GOVERNMENT POLYTECHNIC, NAYAGARH

SUB :- ENGG.PHYSICS

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UNIT-1

Unit-1 UNITS AND DIMENSIONS

- **Physical Quantities :-**

→ A quantitative description of any physical phenomena involving certain measurable quantities are known as Physical quantities.

→ They are of two types. a) Fundamental quantity
b) Derived quantity

Fundamental Quantities :-

→ These quantities are independent in nature

→ They can be expressed independently.

Fundamental Quantities	Fundamental Units
Mass	Kilogram (Kg)
Length	metre (m)
Time	second (s)
Electric Current	ampere (A)
Thermodynamic Temperature	Kelvin (K)
Luminous Intensity	Candela (cd)
Amount of Substance	Mole (mol)

Derived Quantities :-

→ They can be expressed with the help of fundamental quantity.

Example :- Volume, Pressure, Area, Work, Force

Unit :-

It is a standard which is used for the measurement of a physical quantity.

Characteristics of a Unit :-

→ It should be invariable.

→ It should be easily available.

→ It should be nonperishable.

→ It should be convenient in size.

System of Units :-

1. CGS System (French System) :-
- It is a system of measurement in which the fundamental unit of length

mass and time are taken as 1cm, 1gm and 1sec respectively.

- It is also known as Gaussian System.

2. M.K.S System (Metric System) :-

- It is the system of measurement in which the fundamental units of length, mass and time are 1m, 1gm and 1sec. respectively.

3. FPS System :-

- Here the fundamental units of length, mass and time are 1 Foot, 1 Pound, 1 second respectively.

4. SI system :-

It is the international system of units which is also the modern form of the metric system.

Definition of Dimension :-

The dimensions of a derived physical quantity may be defined as the powers to which its base units must be raised to represent it completely.

Dimensional Formula :-

It is an expression which shows how and which of the fundamental units enter into the units of a physical quantity.

Sl No.	Physical Quantity	Relation	Dimensional Formula	Unit
1.	Area	Length x breadth	$[L^1] \times [L^1] = [L^2] = [M^0 L^2 T^0]$	m^2
2.	Volume	Length x breadth x height	$[L^1] \times [L^1] \times [L^1] = [L^3] = [M^0 L^3 T^0]$	m^3
3.	Acceleration	Velocity / Time	$\frac{L/T}{T} = \frac{L}{T^2} = [M^0 L^1 T^{-2}]$	m/s^2
4.	Velocity	Distance / Time	$[L^1]/[T^1] = [M^0 L^1 T^{-1}]$	m/s
5.	Force	Mass x Acceleration	$[M^1] \times [L^1 T^{-2}] = [M^1 L^1 T^{-2}]$	$Kg\,m/s^2$ or Newton
6.	Work	Force x distance	$[M^1 L^1 T^{-2}] \times [L^1] = [M^1 L^2 T^{-2}]$	Joule
7.	Pressure	Force / Area	$\frac{[M^1 L^1 T^{-2}]}{[L^2]} = [M^1 L^{-1} T^{-2}]$	N/m^2
8.	Impulse	Force x Time.	$[M^1 L^1 T^{-2}] \times [T^1] = [M^1 L^1 T^{-1}]$	NS
9.	Power	Work / Time	$\frac{[M^1 L^2 T^{-2}]}{[T]} = [M^1 L^2 T^{-3}]$	Watt
10.	Frequency	1/Time Period	$1/T = [M^0 L^0 T^{-1}]$	$1/s$ or HZ
11.	Velocity gradient	Velocity / distance	$[L^1 T^{-1}]/[L^1] = [M^0 L^0 T^{-1}]$	s^{-1}
12.	Wavelength	Velocity / Frequency	$[L^1 T^{-1}]/[T^{-1}] = [M^0 L^1 T^0]$	m

Sl No.	Physical Quantity	Relation	Dimensional Formula	S.I units
13	Gravitational Constant	$\frac{\text{Force} \times (\text{distance})^2}{(\text{mass})^2}$	$\frac{[M^1 L^1 T^{-2}] \times [L]^2}{[M^2]} = [M^{-1} L^3 T^{-2}]$	$N m^2 kg^{-2}$
14.	Energy	Work	$[M^1 L^2 T^{-2}]$	Joule
15.	Planck's Constant (h)	$\frac{\text{Energy}}{\text{Frequency}}$	$\frac{[M^1 L^2 T^{-2}]}{[T^{-1}]} = [M^1 L^2 T^{-1}]$	$\frac{J}{s^{-1}}$ or Js
16.	Strain	$\frac{\text{Change in length}}{\text{Original length}}$	$[M^0 L^0 T^0]$ (Dimensionless)	Unitless
17.	Stress	Force/Area	$\frac{[M^1 L^1 T^{-2}]}{[L^2]} = [M^1 L^{-1} T^{-2}]$	$N m^{-2}$
18.	Rate of flow	Volume/Time	$\frac{[M^0 L^3 T^0]}{[T^1]} = [M^0 L^3 T^{-1}]$	$m^3 s^{-1}$
19.	Coefficient of elasticity	Stress/Strain	$\frac{[M^1 L^{-1} T^{-2}]}{[M^0 L^0 T^0]} = [M^1 L^{-1} T^{-2}]$	$N m^{-2}$
20.	Co-efficient of viscosity	$\frac{\text{Force}}{\text{Area} \times \text{Velocity gradient}}$	$\frac{[M^1 L^1 T^{-2}]}{[L^2 \times T^{-1}]} = [M^1 L^{-1} T^{-1}]$	$N m^{-2} s$
21	Surface Tension	Force/Length	$[M^1 L^1 T^{-2}]/[L^1] = [M^1 L^0 T^{-2}]$	$N m^{-1}$
22.	Surface Energy	Energy/Area	$[M^1 L^2 T^{-2}]/[L^2] = [M^1 L^0 T^{-2}]$	$J m^{-2}$

Sl No.	Physical Quantity	Relation	Dimensional Formula	SI units
23.	Angle	Length of arc/radius.	$\frac{[L]}{[L]} = [M^0L^0T^0]$. (Dimensionless)	Unitless
24.	Angular velocity	Angle/Time	$\frac{[M^0L^0T^0]}{[T^1]} = [M^0L^0T^{-1}]$	s^{-1}
25.	Angular Acceleration	Angular velocity/Time	$[M^0L^0T^{-1}]/[T^1] = [M^0L^0T^{-2}]$	s^{-2}
26.	Torque	Force x distance	$[M^1L^1T^{-2}] \times [L^1] = [M^1L^2T^{-2}]$	Nm
27.	Angular Momentum	Momentum x distance	$[M^1L^1T^{-1} \times L^1] = [M^1L^2T^{-1}]$	$Kg\,m^2s^{-1}$
28.	Moment of Inertia	mass x (radius)^2	$[M^1L^2] = [M^1L^2T^0]$	$Kg\,m^2$
29.	Radius of gyration	distance	$[M^0L^1T^0]$	m
30.	Coefficient of friction	$\frac{\text{Force}}{\text{Normal Reaction}}$	$\frac{[M^1L^1T^{-2}]}{[M^1L^1T^{-2}]} = [M^0L^0T^0]$ (Dimensionless)	No units
31.	Temperature	Fundamental quantity	$[M^0L^0T^0K^1]$	K
32.	Heat	Energy	$[M^1L^2T^{-2}]$	J
33.	Gas Constant (R)	$\frac{\text{Pressure} \times \text{Volume}}{\text{Temperature}}$	$\frac{[M^1L^{-1}T^{-2}] \times [L^3]}{[K^1]} = [M^1L^2T^{-2}K^{-1}]$	JK^{-1}
34.	Boltzmann constant (K)	$\frac{R}{N}$	$\frac{[M^1L^2T^{-2}K^{-1}]}{[M^0L^0T^0]} = [M^1L^2T^{-2}K^{-1}]$	JK^{-1}

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Sl No.	Physical Quantity	Relation	Dimensional Formula	S.I Unit
35	Coefficient of thermal conductivity	$\frac{Qd}{A(\theta_2-\theta_1)t}$	$\frac{[M^1L^2T^{-2}] \times L}{[L^2]\times[K^1]\times[T^1]} = [M^1L^1T^{-3}K^{-1}]$	$Wm^{-1}K^{-1}$.
36	Electric current (i)	Fundamental Quantity	$[M^0L^0T^0A^1]$	A
37	Potential difference	Work/charge	$[M^1L^2T^{-2}]/[A^1T^1] = [M^1L^2T^{-3}A^{-1}]$	V
38	Resistance	$\frac{\text{Potential difference}}{\text{Current}}$	$\frac{[M^1L^2T^{-3}A^{-1}]}{[A]} = [M^1L^2T^{-3}A^{-2}]$	Ohm
39.	Resistivity (ρ)	$\frac{\text{Resistance} \times \text{Area}}{\text{length}}$	$\frac{[M^1L^2T^{-3}A^{-2}] \times [L^2]}{[L^1]} = [M^1L^3T^{-3}A^{-2}]$	Ωm
40.	Capacitance (c)	charge/Potential difference	$\frac{[A^1T^1]}{[M^1L^2T^{-3}A^{-1}]} = [M^{-1}L^{-2}T^4A^2]$	F
41.	Permittivity (ε)	$(\text{Charge})^2/\text{Force} \times (\text{distance})^2$	$\frac{[A^1T^1]^2}{[M^1L^1T^{-2}] \times [L^1]^2} = [M^{-1}L^{-3}T^4A^2]$	Fm^{-1}
42.	Magnetic flux density (B)	$\frac{\text{Force}}{\text{charge} \times \text{Velocity}}$	$\frac{[M^1L^1T^{-2}]}{[A^1T^1]\times[L^1T^{-1}]} = [M^1L^0T^{-2}A^{-1}]$	$NA^{-1}m^{-1}$ or Wbm^{-2}
43.	Magnetic Pole (m)	$\frac{\text{Force}}{\text{magnetic flux density}}$	$\frac{[M^1L^1T^{-2}]}{[M^1L^0T^{-2}A^{-1}]} = [L^1A^1]$	Am
44.	Magnetic Permeability (μ)	$\frac{\text{Force} \times (\text{distance})^2}{(\text{Pole strength})^2}$	$\frac{[M^1L^1T^{-2}] \times [L^2]}{[L^1A^1]^2} = [M^1L^1T^{-2}A^{-2}]$	NA^{-2}

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Dimensional Equation:-

An equation written in the following manner is called dimensional equation: Area = $[M^0 L^2 T^0]$

Principle of homogeneity:-

It states that the dimensional formula of every term on the two sides of a correct relation must be same.

Checking the dimensional correctness of Physical Relations:-

1. Check the correctness of formula $v = u + at$

A:- The dimensional Formula of $v = [M^0 L^1 T^{-1}]$

The dimensional formula of $u = [M^0 L^1 T^{-1}]$

The dimensional Formula of $at = [M^0 L^1 T^{-2}][T^1]$

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

Hence the formula is dimensionally correct.

2. Check the Correctness of formula $S = ut + \frac{1}{2} at^2$

A:- The dimensional formula of $S = [M^0 L^1 T^0]$

The dimensional formula of $ut = [M^0 L^1 T^{-1}][T^1]$

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

The dimensional formula of $\frac{1}{2} at^2 = [M^0 L^1 T^{-2}][T^2] = [M^0 L^1 T^0]$

Hence the formula is dimensionally correct.

3. Check the Correctness of formula $v^2 - u^2 = 2as$

A:- The dimensional formula of $v^2 = [M^0 L^1 T^{-1}]^2 = [M^0 L^2 T^{-2}]$

The dimensional formula of $u^2 = [M^0 L^1 T^{-1}]^2 = [M^0 L^2 T^{-2}]$

The dimensional formula of $2as = [M^0 L^1 T^{-2}][L^1] = [M^0 L^2 T^{-2}]$

Hence the formula is dimensionally correct

UNIT-2

Unit-2 SCALARS AND VECTORS

Scalar Quantities:-

- Scalar quantities are those quantities which require only the magnitude for their complete specifications.
- E.g → Mass, length, volume, density, energy, temperature etc.

Vector Quantities:-

- Vector quantities are those quantities which require magnitude as well as direction for their complete specification.

E.g →. Displacement, Velocity, acceleration etc.

Representation of a Vector:-

A vector can be represented by observing the following steps.

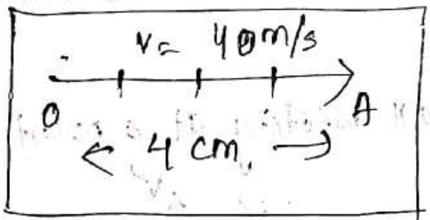
i) A line is drawn parallel to the direction of vector.

ii) The length of the line is cut so that it represents the magnitude of the vector on a certain convenient scale.

iii) An arrowhead is put in the direction of the vector. The arrowhead line represents the given vector.

Examples:- Consider a body moving with a velocity 40m/s due east. We want to represent it vectorically.

Let's select a scale that 10 m/s = 1 cm.



(Here a line is drawn (4cm) along west-east direction. An arrowhead is put along east. This vector represents a velocity of 40m/s due east.)

Types of vectors:-

i) Null vector:- It is a vector having zero magnitude and an arbitrary direction.

Properties of a Null Vector:-

a) It has zero magnitude.

b) It has arbitrary direction.

c) It is represented by a point

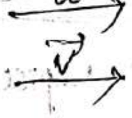
d) When a null vector is added or subtracted from a given vector the resultant vector is same as the given vector.

e) Dot product of a null vector with any vector is always zero.

f) Cross Product of a null vector with any other vector is also a null vector.

ii) Equal vectors :-

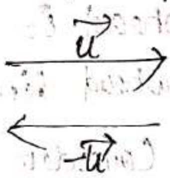
- Two vectors are said to be equal if they possess the same magnitude and direction.
- They can be represented by two parallel straight lines of equal lengths and pointing in same direction.



Here $\vec{u} = \vec{v}$

iii) Negative vectors :-

A vector is said to be a negative vector of another one, if it is represented by a line having same length as that of the second and is directed in opposite direction.



iv) Co-initial vectors :-

A number of vectors having a common initial point are called co-initial vectors.

E.g → Vectors $\vec{u}$, $\vec{v}$, $\vec{w}$, $\vec{x}$ and $\vec{y}$ all meeting at a point P are co-initial vectors.

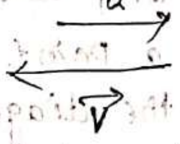
v) Collinear vectors :- Vectors having a common line of action are called collinear vectors.

There are two types of collinear vectors.

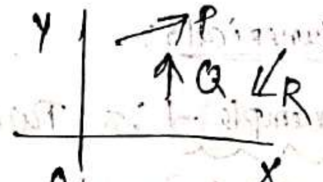
a) Parallel vectors ($\theta = 0°$) :- Two vectors (which may have different magnitudes) acting along same direction are called parallel vectors. Angle between them is zero.

b) Antiparallel vectors ($\theta = 180°$):

Two vectors which are directed in opposite directions are called antiparallel vectors.



vi) Co-Planar Vectors:- Vectors situated in one plane, irrespective of their directions are known as coplanar vectors.



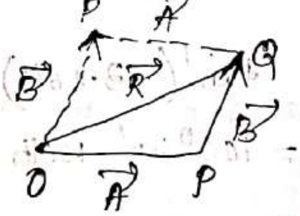
vii) Localised vectors:- Vector whose initial point is fixed is said to be a localised or fixed vector.

viii) Nonlocalised vectors:- vector whose initial point (tail) is not fixed is said to be a nonlocalised vector or a free vector.
E.g → Vectors representing force, momentum, impulse etc. are nonlocalised vectors.

Triangle's Law of Vector Addition:- It states that

" If two vectors are represented (in magnitude and direction) by the two sides of a triangle, taken in same order then their resultant is represented (in magnitude and direction) by the third side of the triangle taken in opposite order."

Resultant of two vectors $\vec{A}$ and $\vec{B}$ acting at a point can be determined by triangle's law in either of the following two ways:



i) $\vec{R} = \vec{OQ} = \vec{A} + \vec{B} = \vec{B} + \vec{A}$

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

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

$\Rightarrow \beta = \tan^{-1}\dfrac{B\sin\theta}{A + B\cos\theta}$

Parallelogram law of Vector Addition :- It states that

"If two vectors acting simultaneously at a point are represented in magnitude and direction by the two sides of a parallelogram drawn from a point, their resultant is given in magnitude and direction by the diagonal of the parallelogram passing through that point."

