PREPARED BY

ABAKASH PRADHANI

LECTURER IN PHYSICS
GOVERNMENT POLYTECHNIC, MALKANGIRI
PRADHANIGUDA, ODISHA (764045)
MAIL ID – coolabakash@gmail.com

Engg. Physics (Th 2a)

Branch - CIVIL & ELECTRICAL

Date - 05/12/2022

Assignment - 1
(Unit - 1)

① 2 Marks Questions :

(a) Write the SI units of (i) Frequency (ii) Temperature.

(b) Write down SI units of work, angular velocity, electric potential and acceleration.

(c) Name the basic units in SI System.

(d) State the principle of Homogeneity.

(e) Write down dimensional formulae of (i) Pressure and (ii) Universal Gravitational Constant (G).

(f) Write down the dimensional formula of
(i) Acceleration (ii) Kinetic Energy

(g) Write down the units of the following physical quantities:
(i) Power (ii) Wavelength (iii) Stress (iv) Torque

② 5 Marks Questions :

(a) Check the correctness of $T = 2\pi\sqrt{\frac{l}{g}}$ using Dimensional analysis. Where the symbols used have their usual meaning

(b) Check the dimensional correctness of the physical relations
(i) $s = 6ut + 4at^2$ (ii) $v^2 - u^2 = 9as$

(c) State principle of Homogeneity and check the correctness of given relation $v^2 - u^2 = 8as$.

Engg. Physics (Ph2a) Assignment - 1 (Solution)

① 2 Marks Questions :

(a) SI units of (i) frequency → (s^{-1}) or [Hertz (Hz)]

(ii) Temperature → Kelvin (K)

(b) SI units of (i) work → Joule (J)

(ii) Angular velocity → rad s^{-1} or rad/s

(iii) Electric Potential → Volt (V)

(iv) Acceleration → m/s^2 or ms^{-2}

(c) Basic units in SI System →

Length → meter (m)

Mass → kilogram (kg)

Time → second (s)

Temperature → kelvin (K)

Current → Ampere (A)

Luminous Intensity → Candela (cd)

Amount of substance → Mole (mol)

(d) Principle of Homogeneity; states that the dimensional formula of every term of a correct relation must be same.

(e) Dimensional formula of :

(i) Pressure = $\left[\frac{\text{Force}}{\text{Area}}\right] = \left[\frac{MLT^{-2}}{L^2}\right] = [M^1L^{-1}T^{-2}]$

(ii) Universal Gravitational Constant (G) = $\left[\frac{FR^2}{M^2}\right]$

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

(f) Dimensional formula of :

(i) Acceleration = $\left[\frac{\text{Velocity}}{\text{Time}}\right] = \left[\frac{LT^{-1}}{T}\right] = [LT^{-2}]$

(ii) Kinetic energy $= [K] = \left[\frac{1}{2}mv^2\right]$

$$= \left[1 \times M \times (LT^{-1})^2\right]$$

$$= \left[ML^2T^{-2}\right]$$

(g) SI units of → (i) Power → Watt or Js^{-1}

(ii) Wavelength → meter (m)

(iii) Stress → N/m^2 or Nm^{-2}

(iv) Torque → Nm

② 5 Mark Questions →

(a) The given equation $T = 2\pi\sqrt{\frac{l}{g}}$ is dimensionally correct if it satisfied principle of Homogeneity.

For that $[T] = \left[2\pi\sqrt{\frac{l}{g}}\right]$

LHS → $[T] = [T]$

RHS → $\left[2\pi\sqrt{\frac{l}{g}}\right] = \left[1 \times \left(\frac{L}{LT^{-2}}\right)^{1/2}\right] = \left[(T^2)^{1/2}\right] = [T]$

As, $[T] = \left[2\pi\sqrt{\frac{l}{g}}\right]$; we have,

" The given equation $T = 2\pi\sqrt{\frac{l}{g}}$ is dimensionally correct.

