (Dynamic friction) :-

This is the opposing force which exist when two solid surface move over one another.

Ex:- Pushing a chair acrossing the floor

→ Walking on the Road

③ Rolling friction :-

The opposing force which exist between moving surface when one body rolls over the other.

Ex:- Car moving on a road.

→ Rolling a ball down the lane etc.

④ Fluid friction (Viscosity) :-

The opposing force which exist when something tries to move on or through the liquid is called the viscosity (fluid friction). ~~viscous~~

Ex:- Pushing the water backward while swimming.

ref. Q11-3)

Friction

⑤ Static friction :-

① The force of friction which comes into play when there is no relative motion between the two surfaces in contact.

② Force of static friction is opposite and equal to the applied force till the body is at rest.

③ The maximum value of static friction is called the limiting friction.

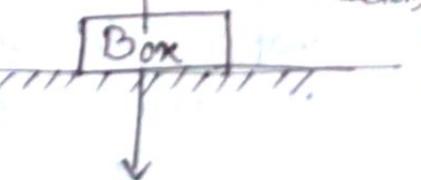
Once the limiting friction is reached the body starts to move and kinetic friction comes to picture.

$$f_s = \mu_s R$$

where, f_s = force of limiting

μ_s = Coefficient of static friction

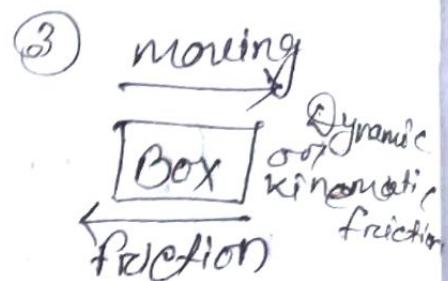
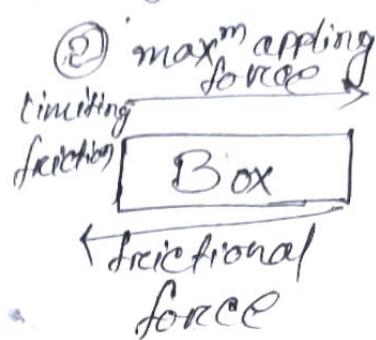
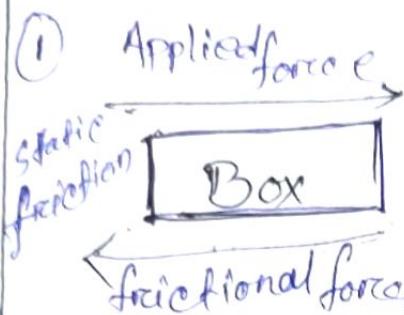
R = Normal reaction.



$$W = mg$$

Kinetic or Dynamic friction:-

The force of friction which comes in to play when there is relative motion between two surfaces in contact is called the force of kinetic friction or dynamic friction.



Laws of limiting friction:-

- ① The direction of force of friction is always opposite to the direction of motion.
- ② The force of limiting friction depends on the nature and the state of polish of the surface in contact and acts tangentially to the interface between the two surfaces.
- ③ The magnitude of the limiting friction (f_L) is directly proportional to the magnitude of the normal reaction (R) between the two surfaces in contact i.e.

$$f_L \propto R$$

- ④ The magnitude of the limiting friction between two surfaces is independent of the area and shape of the surface in contact as known as the normal reaction remains same.

2nd Dec. 2021

Coefficient of friction:-

The coefficient of friction is defined as the ratio of frictional force to the normal reaction.

Mathematically,

$$\mu = \frac{f}{R}$$

Hence, μ = coefficient of friction.

f = Frictional force

R = Normal reaction

Q. A box of mass 30kg is pulled on a horizontal surface by applying a horizontal force. If the coefficient of dynamic friction between the box and the horizontal surface is 0.25, find the force of friction exerted by the horizontal surface on the box.

Given, mass (m) = 30kg $g = 9.8$

$$\mu = 0.25$$

$$f = ?$$

$$\text{Here, } R = mg = 30 \times 9.8 \text{ N}$$

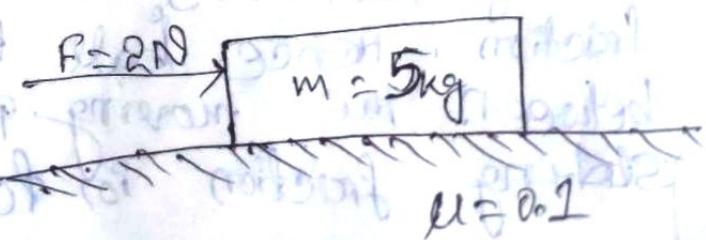
$$\therefore f = \mu R = 0.25 \times 30 \times 9.8 \text{ N}$$

$$\Rightarrow f = 0.25 \times 30 \times 9.8 \text{ N} = 73.5 \text{ N}$$

$$= 73.5 \text{ N (Ans)}$$

Q. Find the force of friction (f) limiting friction if static friction is the situation as shown in the figure.

$$\text{Take } g = 10 \text{ m/s}^2$$



Given $\mu = 0.1$

$$m = 5 \text{ kg}$$

$$P = 2 \text{ N}$$

$$\text{Take } g = 10 \text{ m/s}^2$$

(i) limiting friction $f_L = \mu mg$

$$= 0.1 \times 50 = 5 \text{ N}$$

$$= 5 \times 10 \text{ m/s}^2 \\ = 50$$

$$= 5 \text{ N}$$

Method of reducing friction :-

* By Polishing or Rubbing

The roughness of the surface can be reduced by rubbing or polishing it. The irregularities of the surface are smoothed which avoids the chance of getting the irregularities interlocked.

By Lubricants:-

A Lubricant is an oil or grease which when spread over the surface fills the irregularities and forms a thin layer between them. Hence this improves the smoothness between the upper surface and the lower layers of lubricant.

C By Converting sliding to rolling friction

If we slide a heavy object on the floor we need a big force. If we put it on wheels we can move it easily. This is because rolling friction is much lesser than sliding friction. Hence ball bearing can be placed between the moving parts to convert sliding friction to rolling friction.

By Streamlining:

(vi)

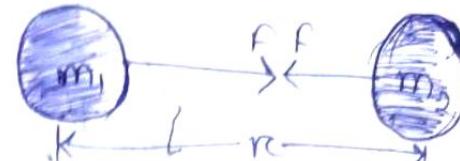
As a body is driven through fluid, fluid friction depends upon the shape of the body. It is minimum for a shape called stream lined shape. This shape is pin pointed one. For this reason all high speed bodies, Aeroplanes, Rockets, ships etc have pin pointed shape.

SQ: 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 and inversely as the square of distance between them.

mathematically, $F \propto m_1 m_2$



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

Combining eq ① and ②, we get

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

$$F = G \frac{m_1 m_2}{r^2} \quad \text{③}$$

where,

G = Universal gravitational constant

m_1 = Mass of the first (1st) body

m_2 = Mass of the 2nd body

r = Distance between the two bodies

If $m_1 = m_2 = 1$ unit

and $r = 1$ unit

so, eq ③ becomes, $F = G$

Hence the universal gravitational constant can be defined as the magnitude of force of attraction between two bodies each of unit mass and separated by a unit

distance from each other:

Hence,

SI unit

$$G = \frac{N \cdot m^2}{kg^2}$$

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

$$\Rightarrow N = G \frac{kg \times kg}{m^2}$$

$$G = \frac{N \cdot m^2}{kg^2}$$

* Value of $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

→ Dimension formula

$$G = \frac{F r^2}{M_1 \times m_2}$$

$$= \frac{\cancel{mass} \times \cancel{accel^2} \times \cancel{length^2}}{\cancel{mass} \times \cancel{mass}}$$

$$= \frac{\cancel{accel^2} \times \cancel{length^2}}{\cancel{mass}}$$

$$= \frac{[M^0 L^1 T^{-2}] \times [M^0 L^2 T^0]}{[M^1 L^0 T^0]}$$

$$= [M^{-1} L^3 T^2]$$

* Acceleration due to Gravity (g) :- (GRAVITY)

Gravity is a special case of gravitation in which one body is earth and the 2nd (second) body is placed on the earth or near to it.

The acceleration produced by gravity, is called acceleration due to gravity. So $F = mg$ - ①



Since, the body is placed on the surface of the earth, so according to Newton's

law of gravitation

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

$$f = G \frac{Mm}{R^2} \quad \textcircled{2}$$

from eqn ① and ② we get

$$mg = G \frac{Mm}{R^2} \Rightarrow g = G \frac{M}{R^2} \frac{m}{m}$$

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

where, m = mass of the Earth

g = acceleration due to gravity

G = universal gravitational constant

SI unit:-

$$g = \frac{Gm}{R^2} = \text{m/s}^2$$

Dimensional formula = $[M^0 L^1 T^{-2}]$

~~Mass and Weight~~

Differentiate between mass and weight

MASS

WEIGHT

① It is the amount of matter contained in a body.

② It is a scalar quantity.

③ Its SI unit is kg.

④ It is a constant quantity.

① It is the force by which a body is attracted towards the centre of the earth.

② It is a vector quantity.

③ Its SI unit is newton(N).

④ It varies from place to place as it depends upon the value of g .

⑨ It is a never zero(0) force a body:

⑥ It is an essential property of material bodies.

⑤ It is zero(0) at the centre of the earth.

⑥ It is not an essential property of a material body.

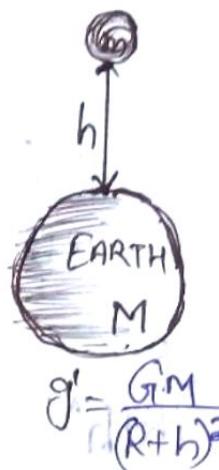
VARIATION of 'g' with altitude:-

fig - 1



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

Fig-2



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

Consider a body of mass m placed on the surface of the earth. (fig-1)

Let m and R denotes the mass and radius of the earth, respectively. Let 'g' be the value of acceleration due to gravity on the surface of the Earth.

$$g = G \frac{M}{R^2} \quad \text{where } G = \text{universal}$$

where G = universal gravitational constant.

Now suppose the body is raised to a height 'h' (Fig-2) above the surface of the Earth.

Let g' be the acceleration due to gravity at this height so, $g' = \frac{GM}{(R_{\text{th}} + h)^2}$

where,

$R+h$ = the distance between body and the centre of the Earth.

Now dividing eqn 2 by eqn 1

$$eqn 2 \div eqn 1$$

we get

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

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

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

Solving by Binomial theorem we get

$$\Rightarrow \frac{g'}{g} = 1 - \frac{2h}{R}$$

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

$$\Rightarrow g' = g - \frac{2hg}{R}$$

$$\Rightarrow g - g' = \frac{2h}{R} g$$

$g - g'$ gives the value of change in g since g and R constant,

we can write $g - g' \propto h$

Thus the value of acceleration due to gravity decreases with increase in height.

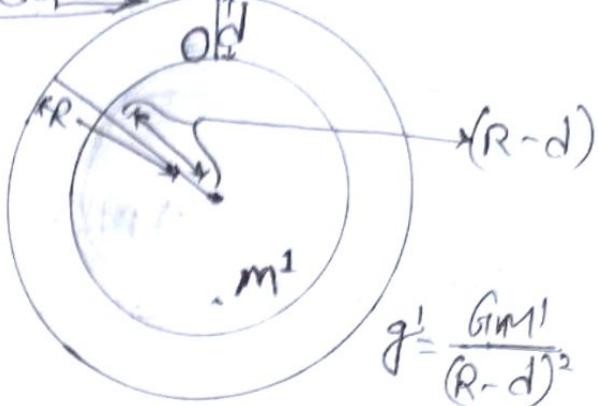
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* Variation of 'g' with depth fig-2

fig-1



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



$$g_1 = \frac{Gm_1}{(R-d)^2}$$

Consider a body placed on the surface of the earth (fig-1).

Let, M and R be the mass and radius of the earth respectively, so the acceleration due to gravity is given by g .

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

But we know,

$$\text{mass} = \text{Density} \times \text{volume}$$

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

Putting the value of M in eq? ① we get,

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

$$\Rightarrow g = G \rho \times \frac{4}{3} \pi R \quad \text{--- (2)}$$

Now, the body is taken to a depth ' d ' (fig-2)

Let m_1 and $(R-d)$ be the mass and radius of the new surface respectively.

So the acceleration due to gravity is given by ' g' .