Numericals :-

Example -1 :- Two forces 5 N and 20N are acting at an angle of 120^0 between them. Find the resultant force in magnitude and direction.

Solution :- According to parallelogram's law of vector addition,

$$R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

Here $F_1 = 5N$, $F_2 = 20N$, $\theta = 120^0$

$\sin\theta = \sin 120^0 = \sqrt{3}/2$

$\cos\theta = \cos 120^0 = -1/2$

$$R = \sqrt{(5)^2 + (20)^2 + 2\times 5\times 20 \times \left(-\frac{1}{2}\right)}\ N$$

$$= \sqrt{25 + 400 - 100}\ N$$

$$= \sqrt{325}\ N$$

$$\Rightarrow \boxed{R = 18.03N}$$

$$\tan\beta = \frac{F_2\sin\theta}{F_1 + F_2\cos\theta} = \frac{20\sqrt{3}/2}{5 + 20(-1/2)} = -3.464$$

$$\Rightarrow \beta = \tan^{-1}(-3.464)$$

$= 105^0 23'$ with the direction of 5N.

Example-2 :- Two forces, equal in magnitude, have magnitude of their resultant equal to either. Find the angle between them.

Solution :- Here $F_1 = F_2 = R = F$ (say)

So $R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

Substituting for F_1 and F_2

$$R = \sqrt{F^2 + F^2 + 2F^2\cos\theta}$$

$$\Rightarrow F^2 = 2F^2 + 2F^2\cos\theta$$

$$\Rightarrow F^2 = 2F^2(1+\cos\theta)$$

$$\Rightarrow 1+\cos\theta = 1/2$$

$$\Rightarrow \cos\theta = -1/2 = \cos 120^0$$

$$\Rightarrow \boxed{\theta = 120^0}$$

Example-3:- Resultant of two forces equal in magnitude, at right angles to each other is 1414 N. Find the magnitude of each force.

Solution:- Since $R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

Here $F_1 = F_2 = F$

$R = 1414\,N$, $\theta = 90^0$

$$\Rightarrow 1414 = \sqrt{F^2 + F^2 + 2F^2\cos 90^0}$$

$$= \sqrt{2F^2}$$

$$\Rightarrow \frac{1414 \times 1414}{2} = F^2$$

$$\Rightarrow \boxed{F = 999.84N}$$

Resolutions of vector:-

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

Let $\vec{OP} = \vec{R}$

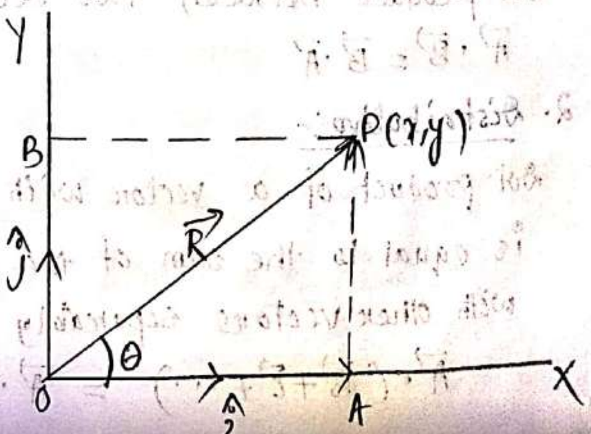
P is the position vector of a point $P(x,y)$. PA and PB are perpendicular on x-axis and y-axis respectively.

Thus $OA = x$, $AP = OB = y$

If $\hat{i}$ and $\hat{j}$ are the unit vectors along x-axis and y-axis. Then vectors along x-axis and y-axis then

$\vec{OA} = x\hat{i}$, $\vec{OB} = y\hat{j}$

According to triangle's law of vector addition



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$\therefore \vec{OP} = \vec{OA} + \vec{AP}$

$$\boxed{\vec{R} = x\hat{i} + y\hat{j}}$$

In ΔOAP, $\cos\theta = \frac{OA}{OP}$

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

$\Rightarrow x = R\cos\theta$

$\sin\theta = \frac{AP}{OP}$

$= \frac{y}{R}$

$\Rightarrow y = R\sin\theta$

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

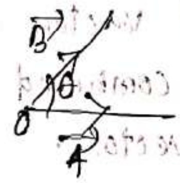
Vector Multiplication:-

i) Scalar Product / Dot Product:-

- Dot product of two vectors is defined as the product of their magnitudes and the cosine of smaller angle between the two.
- It is written by putting a Dot (•) between two vectors.

Consider two vector $\vec{A}$ and $\vec{B}$ drawn from a point O and inclined to eachother at an angle θ.

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



Characteristics of Dot Product!-

1. Commutative :-

Dot product between two vectors is commutative in nature.

$\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$

2. Distributive :-

Dot product of a vector with the sum of number of other vectors is equal to the sum of the dot products of the vector taken with other vectors separately.

$\vec{A}\cdot(\vec{B}+\vec{C}+\cdots) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C} + \cdots$

3. Perpendicular :-

Here $\theta = 90^0$

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

$= 0$

In case of orthogonal unit vectors

$\boxed{\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0}$ (since $\hat{i}, \hat{j}, \hat{k}$ are mutually perpendicular eachother)

4. Collinear vectors :-

a) Parallel :-

Here $\theta = 0^0$

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

$= AB\cos 0^0$

$= AB$

b) Antiparallel :-

$\theta = 180^0$

$\vec{A}\cdot\vec{B} = AB\cos 180^0$

$= -AB$

Therefore the dot product of collinear vectors is equal to the product of their magnitudes. It is positive if they are parallel and negative if they are antiparallel. This statement is called condition of collinearity.

5. Equal vector :-

$\theta = 0^0$

$\vec{A}\cdot\vec{B} = \vec{A}\cdot\vec{A}$

$= AA\cos 0^0$

$= A^2$

In case of orthogonal unit vectors $\boxed{\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1}$

6. Dot Product in terms of rectangular components :-

Let $\vec{A_x}, \vec{A_y}, \vec{A_z}$ and $\vec{B_x}, \vec{B_y}, \vec{B_z}$ are rectangular component of $\vec{A}$ & $\vec{B}$.

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

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

$= A_xB_x(\hat{i}\cdot\hat{i}) + A_xB_y(\hat{i}\cdot\hat{j}) + A_xB_z(\hat{i}\cdot\hat{k}) + A_yB_x(\hat{j}\cdot\hat{i}) + A_yB_y(\hat{j}\cdot\hat{j})$
$+ A_yB_z(\hat{j}\cdot\hat{k}) + A_zB_x(\hat{k}\cdot\hat{i}) + A_zB_z(\hat{k}\cdot\hat{j}) + A_zB_z(\hat{k}\cdot\hat{k})$

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

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

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

Now $\vec{A}\cdot\vec{B} = A_xB_x(\hat{i}\cdot\hat{i}) + A_yB_y(\hat{j}\cdot\hat{j}) + A_zB_z(\hat{k}\cdot\hat{k})$

$\Rightarrow \boxed{\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z}$

ii) Vector Product / Cross Product :-

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

$$\boxed{\vec{A}\times\vec{B} = \vec{C} = AB\sin\theta\,\hat{n}}$$

Characteristics of Cross Product :-

1. Not Commutative :-

$\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$

Cross Product of two vectors is not commutative in nature.

2. Distributive :-

$$\vec{A}\times(\vec{B}+\vec{C}+\cdots) = \vec{A}\times\vec{B} + \vec{A}\times\vec{C} + \cdots$$

3. Collinear vectors :-

a. Parallel vectors :-

In this case, $\theta = 0^\circ$, $\sin\theta = 0$

$\vec{A}\times\vec{B} = (AB\sin\theta)\hat{n} = 0(\hat{n}) =$ a null vector

b. AntiParallel Vectors :-

In this case, $\theta = 180^\circ$, $\sin\theta = 0$

$\vec{A}\times\vec{B} = (AB\sin\theta)\hat{n} = 0(\hat{n}) =$ a null vector

Therefore cross product of two collinear vectors is always a null vector.

4. Equal vectors :-

$\theta = 0^\circ$

$\vec{A}\times\vec{B} = AB\sin 0^\circ\,\hat{n}$

$= 0(\hat{n}) =$ null vector

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

5. Perpendicular Vector :-

$\theta = 90^\circ$

$$\vec{A}\times\vec{B} = AB\sin\theta\,\hat{n}$$
$$= AB\sin 90^\circ\,\hat{n}$$
$$= AB\,\hat{n}$$
$$|\vec{A}\times\vec{B}| = AB$$

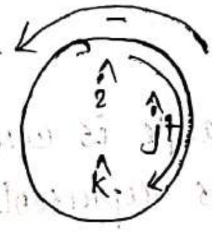
The magnitude of the cross product of two perpendicular vector is equal to the product of their individual magnitude.

In case of Orthogonal unit vectors :

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

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

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



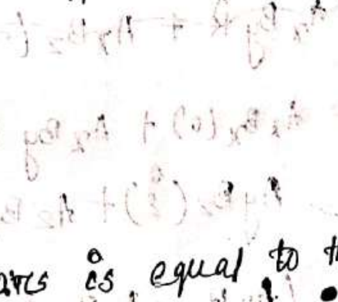
6. Area of Parallelogram :-

Let oacb be a Parallelogram having two vectors $\vec{A}$ and $\vec{B}$ as its two sides.

Area of Parallelogram = base × height
$$= oa \times bd$$

In $\Delta\, obd$, $\sin\theta = \dfrac{bd}{ob}$

$$\Rightarrow bd = ob\sin\theta$$
$$= B\sin\theta$$



Now area of Parallelogram $= oa \times bd$
$$= A\times B\sin\theta$$
$$= AB\sin\theta$$
$$= |\vec{A}\times\vec{B}|$$

The magnitude of cross product of two vectors is equal to the area of the parallelogram formed with the two vectors as the two sides.

UNIT-3

UNIT-3 KINEMATICS

Concept of Rest:-

- If a body doesnot change its position with respect to its surrounding and time, the body is said to be at rest for that time.
- In case of rest, the co-ordinates (x, y, z) of a point remain fixed with respect to its origin.
- Rest can be classified into two categories.

1. Absolute Rest:- If both frame of reference and the body are at rest, the case is said to be of "absolute rest".
2. Relative Rest:- If the frame of reference and body both move with some velocity, they are said to be relative rest w.r.t eachother.

Concept of Motion:-

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

Motion can be classified into the following ways.

A) According to frame of reference:-

i) Absolute Motion:- If the frame of reference is at absolute rest and the body is in motion, the motion is called absolute motion.

ii) Relative Motion:- If both the frame of reference and the body are in motion with different velocities, this is called relative motion.
E.g → A car moving along a road.

B) According to change of Coordinates:-

i) One dimensional Motion:- Motion of a body is said to be one dimensional if it can be expressed in terms of a change in one co-ordinate in the cartesian Coordinate system.

ii) Two dimensional Motion:- Motion of a Particle is said to be two dimensional if it can be expressed in terms of a change in two of its co-ordinates in the cartesian coordinate system.

iii) Three dimensional Motion:- Motion of a particle is said to be three dimensional if all the three coordinates associated with it undergo a change due to displacement.

c) Motion According to constraints on body :-

1. Translatory Motion :- It is of two types.

i) Rectilinear Motion :- If a body moves along a straight line from one point to another point the motion is called rectilinear motion.

E.g → A vehicle travelling a straight road.

ii) Curvilinear Motion :- If the body moves in a curved path, from one point to another, the motion is called curvilinear motion.

E.g → Motion of a basket ball

2. Rotational Motion :-

If a body moves in such a manner that its distance from a fixed axis remains constant, the motion is said to be rotational motion.

E.g → Spinning wheel

3. Vibrational Motion :-

The to and fro motion of a body about a fixed position is called vibrational motion.

D) Motion dependent on time parametre :-

1. Periodic Motion :- Any motion that repeats itself after a definite interval of time is called periodic motion.

E.g → Motion of Planet around sun

2. Aperiodic Motion :- The motion which doesnot repeat itself after a particular interval of time is called aperiodic motion

E.g → Motion of a cricket ball

E) Multiple / Complex motion :- A motion which is combination of two or more types of motion.

E.g → Motion of a ball rolling on ground.

F) Random Motion :- (Zig-zag Motion) :-

Motion in which a moving object frequently changes its direction is called random motion or zigzag motion or irregular motion.

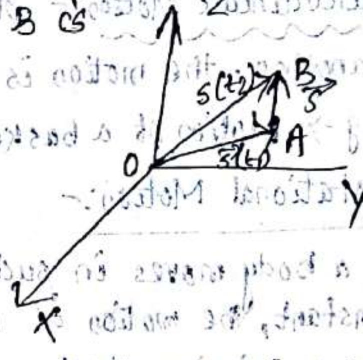
E.g → Motion of gas molecule

Displacement :-

Definition :- Displacement of a body is a vector connecting the initial and final positions of the body and is directed away from initial towards the final position irrespective of path followed by the body.

- Let A and B be the points representing the position of the body at times t_1 and t_2 respectively.

The displacement x as the body moves from A to B is given by $\boxed{\vec{s} = \vec{s}(t_2) - \vec{s}(t_1)}$



- The dimensional formula for displacement is $[M^0 L^1 T^0]$
- The S.I unit is metre

Speed :-

- Definition :- Speed of a body is defined as the distance covered by the body in one second.
- If Δs is the distance covered by a body in time Δt.

$$\boxed{\text{Average speed} = \frac{\Delta s}{\Delta t}}$$

- If the time interval Δt is chosen to be very small i.e $\Delta t \to 0$, then

$$\text{Instantaneous speed} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

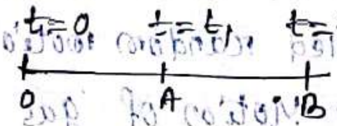
- The dimensional formula for speed is $[M^0 L^1 T^{-1}]$
- Its S.I unit is m/s

Velocity :-

- Definition :- Velocity of a body is defined as the time rate of change of displacement.

Consider a body starting from O at $t=0$ and reaching A at time $t=t_1$ and B at time $t=t_2$ such that its displacement at these instants are $\vec{s_1}$ and $\vec{s_2}$ respectively.

$$\text{Average velocity, } \vec{V} = \frac{\vec{s_2} - \vec{s_1}}{t_2 - t_1} = \frac{\vec{\Delta s}}{\Delta t}$$



If Δt is very small, then

$$\text{Instantaneous velocity } \vec{V} = \lim_{\Delta t \to 0} \frac{\vec{\Delta s}}{\Delta t} = \frac{\vec{ds}}{dt}$$

- The dimensional formula for velocity is $[M^0 L^1 T^{-1}]$
- Its S.I unit is m/s

Acceleration:-

- Definition :- Acceleration is defined as the time rate of change of velocity.
- The average acceleration of a body is

$$\boxed{\vec{a}_{av} = \frac{\vec{v_2} - \vec{v_1}}{t_2 - t_1} = \frac{\vec{\Delta v}}{\Delta t}}$$

where change in velocity is $v_2 - v_1$ in a time interval of $t_2 - t_1$

- The instantaneous acceleration is

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\vec{\Delta v}}{\Delta t} = \frac{\vec{dv}}{dt}$$

- The dimensional formula for acceleration is $[M^0 L^1 T^{-2}]$
- Its S.I unit is m/s^2

Force:-

- Definition :- Force is defined as that pull or push which produces or tends to produce, destroys or tends to destroy motion in a body, increases or decreases the speed of the body or changes its direction of motion.

- $F = ma$
- The dimensional formula for force is $[M^1 L^1 T^{-2}]$
- Its S.I unit is Newton.