(2) (b) (i) $s = 6ut + 4at^2$

Let's check whether the given eq^n satisfies principle of homogeneity or not.

$$[s] = [L]$$

$$[6ut] = [1 \times LT^{-1} \times T] = [L]$$

$$[4at^2] = [1 \times LT^{-2} \times T^2] = [L]$$

As; $[s] = [6ut] = [4at^2]$; the given equation $s = 6ut + 4at^2$ is dimensionally correct.

(ii) $v^2 - u^2 = 9as$

Let's check whether the given eq^n satisfies principle of homogeneity or not.

$$[v^2] = [(LT^{-1})^2] = [L^2T^{-2}]$$

$$[u^2] = [(LT^{-1})^2] = [L^2T^{-2}]$$

$$[9as] = [1 \times LT^{-2} \times L] = [L^2T^{-2}]$$

Since Principle of homogeneity is satisfied, i.e.,

$$[v^2] = [u^2] = [9as];$$

we can say that, the given equation $v^2 - u^2 = 9as$ is dimensionally correct.

(c) Principle of homogeneity; states that the dimensional formula of every term of a correct relation must be same.

The given relation $v^2 - u^2 = 8as$ is dimensionally correct if principle of homogeneity is satisfied, i.e.,

$$[v^2] = [u^2] = [8as]$$

Now; $[v^2] = [(LT^{-1})^2] = [L^2T^{-2}]$

$[u^2] = [(LT^{-1})^2] = [L^2T^{-2}]$

$[8as] = [1 \times LT^{-2} \times L] = [L^2T^{-2}]$

We have, $[v^2] = [u^2] = [8as]$

As principle of homogeneity is satisfied, the given relation $v^2 - u^2 = 8as$ is dimensionally correct.

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Engg. Physics (Th 2a)

Branch - CIVIL & ELECTRICAL

Date - 07/12/2022

Assignment - 2 (Unit-2)

① 2 Marks Questions :

(a) Define Dot product of two vectors.

(b) Define cross product of two vectors.

(c) Find $\vec{A}\cdot\vec{B}$, if $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$ and $\vec{B} = 3\hat{i} - 2\hat{k}$.

(d) Find $\vec{A}\times\vec{B}$, if $\vec{A} = 4\hat{i} + 3\hat{j} + 2\hat{k}$ and $\vec{B} = 5\hat{i} + 2\hat{j} + \hat{k}$.

(e) Find $\vec{A}\cdot\vec{B}$, if $\vec{A} = 3\hat{i} + 2\hat{j} + 4\hat{k}$ and $\vec{B} = 4\hat{i} - 3\hat{j} + 5\hat{k}$.

(f) State parallelogram law of vector addition.

(g) State triangle law of vector addition.

② 5 Marks Questions :-

(a) At what angle two forces $(A+B)$ and $(A-B)$ should be inclined to have a resultant $\sqrt{3A^2+B^2}$.

(b) Two forces equal in magnitude, have magnitude of their resultant equal to either. Find the angle between them.

(c) With a neat diagram explain resolution of a vector.

(d) A force of 100N is resolved into two equal components at 60° to each other. Find the magnitude of each component.

(e) Find the angle between $\vec{A}$ & $\vec{B}$, if $\vec{A} = 3\hat{i} + 2\hat{j} - \hat{k}$ and $\vec{B} = 5\hat{i} + 2\hat{j} + 3\hat{k}$

(f) Find the unit vector along $(\vec{A}\times\vec{B})$, if $\vec{A} = 4\hat{i} + 3\hat{j} + 2\hat{k}$ and $\vec{B} = 5\hat{i} - 2\hat{j} + 3\hat{k}$

Engg. Physics (Th2a) Assignment - 2 (Unit - 2)

(1) (a) Dot / Scalar product of two vectors may be defined as the product of cosine of angle between two vectors and magnitude of two vectors.

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

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

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

(b) The magnitude of Cross/Vector product of two vectors may be defined as the product of magnitude of two vectors and sine of angle between them. The direction of the cross product of two vectors is always perpendicular to the plane cointaining the vectors originating from the common point of two vectors. The exact direction can be found out using right hand thumb rule or screw rule.

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

$|\vec{A} \times \vec{B}| = AB\sin\theta =$ magnitude of $\vec{A} \times \vec{B}$

$\hat{n} \rightarrow$ direction of $\vec{A} \times \vec{B}$.