Hence $g' = \frac{Gm'}{(R-d)^2}$ (3)

But we know, mass = Density \times volume

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

Putting the value of M in eqn (3)
we get,

$$g' = \frac{G \times \rho \times \frac{4}{3}\pi(R-d)^3}{(R-d)^2}$$

$$\Rightarrow g' = G\rho \times \frac{4\pi}{3}(R-d) \quad (4)$$

Now dividing eqn (4) with eqn (2)
we get

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

$$\Rightarrow \frac{g'}{g} = \frac{R-d}{R} \Rightarrow \frac{g'}{g} = \frac{R}{R} - \frac{d}{R}$$

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

$$\boxed{\Rightarrow g' = g - \frac{gd}{R}}$$

Hence from the above equation we conclude that with increase in depth the acceleration due to gravity decreases.

~~KEPLERS LAW OF PLANETARY MOTION~~

A Law of ELLIPTICAL ORBIT:-

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

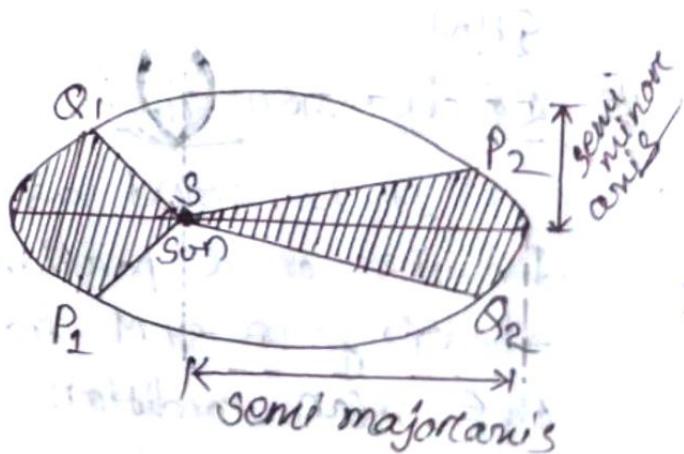
B Law of AREA VELOCITY:-

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 area in equal interval of time.)

C Law of TIME PERIODS:- (the Harmonic law)

A planets move around the sun in such a way that the square of its time period is directly proportional to the cube of semi-major axis of its elliptical orbit.

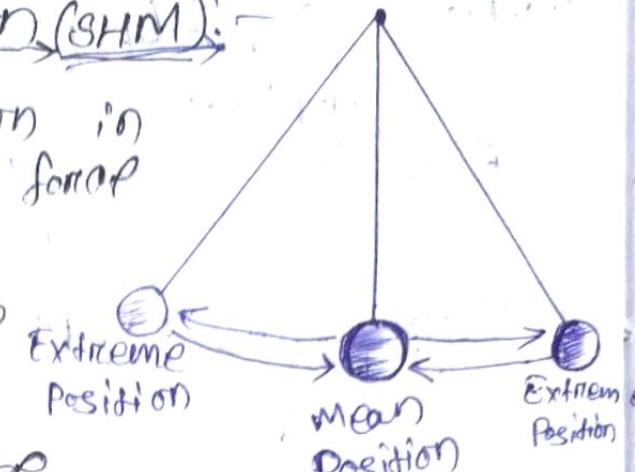
$$\text{i.e. } T^2 \propto R^3$$



The force of attraction between any two bodies in the universe is known as the force of gravitation

① Simple Harmonic motion (SHM):

SHM is the motion in which the restoring force is proportional to the displacement from the mean position and opposes its increase.



Eg: ① Vibration of a simple pendulum,

② Vibration of stretch string, spring.

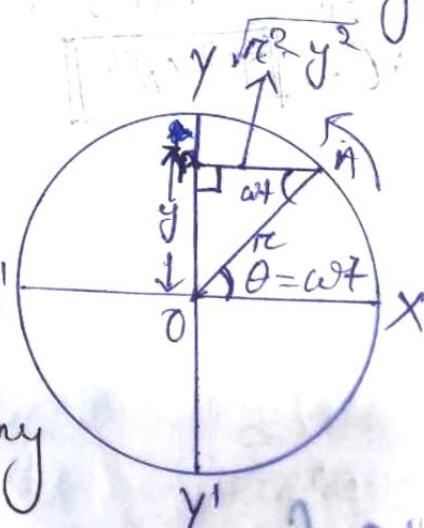
③ Vertical vibration of a loaded spring.

→ A particle is said to be in SHM if its acceleration is proportional to the displacement and is always directed towards the mean position.

~~10 marks~~
Find the expression for displacement, velocity and acceleration of a body in SHM.

Ans Displacement (y)

It is defined as the distance of a particle vibrating in SHM from the mean condition at any instant.



Let 'P' be the position of 'A' at any instant of time 't'.

So, in Δ AOP,

$$\Rightarrow \sin \theta = \frac{OP}{OA}$$

$$\text{So } OP = OA \sin \theta$$

$$\Rightarrow y = r \sin \theta$$

$$\Rightarrow y = r \sin(\omega t) \quad \text{---} \quad (1)$$

for extreme values, $\sin \omega t = \pm 1$

So,

$$y = \pm r$$

where r is called the amplitude of vibration.

Amplitude of a particle vibrating in simple harmonic motion (SHM) is defined as the maximum displacement on the either side of the mean position.

VELOCITY:

It is given by differentiating equation one with respect to time.

$$\Rightarrow V = \frac{dy}{dt}$$

$$\Rightarrow V = \frac{d(r \sin \omega t)}{dt}$$

$$\Rightarrow V = r \frac{d}{dt} (\sin \omega t) = r \cos \omega t \frac{d}{dt} \omega t$$

$$\Rightarrow V = r \omega \cos \omega t$$

$$\Rightarrow V = r \cos \omega t \quad \text{---} \quad (2)$$

again in $\triangle OAP$, $\cos \omega t = \frac{AP}{OA} = \frac{\sqrt{r^2 - y^2}}{r} = \frac{b}{r}$ ($\because \cos \theta = \frac{b}{5}$)

Putting this value of $\cos \omega t$ in eqn ② we get

$$\Rightarrow V = \omega \sqrt{r^2 - y^2} \quad \text{--- (2)}$$

since $V = r\omega$

$$\Rightarrow V = r\omega \frac{\sqrt{r^2 - y^2}}{r}$$

$$\Rightarrow V = \omega \sqrt{r^2 - y^2} \quad \text{--- (3)}$$

at point 'O', $y = 0$

so eqn ③ becomes

$$V = \omega \sqrt{r^2 - 0}$$

$$\Rightarrow V = \omega r$$

$$\Rightarrow V = v \quad (\text{maximum velocity}) \quad \text{--- (4)}$$

A particle vibrating in SHM passes with maximum velocity through the mean position and is at rest at extremum position.

At y and y' , $y = \pm r$

$$V = 0$$

Acceleration:

It can be obtained by differentiating eqn for velocity i.e. $a = \frac{dv}{dt}$

$$\Rightarrow a = \frac{d(\cos \omega t)}{dt} \leq V \frac{d(\cos \omega t)}{dt}$$

$$\Rightarrow a = V - \sin \omega t \frac{d(\omega t)}{dt}$$

$$\Rightarrow a = V (-\sin \omega t)(\omega) \quad \left(\because \frac{d \cos \theta}{d \theta} = -\sin \theta \right)$$

$$2) a = -\nu \omega \sin \omega t$$

$$2) a = -\nu \cdot \frac{\nu}{R} \sin \omega t$$

$$3) a = -\frac{\nu^2}{R} \sin \omega t \quad \text{--- (5)}$$

$$\text{in } \triangle OAP \sin \omega t = \frac{OP}{OA}$$

$$\Rightarrow \sin \omega t = \frac{y}{r} \quad \text{--- (5)}$$

Putting the value of $\sin \omega t$ in eqn (5)

$$\Rightarrow a = -\frac{\nu^2 y}{r^2} = -\frac{\nu^2 y}{r^2}$$

$$\Rightarrow a = -\frac{r \omega^2 y}{r^2} = -\frac{r \cdot \omega^2 y}{r^2}$$

$$\therefore a = -\omega^2 y \quad \text{--- (6)}$$

at Point O, $y = 0$

so, $a = 0$
at point y and y

$$y = \pm r$$

$$\text{so, } a = \pm \omega^2 r$$

Hence, a particle vibrating in SHM has zero(0) acceleration while passing through the mean position and has maximum acceleration at the extreme position

WAVE MOTION

Wave motion is the disturbance that travels through the medium and is due to repeated periodic motion of the particle of the medium of the motion being handed over

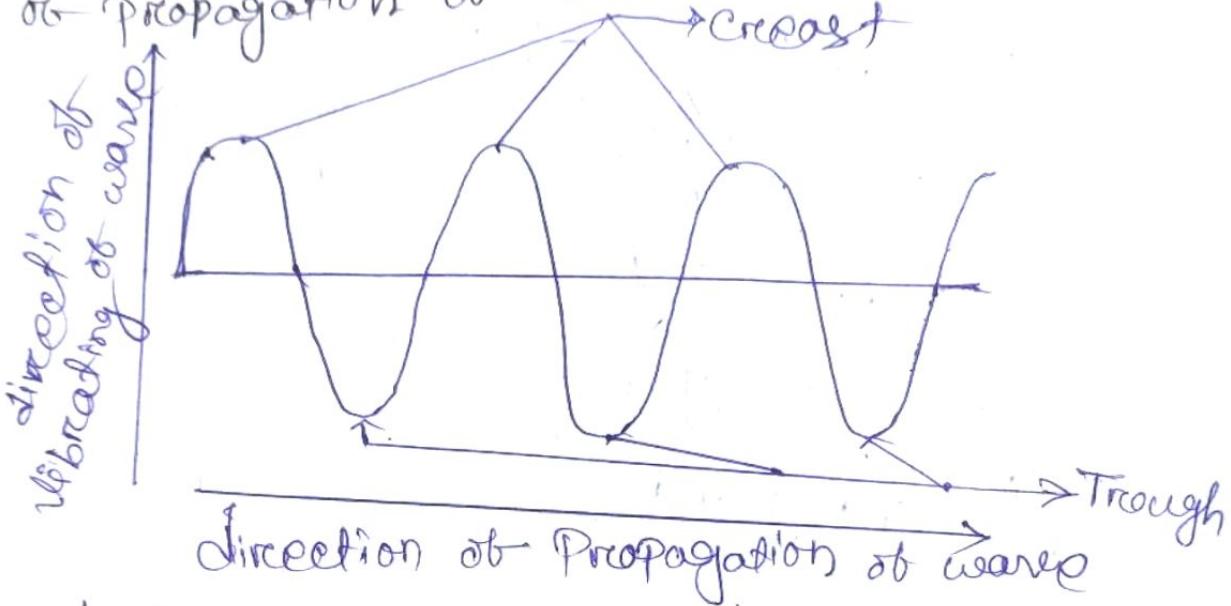
from particle to particle.

Types of wave motion:

It is of two types; (a) Transverse wave motion
(b) Longitudinal wave motion

(a) TRANSVERSE WAVE MOTION:

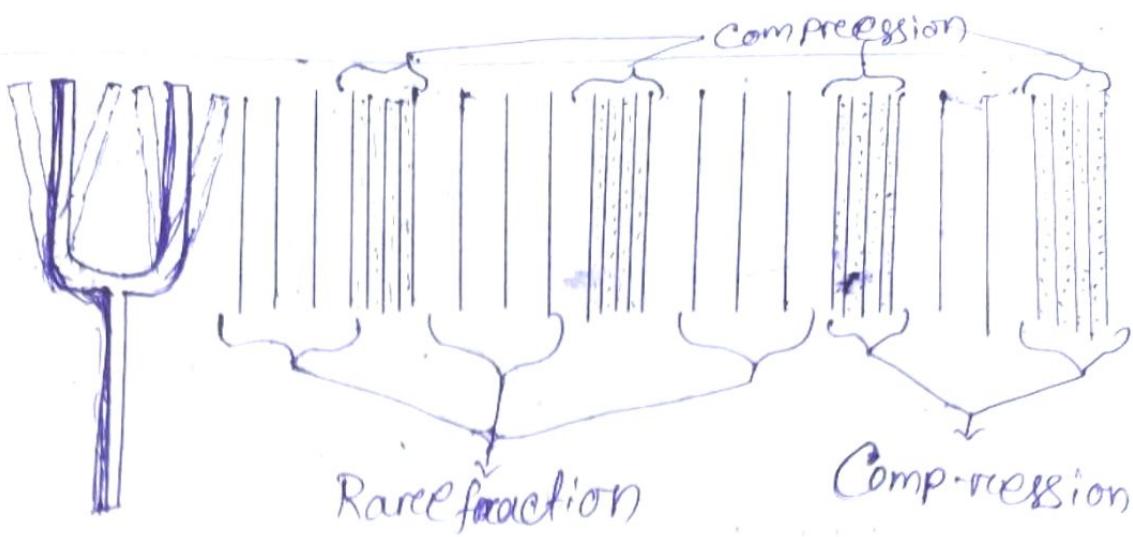
It is the type of wave motion in which the particles of the medium are vibrating in a direction at right angles to the direction of propagation of waves.