Equations of Motion:-

The equations of motion are
1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 - u^2 = 2as$
4. $S_{nth} = u + \frac{a}{2}(2n-1)$

Equations of motion under gravity:- (Downward motion)

For a freely falling body, these equations are (substituting 'a' as 'g')

1. $v = u + gt$
2. $s = ut + \frac{1}{2}gt^2$
3. $v^2 - u^2 = 2gs$
4. $S_{nth} = u + \frac{g}{2}(2n-1)$

For Upward Motion:-

The equations of motion are (Substituting 'a' as '$-g$')

1. $v = u - gt$
2. $s = ut - \frac{1}{2}gt^2$
3. $v^2 - u^2 = -2gs$
4. $s_{nth} = u - \frac{g}{2}(2n-1)$

Circular Motion:-

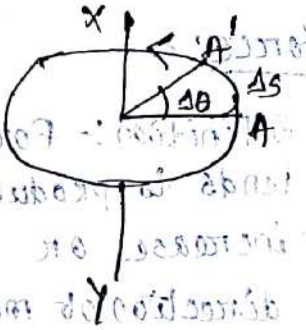
Definition:- The motion of a body is said to be circular if it moves in such a way that its distance from a certain fixed point always remains the same.

Angular Displacement:-

- It is defined as the angle turned by its radius vector.
- $\Delta\theta = \frac{\Delta s}{r}$

$\Rightarrow \boxed{\Delta s = r\Delta\theta}$

$\Rightarrow$ Linear displacement = radius × angular displacement



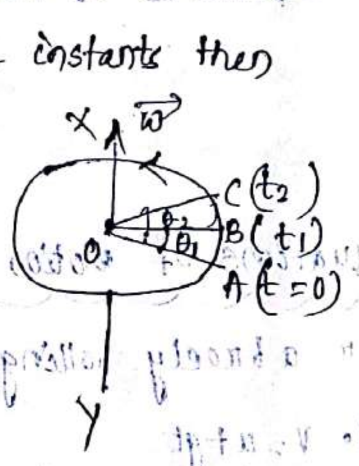
Angular Velocity:-

- It is defined as the rate of change of angular displacement with time.

Let the particle moves from A to B in a time t_1 and to C in a time t_2.

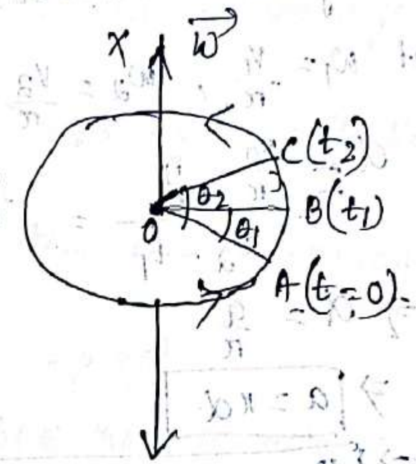
If θ_1 and θ_2 are its angular displacements at these instants then average angular velocity $\vec{\omega}_{av}$ is given by

$$\boxed{\vec{\omega}_{av} = \frac{\vec{\theta}_2 - \vec{\theta}_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t}}$$



- Its S.I unit is s^{-1}.

Relation between Linear velocity and angular velocity:-



Let v be the magnitude of the linear velocity of the body. Since it takes a time t_1 to go from A to B

$\therefore AB = vt_1$ ——— (1)

Also $\theta_1 = \frac{AB}{r}$

$\Rightarrow AB = r\theta_1$ ——— (2)

From equation (1) & (2)

$vt_1 = r\theta_1$

$\Rightarrow v = r\frac{\theta_1}{t_1}$

But $\frac{\theta_1}{t_1} = \omega$

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

So $\boxed{\text{Linear Velocity} = \text{radius} \times \text{angular velocity}}$

Vector form :- $\boxed{\vec{v} = \vec{\omega} \times \vec{r}}$

Angular Acceleration:-

- It is defined as the rate of change of its angular velocity with time.
- If ω_1 and ω_2 are the angular velocities of the Particle at A and B, average angular acceleration $\vec{\alpha}_{av} = \frac{\vec{\omega_2} - \vec{\omega_1}}{t_2 - t_1} = \frac{\vec{\Delta\omega}}{\Delta t}$
- Instantaneous angular acceleration
  $\vec{\alpha} = \lim_{\Delta t \to 0} \frac{\vec{\Delta\omega}}{\Delta t} = \frac{d\vec{\omega}}{dt}$
- Its S.I unit is s^{-2}.

Relation between Linear and Angular Acceleration:-

Scalar form:-

Let ω_1 and ω_2 be the angular velocities of the body at two instants at time t_1 and t_2.

Now angular acceleration $\alpha = \frac{\omega_2 - \omega_1}{t_2 - t_1}$

But $\omega_1 = \frac{v_1}{r}$, $\omega_2 = \frac{v_2}{r}$

So $\alpha = \frac{\frac{v_2}{r} - \frac{v_1}{r}}{t_2 - t_1} = \frac{1}{r}\frac{(v_2 - v_1)}{t_2 - t_1}$

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

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

$\Rightarrow$ **Linear Acceleration = Radius × angular acceleration**

Vector form:-

$\vec{v} = \vec{\omega} \times \vec{r}$

Differentiating both the sides with respect to t

$\frac{d\vec{v}}{dt} = \frac{d}{dt}(\vec{\omega} \times \vec{r})$

$\Rightarrow \vec{a} = \frac{d\vec{v}}{dt} = \frac{d\vec{\omega}}{dt} \times \vec{r} + \vec{\omega} \times \frac{d\vec{r}}{dt}$

But $\frac{d\vec{\omega}}{dt} = \vec{\alpha}$ and $\frac{d\vec{r}}{dt} = v$.

So $\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times v$

Here the linear acceleration $\vec{a}$ is composed of two components.

1. $\vec{a_T} = (\vec{\alpha} \times \vec{r}) \rightarrow$ This is the tangential component
2. $\vec{a_r} = (\vec{\omega} \times \vec{v}) \rightarrow$ This is the radial component

Projectile:-

Definition:- A body projected into the space and is no longer propelled by fuel is called a projectile.

E.g $\rightarrow$

i) A bullet fired by a rifle.

ii) A cricket ball thrown into space.

iii) A bomb or small bag dropped from an aeroplane.

Facts about Projectile:-

1. Every projectile experiences one signal force and that is due to gravity only.
2. Horizontal velocity of a projectile remains the same throughout its flight.
3. No projectile ever experiences any acceleration in the horizontal direction.
4. Vertical acceleration of every projectile is $-g\ m/s^2$.
5. The path of projectile is parabolic except for those projected along vertical direction.
6. The horizontal and vertical motion of a projectile are independent of eachother.

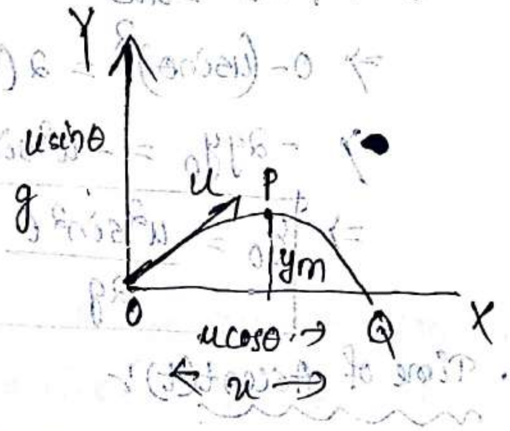
Projectile fired at an angle θ with the horizontal:-

Consider a projectile fired, with velocity u, at an angle θ with the horizontal. The projectile rises to the highest point P and falls back Q lying on the level of projection.

Here u is resolved into two categories

i) $u\cos\theta$ along horizontal:-

This component is uniform, since acceleration due to gravity has no component in this direction.



ii) $u\sin\theta$ along vertical:-

This is non uniform,

1. Equation of trajectory:-

Horizontal equation of motion:-

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

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

Vertical equation of motion: $y = u\sin\theta t - \frac{1}{2}gt^2$ ——— (2)

From equation (1), $t = \frac{x}{u\cos\theta}$

Putting this value in equation (2)

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

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

This is the equation of parabola, symmetric about a line parallel to y-axis

2. Maximum Height (y_0):-

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

Let's consider the motion of the projectile in vertical direction only.

At O, initial vertical velocity = $u\sin\theta$

At P, final vertical velocity = 0

Acceleration = $-g$

Vertical distance travelled = y_0

Applying Kinematic relation

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

$$\Rightarrow 0 - (u\sin\theta)^2 = 2(-g)y_0$$

$$\Rightarrow -2gy_0 = -u^2\sin^2\theta$$

$$\Rightarrow \boxed{y_0 = \frac{u^2\sin^2\theta}{2g}}$$

3. Time of Ascent(t):-

It is the time taken by the projectile to rise to the highest point.

Consider the motion in vertical direction only

At O, initial vertical velocity = $u\sin\theta$

At P, final vertical velocity = 0

Acceleration = $-g$

time = t

Applying Kinematic equation $v = u + at$

$$\Rightarrow 0 = u\sin\theta - gt$$

$$\Rightarrow gt = u\sin\theta$$

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

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4. Total time of flight (T) :-

It is the time taken by the projectile to comeback to the same level from which it was projected.

Since the motion from O to P and P to Q is symmetric with respect to eachother, total time of flight is twice the time taken to reach the highest point.

$\therefore T = 2t$

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

5. Horizontal Range :-

It is the distance travelled by the projectile in the horizontal direction.

x = horizontal velocity $\times$ total time of flight

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

$$= \frac{u^2\, 2\sin\theta\cos\theta}{g}$$

$$\Rightarrow \boxed{x = \frac{u^2 \sin 2\theta}{g}} \qquad (3)$$

Condition for maximum horizontal Range :-

From equation (3) it is clear that horizontal range depends upon the value of velocity u and angle θ. For a fixed u, range can be changed by changing θ.

Range will be maximum if $\sin 2\theta$ is maximum i.e one

$$\sin 2\theta = 1 = \sin 90^\circ$$

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

$$\Rightarrow \boxed{\theta = 45^\circ}$$

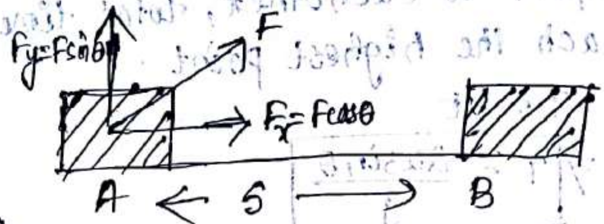
which is the condition for maximum horizontal range.

UNIT-4

UNIT-4 WORK AND FRICTION

WORK:- Work is said to be done if a force acting on a certain body displaces the body through a distances and the force has some component along the displacement.

Workdone by a constant force:-



Consider a body having a force F in a direction inclined at an angle θ with the positive direction of x-axis. Here the body is displaced from A to B which is distance s.

First definition:-

Work done is defined as the dot product of force and displacement.

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

Here $\vec{F} = F_x\hat{i} + F_y\hat{j}$

$\vec{s} = s\hat{i}$

$\Rightarrow W = (F_x\hat{i} + F_y\hat{j})\cdot(s\hat{i})$

$= F_x s(\hat{i}\cdot\hat{i}) + F_y s\cancel{(\hat{j}\cdot\hat{i})}^{0}$

$= F_x s$

$\Rightarrow \boxed{W = F\cos\theta\, s}$ ——— (1)

Second definition:-

Hence work is defined as the product of magnitude of displacement and the component of the force along the displacement.

Equation (1) can also be written as $\boxed{W = Fs\cos\theta}$

Third definition:-

Work is also defined as the product of magnitude of force and the component of the displacement along the direction of force.

Special Case:-

Case-1 (Positive Work)

Here $\theta = 0^0$

$W = Fs\cos\theta$

$= Fs\cos 0^0$

$\boxed{W = FS}$

When the force and displacement are in same direction work done is positive.

E.g → A block placed on the table and being pulled by a string has positive workdone by the applied force.

Case-II (Zero work)

Here $\theta = 90^0$

$W = FS\cos 90^0 = 0$

When the force acts on a direction at right angle to the direction of displacement no work is done.

E.g → A person carrying a box over his head and walking on a horizontal road.

Case-III (Negative work)

Here $\theta = 180^0$

$W = FS\cos 180^0$

$\Rightarrow \boxed{W = -FS}$

When force and displacement are in opposite direction workdone is negative.

E.g → Climbing on a hill, Pulling water from a well.

S.I unit of Work:-

$W = FS$

$= 1N \times 1m$

$= 1$ Joule

Work done is said to be one Joule if a force of 1N displaces a body through a distance of 1m along the direction of forces.

Friction:-

Whenever a body tends to slide over another surface, an opposing force comes into play. this force is known as force of friction.

There are 3 types of friction. (1) Sliding Friction

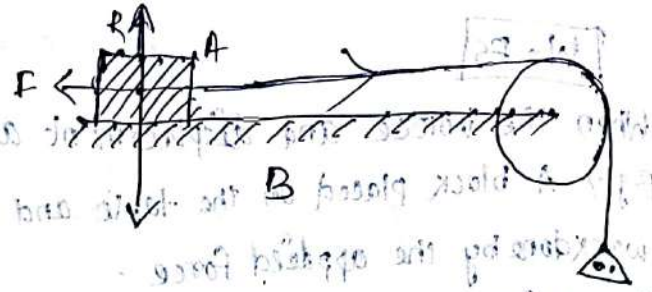
(2) Rolling Friction

(3) Fluid

Sliding Friction:-

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

Consider a body A of mass m placed over a surface. A string tied to the body, passes over a pulley and has a scale pan suspended from its other end.



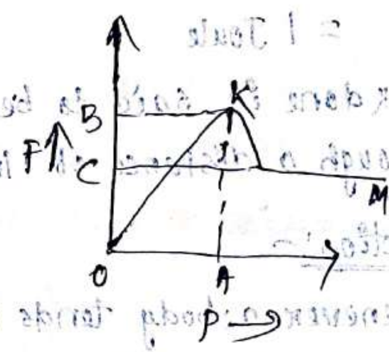
Some weights can be put in the pan as a result of which the string pulls the body A in forward direction. But here force of friction opposes the motion.

Various forces acting on the body are as follows:

1. Weight mg acting vertically downward
2. Normal Reaction R acting vertically upward.
3. Force P due to tension in the string in the forward direction.
4. Force of friction F in backward direction.

- Here mg and normal reaction (R) being vertical donot contribute towards the sliding friction.
- When P increases gradually the body does not slide. This indicate that F increases along with P, automatically keeps itself equal to the applied force. Hence friction is a self adjusting force.
- A graph between P and F will be a straight line OK passing through the origin and inclined to the x-axis at angle of 45^0.

Value of force of friction corresponding to any point on this line is called static friction.



Definition of Static friction:-

Static friction is the force of friction between two surfaces so long as there is no relative motion between them.

Limiting Friction:-

It will be observed that value of static friction increases to certain maximum value OB, beyond. This maximum value of force of friction is called limiting friction.

On increasing P beyond OA, the body starts sliding from OB to OC and then remains constant throughout. Further increasing P will produce an acceleration in the body.

Dynamic Friction:- It is the force of friction which comes to play when there is relative motion between the surfaces.

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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 upon the nature and state of polish of the surfaces in contact and acts tangentially to the interface between the two surfaces.
3. The magnitude of limiting friction F is directly proportional to the magnitude of the normal reaction R between the two surfaces in contact.

   $F \propto R$

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

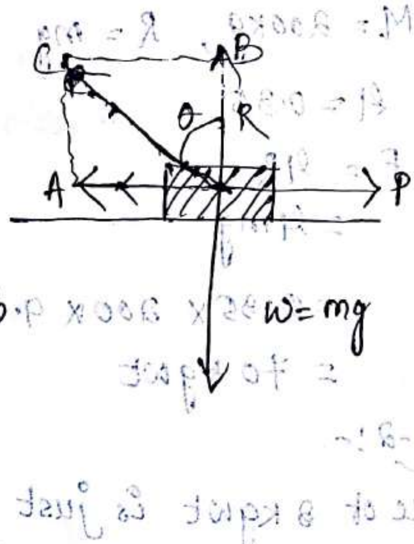
Co-efficient of Friction:-

i) Coefficient of friction of a pair of surfaces in contact is defined as the ratio between the force of limiting friction F to the normal reaction R.

ii) It is denoted by μ.

iii) $\mu = \frac{F}{R}$

Angle of friction:-



Here OC is the resultant of F and R.
Angle of friction is the angle which the resultant of force of limiting friction and normal reaction makes with the normal reaction.