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

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

(c) $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$ and $\vec{B} = 3\hat{i} - 2\hat{k}$

$A_x = 2, A_y = 3, A_z = -1$ & $B_x = 3, B_y = 0, B_z = -2$

$$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$$
$$= 2\times3 + 3\times0 + (-1)\times(-2)$$
$$= 6 + 0 + 2 = 8$$

Hence, $\vec{A}\cdot\vec{B} = 8$ (Ans)

(d) $\vec{A} = 4\hat{i} + 3\hat{j} + 2\hat{k}$ and
$\vec{B} = 5\hat{i} + 2\hat{j} + \hat{k}$

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 4 & 3 & 2 \\ 5 & 2 & 1 \end{vmatrix} = \hat{i}(3\times1 - 2\times2) + \hat{j}(5\times2 - 4\times1) + \hat{k}(4\times2 - 5\times3)$$

$$= -\hat{i} + 6\hat{j} - 7\hat{k}$$

Hence, $\vec{A}\times\vec{B} = -\hat{i} + 6\hat{j} - 7\hat{k}$ (Ans)

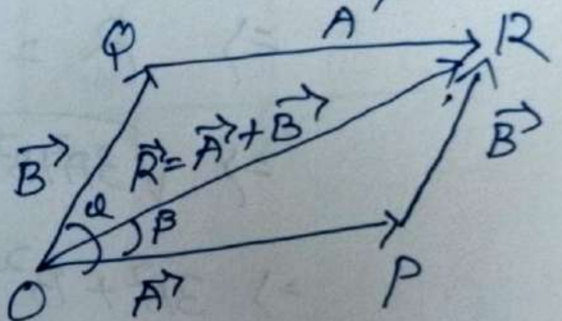
(e) $\vec{A} = 3\hat{i} + 2\hat{j} + 4\hat{k}$
$\vec{B} = 4\hat{i} - 3\hat{j} + 5\hat{k}$

$$\vec{A}\cdot\vec{B} = 3\times4 + 2\times(-3) + 4\times5$$
$$= 12 - 6 + 20$$
$$= 26$$

Hence, $\vec{A}\cdot\vec{B} = 26$ (Ans)

(1)(f) Parallelogram law of vector addition may be defined as:-

"If two vectors (in magnitude and direction) can be represented as two consicutive sides of a parallelogram originating from a common point, their resultant may be represented as the diagonal of the parallelogram (in magnitude and direction) originating from that common point".



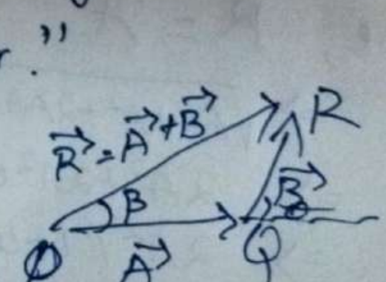
Mathematically,
If, $\vec{OP}$ & $\vec{OQ}$ can be represented as $\vec{A}$ & $\vec{B}$ respectively, then $\vec{OR}=\vec{R}=\vec{A}+\vec{B}$.

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

$$\beta = \text{Angle between } \vec{R} \text{ \& } \vec{A} = \tan^{-1}\left(\frac{B\sin\alpha}{A+B\cos\theta}\right)$$

(g) Triangle law of vector addition may be defined as:-

"If two vectors (in magnitude and direction) can be represented as two sides of a triangle taken in same order, then their resultant can be represented as third side of the triangle (in magnitud and direction) taken in opposite order."

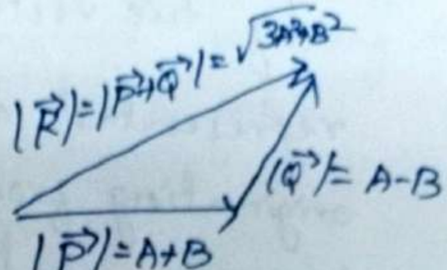


If $\vec{PQ}=\vec{A}$ & $\vec{QR}=\vec{B}$, then
$\vec{PR}=\vec{R}=\vec{A}+\vec{B}$.

and $R=\sqrt{A^2+B^2+2AB\cos\theta}$ & $\beta=\tan^{-1}\left(\frac{B\sin\theta}{A+B\cos\theta}\right)$

(2) (a) Let $\vec{P}$ & $\vec{Q}$ are two vectors (forces) having magnitude $(A+B)$ & $(A-B)$ respectively.