As the transverse wave propagates through a medium, some portion of the medium gets raised above its normal level, this is also called the crest. And some other portion gets depressed below the normal level, this is called the trough.

(b) LONGITUDINAL WAVE MOTION:

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



A vibrating tuning fork produces longitudinal waves, in such case some portion of the medium gets compressed together and is called compression, while some other portion gets rarefied and is called rarefaction medium.

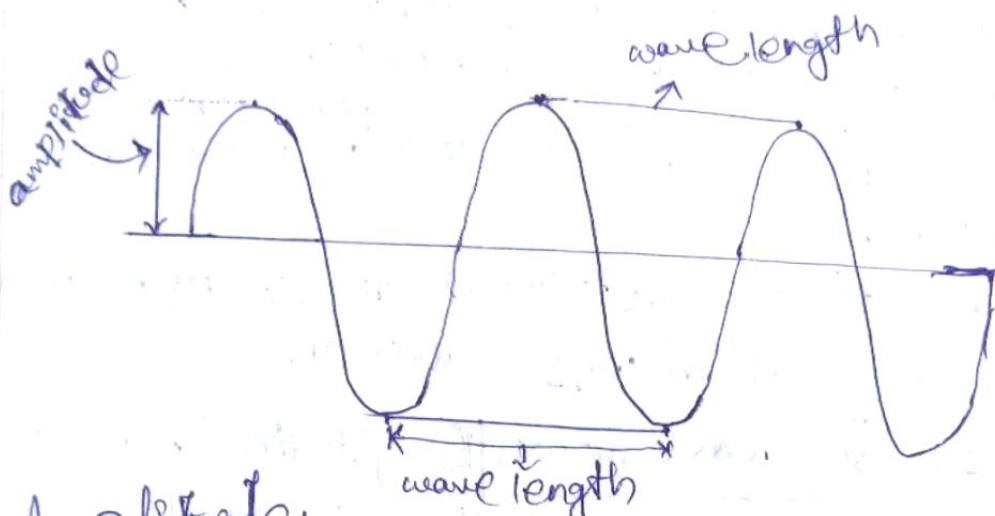
^{16.10.2021} Differentiate between transverse wave and longitudinal wave motion.

Transverse wave motion Longitudinal wave motion

<ul style="list-style-type: none"> ① In transverse wave motion, the particle of a medium vibrates in a direction perpendicular to the direction of propagation of wave. ② Crests and troughs are formed during the propagation of transverse wave. ③ causes temporary change in shape of the medium. ④ Transverse wave may or may not requires a medium for its propagation. 	<ul style="list-style-type: none"> ① In longitudinal wave motion the vibration of particle are parallel to the direction of propagation of wave. ② Compression and rarefaction are formed during the propagation of longitudinal wave. ③ causes temporary change in size of the medium. ④ Longitudinal waves requires a medium for its propagation.
--	---

- | | |
|--|--|
| ④ Density of the medium does not vary (change). | ⑤ Density of the medium is higher at compression and lower at rarefaction. |
| ⑥ It travels through solids and some liquids but not so through the gases. | ⑦ It travels through solids, liquids and gases. |

Definition of Different wave Parameters



⑧ Amplitude:-

The amplitude of a wave is a measure of the maximum displacement of the wave from its equilibrium position in either side.

SI unit = meter (m)

Dimension formula = $[M^0 L^1 T^0]$

⑨ Wave length (λ):-

If is the distance covered by a wave during one full cycle.

The distance between two consecutive crests or troughs is called so.

SI unit:- meter(m)

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

④ Time Period (T):

The time taken by a particle of the medium to complete one full cycle of a wave, is called the time period.

SI unit = second

Dimension formula = $[M^0 L^0 T^1]$

⑤ Frequency (f):-

It is the number of complete full cycle of a wave in one second.

frequency = $\frac{1}{\text{time period}}$.

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

SI unit = second \rightarrow or Hertz (Hz)

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

⑥ Wave Velocity:-

The distance covered by a wave per unit time is known as wave velocity.

SI unit = m/sec

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

Q) Give a relation between velocity, frequency and wave length for a wave?

Sol) The wave velocity is the distance covered

by a wave per unit time, But we know the distance covered in time period (T) is the wavelength (λ).

hence we can write -

$$\Rightarrow V = \frac{D}{T}$$

$$\Rightarrow V = \frac{\lambda}{T}$$

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

Putting value of λf in eqn ① we get

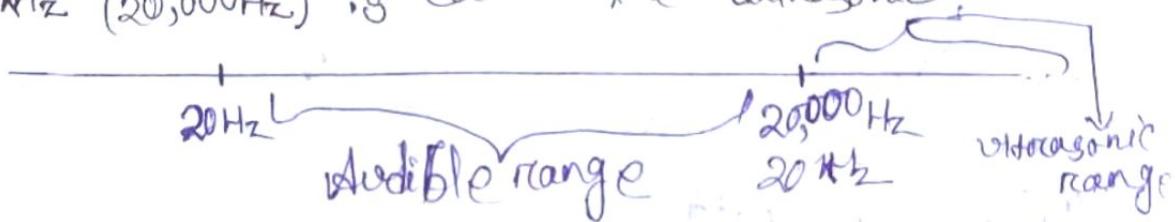
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$$\boxed{V = f\lambda}$$

★ ULTRASONICS

It is the branch of physics which deals with the study of ultrasonic wave is called ultrasonics.

The sound wave whose frequency is above 20kHz (20,000Hz) is called the ultrasonic wave.



5 marks

Properties of ultrasonic waves →

- ① Ultrasonic waves have high frequency and hence high energy.
- ② The wave length of the ultrasonic waves is very small.

③ They require material medium for their propagation.

④ Ultrasonic waves produce heating effect on the medium through which they pass, because of their high energy.

④ Ultrasonic wave accelerate chemical reaction and hence used for material synthesis.

Application of ultrasonic waves:-

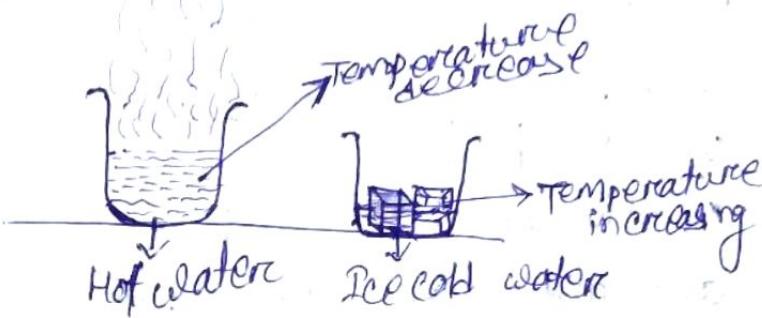
- a. In SONAR system, ultrasonic waves are used to estimate the depth of ocean.
- b. Ultrasonic is used to locate divers, fish and to detect sunken ships and other under water bodies.
- c. Ultrasonic is used in scanning to detect any anomaly in the internal organ.
- d. Ultrasonic waves are used for localized destruction of unwanted body cells or bacteria.
- e. ~~Ultrasonic~~ Ultrasonic drills are used for shaping, cutting and machining of materials.
- f. Ultrasonic baths are used in industries, and laboratories for cleaning remote parts of machines.
- g. Fine particle of dust smoke and ash coagulate when they are subjected to ultrasonic waves. This method is used by the industries to remove smoke from industrial stack, acid fumes etc.

UNIT - 7 HEAT AND THERMODYNAMICS

20. Dec. 2022

* HEAT: Heat is defined as the form of energy transfer between two or more system and its surrounding due to difference in temperature.

e.g. If a glass of ice cold water left on a table on a hot summer day, it warms up, whereas a cup of hot water on the same table cools down.



TEMPERATURE

It is the measure of hotness or coldness of a body.

* Difference between Heat and Temperature:

HEAT

TEMPERATURE

① It is the energy which transfers from one body to another body because of temperature difference.

② It flows from Hot body to cold body.

③ It is a derived quantity

④ SI unit \rightarrow Joule

⑤ Heat is exchangeable

① It is the measure of hotness or coldness of a body.

② Temperature raises when object is heated and it cools down when the temperature decreases.

③ It is a fundamental quantity

④ SI unit - kelvin

⑤ Temperature is not exchangeable.

* Units of Heat:-

SI unit \rightarrow Joule

MKS \rightarrow Joule

CPS \rightarrow Calorie

FPS \rightarrow British thermal unit (BTU.)

* Specific Heat :-

It is defined as the amount of heat required to raise the temperature of unit mass of substance through 1° Celsius (1°C)

$$\boxed{M} \quad \boxed{m}$$

Different bodies of different mass requires different amount of heat to raise the temperature to same level, Hence we can say

(i) Greater the mass, greater heat is required so $Q \propto M$,

$Q = \text{Heat}$

$M = \text{Mass}$

(ii) Greater heat is required to raise the temperature higher, $Q \propto \Delta T$

where, $\Delta T = \text{Change in temperature}$

$$\begin{aligned} \Delta T &= T_2 - T_1 \\ &= 30 - 10 \\ &= 20^{\circ}\text{C} \end{aligned}$$

Combining the above equation we get

$Q \propto M \Delta T$

$$\Rightarrow Q = CM\Delta T$$

$$\Rightarrow C = \frac{Q}{M\Delta T} \quad \text{where } C = \text{specific heat}$$

$$\text{Unit SI unit} = \frac{\text{Joule}}{\text{kg Kelvin}} = \frac{\text{J}}{\text{kg} \cdot \text{K}} = \text{J kg}^{-1} \text{K}^{-1}$$

$$\text{we know, } \text{K.E} = \frac{1}{2} m v^2 = [M^1 L^2 T^{-2}]$$

$$W = F.S = [M^1 L^1 T^2] [L] = [M^1 L^2 T^{-2}]$$

$$\text{similarly : heat(Q)} = [M^1 L^2 T^{-2}]$$

$$C = \frac{Q}{M \Delta T} = \frac{[M^1 L^2 T^{-2}]}{[M^1 L^0 T^0] [K]} = [M^0 L^2 T^{-2} K^{-1}]$$

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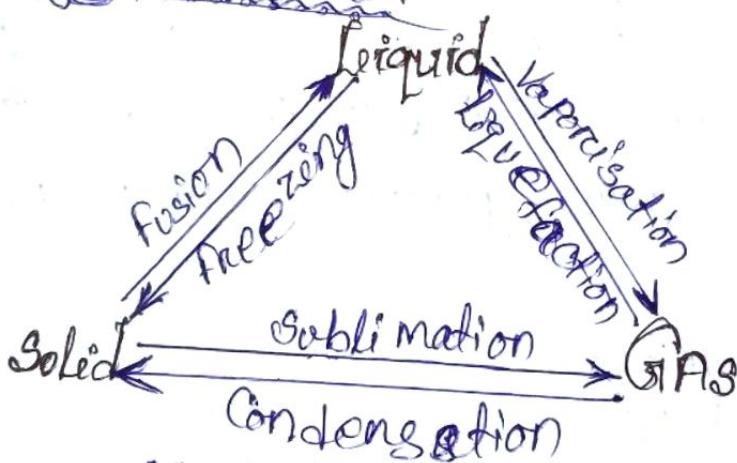
Specific heat of :-

$$\text{① Ice} = 0.5 \text{ cal g}^{-1} \text{ } ^\circ\text{C}^{-1} = 2100 \text{ J kg}^{-1} \text{ } K^{-1}$$

$$\text{② Water} = 1 \text{ cal g}^{-1} \text{ } ^\circ\text{C}^{-1} = 4200 \text{ J kg}^{-1} \text{ } K^{-1}$$

$$\text{③ Steam} = 0.46 \text{ cal g}^{-1} \text{ } ^\circ\text{C}^{-1} = 1932 \text{ J kg}^{-1} \text{ } K^{-1}$$

* Change of state :-



↗ LATENT HEAT :-

Concept :- Whenever a substance undergoes change in state whether from solid to liquid or from liquid to gas, it absorbs some quantity of heat without any rise of temperature, this heat is called Latent heat. LATENT HEAT means 'the 'Hidden' heat'.