In ΔOBC, $\tan\theta = \frac{BC}{OB}$

$= \frac{F}{R}$

$\Rightarrow \boxed{\tan\theta = \mu}$

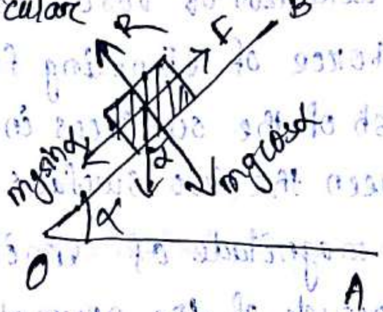
Thus coefficient of friction is the tangent of angle of friction.

Angle of Repose:-

Angle of Repose is the angle which an inclined plane makes with the horizontal so that a body placed over it just begins to slide of its own accord.

Here mg has two component.

$mg\sin\alpha$ along the plane and $mg\cos\alpha$ perpendicular to the plane.



$$mg\sin\alpha = F \quad \text{---(1)}$$

$$mg\cos\alpha = R \quad \text{---(2)}$$

Dividing these two equations

$$\frac{mg\sin\alpha}{mg\cos\alpha} = \frac{F}{R}$$

$$\Rightarrow \tan\alpha = \frac{F}{R}$$

$$\Rightarrow \boxed{\tan\alpha = \mu}$$

We know $\tan\theta = \mu$

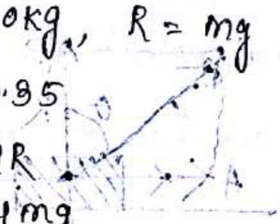
Equating these two $\boxed{\therefore \alpha = \theta}$

Example-1:-

Find the horizontal required to move a body weighing 200 kg on a rough horizontal surface having coefficient of friction 0.35.

A:- $M = 200kg$, $R = mg$

$\mu = 0.35$



$F = \mu R$

$= \mu mg$

$= 0.35 \times 200 \times 9.8\,N$

$= 70\ kg\,wt$

Example-2:-

A force of 3 kgwt is just sufficient to pull a block of 4kg wt over a flat surface. What is the angle of friction?

A:- $F = 3\,kgwt$, $R = 4\,kgwt$

$$\mu = \frac{F}{R} = \frac{3}{4} = 0.75$$

We know $\mu = \tan\theta = 0.75$

$$\Rightarrow \theta = \tan^{-1}(0.75)$$

$$= 36^\circ 52'$$

Example-2 :-

A horizontal force of 1·2 kgf is applied to a 1·5 kg block which rests on a horizontal surface. If the coefficient of friction is 0·3. Find the acceleration produced in the block. ($g = 9.8\ m/s^2$)

Solution :- $R = 1.5$ kgf, $\mu = 0.3$

$$F = \mu R$$
$$= 1.5 \times 0.3$$
$$= 0.45$$

$$\text{Net force} = 1.2 - 0.45$$
$$= 0.75 \text{ kgf}$$
$$= 0.75 \times 9.8\,N$$

Resultant force = mass × acceleration

$$\text{Acceleration} = \frac{\text{Resultant Force}}{\text{mass}}$$

$$= \frac{0.75 \times 9.8}{1.5} = 4.9\ m/s^2$$

Methods of Reducing Friction :-

1. By rubbing and polishing
2. By lubricants
3. By converting sliding into rolling friction.
4. By streamlining.

UNIT-5

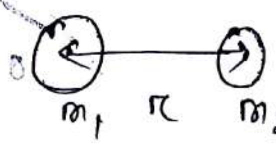
UNIT-5 GRAVITATION

Newton's laws 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 particles and inversly as the square of distance between them.

Explanation:- Consider two bodies of masses m_1 and m_2 and they are separated by a distance r. Let F be magnitude of force of attraction.



Then according to law of gravitation

i) $F \propto m_1 m_2$

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

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

$$\Rightarrow \boxed{F = \frac{G m_1 m_2}{r^2}} \quad \text{---(1)}$$

Where G is known as universal gravitational constant.

Universal Gravitational Constant (G):-

Let $m_1 = m_2 = 1$ unit, $r = 1$ unit

From equation (1) we get

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

$$\Rightarrow F = G$$

Thus universal gravitational constant may be defined as the magnitude of force of attraction between two bodies each of unit mass and separated by a unit distance from eachother.

Unit of G:-

1. **CGS System:-** The unit of G will be dyne $cm^2 gm^{-2}$

The value of G in CGS is 6.67×10^{-8} dyne $cm^2 gm^{-2}$

2. S.I system:-

The unit of G will be $N m^2 kg^{-2}$.

The value of G in S.I is $6.67 \times 10^{-11}\ N m^2 kg^{-2}$

Dimension of G:-

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

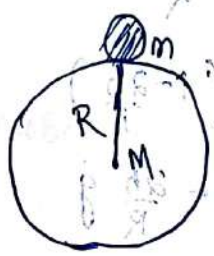
$$= \frac{[M^1 L^1 T^{-2}] \times [L^2]}{[M^2]}$$

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

Acceleration due to gravity:-

- Force between earth and a body near it is called gravity.
- The acceleration produced by gravity is called acceleration due to gravity.
- It is denoted by g.
- Gravity $F = mg$

Relation between g and G:-



Consider a body of mass m which is placed on the surface of earth of mass M and radius R.

According to Newton's law of gravitation

$$F = \frac{GMm}{R^2} \quad \text{——— (1)}$$

We know gravity $F = mg$ ——— (2)

From equation (1) & (2)

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

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

The unit of g is m/s^2 in S.I and cm/s^2 in C.G.S.

Mass	Weight
1. It is the actual amount of material contained in a body.	1. It is the force exerted by the gravity on that object.
2. It is denoted by m.	2. It is denoted by w
3. It is independent.	3. It is dependent.
4. Mass is constant at any place and time.	4. The weight of an object depends on the gravity at that place.
5. It is a scalar quantity.	5. It is a vector quantity.
6. Measured in Kilograms.	6. Measured in Newton.

Variation of g with Altitude:-

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

Suppose the body is taken to a height h, here the value of acceleration due to gravity is g'.

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

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

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

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

$(g - g')$ gives the change in the value of g. Since the value of g at at a given place of earth is constant and R is also constant. So $g - g' \propto h$.

It is clear from above that if h increases g' must decrease because g is constant.

∴ The value of acceleration due to gravity decreases with increase in height above the surface of earth.

Variation of g with depth:-

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

If the body is taken to depth

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

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

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

Since g is constant at a given place on the earth and R is also constant, so $g - g' \propto d$

It is clear from above that if d increases g' must decrease because g is constant.

$\therefore$ The value of acceleration due to gravity decreases as the depth increases.

Weight of a body at the centre of earth:-

At a depth d below the free surface of earth $g' = g\left(1 - \frac{d}{R}\right)$

At the centre of earth, $d = R$

$\therefore g' = g\left(1 - \frac{R}{R}\right) = 0$

If m is the mass of a body placed at the centre of earth, then weight $mg' = 0$

Hence the weight of body at the centre of earth is equal to zero.

Kepler's Laws of Planetary Motion:-

1. Kepler's First Law:- (Law of elliptical Orbit):-

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

2. Kepler's Second Law:- (Law of areal velocities)

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

3. Kepler's Third Law:- (Law of Time Period)

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

$$\boxed{T^2 \propto R^3}$$

UNIT-6

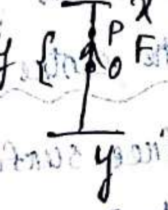
UNIT-6 OSCILLATION AND WAVES

Simple Harmonic Motion:-

Let a particle be displaced a distance y from the mean position O. A restoring force F tends to bring the particle back to 'O' due to property of elasticity. Here the force F is directly proportional to y and opposes the increase of y.

$F \propto y$

$\Rightarrow F = -Ky$



Definition:-

Simple Harmonic Motion is the motion in which the restoring force is proportional to displacement from the mean position opposes its increase.

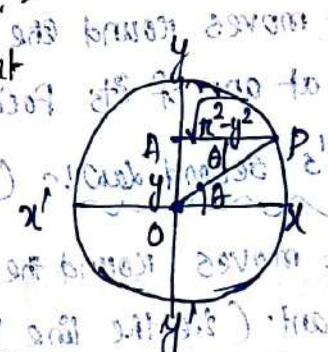
E.g. → 1. Vibrations of a simple pendulum

2. Vibrations of a stretched string

3. Vertical vibrations of a loaded spring

Characteristics of Simple Harmonic Motion:-

i. Displacement or amplitude:- Displacement of a particle vibrating in SHM, at any instant is defined as its distance from the mean position at that instant.



Here P is the projection of A.

In ΔOAP, $\sin\theta = \frac{OA}{OP}$

$\Rightarrow \sin\theta = \frac{y}{r}$

$\Rightarrow y = r\sin\theta$

$\Rightarrow \boxed{y = r\sin\omega t}$ ——— (1)

It is clear from equation (1) that y changes with time. y is maximum when $\sin\omega t$ is maximum. Since extreme values of $\sin\omega t = \pm 1$

$\Rightarrow \boxed{y = \pm r}$ where r is called amplitude of vibration.

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Amplitude:- Amplitude of a particle vibrating in SHM is defined as its maximum displacement on either side of the mean position.

Velocity:-

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

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

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

$$= r\omega\cos\omega t$$

$$= v\cos\omega t$$

In $\triangle OAP$, $\cos\omega t = \frac{AP}{OA} = \frac{\sqrt{r^2-y^2}}{r}$

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

Since $v = r\omega$

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

At Point O, $y = 0$

Now $V = \omega\sqrt{r^2} = \pm\omega r$

At Y or Y', $y = r$

$$\Rightarrow V = 0$$

A particle vibrating in S.H.M passes with maximum velocity through the mean position and is at rest at the extreme positions.

Acceleration:-

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

$$= \frac{d}{dt}(v\cos\omega t)$$

$$= v\frac{d}{dt}(\cos\omega t)$$

$$= v(-\sin\omega t)\frac{d}{dt}(\omega t)$$

$$= -v\omega\sin\omega t$$

$$= -v\frac{v}{r}\sin\omega t$$

$$= -\frac{v^2}{r}\sin\omega t$$

In triangle OAP, $\sin\omega t = \frac{OP}{OA}$

$= \frac{y}{r}$

$$\therefore a = -\frac{v^2}{r}\cdot\frac{y}{r}$$

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

$$= -\omega^2 y$$

At O, $y = 0$

$\Rightarrow a = 0$

At y or y' Position, $y = \pm r$

$\Rightarrow a = \pm\omega^2 r$

A particle vibrating in S.H.M has zero acceleration while passing through mean position and has maximum acceleration while at extreme positions.

Wave Motion :-

Wave Motion is the disturbance that travels through the medium and is due to repeated periodic motion of the particles of the medium, the motion is being handed over from particle to particle.

Transverse Wave Motion :-

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

E.g → A stone thrown in a pond of water produces transverse waves.

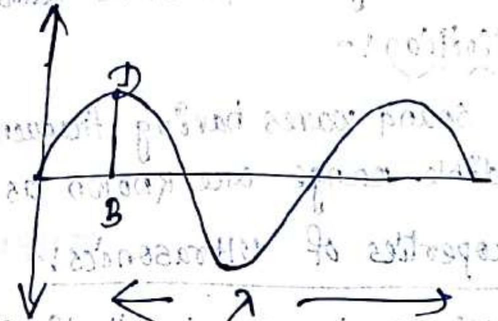
Longitudinal Wave Motion :-

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

E.g → Vibration of tuning fork.

Transverse Waves	Longitudinal Waves
1. Vibrations of the particle of medium are normal to the direction of wave propagation.	1. Vibrations of the particles are parallel to the direction of wave propagation.
2. Crests and troughs are formed during its propagation.	2. Compressions and rarefactions are formed during its propagation.
3. Causes temporary change in shape of the medium.	3. Causes temporary change in size of the medium.
4. It travels through solids and shallow pool of liquid but not through gases.	4. It travels through solid, liquid and gas.
5. Velocity of transverse wave is given by, $V = \sqrt{T/m}$	5. Velocity of longitudinal wave, $V = \sqrt{E/\rho}$

Different Wave Parameters:-



Amplitude:-

The maximum displacement of the particle on eitherside of the mean position is called amplitude.
Here distance BD is called amplitude.

Time Period (T):-

It is the time required to complete one vibration.

Frequency (n):-

It is the number of vibrations performed by the particle in one second.

Wavelength (λ):-

The distance travelled by the wave in one time Period such that in t sec. is called wavelength.

OR Wavelength is the distance between two consecutive crests or troughs.

Relation between Velocity, Frequency and Wavelength:-

We know that velocity is equal to the distance travelled in one second.

Velocity $(V) = \text{Distance}/\text{Time}$.

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We know the velocity is equal to the distance travelled in one second.

Velocity (V) = $\frac{\text{Distance}}{\text{Time}}$

We know wavelength is also the distance travelled in t seconds.

$\therefore$ Velocity = $\frac{\text{Wavelength}}{\text{Time}}$

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

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

$\Rightarrow V = n\lambda$

$\boxed{\text{Velocity} = \text{frequency} \times \text{Wavelength}}$

Ultrasonics :-

- The human ear can hear the sound waves between 20Hz to 20KHz.
- This range is known as audible range.

Definition :-

The sound waves having frequency greater than the upper limit of audible range are known as ultrasonics waves.

Properties of Ultrasonics :-

1. Ultrasonics are longitudinal in nature.
2. These are waves of very high frequency having a range of 2×10^4 to 10^9 Hz.
3. Propagation of ultrasonics through a medium results in the formation of compression and rarefaction.
4. They travel with the speed of sound.
5. Since the energy of sound waves is proportional to the square of their frequency, ultrasonics are highly energetic waves.
6. They show negligible diffraction due to their small wavelength.
7. Ultrasonics can constitute narrow beam.
8. Passage of ultrasonics through a liquid results in a variation of density.

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Applications of Ultrasonics :-

1. Echo Sounding
2. Thickness gauging
3. Flaw detection
4. Fuel gauging
5. Determination of elastic constants
6. Ultrasonic Welding
7. Ultrasonic cleanings
8. Producing stable Emulsions
9. Coagulation
10. Study of microstructure
11. Drilling holes
12. In metallurgical Industry
13. Chemical Effects
14. Diagnostic use
15. Ultrasonic therapy
16. Measurement of velocity of sound in liquids.

UNIT-7

UNIT-7 Heat & Thermodynamics

Heat:-

- Heat is the energy that is transferred from one object to another object because of temperature difference.
- Heat is an agent which produces the sensation of warmth.

Temperature:-

- The temperature of a body is its degree of hotness or coldness.
- It is also defined as the thermal state of a body which determines the direction of flow when bodies are placed in contact.

Comparision between Heat and Temperature:-

Heat	Temperature
1. Heat is the energy that is transferred from one object to another object because of temperature diference.	1. The temperature of a body is its degree of hotness or coldness.
2. Heat is an energy.	2. Temperature is not an energy.
3. It measures both kinetic and Potential energy contained by molecules in an object.	3. It measures averages kinetic energy of molecules in a substance.
4. The symbol of Heat is Q.	4. The symbol of temp. is T.
5. The S.I unit of heat is Joule.	5. The S.I unit of temp is Kelvin

Unit of Heat:-

SI unit - Joule

MKS unit - Joule

CGS unit - Erg

FPS unit - BTU (British Thermal unit)

Specific Heat:-

- To increase the temperature of an agent we must increase the thermal energy of its molecules.
- The amount of heat Q required to change the temperature of substance is directly proportional to the mass m of the substance and

to the temperature change ΔT.

$Q \propto m$

$\propto \Delta T$

$\Rightarrow Q \propto m\Delta T$

$\Rightarrow Q = Cm\Delta T$

where C = Specific heat Capacity

$\Rightarrow C = \frac{Q}{m\Delta T}$

If $m = 1$, $\Delta T = 1^0C$

then $C = Q$

Definition of Specific Heat:-

Specific heat capacity of a matter is different as the amount of heat required to raise the temperature of a unit mass of substance through 1^0C.