The magnitude of the resultant vector, $|\vec{R}| = |\vec{P}+\vec{Q}| = \sqrt{3A^2+B^2}$



If θ is the angle between $\vec{P}$ & $\vec{Q}$, then,

Mathematically, $|\vec{R}| = |\vec{P}+\vec{Q}|$

$$\Rightarrow R = \sqrt{P^2+Q^2+2PQ\cos\theta}$$

$$\Rightarrow \sqrt{3A^2+B^2} = \sqrt{(A+B)^2+(A-B)^2+2(A+B)(A-B)\cos\theta}$$

$$\Rightarrow 3A^2+B^2 = 2(A^2+B^2)+2(A^2-B^2)\cos\theta$$

$$\Rightarrow (A^2-B^2) = 2(A^2-B^2)\cos\theta$$

$$\Rightarrow \cos\theta = \frac{1}{2} = \cos 60^\circ$$

$$\Rightarrow \theta = 60^\circ.$$

Hence, the angle of inclination between two forces should be 60°. (Ans)

(b) Two forces of equal magnitude A (let), have magnitude of their resultant equal to either.

i.e., $R = A$

$$\Rightarrow \sqrt{A^2+A^2+2AA\cos\theta} = A$$

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

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

$$\Rightarrow 1+\cos\theta = \frac{1}{2}$$

$$\Rightarrow \cos\theta = -\frac{1}{2}$$

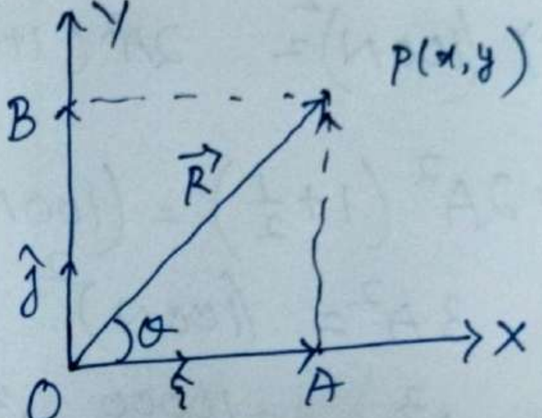
$$\Rightarrow \theta = 120^\circ$$

(Ans)

(2) (c) Resolution of vector →

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

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



Thus; $OA = x$ & $OB = y$

$\hat{i}$ & $\hat{j}$ are the unit 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.

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

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

In ΔOAP; $\cos\theta = \frac{OA}{OP} = \frac{x}{R}$

$$\Rightarrow x = R\cos\theta$$

Again, $\sin\theta = \frac{AP}{OP} = \frac{OB}{OP} = \frac{y}{R}$

$$\Rightarrow y = R\sin\theta.$$

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

(d) A force of 100N is resolved into two equal components (say A) at 60° to each other.

$$R = \sqrt{A^2 + A^2 + 2AA\cos 60^0}$$

$$\Rightarrow (100N)^2 = 2A^2(1+\cos 60)$$

$$\Rightarrow 2A^2\left(1+\frac{1}{2}\right) = (100N)^2$$

$$\Rightarrow 3A^2 = (100N)^2$$

$$\Rightarrow A^2 = \frac{10000}{3} N^2$$

$$\Rightarrow A = \frac{100}{\sqrt{3}} N$$

The two equal components are, $\frac{100}{\sqrt{3}} N$ (Ans)

(e) $\vec{A} = 3\hat{i} + 2\hat{j} - \hat{k}$ $\Rightarrow A = \sqrt{3^2 + 2^2 + (-1)^2} = \sqrt{9+4+1} = \sqrt{14}$

$\vec{B} = 5\hat{i} + 2\hat{j} + 3\hat{k}$ $\Rightarrow B = \sqrt{5^2 + 2^2 + 3^2} = \sqrt{25+4+9} = \sqrt{28}$