Definition: - the amount of heat required to change the state of unit mass of substance at constant temperature.

* Types of Latent heat (L)

(a) Latent heat of fusion (Lf) :-

It is defined as the amount of heat required to change a unit mass of substance from solid to liquid state. at the melting point without any change in temperature.

(b) Latent heat of vaporisation (Lv) :-

It is defined as the amount of heat required to change a unit mass of liquid into its vapour, at its boiling point, without any change (rise) of temperature.

formula for Latent heat:

$$L = \frac{Q}{M}$$

$$\text{SI units} = \frac{\text{Joule}}{\text{kg}} = \text{J kg}^{-1}$$

C.G.S unit = cal g⁻¹

Dimension formula:

$$L = \frac{Q}{M} = \frac{[M^1 L^2 T^{-2}]}{[M^1 L^0 T^0]} = [M^0 L^2 T^{-2}]$$

* Note:-

i) For conversion from ice to water, the latent heat of fusion of ice is

$$Lf = 80 \text{ kJ/kg} = 80 \text{ cal/g} = 335 \text{ J/g} = 335000 \text{ J/kg}$$

Q) For conversion from water to steam, the latent heat of vapourisation of steam is

$$L_v = 540 \text{ kJ/kg} = 540 \text{ cal/g} \times 2260 \frac{\text{J}}{\text{cal}} = 2260000 \text{ J/kg}$$

Q) How much heat is required to melt 7 gram of ice completely? The latent heat of fusion of ice is 80 calorie per gram.

~~Ans~~ $L_f = 80 \text{ cal/g}$

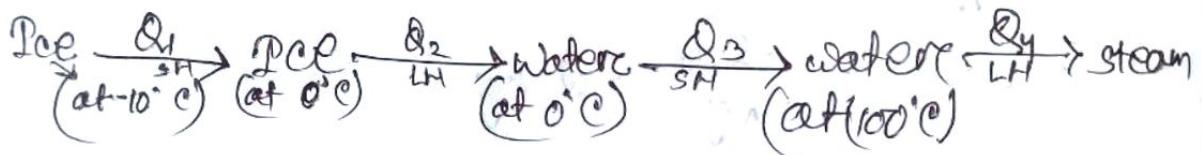
$$L = Q/m$$

$$\Rightarrow 80 \text{ cal/g} = \frac{Q}{m}$$

$$\Rightarrow Q = 560 \text{ cal}$$

~~Ans~~ Calculate the amount of heat required to convert 15 gram of ice at -10°C to steam.

Soln $m = 15 \text{ g}, t = -10^\circ\text{C}$



$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

$$\Delta T = 0 - (-10)$$

$$= 10^\circ\text{C}$$

$$Q_1 = C_m \Delta T$$

$$= 0.5 \frac{\text{cal}}{\text{g}\text{C}} \times 15 \text{ g} \times 10^\circ\text{C}$$

$$= 0.5 \times 150$$

$$= 75 \text{ cal}$$

$$Q_2 = Q = m L_f$$

$$= 15 \text{ g} \times 80 \frac{\text{cal}}{\text{g}}$$

$$= 1200 \text{ cal}$$

$$\therefore C = \frac{Q}{M \Delta T}$$

$$\Rightarrow Q = C M \Delta T$$

$$\therefore L = Q/M$$

$$\Rightarrow Q = M L$$

$$Q_3 = Cm\Delta T = \frac{1 \text{ cal}}{\text{g}^\circ\text{C}} \times 15 \text{ g} \times 100^\circ\text{C}$$

$$= 1500 \text{ cal}$$

$$Q_4 = Q = M \times L$$

$$= 15 \text{ g} \times 540 \frac{\text{cal}}{\text{g}}$$

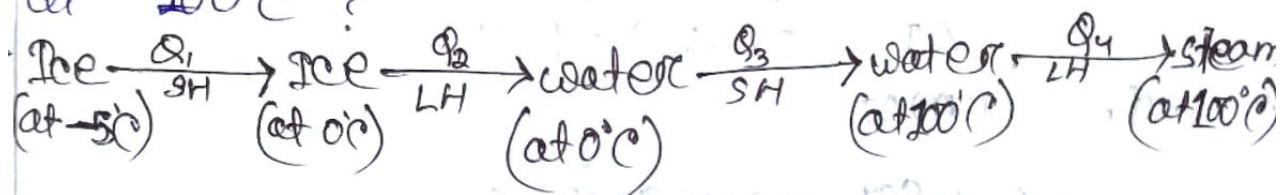
$$= 8100 \text{ cal}$$

Hence $Q = Q_1 + Q_2 + Q_3 + Q_4$

$$Q = 750 + 1200^\circ\text{C} + 1500 + 8100^\circ\text{C}$$

$$= 10,875^\circ\text{C}$$

Calculate the amount of heat required to convert 10 gram of ice at -5°C to steam at 100°C ?



Given $m = 10 \text{ g}$

$t = -5^\circ\text{C}$

$$\Delta t = 0 - (-5)$$

$$= 5^\circ\text{C}$$

$$Q_1 = Cm\Delta t$$

$$= 0.5 \frac{\text{cal}}{\text{g}^\circ\text{C}} \times 10 \text{ g} \times 5^\circ\text{C}$$

$$= \frac{5}{10} \times 10 \times 5$$

$$= 25 \text{ cal}$$

$$Q_2 = mL = 10 \text{ g} \times 80 \frac{\text{cal}}{\text{g}}$$

$$= 800 \text{ cal}$$

$$Q_3 = Cm\Delta T = \frac{1 \text{ cal}}{\text{g}^\circ\text{C}} \times 10 \text{ g} \times 100^\circ\text{C}$$

$$= 1000 \text{ cal}$$

$$(\because \Delta t = 100^\circ\text{C} - 0)$$

$$Q_4 = mL = 100 \times \frac{540 \text{ cal}}{\text{g}}$$

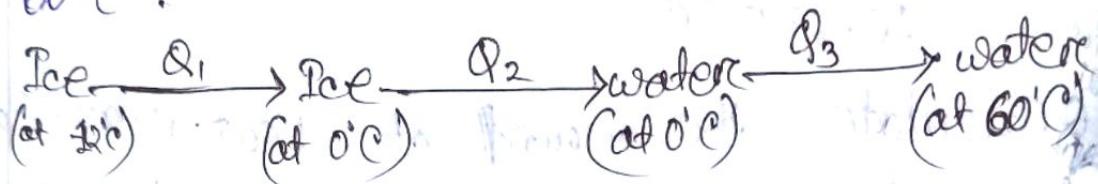
$$= 5400 \text{ cal}$$

$$\text{Hence } Q = Q_1 + Q_2 + Q_3 + Q_4$$

$$= 250 \text{ cal} + 800 \text{ cal} + 1000 \text{ cal} + 5400 \text{ cal}$$

$$= 7225 \text{ cal}$$

Q Calculate the amount of heat required to convert 2kg of ice at -12°C to water at 60°C ?



$$\text{Given } m = 2 \text{ kg} = 2000 \text{ g}$$

$$\Delta T = 0 - (-12) = 12^\circ\text{C}$$

$$Q_1 = cm\Delta T$$

$$= 0.5 \frac{\text{cal}}{\text{g}^\circ\text{C}} \times 2000 \text{ g} \times 12^\circ\text{C}$$

$$= \frac{5}{10} \times 2000 \times 12$$

$$= 12000 \text{ cal}$$

$$Q_2 = mL = 2000 \text{ g} \times 80 \frac{\text{cal}}{\text{g}}$$

$$= 160000 \text{ cal}$$

$$Q_3 = cm\Delta T$$

$$= \frac{1 \text{ cal}}{^\circ\text{C}} \times 2000 \text{ g} \times 60^\circ\text{C}$$

$$= 120000 \text{ cal}$$

$$\text{Hence, } Q = Q_1 + Q_2 + Q_3 = 12000 + 160000 + 120000 = 292000 \text{ cal}$$

$$\because \Delta T = 60^\circ\text{C} - 0^\circ\text{C}$$

$$= 60^\circ\text{C}$$

THERMAL EXPANSION:-

When an object is heated whether it be a solid, liquid or gas, it expands. This expansion due to heat is called thermal expansion.

There are three types of expansion in solid

- ① One dimensional or Linear expansion
- ② Two dimensional or Superficial expansion
- ③ Three dimensional or Cubical expansion

* Coefficient of expansion:-

① Expansion along one dimension or "Linear expansion"

A long and thin rod can be considered to be one dimensional if its length is very large as compared to its diameter. ($l \gg d$)

Let ' l_0 ' be the length of the rod at 0°C . On heating, the rod expands. Let ' l_t ' be the length at $t^\circ\text{C}$.

So that ' $l_t - l_0$ ' is the change in length

This change in length $l_t - l_0$ depends upon

① Original length ' l_0 '

$$l_t - l_0 \propto l_0 \quad \text{--- (1)}$$

② rise in temperature t

$$\text{So } l_t - l_0 \propto t \quad \text{--- (2)}$$

Combining above two eqⁿ, we get

$$l_t - l_0 \propto \Delta t$$

$$\Rightarrow l_t - l_0 = \alpha \Delta t$$

$$\Rightarrow \boxed{\alpha = \frac{l_t - l_0}{\Delta t}}$$

(3)

where, α is the coefficient of linear expansion.

Q) Expansion along 2 Dimension (Superficial expansion):-

Consider a square sheet having some length and breadth but negligible thickness for 2 dimensions.

Let, S_0 be the area at $0^\circ C$

After heating



After heat

S_t be the area at $t^\circ C$



So, $S_t - S_0$ is the change in area

i.e. $S_t - S_0$ depends upon

a) Original area S_0

i.e. $S_t - S_0 \propto S_0$

(4)

b) Rise in temperature

i.e. $S_t - S_0 \propto t$

(5)

Combining above two eqⁿ we get

$$\Rightarrow S_t - S_0 \propto S_0 t$$

$$\Rightarrow S_t - S_0 = \beta S_0 t$$

$$\Rightarrow \boxed{\beta = \frac{S_t - S_0}{S_0 t}}$$

(6)

β is the coefficient of superficial expansion.

③ Expansion along Three Dimension (Cubical expansion):

Consider a Cube having length, breadth and height for three Dimension.

Let V_0 be the volume at 0°C after heating

V_t be the volume at $t^\circ\text{C}$

So, $V_t - V_0$ is the change in volume

This change in volume i.e. $V_t - V_0$ depends upon

(a) Original volume V_0 at 0°C

$$\therefore \text{e } V_t - V_0 \propto V_0 \quad \text{--- (7)}$$

(b) Rise in temperature ' t '

$$\text{So, } V_t - V_0 \propto t \quad \text{--- (8)}$$

Combining $V_t - V_0 \propto V_0 t$

$$\therefore \text{e } V_t - V_0 = \gamma V_0 t$$

$$\Rightarrow \gamma = \frac{V_t - V_0}{V_0 t} \quad \text{--- (9)}$$

γ is the coefficient of cubical expansion.

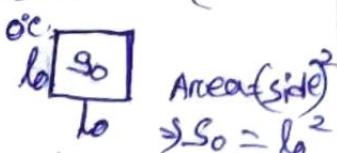
~~Relation Between Coefficient of expansion:~~

④ Relation between ' α ' and ' β '

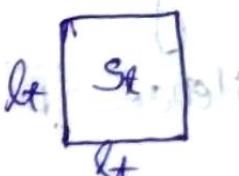
Consider a Square sheet of side l_0 at 0°C

$$\text{Area 'S' at } 0^\circ\text{C}, S_0 = l_0^2$$

on heating, the sheet at $t^\circ\text{C}$ each side expands to l_t



After heat



$$\left. \begin{array}{l} l_t = l_0 + \alpha l_0 t \\ l_t = l_0 (1 + \alpha t) \end{array} \right\} \begin{array}{l} \text{from eqn 1} \\ \text{from eqn 2} \end{array}$$

So,

$$\text{Area at } t^\circ C, S_t = l_t^2$$

$$= \{l_0 (1 + \alpha t)\}^2$$

$$= l_0^2 (1 + \alpha t)^2 \quad (\because \text{using eqn 3})$$

$$\text{But we know, } B = \frac{S_t - S_0}{S_0 t}$$

$$B = \frac{l_0^2 (1 + \alpha t)^2 - l_0^2}{l_0^2 t}$$

$$= \frac{l_0^2 \{(1 + \alpha t)^2 - 1\}}{l_0^2 t}$$

$$= \frac{(1 + \alpha t)^2 - 1}{t}$$

$$= \frac{1 + \alpha^2 t^2 + 2\alpha t - 1}{t} = \frac{\alpha^2 t^2 + 2\alpha t}{t}$$

$$= \underline{t(\alpha^2 + 2\alpha)}$$

$$\Rightarrow B = \alpha^2 t + 2\alpha$$

Since α is very small, $\alpha^2 t$ will be very very small.