S.I unit $C = \frac{Q}{m\Delta T}$

$= \frac{Joule}{Kg^1 K^1}$

$= Joule\ Kg^{-1} K^{-1}$

Dimension of $C = \frac{Q}{m\Delta T}$

$= \frac{[M^1 L^2 T^{-2}]}{[M^1] \cdot [K^1]}$

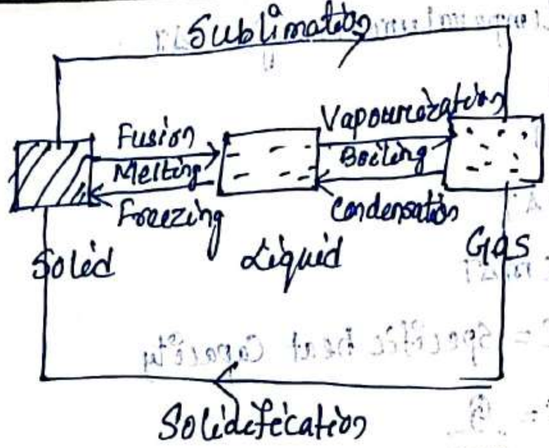
$= [M^0 L^2 T^{-2} K^{-1}]$

Common Material of Specific Heat:-

Material	Specific Heat (Joule/gram°c)
Water	4.18
Ice	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38

Change of state:-

- The three states of matter can be converted into one another.



Fusion:-

- The process in which a solid changes to a liquid is called fusion.
- The temperature at which a solid changes to a liquid is called melting point
- The melting point of ice is 0^0c

Freezing:-

- Conversion of liquid into solid is known as freezing.
- The temperature at which a liquid changes to a solid is known as freezing point.
- The freezing point of water is 0^0c.

Vapourization:-

- The process in which a liquid boils and changes to a gas is called vapourization.
- The temperature at which liquid boils is its boiling point
- The boiling point of water is 100^0c.

Condensation:-

The process in which gas changes to liquid is known as condensation.

Sublimation:-

The process in which solid directly changes into gas is known as sublimation.

Solidification:-

The process in which gas directly changes into solid is known as solidification.

Latent Heat:-

- Whenever heat is supplied to a solid its temperature rises. Process of conversion of solid into liquid is called fusion.

- Temperature of substance remains constant till whole of the solid has been converted into liquid because the heat supplied during fusion goes to increase the potential energy of the substance rather than the Kinetic energy.
- Hence the heat is hidden in the substance. This amount of heat is called Latent Heat.
- Dimensional formula of latent heat is $[M^0L^2T^{-2}]$
- S.I unit of Latent heat is Kcal/Joule.

Latent heat of fusion :- (L_f) :-

- It is defined as the amount of heat required to convert 1gm of substance from solid to liquid state at the melting point without any change of temperature.
- The specific latent heat of fusion for ice is 80 Kcal/kg

Latent heat of vapourization (L_v) :-

- It is defined as the amount of heat required to convert 1 gm of liquid into vapours at its boiling point without rise of temperature.
- The specific latent heat of vapourization for steam is 540 Kcal/kg.

Q: Study of Conversion of a block of ice of mass 1kg at temperature -50^0c to steam:-

A:- i) Ice at -50^0c to Ice at 0^0c (Heat absorbed):-

$Q_1 = mc\theta$

$= 1 \times 0.5 \times 50$

$= 25$ Kcal

ii) Ice at 0^0c to Water at 0^0c (fusion takes place)

$Q_2 = m \times L_f$

$= 1kg \times 80 Kcal/kg$

$= 80$ Kcal

iii) Water at $0^\circ C$ to Water at $100^\circ C$ (Heat absorbed)

$Q_3 = mc\theta$

$= 1 \times 1 \times (100-0)$

$= 1 \times 1 \times 100$

$= 100$ Kcal

iv) Water at $100^\circ C$ to steam (Vapourization takes place)

$Q_4 = mL_v$

$= 1 \times 540$

$= 540$ Kcal

Total heat required $= Q_1 + Q_2 + Q_3 + Q_4$

$= 25 + 80 + 100 + 540$

$= 745$ Kcal

2. Calculate the latent heat for 10 gm of Ice. (L_f of Ice $= 80$ cal/gm)

Ans:- $m = 10$ gm, $L_f = 80$ cal/gm

$H = mL_f$

$= 10 \text{ gm} \times 80 \text{ cal/gm}$

$= 800$ Cal

3. What mass of ether at $0^\circ C$ must be evaporated in order to freeze 0.005 Kg of water at $0^\circ C$? (The specific latent heat of ether is 95 Kcal/Kg)

A:- Let m be the mass of ether evaporated.

Heat absorbed by ether $= mL_f$

$= m \times 95$ Kcal

Heat required to be taken out from water $= mL_f$

$= 0.005 \times 80$

$= 0.4$ Kcal

Heat absorbed by ether = Heat required to be taken out of water

$\Rightarrow m \times 95 = 0.4$

$\Rightarrow m = 0.4/95 = 0.00421$ Kg

4. Calculate the quantity of heat required to raise the temp. of 10 gm of Ice at $-10°c$ to water at $60°c$.

Ans:- i) Ice at $-10°c$ to Ice at $0°c$:- (Heat absorbed)

$$Q_1 = mc\theta$$
$$= 10 \times 0.5 \times 0-(-10)$$
$$= 50 \text{ cal}$$

ii) Ice at $0°c$ to water at $0°c$ (Fusion takes place)

$$Q_2 = m \times L_f$$
$$= 10 \times 80$$
$$= 800 \text{ cal}$$

iii) Water at $0°c$ to water at $60°c$ (Heat absorbed):-

$$Q_3 = mc\theta$$
$$= 10 \times 1 \times (60-0)$$
$$= 10 \times 1 \times 60$$
$$= 600 \text{ cal}$$

Total heat required $= Q_1 + Q_2 + Q_3$
$$= 50 + 800 + 600$$
$$= 1450 \text{ cal}$$

5. Howmuch steam at $100°c$ required to melt 3.2 kg of ice at $-10°c$?

Ans:- Heat gained by Ice = Heat gained by ice from $-10°c$ to $0°c$ + Heat gained during fusion

$$= mc\theta + mL_f$$
$$= 3.2 \times 0.5 \times 0-(-10) + 3.2 \times 80$$
$$= \cancel{3.20 kg} = 27.2 \text{ Kcal}$$

Let the mass of the steam be m.

Heat lost by steam = Heat lost by condensed water + Heat lost during vapourization

$$= mc\theta + mL_f$$
$$= m \times 1 \times (100-0) + m \times 540$$
$$= 100 + 540m$$

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Heat gained = Heat Lost

$\Rightarrow 272\ Kcal = 640m$

$\Rightarrow m = \frac{272}{640}$

$= 0.425\ Kg$

Thermal Expansion:-

When an object is heated wheather it be a solid, liquid or gas, it expands.

E.g → 1. In Railway track a gap is left in between consecutive pieces of rails. In summer the rails expand. If this gap is not there the rails may bend thereby causing derailment of trains.

2. Concrete floors are laid in the form of small sections having a gap in between them.

Co-efficient of Expansion:-

When a body is heated, it expands in all dimensions such that along its length, breadth and thickness simultaneously

i) Expansion along one dimension (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.

Let l_0 be the length of the rod at $0°c$. On heating, the rod expands. Let l_t be the length of rod at $t°c$, so that $l_t - l_0$ the length is the increase in the length of the rod due to $t°c$ rise of temperature.

$l_t - l_0$ for any rod depends upon two factors

i) Upon original length l_0 of the rod

$$l_t - l_0 \propto l_0$$

ii) Upon rise of temperature t

$$l_t - l_0 \propto t°c$$

$$\Rightarrow l_t - l_0 \propto l_0 t$$

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$\Rightarrow l_t - l_0 = \alpha l_0 t$ ——— (1)

Where α = Coefficient of linear expansion :

$\Rightarrow l_t = l_0 + \alpha l_0 t$

$\Rightarrow \boxed{l_t = l_0(1+\alpha t)}$ ——— (2)

From equation 1.

$\alpha = \frac{l_t - l_0}{l_0 t}$

If $l_0 = 1$, $t = 1^0 c$ then $\alpha = l_t - l_0$

Therefore coefficient of linear expansion of the material of a rod is defined as the change in length per unit length, at $0^0 c$ per degree centigrade rise of temperature.

ii) Expansion in two dimension (Superficial Expansion) :-

A surface area having some length and breadth but having negligible can be considered as two dimensional.

Consider a thin sheet having area S_0 at $0^0 c$ and S_t at $t^0 c$.

Increase in area due to $t^0 c$ rise of temperature = $S_t - S_0$

$S_t - S_0$ depends upon

i) Original area S_0 at $0^0 c$

$S_t - S_0 \propto S_0$

ii) Rise of temperature $t^0 c$

$S_t - S_0 \propto t^0 c$

$\Rightarrow S_t - S_0 \propto S_0 t$

$\Rightarrow S_t - S_0 = \beta S_0 t$ ——— (3)

Where β = Coefficient of superficial expansion

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

$\Rightarrow S_t = S_0(1+\beta t)$ ——— (4)

From equation (3) $\beta = \frac{S_t - S_0}{S_0 t}$

If $S_0 = 1$, $t = 1^0C$ then $\beta = S_t - S_0$

Hence coefficient of superficial expansion is defined as change in area of the surface per unit area at 0^0C per degree centigrade rise of temperature.

iii) Expansion in three dimension (Cubical Expansion)

A body having length, breadth and thickness is said to be three dimensional.

Let V_0 be the volume of cube at 0^0C and V_t at t^0C. Now change in volume equal to $V_t - V_0$

$V_t - V_0$ depends upon

i) $V_t - V_0 \propto V_0$ (Original volume)

ii) $V_t - V_0 \propto t^0$

$\Rightarrow V_t - V_0 \propto V_0 t$

$\Rightarrow V_t - V_0 = \gamma V_0 t$ —— (5)

Where γ = Coefficient of cubical expansion.

$\Rightarrow V_t = V_0 + \gamma V_0 t$

$\Rightarrow V_t = V_0 (1 + \gamma t)$ —— (6)

From equation (5)

$$\gamma = \frac{V_t - V_0}{V_0 t}$$

If $V_0 = 1$, $t = 1^0C$ then $\gamma = V_t - V_0$

Coefficient of cubical expansion is defined as the change in volume per unit volume at 0^0C per degree centigrade rise of temperature.

Relation between α, β and γ:-

i) Relation between α and β:-

Consider a square sheet having each side l_0 at 0^0C

Area S_0 at 0^0C, $S_0 = l_0^2$

On heating the sheet to t^0c, each side expands to l_t :

Now $S_t = l_t^2$

$\Rightarrow S_t = [l_0(1+\alpha t)]^2$

$\Rightarrow S_t = l_0^2 (1+\alpha t)^2$

We know $\beta = \dfrac{S_t - S_0}{S_0 t}$

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

$= \dfrac{\cancel{l_0^2}[(1+\alpha t)^2 - 1]}{\cancel{l_0^2} t}$

$\Rightarrow \beta = \dfrac{\cancel{1} + \alpha^2 t^2 + 2\cdot 1\cdot \alpha t - \cancel{1}}{t}$

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

Since the value of α is very very small, neglecting higher order terms

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

ii) Relation between α and γ:-

Let V_0 and V_t be the volumes of a cube at 0^0c and t^0c.

l_0 and l_t are the sides of cube at 0^0c and t^0c.

$V_0 = l_0^3$

Now $V_t = l_t^3$

$\Rightarrow V_t = [l_0(1+\alpha t)]^3$

$\Rightarrow V_t = l_0^3(1+\alpha t)^3$

We know $\gamma = \dfrac{V_t - V_0}{V_0 t}$

$= \dfrac{l_0^3(1+\alpha t)^3 - l_0^3}{l_0^3 t}$

$= \dfrac{\cancel{l_0^3}[(1+\alpha t)^3 - 1]}{\cancel{l_0^3} t}$

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

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

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

Since the value of α is very very small neglecting higher order terms

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

$$\therefore \boxed{\alpha : \beta : \gamma = 1:2:3}$$

Joule's Mechanical Equivalent of heat:-

Heat is a form of mechanical energy. Work is also a form of mechanical energy. Heat and work should be interconvertible.

According to Dr. Joule "whenever heat is converted into work or work into heat, the quantity of energy disappearing in one form is equivalent to the quantity of energy appearing the other."

$W \propto H$

$\Rightarrow W = JH$

Where J = Joule's mechanical equivalent of heat

$\Rightarrow J = \frac{W}{H}$

If $H = 1$ unit then $J = W$

Joule's mechanical equivalent of heat is defined as the amount of work required to produce a unit quantity of heat.

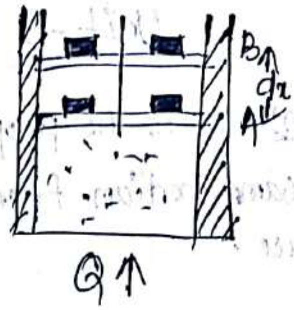
Value of $J = 4.2 \ J cal^{-1}$

$= 4.2 \times 10^7 \ erg \ cal^{-1}$

First Law of Thermodynamics:-

Consider some gas enclosed in a barrel having insulating walls and conducting bottom. Let an amount of heat Q be added to the system through the bottom.

Here U_1 is the initial energy of the system.



Total energy of the system in the beginning $= U_1 + Q$

After gaining heat the gas tends to expand pushing the piston from A to B. As a result of this some work W is done by the gas.

If U_2 is final internal energy of the system then

Total energy of the system at the end $= U_2 + W$

According to the law of conservation of energy

$$U_1 + Q = U_2 + W$$

$$\Rightarrow \boxed{Q = (U_2 - U_1) + W}$$

When small amount of heat dQ is added to the system, corresponding changes in internal energy is du and external work done is dw;

$$\boxed{dQ = du + dw}$$

Statement :-

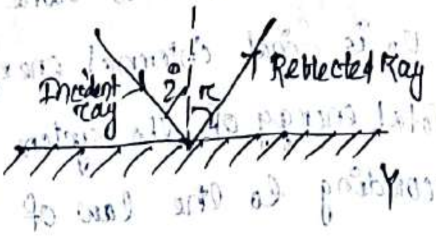
First law of Thermodynamics states that

" If the quantity of heat supplied to a system is capable of doing some work, then the quantity of heat absorbed by the system is equal to the sum of the increase in the internal energy of the system and the external workdone by it."

UNIT-8

Unit-8 Optics

Reflection:- It is the property of light by virtue of which light is sent back into the same medium from which it is coming after being obstructed by a surface.



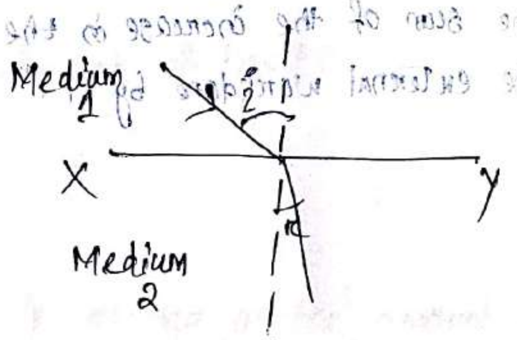
Laws of Reflection:-

1st Law:- The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in one plane and that plane is perpendicular to the reflecting surface.

2nd Law:- The angle of incidence is equal to the angle of reflection i.e
$\angle i = \angle r$

Refraction:-

- It is the phenomenon by virtue of which a ray of light going from one medium to the other undergoes a change in velocity.
- If light travels from rarer to denser medium, it bends towards the normal. If it travels from denser to rarer medium, it bends away from the normal.



Laws of Refraction:-

1st Law:- The ratio between sine of angle of incidence and sine of angle of refraction is constant.

$$\frac{\sin i}{\sin r} = \text{constant}$$

This is known as Snell's law.

2nd Law:- The incident ray, the refracted ray and the normal at the point of incidence all lie in one plane and that plane is perpendicular to the reflecting surface.

Refractive Index :-

Definition-1 :- Let xy be the interface of medium separating two media 1 & 2 from eachother. Let i and r be the angle of incidence and refraction respectively

According to Snell's law $\dfrac{\sin i}{\sin r} = \text{constant} = {}^{1}\mu_{2}$

Where ${}^{1}\mu_{2}$ is called the refractive index of second medium with respect to first.

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

Definition-2 :-

- It is also defined as the ratio between velocity of light in medium 1 to the velocity of light in medium 2.

$$\boxed{{}^{1}\mu_{2} = \frac{v_1}{v_2}}$$

- If the first medium is air or vacuum the refractive index is written as ${}^{0}\mu_{2}$ or simply as μ and is known as absolute refractive index.