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

$$\Rightarrow [3\times 5 + 2\times 2 + (-1)\times 3] = \sqrt{14}\,\sqrt{28}\cos\theta$$

$$\Rightarrow \cos\theta = \frac{8+4-3}{\sqrt{14}\,\sqrt{28}} = \frac{9}{14\sqrt{2}}$$

$$\Rightarrow \theta = \cos^{-1}\left(\frac{9}{14\sqrt{2}}\right) \quad \text{(Ans)}$$

(2) (f) Find the unit vector along $(\vec{A} \times \vec{B})$, if

$\vec{A} = 4\hat{i} + 3\hat{j} + 2\hat{k}$

& $\vec{B} = 5\hat{i} - 2\hat{j} + 3\hat{k}$

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

$$= \hat{i}(9+4) - \hat{j}(12-10) + \hat{k}(-8-15)$$

$$= 13\hat{i} - 2\hat{j} - 23\hat{k}$$

$$|\vec{A} \times \vec{B}| = \sqrt{13^2 + (-2)^2 + (-23)^2}$$

$$= \sqrt{702}$$

Unit vector along $(\vec{A} \times \vec{B})$ is ; $\dfrac{\vec{A} \times \vec{B}}{|\vec{A} \times \vec{B}|}$

$$= \frac{13\hat{i} - 2\hat{j} - 23\hat{k}}{\sqrt{702}} \text{ (Ans)}$$

Engg. Physics (Th2a) | Assignment - 3 (Unit-3 & 4) | Branch - CIVIL & ELECTRICAL
Date - 02/01/2023

① 2 Marks Questions →

(a) What is static friction?
(b) What is the condition for maximum horizontal range?
(c) What is Dynamic friction?
(d) Mention the relationship between (i) Linear & Angular velocity (ii) Linear & Angular acceleration.
(e) Define uniform circular motion.
(f) State two methods to reduce friction.
(g) What do you mean by Limiting friction?
(h) Define projectile and projectile motion.
(i) Write down the equations of Motion under gravity.

② 5 Marks Questions →

(a) State laws of Limiting friction.
(b) What are different methods of reducing friction.
(c) Define coefficient of friction. Derive relation between coefficient and angle of friction.
(d) Derive relationship between (i) Linear & Angular velocity (ii) Linear & Angular acceleration.
(e) A stone is thrown vertically upwards with an initial velocity 14 m/s. Find the maximum height reached, and the time of decent. $g = 9.8\ m/s^2$.

(3) 10 Marks Questions →

(a) Derive expressions for eqⁿ of trajectory, time of flight, maximum height and horizontal range of a projectile fired at an angle θ with the horizontal.

Sol^n to Assignment - 3
(Unit - 3 & 4)

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

Static friction is always equal to the applied force.

(b) Condition for maximum horizontal range :

Horizontal range is, $X = \frac{u^2 \sin 2\theta}{g}$

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

$$\sin 2\theta = 1 = \sin 90^\circ$$
$$2\theta = 90^\circ \text{ or } \theta = 45^\circ$$

$$\boxed{X_{max} = \frac{u^2}{g}}$$

(c) Dynamic friction is the force of friction which comes into play between two surfaces when there is some relative motion between them.

Dynamic friction is slightly less than limiting friction.

(d) Relation between; (i) Linear & Angular velocity

$v = r\omega$ (scalar form)

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

(ii) Linear & Angular acceleration

$a = r\alpha$ (scalar form)

$\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$ (vector form)

Here, $\vec{a}_T = \vec{\alpha} \times \vec{r}$ and $\vec{a}_r = \vec{\omega} \times \vec{v}$.

(D)(e) The motion of a body is said to be circular if it moves in such a way that it's distance from a certain fixed point known as center is always remains the same.

The circular motion is said to be uniform if the speed of the particle along the circular path remains constant.