Hence, $B = 2\alpha$

Relation between α and n :

Let V_0 and V_t be the volume of a cube at 0°C and $t^\circ\text{C}$ respectively. If b_0 and b_t are the sides of the cube at 0°C and $t^\circ\text{C}$.

$$\text{So, } V_0 = b_0^3$$

$$\text{and } V_t = b_t^3$$

$$\begin{aligned} \Rightarrow V_t &= \{b_0(1+\alpha t)\}^3 \\ &= b_0^3 (1+\alpha t)^3 \quad (\because \text{using eqn 3}) \end{aligned}$$

$$\text{But we know } r = \frac{V_t - V_0}{V_0 t}$$

$$= \frac{b_0^3 (1+\alpha t)^3 - b_0^3}{b_0^3 t}$$

$$r = \frac{b_0^3 \{(1+\alpha t)^3 - 1\}}{b_0^3 t}$$

$$= \frac{(1+\alpha t)^3 - 1}{t}$$

$$= \frac{\alpha^3 t^3 + 3\alpha^2 t^2 + 3\alpha t + 1 - 1}{t}$$

$$= \frac{\alpha^3 t^3 + 3\alpha^2 t^2 + 3\alpha t}{t}$$

$$\Rightarrow r = \alpha^3 t^2 + 3\alpha^2 t + 3\alpha$$

Since α is very small, α^2 and α^3 term will be very very small

$$r = 3\alpha$$

(11)

finally

$$B = 2\alpha$$

$$\text{and } r = 3\alpha$$

$$\Rightarrow \alpha = \frac{B}{2}$$

$$\Rightarrow \alpha = \frac{r}{3}$$

or

$$\alpha = \frac{B}{2} = \frac{r}{3}$$

(12)

 Give a relation between the coefficient of expansion or give a relation between α , B and r

or Prove that $\alpha : B : r = 1 : 2 : 3$

25.12
2021
★

WORK AND HEAT:-

Whenever heat converted to work or work is converted to heat, the quantity of energy disappearing in ~~the~~ one form is equal to the quantity of energy appearing in another form.

So, $W \propto H$

$$\Rightarrow W = JH$$

whereas J is called Joule's mechanical equivalent of heat.

W = work

H = Heat

If $H = 1$,

$$\Rightarrow W = J$$

Hence, Joule's mechanical equivalent of heat can be defined as the amount of work required to produce a unit quantity of heat.

$$\text{Unit} = \frac{\text{Joules}}{\text{Calories}} = \text{J/cal}$$

Value of $J = 4.2 \text{ J/cal}$

1st law of thermodynamics

I now do thermodynamics: statement: If the quantity of heat supplied to a system is capable of doing work, then the quantity of heat absorbed by the system is equal to the sum of increases in internal energy of the system and the external work done by it.

Mathematically,

~~skyscraper~~

$$d\alpha = dv + dw$$

where $d\alpha$ = Heat absorbed

dQ = Heat absorbed
 dU = Increase in internal energy

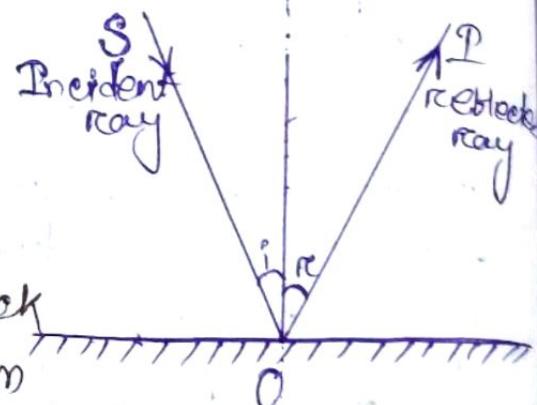
$$d\omega = \cancel{\text{work done}}$$

UNIT-8 {OPTICS}

The branch of physics which deals with the study of light and its phenomena is called "Optics".

* Reflection

It is the property of light by virtue of which a light is sent back in to the same medium from which it is coming after being obstructed by the surface.



i = angle of incidence
 r = angle of reflection
 O = Point of incidence

* Law of Reflection:

i) The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence all lie in one plane and the plane is perpendicular to the reflecting surface.

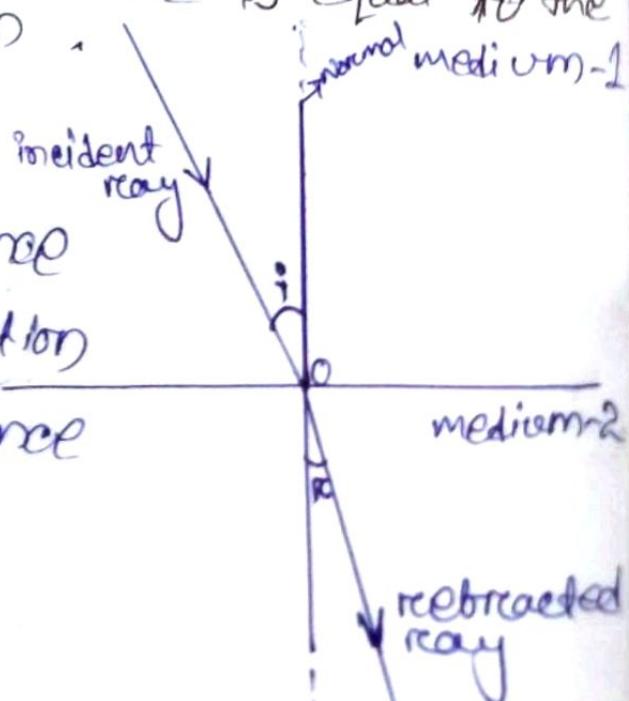
ii) The angle of incidence is equal to the angle of reflection.
 i.e. $i = r$

* Refraction:

i = angle of incidence

r = angle of refraction

O = Point of incidence



Definition:-

It is the property of light by virtue of which a ray of light travels from one medium to another medium with some change in its velocity.

* Laws of Refraction:-

(i) The ratio of sine of angle of incidence to the sine of angle of refraction is constant, this law is also called as Snell's law.
i.e. $\frac{\sin i}{\sin r} = \text{constant}$

(ii) The incident ray, refracted ray and the normal to the interface at the point of incidence all lie in one plane and the plane is perpendicular to the interface.

* Refractive index (n):-

Refractive index of a medium with respect to another medium is defined as the ratio between sine of angle of incidence to the sine of angle of refraction.

$$\text{i.e. } \frac{\sin i}{\sin r} = \text{constant} = n$$

~~ote~~ Refractive index of 2nd medium with respect to 1st medium is defined as the ratio between velocity of light in 1st medium to the velocity of light in 2nd medium

$$\text{i.e. } n_2 = \frac{v_1}{v_2}$$

* If the 1st medium is air or vacuum then the refractive index is called

absolute refractive index

So $\mu = \frac{c}{v}$, where, c = velocity of light in
vacuum
 v = velocity of light in
2nd medium.

Now

$$\mu_2 = \frac{v_1}{v_2}$$

$$\text{So } \mu_2 = \frac{c}{\mu_1} \div \frac{c}{\mu_2}$$

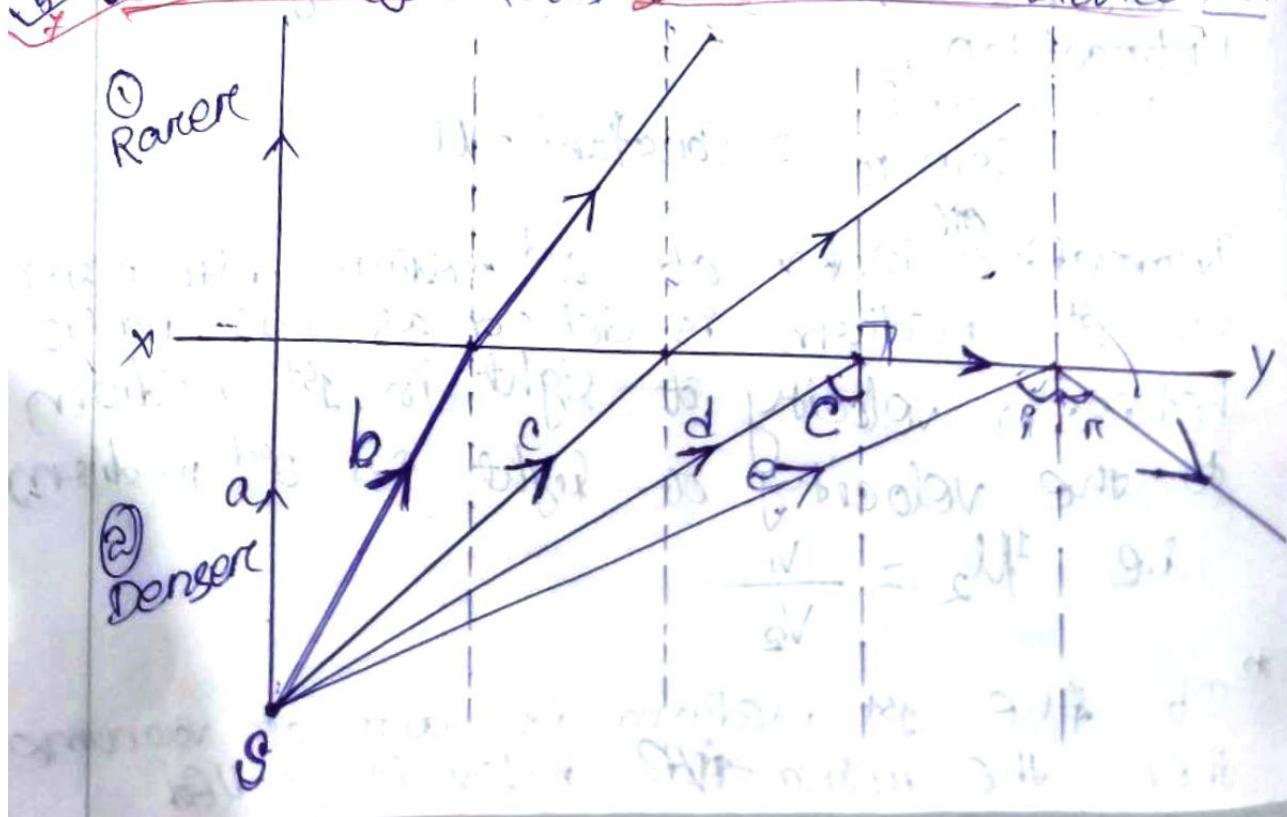
$$\left[\begin{array}{l} \therefore \mu_1 = \frac{c}{v_1} \\ v_1 = \frac{c}{\mu_1} \\ v_2 = \frac{c}{\mu_2} \end{array} \right]$$

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

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

μ_2 = Refractive index of 2nd medium
with respect to 1st medium $1 \rightarrow 2$

Critical angle and total Internal Reflection:



consider a light source 'S' situated in the denser medium (water). Rays of light start traveling from Denser medium to rarer medium (air). A ray 'a' incident normally on the interface "xy" goes undeviated. Rays 'b' and 'c' are incident on the interface at gradually increasing angle of incidence. Therefore they deviate more and more away from the normal. A ray 'd' is incident at a particular angle of incidence 'C' such that the angle of refraction is 90° . This angle of incidence C is called the critical angle. If the angle of incidence is increased further than critical angle, it is reflected back into the same medium. This phenomenon is called total internal reflection.

Definition:-

① 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° .

② Total internal Reflection: - It is the phenomena by which a ray of light travelling from denser medium to rarer medium, is sent back in the same medium, if it is made incident on the interface at angle greater than critical angle.