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

Definition-3 :-

We know that $v = n\lambda$

If $v_1 = n\lambda_1$, $v_2 = n\lambda_2$

then ${}^{1}\mu_{2} = \dfrac{n\lambda_1}{n\lambda_2}$

$$\Rightarrow \boxed{{}^{1}\mu_{2} = \frac{\lambda_1}{\lambda_2}}$$

It is defined as the ratio between wavelength of light in medium 1 to the wavelength of light in medium 2.

Definition-4:- $^1\mu_2 = \frac{\mu_2}{\mu_1}$

Numericals:-

A ray of light travelling in water is incident at an angle of 30^0 on a water glass interface. Calculate the angle of refraction in glass, if refractive index of water is 4/3 and that of glass is 3/2.

Ans:- Let XY be the interface.

$$\frac{\sin i}{\sin r} = {}^w\mu_g$$

But $^w\mu_g = \frac{\mu_g}{\mu_w}$ $\left[\because {}^1\mu_2 = \frac{\mu_2}{\mu_1}\right]$

$$= \frac{3/2}{4/3} = 9/8$$

Since $i = 30^0$

$$\frac{\sin 30^0}{\sin r} = \frac{9}{8}$$

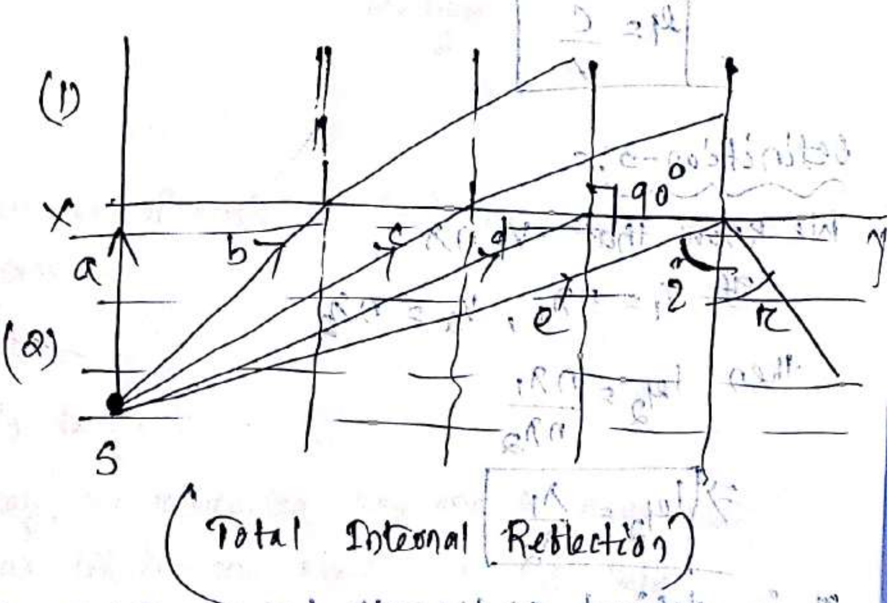
$\Rightarrow \sin r \times \frac{9}{8} = \sin 30^0$

$\Rightarrow \sin r = \frac{8}{9} \times \frac{1}{2} = \frac{4}{9} = 0.4444$

$\Rightarrow r = 26.4^0$

Critical Angle & Total Internal Reflection:-

Consider a source of light S situated in a denser medium (water). Rays starting from S travel from water to air. (from denser to rarer medium). A ray 'a' incident normally on the interface XY goes undeviated.



(Total Internal Reflection)

Ray 'b' and 'c' are incident on the interface at gradually increasing angles 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 refracted ray is parallel to the surface i.e. $r = 90^0$. The angle of incidence C is called the critical angle.

Definition of 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 90^0.

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

Definition of Total Internal Reflection :- (TIR)

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

Consider refraction of ray d. Since the ray goes from medium 2 to medium 1.

$$ {}_2\mu_1 = \frac{\sin c}{\sin 90^0} = \frac{\sin c}{1} = \sin c $$

$$ {}_1\mu_2 = \frac{1}{{}_2\mu_1} = \frac{1}{\sin c} $$

Incase, the first medium is air, so ${}_1\mu_2 = \mu$

$$ \boxed{\mu = \frac{1}{\sin c}} $$

Thus absolute refractive index of medium is equal to the reciprocal of the sine of the critical angle for that medium.

E.g → Brilliance of diamonds, Mirage, a coin floating in air, fire fountain experiment.

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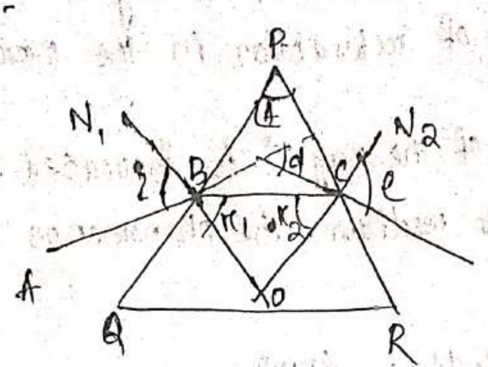
Refraction Through a Prism:-

The refraction through a prism is taking place in two different ways.
1. Deviation
2. Dispersion

Deviation:-

- When a ray of monochromatic light is incident on a prism after final refraction it deviates towards the base of prism. Such a process is known as deviation.

Ray Diagram:-



Formula :- $$\boxed{{}^1\mu_2 = \frac{\sin\frac{A+d_m}{2}}{\sin\frac{A}{2}}}$$

where $\angle A$ = Angle of Prism

d_m = Angle of minimum deviation

Minimum deviation condition:-

It is the position of a prism in which its angle of deviation is minimum.

Under this Position $\boxed{d = d_m,\ \angle i = \angle e,\ r_1 = r_2}$

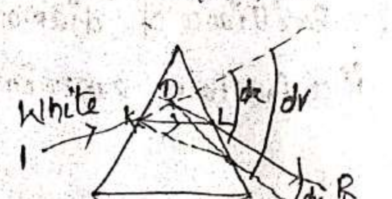
Dispersion:-

When a ray of light passes through a prism, it splits into a number of rays. That means splitting up into a number of rays. That means splitting up of white light into seven constituent colours is known as dispersion.

$$d_v - d_r = (\mu_v - \mu_r)A$$

$$\Rightarrow \frac{d_v - d_r}{d} = \frac{\mu_v - \mu_r}{\mu - 1} = \omega$$

where ω = dispersive power of Prism



Fibre Optics:-

Definition:- A technology that uses glass (or Plastic) threads to transmit data. A fibre optic cable consists of a bundle of glass threads each of which is capable of transmitting messages modulated onto light waves.

Properties:-

- Fibre optic cables have a much greater bandwidth than metal cables. This means that they can carry more data.
- They are less susceptible.
- They are much thinner and lighter than metal wires.
- Data is communicated at higher speed.
- No risk of short circuits or electrical spark.
- Tempering of data not easy.
- More resistive to corrosive atmosphere.
- Installation and maintenance over long distances less costly.
- Greater operational life.
- Data transmission rate is 1Gbits^{-1}.

Applications:-

- It is particularly popular technology for Local Area Networks.
- Telephone companies are steadily replacing traditional telephone lines with fibre optic cables.
- It is used in high speed communications such as cable TV and high speed broadband services.

UNIT-9

Unit-9 Electrostatics & Magnetostatics

Electrostatics :-

- It is a branch of Physics that deals with electric charges are rest.
- Since classical Physics, it has been known that some materials such as amber attract light weight particles after rubbing. The Greek word for amber or electron was the source of word electricity.
- Electrostatic phenomena arise from the forces that electric charges exert on eachother.
- Electrostatics involves the buildup of charge on the surface of objects due to contact with other surfaces.
- Although charge exchange happens whenever any two surfaces contact and separate, the effects of charge exchange are usually only noticed when atleast one of the surfaces has a high resistance to electric flow.

E.g → Attraction of plastic wrap to one's hand after it is removed from a package.

Coulomb's law in Electrostatics :-

Statement:-

It states that the electrostatic force of attraction or repulsion between two charged bodies is directly proportional to the product of their charges and varies inversly as the square of the distance between two bodies.

Explanation:-

Suppose two point charges q_1 and q_2 are situated at a distance r from eachother.

Now $F \propto q_1 q_2$

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

$\Rightarrow F \propto \frac{q_1 q_2}{r^2}$

$$\Rightarrow \boxed{F = \beta \frac{q_1 q_2}{r^2}} \qquad (1)$$

Where β is proportionality constant.

In C.G.S System :- $\beta = \frac{1}{K}$

where K = dielectric constant of the medium

Putting this in equation(1)

$$\boxed{F = \frac{1}{K}\frac{q_1 q_2}{r^2}} \quad \text{(For any medium)}$$

In free space, K = 1

$$\text{So } \boxed{F = \frac{q_1 q_2}{r^2}} \quad \text{(for free space)}$$

In S.I System :-

$$\beta = \frac{1}{4\pi\epsilon} = \frac{1}{4\pi\epsilon_0\epsilon_r}$$

where ϵ_0 and ϵ_r are the absolute permittivity and relative permittivity respectively.

$$\text{So } \boxed{F = \frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1 q_2}{r^2}} \quad \text{(For any medium)}$$

For free space $\epsilon_r = 1$

$$\text{So } \boxed{F = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r^2}} \quad \text{(For free space)}$$

Definition of unit Charge :-

In C.G.S :-

Electrostatic unit of charge is that 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.

According to Coulomb's law

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

For vacuum $K = 1$

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

If $q_1 = q_2 = q$, $r = 1$ cm & $F = 1$ dyne then $1 = \frac{q^2}{1} \Rightarrow q^2 = 1$

$\Rightarrow q = \pm 1$ (e.s.u)

In S.I:-

For free space $F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$

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

If $q_1 = q_2 = q$, $r = 1\,m$, $F = 9\times10^9$ newton

then $9\times10^9 = 9\times10^9 \frac{q^2}{1}$

$$\Rightarrow q^2 = 1$$

$$\Rightarrow q = \pm 1 \text{ Coulomb}$$

One coulomb of charge is defined as that charge which when placed in air, at a distance of 1 metre from an equal and similar charge repels it with a force of 9×10^9 newton.

$\boxed{1 \text{ coulomb} = 3\times10^9 \text{ statcoulomb}}$

Permittivity:- (ϵ)

It is a characteristic of a medium which determines the capability of the medium to convey the effect of a charge from one point to another in the same medium.

Absolute Permittivity:- (ϵ_0)

It is the permittivity of free space.

Its value is $\epsilon_0 = 8.854\times10^{-12}\, C^2 N^{-1} m^{-2}$

Relative Permittivity:- (ϵ_r)

It is the ratio between permittivity of medium to the permittivity of free space.

$$\epsilon_r = \frac{\epsilon}{\epsilon_0}$$

$$\Rightarrow \boxed{\epsilon = \epsilon_0 \epsilon_r}$$

Since it is a ratio of two similar quantities, it has no unit.

Electric Potential:-

Electric Potential is defined as the quantity which determines the direction of flow of charge between two bodies.

Electric Potential Difference :-

- Potential difference between any two points in an electric field is the negative line integral of electric field between them along any curve joining them together.

$$V(\vec{r}) = \int_{-\infty}^{\vec{r}} \vec{E}(r) \cdot \vec{dl}$$

- Potential, at any point, in an electric field, is defined as the workdone in moving a unit positive charge from infinity to that point against the electric field along any path. $V(\vec{r}) = \frac{W}{\delta q}$

S.I unit :-

$$V(\vec{r}) = \frac{W}{\delta q}$$

$$= 1J/1C = 1 \text{volt}$$

So unit of potential is volt.

$$\boxed{\begin{array}{c} 1 \text{volt} = \frac{1}{300} \text{statvolt} \\ 1 \text{volt} = 10^8 \text{abvolt} \end{array}}$$

Electric field :-

- The modified space around an electric charge is called electric field.
- The charge is known as source of electric field.

Electric field Intensity :-

- Definition :- The strength of an electric field or field intensity is defined as the force experienced by a unit positive charge placed at that point. The direction of field is given by direction of motion of a unit positive charge if it were free to do so.

Let $\vec{F}(\vec{r})$ be the force experienced by a test charge q_0 placed at a point P where the strength of electric field $\vec{E}(\vec{r})$ is to be calculated.

Then $\vec{E}(\vec{r}) = \lim_{q_0 \to 0} \frac{\vec{F}(\vec{r})}{q_0}$

Unit of $\vec{E}$:-

i) In CGS, $\vec{E} = \frac{\vec{F}}{q}$ = dyne/stat coulomb

ii) In S.I, $\vec{E}$ = newton/coulomb

Capacitance :-

If V is the potential of the conductor due to a charge given to it, then

$Q \propto V$

$\Rightarrow Q = CV$

The proportionality constant C is known as the capacity of the conductor. Thus $C = \frac{Q}{V}$

The capacitance of a conductor is defined as the ratio between the charge on the conductor to its potential.

If $V = 1$ then $C = Q$

It is also defined as the charge required to raise it through a unit potential.

Units of capacitance :-

The S.I unit is Farad

$1\ \text{Farad} = \frac{1\ \text{coulomb}}{1\ \text{Volt}}$

1 Microfarad (μF) $= 10^{-6}$ F

1 micromicrofarad ($\mu\mu F$) or 1 Picofarad $= 10^{-12}$ F

In C.G.S :-

e.s.u of capacity :- Statfarad

e.m.u of capacity :- abfarad

$$\boxed{\begin{aligned} 1\ \text{Farad} &= 9 \times 10^{11}\ \text{statfarad} \\ 1\ \text{Farad} &= \frac{1}{10^9}\ \text{abFarad} \end{aligned}}$$

Grouping of Capacitors :-

i) Capacitors in Parallel :-

$$\boxed{C = C_1 + C_2 + \dots + C_n}$$

The resultant capacity of a number of capacitors, connected in parallel, is equal to the sum of their individual capacities.

ii) Capacitors in series :-

$$\boxed{\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}}$$

Thus, the reciprocal of the resultant capacitance of a number of capacitors, connected in series, is equal to the sum of reciprocal of their individual capacities.

1. Find the total capacity when two capacitors 400 μF and 0.3 mF are connected in series.

A:- Here $C_1 = 400\ \mu F$

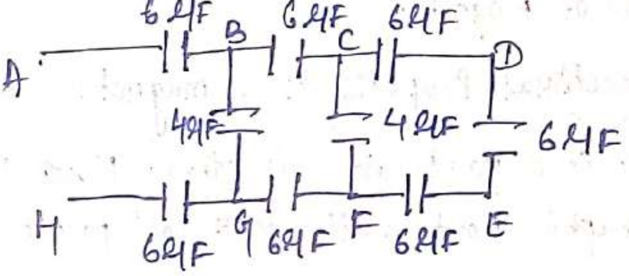
$$C_2 = 0.3\ mF = 0.3 \times 1000\ \mu F$$
$$= 300\ \mu F$$

Now $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

$$= \frac{1}{400} + \frac{1}{300} = \frac{7}{1200}$$

$\Rightarrow C = \frac{1200}{7}\ \mu F = 171.4\ \mu F$

2. Calculate the net capacity of the network in the figure in between the terminals A and H.



Ans:- Three capacitors in arm CDEF are in series.

$$\frac{1}{C_{CDEF}} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{1}{2}$$

$\Rightarrow C_{CDEF} = 2\ \mu F$

Capacity across C and F is a parallel combination of 4 μF & 2 μF.

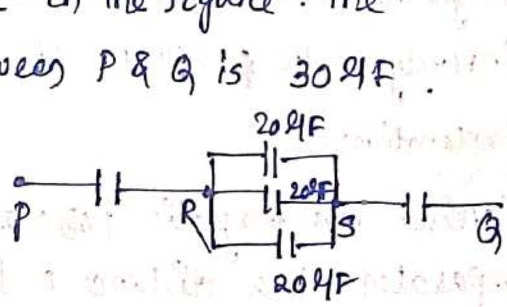
So $C_{CF} = 4 + 2 = 6\ \mu F$

$C_{BG} = 6\ \mu F$

Now $\frac{1}{C_{AH}} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{1}{2}$

Now, $C_{AH} = 2\ \mu F$

3. Calculate the capacitance of the capacitor C in the figure. The equivalent capacitance of the combination between P & Q is 30 μF.