(f) Methods to reduce friction:

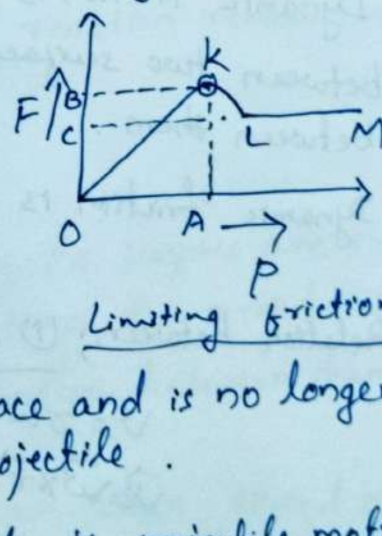
(i) By rubbing and polishing the surfaces friction can be reduced

(ii) By applying lubricants (oil or grease) the friction between surfaces can be reduced.

(g) Limiting friction is the maximum value of force of friction between two surfaces so long as there is no relative motion between them.

OA = OB = Limiting friction.

OC = Dynamic friction.



Limiting friction

(h) A body projected into the space and is no longer being propelled by fuel is called a projectile.

The motion of such projectile is projectile motion.

(i) Equations of Motion under gravity:

(i) $v = u + gt$

(ii) $S = ut + \frac{1}{2}gt^2$ $\quad (\forall a = g)$

(iii) $v^2 - u^2 = 2gS$

(2) (a) Laws of Limiting Friction :

(i) The direction of force of friction is always opposite to the direction of motion.

(ii) 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.

(iii) The magnitude of limiting friction 'F' is directly proportional to the magnitude of the normal reaction R between the two surfaces in contact, i.e, $F \propto R$

(iv) 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 are same.

(b) Methods of Reducing Friction :

(i) By rubbing, the irregularities of the surface are smoothened, thus avoiding the chance of getting the irregularities interlocked. This reduces the friction between them.

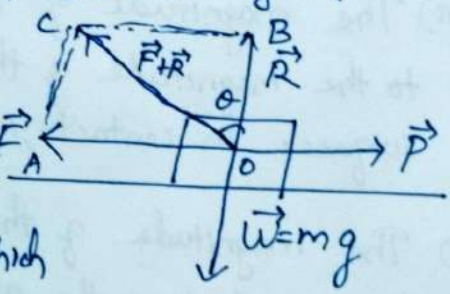
(ii) A lubricant is an oil or grease which when spread over the surfaces fills the irregularities and forms a thin layer between them, thus avoiding their interlockings. This reduces the friction between two surfaces.

(iii) By converting sliding into rolling friction by means of a system known as ball bearing system the friction can be reduced.

(iv) By streamlining :- As a body is driven through fluid, fluid friction depends upon the shape of body. It is minimum for a shape known as streamlined shape. Thus by streamlining we can reduce the friction.

2(c) 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'. It is denoted by 'μ'.

$$\boxed{\mu = \frac{F}{R}}$$



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

In ΔOBC, $\tan\theta = \frac{BC}{OB} = \frac{OA}{OB} = \frac{F}{R}$

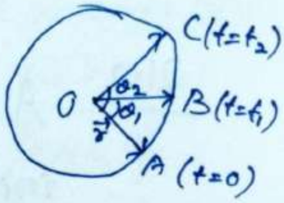
But $\frac{F}{R} = \mu$ (co-efficient of friction)

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

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

(2)(d)(i) Relation between Linear & Angular Velocity →

Let v = magnitude of linear velocity of the body



$$AB = vt_1 \quad \& \quad AB = r\theta_1$$

$$\Rightarrow v_1 t_1 = r\theta_1 \Rightarrow v = \frac{\theta_1}{t_1} \cdot r$$

$$\Rightarrow \boxed{v = r\omega} \quad \left[\because \omega = \frac{\theta_1}{t_1}\right)$$

Linear speed = radius × angular velocity

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

(ii) Relation between Linear & Angular Acceleration →

(a) Scalar form →

$$\alpha = \frac{\text{change in angular velocity}}{\text{change in Time}}$$

$$\Rightarrow \alpha = \frac{\omega_2 - \omega_1}{t_2 - t_1}$$

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

$$\Rightarrow \alpha = \frac{1}{r} \times \left(\frac{v_2 - v_1}{t_2 - t_1}\right) = \frac{a}{r} \quad \left(\because a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}\right)$$