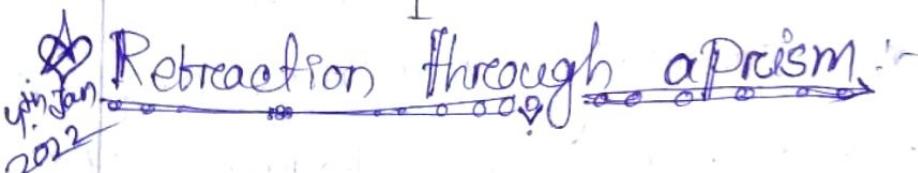
i.e

$2 \rightarrow 1$ (medium)

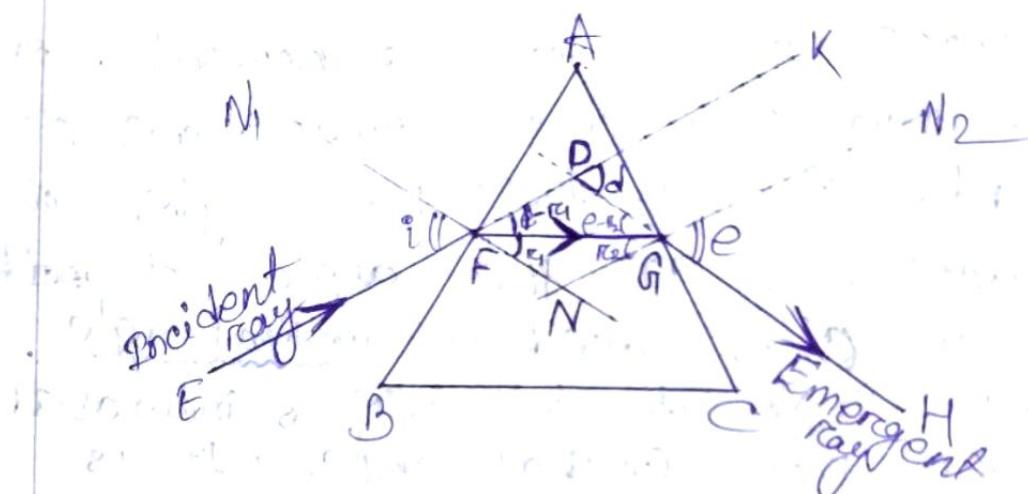
$$^2\mu_1 = \frac{\sin i}{\sin r_1}$$

$$\Rightarrow ^2\mu_1 = \frac{\sin c}{\sin 90^\circ}$$

$$\Rightarrow ^2\mu_1 = \frac{\sin c}{1} = \sin c$$


Retraction through a prism

Jan 2022



With $\triangle ABC$ represents the principle section of a glass Prism, a ray "EP" is incident on the face AB at Point F .

In the absence of Prism, the incident ray "EP" would have gone straight, but due to retraction through Prism, the ray passes along the direction "DGH". Hence angle $\angle KDH$ gives the angle of deviation.

(The angle through which the incident ray gets deviated in passing through the Prism is called angle of deviation)

$$\text{In } \triangle DFG, \Rightarrow d = i - r_1 + r_2$$

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

①

20. Quadrilateral AFNG ,

$$\angle \text{AFN} + \angle \text{AGN} = 180^\circ$$

$$\text{So } \angle \text{FAG} + \angle \text{FNG} = 180^\circ$$

(\because sum of all the angles
of a quadrilateral is 360°)

Again in $\triangle \text{FNG}$,

$$\Rightarrow \angle \text{I}_1 + \angle \text{I}_2 + \angle \text{N} = 180^\circ$$
 (3)

(\because sum of all the angles
of \triangle is 180°)

From equation (1) & (3) we get

$$\Rightarrow \angle \text{I}_1 + \angle \text{I}_2 + \angle \text{FNG} = \angle \text{FNG} + \angle \text{FAG}$$

$$\Rightarrow \angle \text{I}_1 + \angle \text{I}_2 = \angle \text{FAG}$$

$$\Rightarrow \boxed{\angle A = \angle \text{I}_1 + \angle \text{I}_2} \quad \rightarrow (4)$$

The minimum value of the angle of deviation when a ray of light passes through a prism is called the angle of minimum deviation.

For minimum deviation $i = r$

So eqn (4) becomes

$$\Rightarrow r + r = A + d_m$$

($\because d_m$ = minimum deviation)

$$\Rightarrow 2r = A + d_m$$

$$\Rightarrow \boxed{i = \frac{A + d_m}{2}} \quad \rightarrow (5)$$

Again for minimum deviation

$$r_1 = r_2 = r$$

So eqn (4) becomes $\Rightarrow A = r_1 + r_2$

$$\Rightarrow A = r + r$$

$$\Rightarrow A = 2r \Rightarrow 2r = A$$

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

(7)

$$\text{Hence } \mu = \frac{\sin \ell}{\sin r}$$

$$\therefore \mu = \frac{\sin \left(\frac{\pi + dm}{2} \right)}{\sin \frac{\pi}{2}}$$

8

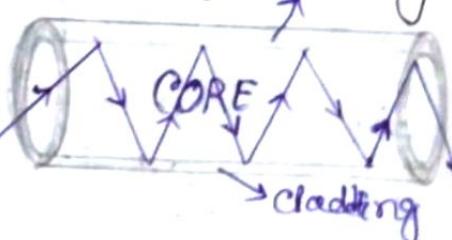
equation 8 gives the relation between refractive index of the material of the Prism and the angle of minimum deviation.

* OPTICAL FIBRE

Optical fibre works on the principle of total internal reflection and are not affected by electro magnetic interference. Optical fibre are design such that they bend all the light rays inwards.

Definition: An optical fibre is a dielectric cylindrical wave guide consisting of two layers i.e. core and surrounded by cladding.

The refractive index of the material of the core is higher than that of cladding.



Both are made up of thin, flexible, high quality, transparent fibre of glass or plastic, where light undergoes continuous total internal reflection along the length of the fibre and finally comes out at the other end.

6th Jan. 2022

- Properties of optical fibres :-
 - (i) It has a large band width, the optical frequency of 2×10^4 Hz can be used.
 - (ii) Optical fibres are small in size; and have less weight as compared to electric cables.
 - (iii) Optical fibres are flexible and high tensile strength for which they can be twisted and bent easily.
 - (iv) Optical fibres provides high degree of signal security.
 - (v) Optical fibre communication is free from electro magnetic interference.
 - (vi) Optical fibre does not carry any high voltage or current hence they are more safer than electric cables.

○ Applications of Optical fibres:-

- (i) Optical fibres are used in the field of communication for transmitting audio and video signals over long distance.
- (ii) Fibre optics is used for sensing purpose, in which light is delivered from remote source to a detector to obtain pressure, temperature etc.
- (iii) Optical fibres can deliver high levels of power used for different task like laser cutting, welding, drilling etc.
- (iv) Optical fibres are used to transmit high intensity laser light inside the body for medical ~~purposes~~ purposes.

⑩ They are used for the study of tissues and blood vessels far below the skin.

⑪ These are used to study the interior of lungs and other parts of the body, which can not be viewed directly.

ELECTROSTATICS AND MAGNETOSTATICS→ ELECTROSTATICS:-

The branch of Physics which deals the study of the electrical effect of charge of mass is called electrostatics.

→ Permittivity (ϵ):

Definition It is the characteristics of a medium which determines the capability of a medium to deliver / carry the effect of a charge come from one point to another in the same medium.

- It is a property of a media through which it allows electric lines of flux to pass through.

ie. The ratio of electric flux density D to the

field intensity E at a point is also called as permittivity.

$$\epsilon = \frac{D}{E}$$

- It plays an important role in electrostatic phenomena.
- The greater the permittivity of the medium and lesser the force between the charge bodies.

- Formulae

$$\epsilon = \epsilon_r \epsilon_0 \frac{F}{m \text{ or}}$$

$$\epsilon = \frac{D}{E}$$

Where D = Electric flux density.
 E = Electric field strength.

Permittivity of any medium are two types.

- (i) Absolute permittivity (ϵ_0)
- (ii) Relative permittivity (ϵ_r)

→ Absolute permittivity (ϵ_0)

- The absolute permittivity or simply permittivity of a medium can be define as the property of the medium which determines certain electric field intensity at a point in the field creates how much flux density at the point.
- Absolute permittivity is also known as actual permittivity.
- It is also the permittivity of a free space
- The absolute permittivity of air or vacuum is minimum.
- S.I unit: C^2/Nm^2

$$\Rightarrow \epsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$$

→ Relative Permittivity (ϵ_r) :-

- It is the ratio of the permittivity of the medium to the absolute permittivity.

or

The ratio of permittivity ' ϵ ' of any medium to that of absolute permittivity ' ϵ_0 ' of air or Vacuum is called relative permittivity.

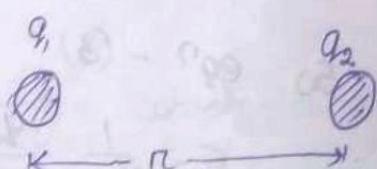
- The relative permittivity of vacuum with reference to it self is unity.

∴ Mathematically $\epsilon_r = \frac{\epsilon}{\epsilon_0}$ (It has no unit)
Because it is a constant

marks

⇒ COULOMB'S LAW IN ELECTROSTATIC :-

The Law states that the electromagnetic force of attraction or repulsion between two charge bodies is directly proportional to the product of their two charges and inversely proportional to the square of the distance between them.



- The force is proportional to the product of magnitude of charges.

$$F \propto q_1 \cdot q_2 \quad \text{--- (i)}$$

- The force is inversely proportional to the square of distance between the charges.

$$F \propto \frac{1}{r^2} \quad \text{--- (ii)}$$

On combining the eqn (i) and (ii)

we get $F \propto \frac{q_1 \cdot q_2}{r^2}$

$$\boxed{\Rightarrow F = \beta \frac{q_1 q_2}{r^2}} \quad \text{--- (iii)}$$

- In CGS

$$\beta = \frac{1}{k}$$

Where k = dielectric constant

so eqn - (3) becomes

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

For free space, $k=1$

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

- In SI

$$\rho = \frac{1}{4\pi\epsilon_0} : \frac{1}{4\pi\epsilon_0\epsilon_r}$$

ϵ_0 in - ~~air~~ becomes

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

For free space $\epsilon_0 = 1$

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

- UNIT CHARGE :-

Defn:

It is the amount of charge which when placed in air at a distance of 1 cm from a similar charge repels it with a force of 1 dyne.

- UNIT - Statcoulomb

- In SI :-

It is the amount of charge which when placed in air at a distance of 1 meter from a similar charge repels it with a force of 9×10^9 newton (N).

- Unit - coulomb.

→ Electric potential :-

Meaning :- The ~~quant~~ quantity which determines the direction of flow of charge between two bodies.

→ Electric potential at any point in an electric field may be defined, as the work done in bringing a unit positive charge of one coulomb from infinity to that point against the electric field along any path.

→ POTENTIAL DIFFERENCE :-

The potential difference between two points is defined as the work done in bringing a unit positive charge from one point to another.

$$\text{Formula, } V = \frac{W}{Q}$$

$$\text{SI unit} = \frac{\text{Joule}}{\text{Coulomb}} = \text{Volt}$$

$$\text{or } V = \frac{W}{Q}$$

$$\text{C.G.S} \rightarrow \frac{\text{erg}}{\text{statcoulomb}} = \text{stat volt}$$

\rightarrow Electric field AND Electric field Intensity :-

An electric field is the physical field that surrounds each charge & exerts force on all charges in the field either attracting or repelling them.

\rightarrow Electric field originate from electric charges or from time varying magnetic field.

- Electric field Intensity \Rightarrow (Electric field strength)

- The electric field intensity at any point inside the electric field is defined as the force experienced by the unit positive charge placed at that point.

From coulomb's Law,

→ CAPACITANCE :-

Capacitance is the property of an electric conductor or set of conductors that is measured by the amount of separated electric charge that can be stored on it per unit charge in electrical potential.

→ It is denoted by (C).

It is ^{or} the ratio of the amount of electric charge stored on the conductor to the difference in electric potential.

Mathematically ,
$$C = \frac{Q}{V}$$

SI unit of Capacitance is Farad.

$$1 \text{ farad} \text{ or } 1F = \frac{1C}{1V}$$

$$1 \text{ mF} = 10^{-3} \text{ F}$$

$$1 \mu\text{F} = 10^{-6} \text{ F}$$

In C.G.S.