Ans:- $\frac{1}{C} + \frac{1}{60} = \frac{1}{30}$

$$\Rightarrow \frac{1}{C} = \frac{1}{30} - \frac{1}{60}$$
$$= \frac{1}{60}$$

$\Rightarrow C = 60\ \mu F$

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Magnet:-

A piece of substance which possesses the property of attracting small pieces of iron towards it is called a magnet.

Properties of Magnet:-

1. Two poles of a magnet:- A magnet has two poles. One is north pole and another one is south pole. Face to face length of magnet is called geometric length while pole to pole length is called magnetic length of the magnet.

2. Attracting Property of a magnet:- A magnet is capable of attracting small pieces of iron towards it. These pieces are attracted towards both poles, north as well as south. This attraction is greatest at the poles and decreases as move towards the centre of magnet.

3. Directional Property of a magnet:- When freely suspended a magnet always points in a particular direction. North pole of the magnet points towards geographic north while south pole points towards the geographic south.

4. No existence of isolated magnetic poles:- The magnetic poles exist only in pairs of opposite nature. It is not possible to obtain an isolated magnetic pole.

5. Nature of force between two poles:- The nature of force between similar poles is repulsive while that between opposite poles is attractive.

Coulomb's Law of Magnetostatics:-

Statement:- It states that the magnitude of the force between two magnetic poles varies directly as the product of their poles and inversly as the square of the distance between them.

Explanation:-

Consider two magnetic poles of similar nature of strength m_1 and m_2 separated at a distance r from eachother. The force of repulsion between them is

$F \propto m_1 m_2$

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

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

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

where K is the proportionality constant

In S.I :- $K = \frac{\mu_0}{4\pi}$

$$\therefore \boxed{F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}}$$

where $\mu_0 = 4\pi \times 10^{-7}\ wb A^{-1} m^{-1}$

μ_0 is called the absolute magnetic permeability of free space.

In C.G.S :- $K = 1$

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

Unit Pole :-

In S.I System :-

$$F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}$$

Since $\mu_0 = 4\pi \times 10^{-7}\ wb A^{-1} m^{-1}$.

$$F = \frac{4\pi \times 10^{-7}}{4\pi}\frac{m_1 m_2}{r^2}$$

If $F = 10^{-7} N$, $m_1 = m_2 = m$ and $r = 1$

$$10^{-7} = 10^{-7} \times \frac{m^2}{1}$$

$$\Rightarrow m^2 = 1 \quad \text{or} \quad m = \pm 1$$

A unit pole, in S.I is that pole which when placed in air at a distance of 1m from a similar pole repels it with a force of 10^{-7} N.

In C.G.S System :-

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

If $F = 1$ dyne, $m_1 = m_2 = m$ and $r = 1$ cm

$$\Rightarrow 1 = \frac{m^2}{1}$$

$$\Rightarrow m = \pm 1$$

A unit pole, in CGS system, is that pole which when placed in air at a distance of 1cm from a similar pole repels it with a force of 1 dyne.

Magnetic Field:-

Magnetic field, of any magnetic pole, is the region or space around it in which its magnetic influence can be realised.

Magnetic field Intensity (B):-

Strength of magnetic field or magnetic field intensity, at any point, is defined as the force experienced by a unit north pole placed at that point. The direction of magnetic intensity is the direction in which the unit north pole would move if it were free to do so.

In S.I:-

Force between two poles is $F = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}$

If $m_1 = m$, $m_2 = 1$

So $\boxed{F = \frac{\mu_0}{4\pi} \frac{m}{r^2}}$

This gives the magnetic intensity at any point distant r from a magnetic pole of strength m.

In C.G.S:-

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

If $m_1 = m$, $m_2 = 1$

$\boxed{F = \frac{m}{r^2}}$

• S.I unit is $NA^{-1}m^{-1}$

Magnetic Lines of Force:-

Definition:- Lines of force is the path along which a unit north pole would move if it were free to do so.

Properties of magnetic lines of Force:-

1. Lines of force are directed away from a north pole and are directed towards a south pole. A line of force starts from a north pole and ends at a south pole. (if they are isolated poles)

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2. Tangent, at any point, to the magnetic line of force gives the direction of magnetic intensity at that point.

3. Two lines of force never cross eachother.

4. The number of lines of force per unit area is proportional to magnitude of strength of field at that point. Thus more concentration of lines represents stronger magnetic field.

5. The lines of force tend to contract longitudinally or lengthwise i.e they possess longitudinal strain. Due to this property two unlike poles attract eachother.

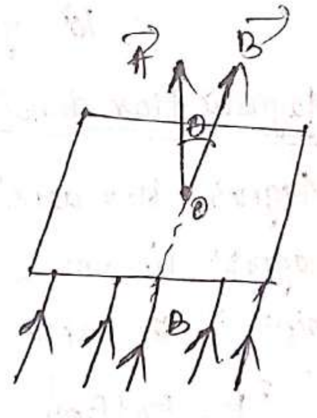
6. The lines of force tend to exert lateral pressure i.e they repel eachother laterally. This explains the repulsion between two similar poles.

7. 4π lines of force start from a unit magnetic pole.

Magnetic Flux:-

- Flux is a word used in the study of the quantity of certain fluids flowing across any area.
- Magnetic flux deals with the study of the number of lines of force of magnetic field crossing a certain area.

Consider an area A placed in a magnetic field having magnetic induction B.
Let the area be inclined to the direction of B at an angle θ.
Then magnetic flux ϕ_B through area A is given by



$$\phi_B = \vec{B} \cdot \vec{A}$$

$$\Rightarrow \phi_B = BA\cos\theta$$

$$\Rightarrow \boxed{\phi_B = A(B\cos\theta)}$$

Magnetic flux linked with a surface, is defined as the product of area and the component of B perpendicular to the area.

Case-1 :- If $\theta = 90^\circ$, $\cos\theta = 0$

$\therefore \phi_B = BA \times 0 = 0$

No magnetic flux is linked with the surface when the field is parallel to the surface.

Case-2 :- If $\theta = 0^\circ$, $\cos\theta = 1$

$$(\phi_B)_{max} = B \times A \times 1 = BA$$

Magnetic flux linked with a surface is maximum when area is held perpendicular to the direction of field.

Units of magnetic flux :-

SI unit :- $\phi_B = BA$

If $B = 1$ tesla, $A = 1 m^2$

$\phi_B = 1 \times 1 = 1$ weber

1 weber = 1 tesla metre^2

So SI unit of magnetic flux is weber.

CGS unit :-

If $B = 1$ gauss, $A = 1 cm^2$

$\phi_B = 1 \times 1 = 1$ maxwell

So CGS unit of magnetic flux is maxwell

Relation between weber & Maxwell :-

$$1 \text{ Weber} = 1 \text{ tesla} \times 1 m^2$$
$$= 10^4 \text{ gauss} \times (100 cm)^2$$
$$= 10^8 \text{ gauss } cm^2$$

Magnetic flux density :- (B)

Magnetic flux density, at any point is defined as the number of magnetic lines of force passing through a unit area placed at that point if the area is held perpendicular to the direction of lines.

$$\boxed{B = B_0 + B_m}$$

Where B_0 is magnetic flux density which the external field would produce in vacuum and B_m is the magnetic flux density due to induced poles developed at two ends of material.

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UNIT-10

UNIT-10 Current Electricity

Electric Current:-

- Current, in a conductor, is defined as the rate of flow of charge across any cross section of the conductor.
- If a charge q flows across any cross section in t second, current i is given by $\boxed{i = \frac{q}{t}}$
- In case of nonuniform flow, let Δq be the small amount of charge flowing across any crosssection of the conductor in a small interval of time Δt, then current i is given by

$$i = \frac{\Delta q}{\Delta t}$$

If the time interval is very small,

$$i = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$$

S.I unit :- The SI unit of current is ampere.

CGS unit:- e.s.u of current = stat ampere
e.m.u of current = ab ampere.

$$\boxed{\begin{aligned} 1 \text{ ampere} &= 3 \times 10^9 \text{ stat ampere} \\ 1 \text{ ampere} &= \frac{1}{10} \text{ abampere} \end{aligned}}$$

Ohm's Law:-

statement:-

It states that, at constant temperature, the current flowing through a conductor of uniform area of cross section is directly proportional to the difference of potential across the two ends of conductor.

Let V = Potential diference across the two ends of conductor.
i = current flowing the conductor.

According to ohm's law

$$i \propto V$$

$$\Rightarrow \frac{V}{i} = \text{constant}$$

$$\Rightarrow \boxed{\frac{V}{i} = R}$$

$R = \frac{\rho l}{A}$ $\left(\text{Where } \rho = \frac{m}{ne^2 \tau}\right)$

R is resistance of the conductor.

Applications of Ohm's law:-

1. **Power supplied to electrical heater:-**

We can calculate the power supplied to a heater using Ohm's law.

2. **Selection of fuses:-**

The current rating of the fuse is calculated by using Ohm's law,

3. **Design of Electronics Devices:-**

The electronic devices such as laptop and mobile phones require a dc power supply specific current rating. Typical mobile phone batteries require 0.7-1A. A resistor is used to control the rate of current flowing through these components. The Ohm's law is used to calculate the rating of current which should be used in the typical circuit.

4. **Sizing of Resistors in consumer electronics!-**

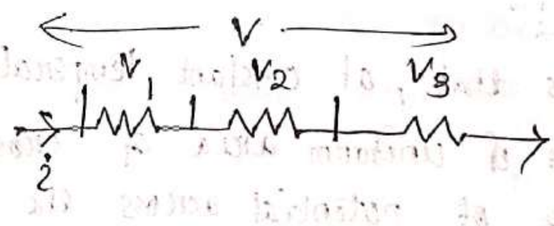
The electronic components such as normal power supplies, uninterruptable supplies, iron, kettle, televisions & similar components use a lot of resistors for their control purposes.

5. **Speed control of conventional fans:-**

It is achieved by using a Potentiometer. It is a variable resistance.

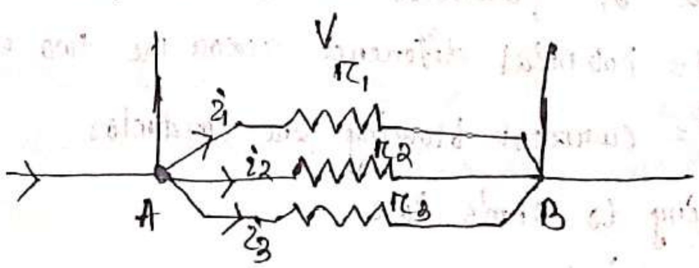
Resistances in Series:-

$$\boxed{R = r_1 + r_2 + r_3}$$



Resistances in Parallel:-

$$\boxed{\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$



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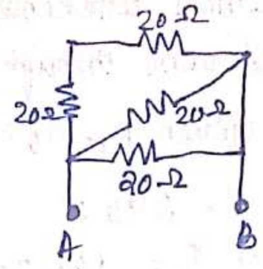
Numericals :-

1. Find the equivalent resistance of the circuit across the two points A and B.



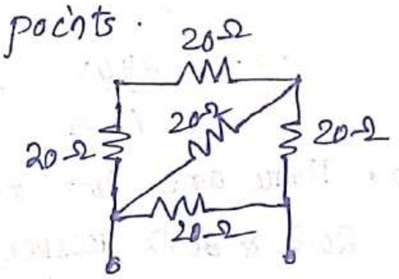
Ans :- $20\Omega + 20\Omega = 40\Omega$

Now $\frac{1}{R} = \frac{1}{40} + \frac{1}{20} + \frac{1}{20}$

$= \frac{5}{40} = \frac{1}{8}$

$\Rightarrow R = 8\Omega$

2. Find the equivalent resistances between two points.



A:- $20 + 20 = 40\Omega$

$\frac{1}{R} = \frac{1}{40} + \frac{1}{20} = \frac{1+2}{40} = \frac{3}{40}$

$\Rightarrow R = \frac{40}{3}$

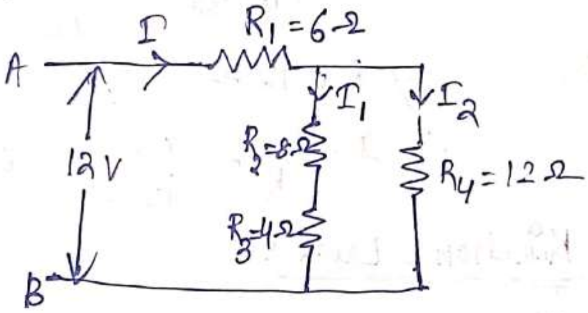
Now $40/3 + 20 = 100/3$

$\frac{1}{R_{eq}} = \frac{1}{100/3} + \frac{1}{20}$

$= \frac{3}{100} + \frac{1}{20} = \frac{8}{100}$

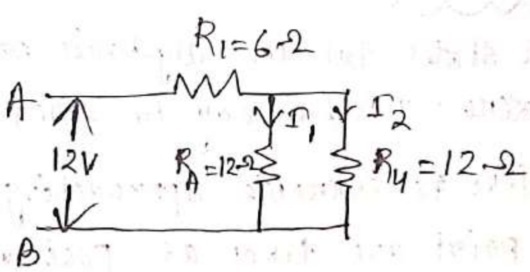
$$\boxed{R_{eq} = \frac{100}{8} = 12.5\Omega}$$

3. In the following circuit calculate the total current (I) taken from 12V supply.



Ans:- R_2 and R_3 are in series.

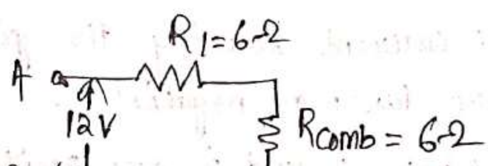
$R_A = R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$



$\frac{1}{R_{comb}} = \frac{1}{R_A} + \frac{1}{R_4}$

$= \frac{1}{12} + \frac{1}{12} = \frac{2}{12} = \frac{1}{6}\Omega$

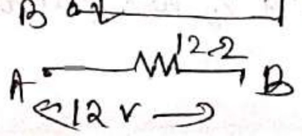
$R_{comb} = 6\Omega$



Now $R = R_{comb} + R_1 = 6\Omega + 6\Omega = 12\Omega$

Now current $I = \frac{V}{R} = \frac{12}{12} = 1$ amp

$\therefore \boxed{I = 1 amp}$



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4. There are three resistors joined in series in a system having resistance equal to 10 Ω, 20 Ω & 30 Ω respectively. If the Potential difference of the circuit is 240 V, find the total resistance & current through the circuit.

Ans :- Given $R_1 = 10\,\Omega$, $R_2 = 20\,\Omega$, $R_3 = 30\,\Omega$

$V = 240\,V$

Now $R = 10 + 20 + 30 = 60\,\Omega$

$$I = \frac{V}{R}$$

$$\Rightarrow I = \frac{240\,V}{60\,\Omega} = 4\,A$$

5. There are two resistors R_1 + R_2 having resistances equal to 20 Ω & 30 Ω respectively are connected in parallel in an electric circuit. If the potential difference across the electric circuit is 5 V. Find I & R.

Ans :- $R_1 = 20\,\Omega$, $R_2 = 30\,\Omega$

$V = 5\,V$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{20} + \frac{1}{30} = \frac{3+2}{60} = \frac{5}{60}\,\Omega$$

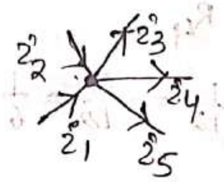
$$\Rightarrow R = 12\,\Omega$$

$$\therefore I = \frac{V}{R} = \frac{5\,V}{12\,\Omega} = 0.416\,A$$

Kirchoff's Laws :-

first law :- (Kirchoff's Current Law) :-

- It states that the algebraic sum of currents meeting at a point is zero. this law may be called Kirchoff's current law (KCL)
- Here the currents approaching a given point are taken as positive.
- The current leaving the given point are taken as negative.



So here i_1 and i_2 are positive while i_3, i_4 and i_5 are negative.