There are 2 type of unit in C.G.S

system.

- 1) e.s.u of capacity on 'standard'
- 2) e.m.u of capacity on abfarad.

- Dimensional

- Dimensional Formula of Capacitance

We know, capacitance = $\frac{\text{Coulomb}}{\text{Volt}}$, $\frac{\text{coulomb}}{\text{Joule/coulomb}}$

$$\Rightarrow C = \frac{Q}{V} = \frac{Q}{W/Q}$$

$$\Rightarrow C = \frac{Q^2}{W}$$

$$\Rightarrow C = \frac{(I \cdot T)^2}{[M' L^2 T^{-2}]} = \frac{[M^0 L^0 T^2 A^2]^2}{M' L^2 T^{-2}}$$

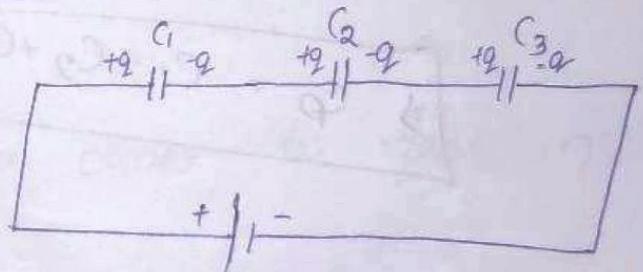
$$\Rightarrow C = \frac{[M^0 L^0 T^2 A^2]}{[M' L^2 T^{-2}]}$$

$$\Rightarrow C = [M^{-1} L^{-2} T^4 A^2]$$

→ Solved Combination of Capacitors

$$V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}, V_3 = \frac{Q}{C_3}$$

$$\text{We know, } V = V_1 + V_2 + V_3 \quad (1)$$



$$\therefore V = \frac{Q}{C_s}$$

$$\therefore \frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\boxed{\therefore \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

→ Parallel Combination of Capacitors.

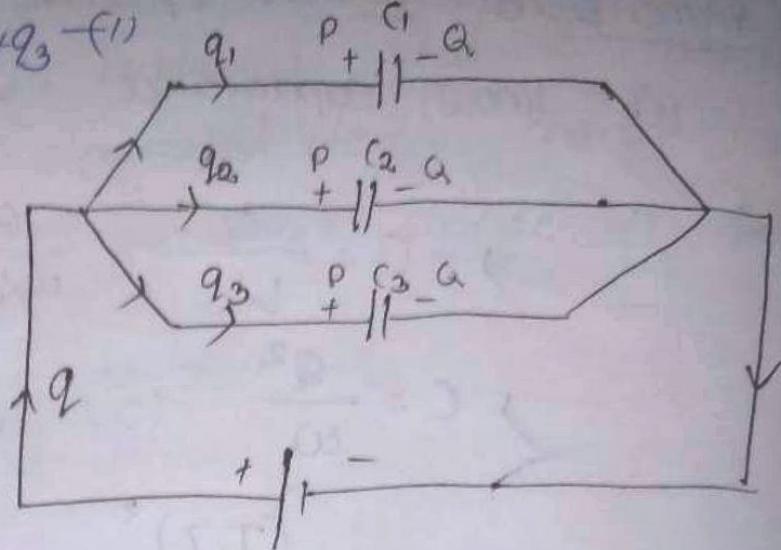
Total charge $Q = Q_1 + Q_2 + Q_3$ (1)

$$\text{Now, } C_1 = \frac{Q_1}{V}$$

$$\therefore Q_1 = C_1 V$$

$$Q_2 = C_2 V$$

$$Q_3 = C_3 V$$



C_p be the capacity
of combination

~~We know~~ $C_p = \frac{Q}{V}$ ~~then~~

We know that $C_p = \frac{Q}{V}$

by putting the value of Q_1, Q_2 & Q_3 we get

$$C_p V = C_1 V + C_2 V + C_3 V$$

$$\boxed{\Rightarrow C_p = C_1 + C_2 + C_3}$$

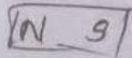
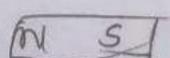
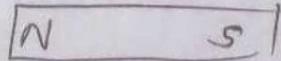
→ MAGNET!-

A substance which attracts small pieces of iron towards it, is called a magnet.

A piece of substance which possesses the property of attracting small pieces of iron towards it, is called a magnet.

- PROPERTIES OF A MAGNET

- (i) A magnet has two pole one is 'north pole' & another is 'south pole'.
- (ii) The face to face length of a magnet is called geometrical length & Pole to Pole length of a magnet is called magnetic length.
- (iii) A freely suspended magnet comes to rest in north south direction.
- (iv) There is no existence of isolated magnetic pole. If we break magnet into a number of pieces, each piece behaves as a small magnet having both the poles.



→ Coulomb's Law in Magnetism

The magnitude of the force of attraction or repulsion between two magnetic poles (supposed isolated) is directly proportional to the product of their their pole strength and inversely proportional to the square of distance between them.

Consider m_1 & m_2 be the strength of two magnetic pole separated by a distance r .



Let, F be the magnitude of force between two poles according to the law of $F \propto m_1 m_2$ — (1)
 $\& F \propto \frac{1}{r^2}$ — (2)

Combining the two eqn, we get

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

$$\boxed{F = K \frac{m_1 m_2}{r^2}} \quad (1)$$

Where K is the proportionality constant.

In S.I

For free space (air/vacuum)

$$K = \frac{\mu_0}{4\pi}$$

Where, μ_0 is the magnetic permeability of free space.

$$\text{Now Force } (F) = \frac{\mu_0}{4\pi} \cdot \frac{m_1 m_2}{r^2}$$

SI unit of pole strength is Amperes × meter (Am).

$$\left(\therefore \mu_0 = \frac{4\pi F r^2}{m_1 m_2} \right) \quad \text{Here } m_1 \text{ & } m_2 \text{ are pole strengths}$$

The value of

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{Nm}^2}{(\text{Am})^2}$$

(on)

$$\Rightarrow \mu_0 = 4\pi \times 10^{-7} \frac{\text{Nm}^2}{\text{A}^2 \text{m}^2}$$

(on)

$$\Rightarrow \mu_0 = 4\pi \times 10^{-7} \frac{\text{N}}{\text{A}^2}$$

(on)

$$\Rightarrow \mu_0 = 4\pi \times 10^{-7} \frac{\text{Weber}}{\text{m}^2}$$

→ MAGNETIC FIELD:

Magnetic field of a magnetic pole is defined as the space around it within which magnetic force is effective.

or

Magnetic field, of any magnetic pole, is the region (space) around it in which its magnetic influence can be realised.

→ Magnetic Field Intensity

Magnetic field intensity at a point in a magnetic field is defined as the force experienced by a unit ~~nonmagnetic~~ pole placed at that point.

MAGNETIC LINES OF FORCE :-

It is laws of free unit north pole in a magnetic field.

On

Line of force is the path along which a unit north pole would move if it were free to do so.

- Properties

(i) Magnetic lines of force are directed away from a north pole & directed towards south pole.

(ii) Two magnetic line of force never cross each other.

(iii) The number of ~~line~~ magnetic lines of force per unit area (area being perpendicular to lines) is directly proportional to the intensity of magnetic field.

(iv) There are 4 π lines of force per unit magnetic pole.

(v) Magnetic lines of force form close curve.

* MAGNETIC FLUX (Φ_B) :-

Magnetic flux deals with the study of the number of lines force of magnetic field crossing a certain Area.

Magnetic flux is a ~~measure~~ measurement of the total magnetic field which passes through a certain Area.

- In S.I unit

Unit of Φ_B = Weber

- In C.G. MS

Unit of Φ_B = maxwell

Here 1 weber = 10^8 maxwell

Magnetic Flux Density (B)

Magnetic flux density at any point is defined as the number of magnetic lines of forces passing through a unit area placed at that point if the area is held perpendicular to the direction of lines.

- S.I unit of magnetic flux density = $\frac{\text{Weber}}{\text{m}^2} = \text{Tesla}$
- C.G.S unit of magnetic flux density = Gauss

→

* Permeability :

Permeability of a substance is a measure of its conduction of magnetic lines of force through it.

(ii) Relative Permeability (μ_r) :

Relative Permeability of a magnetic substance is defined as the ratio of magnetic flux density density per.

Electric Current (I): - It is defined as the rate of flow of charge across any cross-section of the conductor. The time rate flow of charge is called current.

or

The flow of charge per unit time is called current.

$$\text{It is given by, } I = \frac{Q}{t}$$

where, q = charge

SI unit = Ampere or $\frac{\text{Coulombs}}{\text{Sec}}$

Dimensional formula = $[M^0 L^0 T^0 A^{-1}]$

Ohm's Law:-

It states that, at constant temperature the current flowing through a conductor of uniform area of cross-section is directly proportional to the potential difference across the free ends of the conductor.

$$\text{So } I \propto V$$

$$\Rightarrow \frac{V}{I} = \text{constant}$$

$$\Rightarrow \frac{V}{I} = R$$

$$\Rightarrow V = IR \quad (R = \text{Resistance of the conductor})$$

R depends upon 2 factors :-

(i) Temperature

(ii) shape / geometry of the conductor

when,

R is less, I is more $I \propto V$

R is more, I is less $I \propto \frac{1}{R}$

→ Conductor allows current

→ Insulator does not allow current

→ Semiconductor, increase in temp, then increasing in current flow.

→ Application of Ohm's law:-

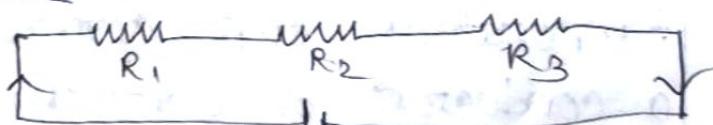
It help us in determining either voltage, current or impedance or resistance of a linear electrical circuit when the other two quantities are known to us.

It also makes power calculation simpler.

To find current, If R & V known, maintain a desired voltage in electrical components. Resistance can be found out.

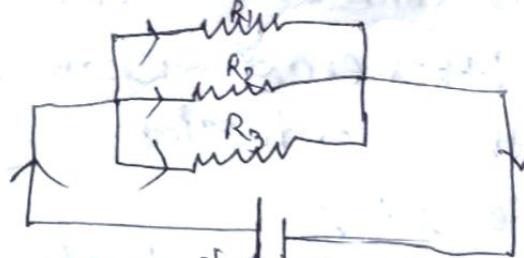
→ Resistance in series:-

$$R = R_1 + R_2 + R_3$$

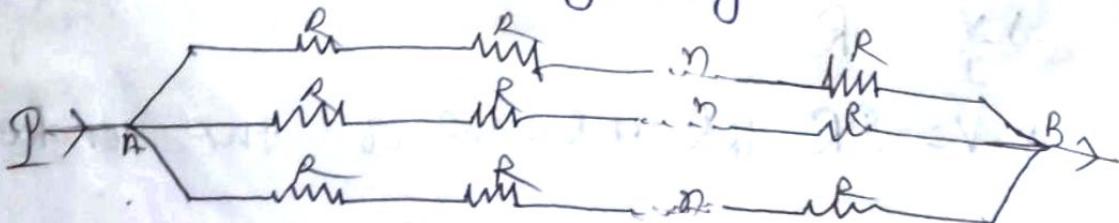


→ Resistance in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



→ Resistance in mixed grouping:-



In one row resistance are connected in series.

$$\text{So, resistance of one row } R = R_1 + R_2 + R_3 + \dots = nR$$

Suppose, m resistances are connected in parallel then the final resistance is given by.

$$\frac{1}{R_f} = \frac{1}{NR} + \frac{1}{NR} + \dots + n \text{ terms}$$

$$\Rightarrow \frac{1}{R_f} = \frac{m}{NR}$$

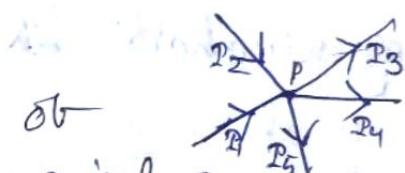
$$\Rightarrow R_f = \frac{NR}{m}$$

Kirchhoff's law :-

• 1st law; Kirchhoff's current law (KCL) :-

It states that the algebraic sum of currents meeting at a point is zero.
Explanation :-

Consider a number of wires connected at a point P.