According to Kirchoff's first law,

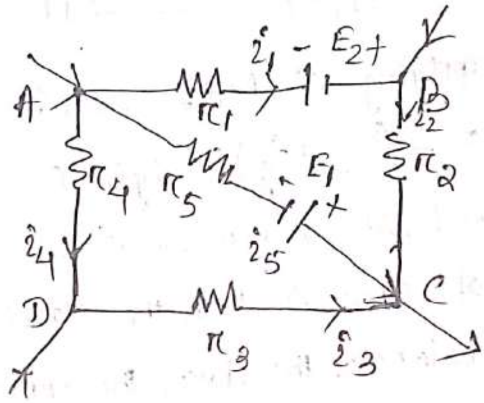
$i_1 + i_2 - i_3 - i_4 - i_5 = 0$

$\Sigma i = 0$

Conclusion:- The current entering a point must be the same as that leaving it.

Second law:- (Kirchoff's Voltage Law)

It states that, in a closed electric circuit, the algebraic sum of e.m.f is equal to the algebraic sum of the products of the resistances and the currents flowing through them.



ABCD containing resistances r_1, r_2, r_3, r_4 and r_5 in the parts AB, BC, CD, DA & AC respectively. Let i_1, i_2, i_3, i_4 and i_5 be the respective currents flowing in these parts. Two sources of emfs E_1 & E_2 are also connected in the mesh.

Sign Conventions:-

i) If the electric current flows through the electrolyte of the cell from negative to positive terminal, the e.m.f of the cell is taken as positive(+E)

ii) If the electric current flows through the electrolyte of the cell from positive terminal to negative terminal the e.m.f of the cell is taken as negative, (-E)

- Applying Kirchhoff's second law to the mesh ABC, we can write

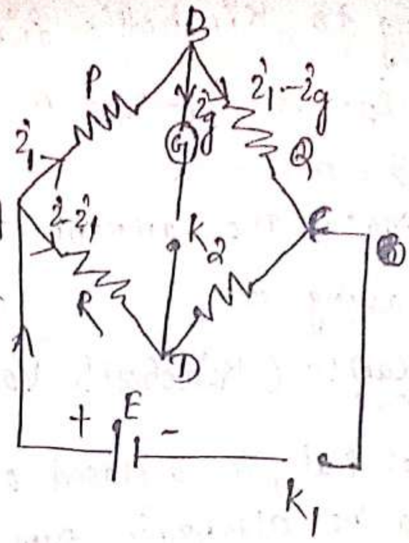
$i_1 r_1 + i_2 r_2 - i_5 r_5 = E_1 - E_2$

Again, applying Kirchoff's second law to the mesh ACD, we get

$i_5 r_5 - i_3 r_3 - i_4 r_4 = E_1$

Wheatstone Bridge:-

It consists of four resistances P, Q, R and S connected in the four arms of a square ABCD. A cell of emf E is connected between the points A and C through a one way Key K_1. A galvanometer of resistance G is connected between the terminals B & D through another one way key K_2. After closing the keys K_1 & K_2, the resistance P, G, R and S are so adjusted that the galvanometre shows no deflection. In this position the wheatstone bridge is said to be balanced.



Now giving positive sign to the currents flowing in clockwise direction & negative sign to the currents flowing in anticlockwise direction & applying Kirchoff's voltage law to the mesh ABD.

$$i_1 P + i_g G - (i - i_1)R = 0 \quad \text{——— (1)}$$

Similarly applying Kirchoff's second law to the mesh BCD,

$$(i_1 - i_g)Q - (i - i_1 + i_g)S - i_g G = 0 \quad \text{——— (2)}$$

The right hand side of both equations (1) & (2) are zero because there is no source of emf in both the closed circuits ABD & BCD. Since the bridge is balanced, therefore, the current i_g flowing through the arm BD is zero.

Putting $i_g = 0$

$$i_1 P - (i - i_1)R = 0 \Rightarrow i_1 P = (i - i_1)R \quad \text{——— (3)}$$

and $i_1 Q - (i - i_1)S = 0$

$$\Rightarrow i_1 Q = (i - i_1)S \quad \text{——— (4)}$$

Dividing equation (3) by equation (4)

$$\frac{i_1 P}{i_1 Q} = \frac{(i - i_1)R}{(i - i_1)S}$$

$$\Rightarrow \boxed{\frac{P}{Q} = \frac{R}{S}}$$

This is the required condition for the bridge to be balanced and gives the principle of wheatstone bridge.

UNIT-11

UNIT-II : Electromagnetism and Electro Magnetic Induction

Electromagnetism :-

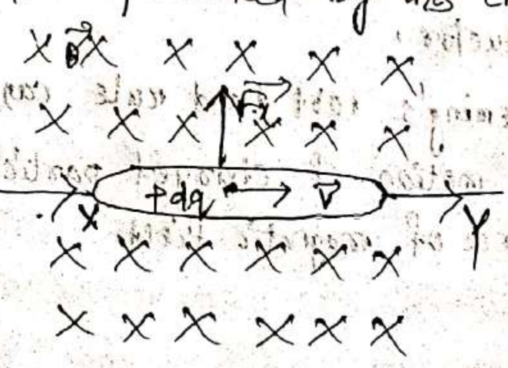
A charged body is capable of producing electric charge in a neighbouring conductor. The phenomenon of Induction of electricity due to electricity is called electric induction. A magnet is capable of producing magnetism in a neighbouring magnetic substance. This phenomenon of production of magnetism due to magnetism is called magnetic induction. A current flowing through a wire produces a magnetic field around itself. This phenomenon of production of magnetism due to electricity is called magnetic effect of currents. This phenomenon of production of electricity due to magnetism is called electromagnetic induction.

Force on a conductor carrying current and placed in a magnetic 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 potential to higher potential with a small velocity. These electrons constitute a current through the conductor. When the electrons move in a magnetic field, they experience a force $\vec{F}$.

Consider a conductor XY placed in a uniform magnetic field $\vec{B}$ acting inwards at right angle to the plane of paper. Let a current i flows through the conductor from X to Y.

Let dq be a small amount of positive charge moving from X to Y with a velocity $\vec{v}$. The force $\vec{dF}$ experienced by this charge is given by $\vec{dF} = dq\,(\vec{v} \times \vec{B})$ —— (1)



If the charge travels a small distance $\vec{dl}$ in time dt, then

$$\vec{v} = \frac{\vec{dl}}{dt}$$

$$\therefore \vec{dF} = dq \times \left(\frac{\vec{dl}}{dt} \times \vec{B}\right)$$

$$= \frac{dq}{dt}\,(\vec{dl} \times \vec{B}) \Rightarrow \vec{dF} = i\,(\vec{dl} \times \vec{B}) \text{ —— (2)}$$

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Direction of the length $\vec{dl}$ is taken to be the direction of advancing current i.e, from X to Y.

Net force $\vec{F}$ acting on the conductor can be obtained by integrating equation (2)

$$F = \int d\vec{F} = \int i\,\vec{dl} \times \vec{B}$$

$$\Rightarrow \vec{F} = i(\vec{l} \times \vec{B})$$

$$\Rightarrow \vec{F} = ilB\sin\theta\,\hat{n}$$

Where $\hat{n}$ is a unit vector in a direction perpendicular to the plane containing $\vec{l}$ & $\vec{B}$, θ is the angle between $\vec{l}$ & $\vec{B}$.

Magnitude of force :-

Magnitude of the force is given by

$$|\vec{F}| = Bil\sin\theta$$

It is clear that the magnitude of the force depends upon the angle between the direction of current & the lines of force of a magnetic field.

Direction of force :-

Direction of force $\vec{F}$ can be obtained by applying Flemming's left hand Rule.

Flemming's Left Hand Rule :-

Stretch first finger, central finger and the thumb of your left hand in mutually perpendicular directions. If the first finger points towards magnetic field, central finger towards electric current then the thumb gives the direction of force acting on the conductor.

☆ Fleming's left hand rule can only be applied when the direction of motion of charged particles is perpendicular to the lines of force of magnetic field.

Faraday's Laws of Electro Magnetic Induction:-

Faraday's law deals with the induction of an e.m.f in an electric circuit when magnetic flux linked with the circuit changes. They are stated as follows:

1. Whenever magnetic flux linked with a circuit changes, an emf is induced in it
2. The induced e.m.f exists in the circuit so long as the change in magnetic flux linked with it continues.
3. The induced e.m.f is directly proportional to the negative rate of change of magnetic flux linked with the circuit.

If $d\phi_B$ is the change in magnetic flux linked with a circuit that takes place in a time dt.

Rate of change of magnetic flux $= \frac{d\phi_B}{dt}$

If E is e.m.f. induced in the circuit as a result of this change,

$$E \propto -\frac{d\phi_B}{dt}$$

$$\Rightarrow \boxed{E = -K\frac{d\phi_B}{dt}}$$

Negative sign is due to direction of induced e.m.f.

Lenz's law :-

- It states that direction of induced e.m.f is such that it tends to oppose the very cause which produces it.

Fleming's Right hand Rule :-

→ It can be stated as

"Stretch first finger, Central finger and the thumb of your right hand in three mutually perpendicular directions. If the first finger points towards the magnetic field, thumb points towards the direction of motion of conductor, the direction of central finger gives the direction of induced current setup in the conductor."

→ It is a rule to find the direction of induced current in a conductor.

Fleming's Left Hand Rule	Fleming's Right hand Rule
1. When a current-carrying conductor is placed under a magnetic field, a force acts on the conductor. The direction of this force can be identified using Fleming's left hand rule.	1. If a moving conductor is brought under a magnetic field, electric current will be induced in that conductor. The direction of the induced current can be found using Fleming's right hand rule.
2. It is mainly applicable to electric motors.	2. It is mainly applicable to electric generators.
3. The thumb represents the direction of the thrust on the conductor.	3. The thumb represents the direction of motion of the conductor.
4. The index finger represents the direction of the magnetic field.	4. The index finger represents the direction of the magnetic field.
5. The middle finger represents the direction of the current.	5. The middle finger represents the direction of the induced current.

UNIT-12

UNIT-12 MODERN PHYSICS

LASER & Laser beam:-

- LASER stands for Light Amplification by stimulated Emission of Radiation.
- A laser beam is extremely intense, coherent & highly parallel beam of light. A device which produces this kind of beam is called a laser.
- T. H. Maiman developed the first Laser.

Stimulated Emission:-

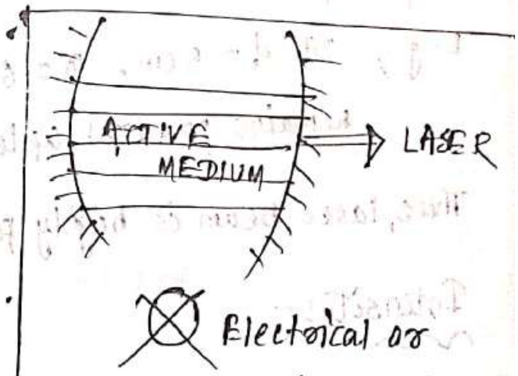
- The excited atoms, under ordinary conditions, de excite within 10^{-5}s sending radiations in random directions. This kind of emission is known as spontaneous emission.
- Under special conditions the excited atoms can be made to stay on in their excited states for a comparatively longer period before they are stimulated by an external stimulating agency to get de-excited. This kind of emission is known as stimulated emission.

Principle of LASER:-

→ Every laser system consists of an active medium having ion/molecules or atoms possessing atleast one metastable state. The active medium is placed in resonating cavity having reflectors at its ends and an electrical or optical pump to excite the atoms of the medium.

→ The basic principle of all lasers is to first bring population inversion.

Population Inversion:- To have more atoms in the metastable state than that in ground state.



(Resonating Cavity)

→ This is done by supplying suitable energy to the atoms of the active medium with the help of a pump. This process of bringing about population inversion is called pumping.

→ Out of these many atoms in the meta-stable state, one atom happens to de-excite emitting a photon known as Fluorescent or Phosphorescent Photon.

→ As this photon happens to pass nearby other atoms, in similar metastable states, stimulates them to de-excite to emit similar photons which in turn make other atoms to de-excite.

→ Before these photons escape from the active medium, they are made to move to and fro in the medium several times so as to build up an intense beam of photons by de-exciting more & more atoms of the medium.

→ All emitted photons possess same frequency, direction and speed as that of primary photon.

→ This constitutes a laser beam.

PROPERTIES OF LASER:-

The characteristics of the LASER beam are:

i) Directionality

ii) Intensity

iii) Monochromaticity

iv) Coherence

Directionality:-

- Laser is emitted in one direction.
- Beam coming from an aperature of diametre d continues moving parallel beam upto distance $\sim \frac{d^2}{\lambda}$ and thereafter diffraction effects make it to spread.

E.g → If $d = 5\text{cm}$, $\lambda = 6943 Å$, then the laser beam of this wavelength remains parallel upto distance of the order of 3.6 Km from source.

Thus, laser beam is highly parallel & directional.

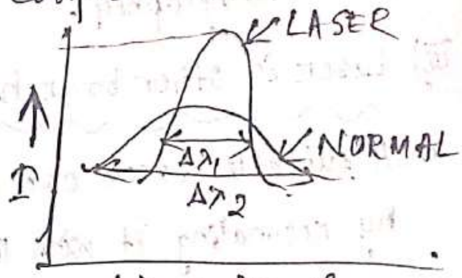
Intensity:-

- As the laser beam has the ability of focus over as small an area as $10^{-6}\ \text{cm}^2$, therefore, it is highly intense beam.

E.g → A 1 watt laser when focused over an area $10^{-6}\ \text{cm}^2$, has intensity $10^6\ \text{watt/cm}^2$ where ordinary 100 watt lamp will not have intensity even 10000th of this. It is because the light from lamp can't be focused over an area less than a cm^2.

Monochromaticity :-

- Monochromaticity is determined by the spread of wavelength around the wavelength corresponding to which intensity is peak.
- Line width of laser light is extremely small in comparision to ordinary light.



Line width of Laser beam.

E.g → Line width of Ruby laser is $\sim 5\times10^{-4}\,\mathring{A}$.

- Hence light emitted from a laser is vastly more monochromatic than that emitted from a conventional sources of light.

Coherence :-

The laser light is highly coherent in space & time.

Applications of LASER :-

i) Laser in Surgery :-

- As the beam is very powerful can cut flesh & seal the blood oozing cells instantly allowing the surgery without wasting of blood.
- It avoids mechanical stitching.
- Painless cleaning and drilling of tooth cavities have become possible with laser beams.
- It is used to break certain kinds of stones in kidneys without any major surgery.
- It is used in eye surgery to attach a detached retina.
- Glaucoma can be treated with laser beam.
- It is employed in the treatment of liver cancer.

ii) Laser in Industry :-

- A laser beam is employed in melting, cutting, drilling and welding metals.
- It can cut a few cm thick iron sheet.

- In industrial chemistry, it is employed to decompose noxious substances from industrial waste to convert harmless substances for living beings.
- It is used in photographic industry. Using beam of ruby laser successive positions of a bullet travelling at the speed of 200 m/s have been photographed.

iii) Laser in other branches of science:-

- A suitable laser can be employed to break a bond in a molecule by resonating it with the bond.
- It can also help to determine the structure of the molecule.
- In astronomy radio-astronomers are frequently using it to determine distances of planets and subplanets.
- Laser can control spaceships upto billion of kilometer.
- Its high monochromaticity & high frequency help in sending million of accoustic messages simultaneously.
- In biology laser is used to derive many properties of a biological sample like structure.

iv) Laser in Warfare:-

- Very intent laser beams are capable of destroying enemy war planes.
- A laser gun can kill humanbeings without any shot sound.

Wireless Transmission:-

Ground waves:-

- Used for a low frequency range transmission, mostly less than 1 MHz.
- This type of propagation employs the use of large antennas. Order of which is equivalent to the wavelength of waves and uses the ground or Troposphere for its propagation.

- Signals over large distances are not sent using this method.
- It causes severe attenuation which increases with increased frequency of the waves.

Sky Wave:-

- Used for the propagation of EM waves with a frequency range of 8-30 MHz.
- Make use of the ionosphere due to presence of charged ions in the region of about 60 to 300 km from the earth surface.
- These ions provide a reflecting medium to the radio or communication waves within a particular frequency range.
- We use this property of the ionosphere for long distance transmission of the waves without much attenuation & loss of signal strength.

Space Wave:-

- Used for a Line of sight communication.
- It basically involves sending a signal in a straight line from the transmitter to the receiver.
- For very large distances, the height of the tower used for transmission is high enough to prevent waves from touching the earth curvature thus preventing attenuation & loss of signal strength.