Currents I_1, I_2, I_3, I_4 and I_5 flow through these wires in the direction as shown. The currents approaching a given point are taken as positive and the currents leaving the given point are taken as negative.

Hence by, Kirchhoff's law,

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

$$\text{or } \sum I = 0$$

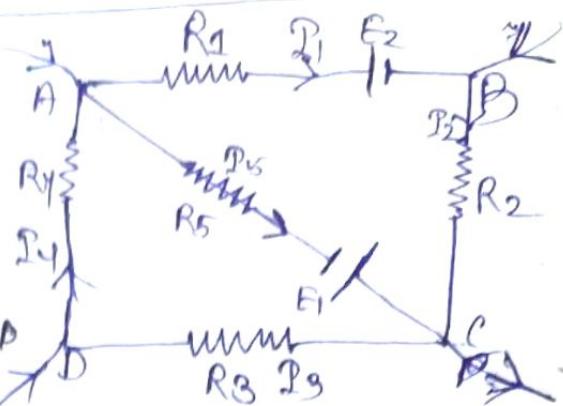
• 2nd law; Kirchhoff's voltage law (KVL) :-

It states that, in a closed electric circuit, the algebraic sum of emf is equal to the algebraic sum of the product of the resistances and the currents flowing through them.

24. Jan. 2022

Explanation :-

A closed circuit ABCD containing resistance R_1, R_2, R_3, R_4, R_5 and EMFs in the parts



AB, BC, CD, DA and AC respectively also. Let I_1, I_2, I_3, I_4 and I_5 be the respective currents flowing in these parts in the direction as shown. P.D. sources at end of E₁ and E₂ are also connected in the mesh.

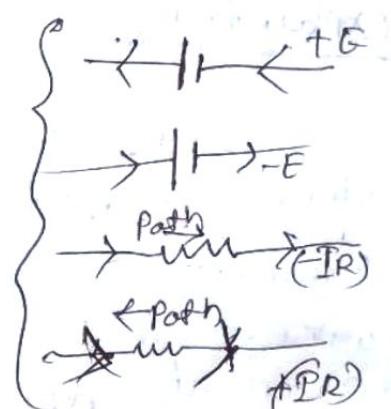
Applying Kirchhoff's law:-

For mesh ABC

$$I_1 R_1 + I_2 R_2 - I_5 R_5 - E_1 - E_2 = 0$$

for mesh ACD

$$I_5 R_5 - I_3 R_3 - I_4 R_4 = E_1$$



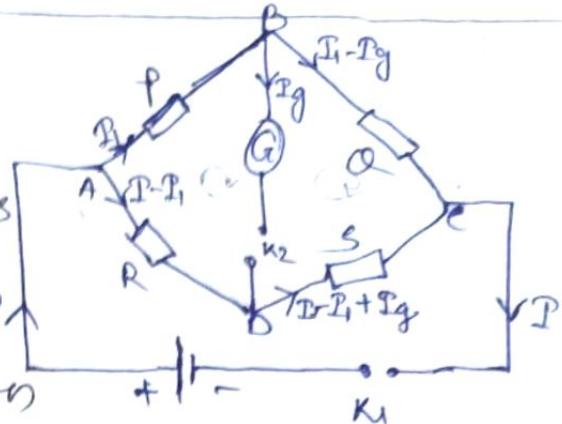
General form, $\sum PR = \sum E$

Sign Convention:-

- ① Current \rightarrow Positive to negative terminal \rightarrow $-Emf(E)$ is negative
- ② Current \rightarrow -ve to +ve \rightarrow $Emf(E)$ is +ve
- ③ Path taken to traverse the resistance is along the direction of current, then PR is -ve
- ④ Path taken to traverse the resistance is along the direction of current, then PR is +ve

Wheat stone bridge:

It is an electrical arrangement which forms the basis of most of the instrument used to determine unknown Resistance.



It consists of 4 resistances P, Q, R and S connected in 4 arms of square ABCD. Key K_1 and K_2 are closed, so that the resistances P, Q, R and S are so adjusted that the galvanometer shows no deflection. This is balanced condition for Wheatstone bridge.

Now giving positive sign to the current flowing in clockwise direction and negative sign to the current flowing in anti-clockwise direction. So applying Kirchhoff's Voltage law in ABD,

$$(I_P + I_Q)R - (I - I_R)R = 0 \quad \textcircled{1}$$

and in BCD,

$$(I - I_R)Q - (I - I_R + I_S)S - I_S G = 0 \quad \textcircled{2}$$

Since bridge is balanced therefore, the current I_S flowing through the arm BD is zero. Putting $I_S = 0$ in eqn ① & ②

$$\Rightarrow I_P - (I - I_R)R = 0$$

$$\Rightarrow I_P = (I - I_R)R \quad \textcircled{3}$$

$$\text{and } I_Q - (I - I_R)S = 0$$

$$\Rightarrow I_Q = (I - I_R)S \quad \textcircled{4}$$

Dividing ③ by ④ we get

$$\frac{P}{Q} = \frac{R(1-\beta)}{S(1-\beta)}$$

$\Rightarrow \frac{P}{Q} = \frac{R}{S}$ } \rightarrow Balanced condition of bridge.

ELECTROMAGNETISM

The Production of magnetic field due to passing of current is called electromagnetism

* Fleming's Left Hand Rule:-

Direction of force is determined by this rule when current and field is known.

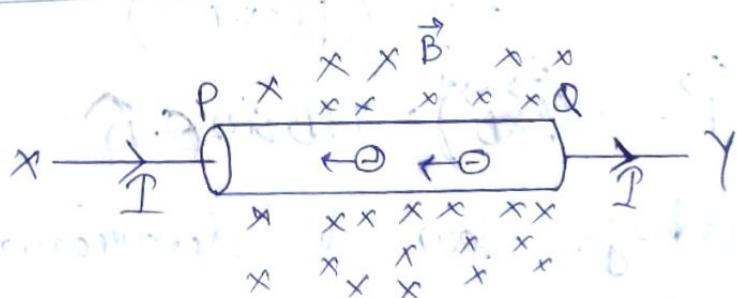


Statement:-

When we stretch out the left hand with fore finger, central finger and thumb at right angle to one another. So if fore finger points towards the magnetic field, central finger towards the current then direction of force (which acts on the conductor) is given by the direction of thumb.

* Force acting on a current carrying conductor placed in a uniform magnetic field.

Field :-



A conductor has free electrons in it, when a potential difference is maintained across the two ends of the conductor, the electrons drift from lower to higher potential with a small velocity and current flows in the conductor. When

the electrons move in a magnetic field, they experience a force \vec{F} .

Let us consider a conductor PQ placed in a uniform magnetic field \vec{B} , acting inward at right angle to the plane of paper. Let $I =$ current flowing through the conductor from X to Y.

$V =$ velocity of moving particles
 $dq =$ small amount of charge moving from X to Y.

So, force experienced by the charge is given by,

$$d\vec{F} = dq (\vec{V} \times \vec{B})$$

If the charge moves a small distance dl in time dt then

$$\text{then } d\vec{F} = dq \left(\frac{dI}{dt} \vec{X} \vec{B} \right) = \frac{dq}{dt} (dI \vec{X} \vec{B}) \\ = I (dI \vec{X} \vec{B})$$

$$\text{so } \vec{F} = I (l \vec{X} \vec{B}) = I l B \sin \theta \hat{n}$$

Faraday's law of Electromagnetic

1st law whenever magnetic flux linked with a circuit changes, an emf is induced in it which exists in the circuit as long as the change in magnetic flux linked with

it continues

2nd law: the Induced emf is directly proportional to the negative rate of change of magnetic flux linked with the circuit.

* Lenz's law: It states that direction of induced current is such that it tends to oppose the very cause which produces it.

* Fleming's Right hand rule:

Direction induced current is determined when magnetic field and direction of motion of conductor (force) is known.

Statement



When we stretch out the right hand which face fingers central finger and thumb finger at right angle to one another so, If the fore finger points towards the magnetic field, thumb points towards the direction of motion of conductor (force) then the direction of central finger gives the direction of induced current set up in the conductor.

Fleming's left hand
Role.

Fleming's right hand
Rule.

- ① It is used for electric motors.

② The electric current and magnetic field interact and they lead to a force which causes motion.

③ Left hand is used because of difference between cause and effect.

④ Direction of motion of force is determined.

① It is used for electric generators.

② The motion & magnetic field exist and they lead to the creation of electric current.

③ Right hand is used because of difference between cause and effect.

④ Direction of induced current is determined.

19. 10. 1937. Two black crows seen. One
was on ground near water hole. Another

25. 12. 1991. 100% 2nd
100% 1st

strong body

~~1941~~ The Atlantic City Boardwalk

• 1539 Wm. M.

Light amplification by the stimulated Emission or Radiation

* Laser:- A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation.

* Laser beam:- A narrow beam of light produced by a laser.

Properties of Laser

① Monochromatic:- The light emitted from a laser is monochromatic, that is it is of one wavelength (colour).

② Directional:-

Laser emit light that is highly directional. Laser light is emitted as a relatively narrow beam in a specific direction.

③ Cohherent

The light from a laser is said to be coherent, which means the waves of the laser light are in phase in space and time.

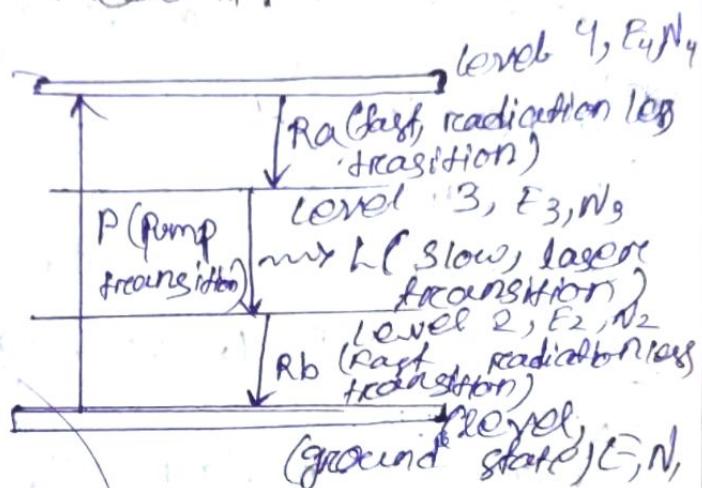
Application of laser

→ They are used in common consumer devices such as optical disk drives, laser printers and barcode scanner.

→ Lasers are used for both fiber optic and free space optical communication.

- They are used in medicine for laser surgery and various skin treatments.
- Lasers are used in industry for cutting and welding materials.
- They are used in military and law enforcement device for making targets and measuring range and speed.
- Laser light displays use laser light as an entertainment medium.

Principle of Laser:



In the higher energy state has a greater population than the lower energy state, then the light in the system undergoes a net increase in intensity and this is called population inversion. But this process cannot be achieved by only two states, because the electrons will eventually reach equilibrium with the de-exciting process or spontaneous and stimulated emission.

Instead an indirect way is adopted with three energy levels ($E_1 < E_2 < E_3$) and energy population N_1, N_2 and N_3 .

respectively. Initially the majority of electrons stay in the ground state. Then the external energy provided to excite them to level 3 is referred as pumping.

In a medium suitable for laser operation we require these excited atoms to quickly decay to level 2, transferring the energy to the phonons of the lattice of the host material. This wouldn't generate a photon, and labelled as R, meaning radiation less. Then electrons at level 2 will decay by spontaneous emission to level 1, labeled as L meaning laser. If the life times of L is much longer than that of R, the population in E₃ will be essentially zero and a population of excited state atoms will accumulate in level 2. When level 2 hosts over half of the total electrons a population inversion is achieved.

Nowadays, the present lasers are 3 level lasers because three level lasers are inefficient. In this case the population of level 2 and 3 are zero and electrons just accumulate in level 3. Laser transition takes place

between level 3 and 2; so the polarization is easily inverted.

Wireless transmission

① Ground waves

Radio waves emitted by a transmitter travel in a straight line. As such these are not able to reach distant point due to the curvature of the earth. The station situated close to the transmitter can however catch these waves directly. Such waves are called ground waves.

② Sky waves - The waves which are transmitted from one station to another after reflection from ionosphere. These waves are called sky waves.

③ Space waves - The ionosphere does not help in reflecting wave at frequencies greater than 300 MHz (usually used in TV). These waves can travel from transmitting station to receiving station along the line of sight. This propagation takes place through highly placed antennae. These waves are called space waves.