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

Linear acceleration = Radius × Angular acceleration

(b) Vector form →

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

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

$$\Rightarrow \boxed{\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}} \quad \left(\because \vec{\alpha} = \frac{d\vec{\omega}}{dt} \ \& \ \vec{v} = \frac{d\vec{r}}{dt}\right)$$

$$\Rightarrow \boxed{\vec{a} = \vec{a_T} + \vec{a_r}} \quad \left(\because \vec{a_T} = \vec{\alpha} \times \vec{r} \ \& \ \vec{a_r} = \vec{\omega} \times \vec{v}\right)$$

2(e) A stone is thrown vertically upwards with an initial velocity 14 m/s.

i.e., $u = 14 \frac{m}{s}$ & $\boxed{g = 9.8\, m/s^2}$

At maximum height; $v = 0\, m/s$

Thus, $v = u - g t_a$ ($a = -g$ for upward motion)

$$\Rightarrow t_a = \frac{u-v}{g} = \frac{14\, m/s}{9.8\, m/s^2}$$

$$= 1.43\, s$$

Time of decent = t_d = time of ascent = t_a

$$\Rightarrow \boxed{t_d = t_a = 1.43\, s}$$

Maximum height reached;

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

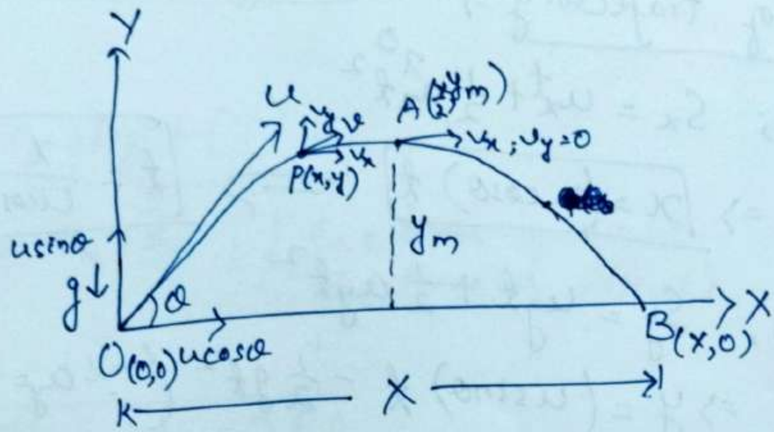
$$\Rightarrow u^2 - v^2 = 2gs$$

$$\Rightarrow s = \frac{u^2 - v^2}{2g} = \frac{14^2 - 0^2\, m^2/s^2}{2 \times 9.8\, m/s}$$

$$\Rightarrow \boxed{s = 10\, m}$$

Maximum height reached is 10 m (Ans)
& time of decent is 1.43 s

(3)(a) Consider a particle fired, with velocity u, at an angle θ with the horizontal. The projectile rises to the highest point A and falls back to B lying on the level of projection.



$\vec{u}$ can be resolved as $u_x = u\cos\theta$ & $u_y = u\sin\theta$, such that,

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

At any point $P(x,y)$ on path of the projectile;

$S_x = x$ & $S_y = y$

$v_x = u_x + a_x t$ & $v_y = u_y + a_y t$ [$\forall$ 't' is the time to reach at P]

$a_x = 0$ & $|\vec{a_y}| = g$

[$\because$ Horizontal acceleration for projectile $= 0$]

$\Rightarrow v_x = u_x = u\cos\theta$; i.e.,

the horizontal component of velocity remains constant.

& $v_y = u_y \pm gt$

$$= \begin{cases} u\sin\theta - g t_a & \text{(from O to A)} \\ +g t_d & \text{(from A to B)} \end{cases}$$

i.e., the vertical component of velocity decreases from 'O' to 'A' and the value of $v_y = 0$ at A and gradually increases from 0 to $u\sin\theta$ again from A to B.

(i) <u>Eq^n of trajectory</u> →

<u>At $P(x,y)$;</u> $S_x = u_x t + \frac{1}{2} a_x t^2$ ($a_x = 0$)

$\Rightarrow \boxed{x = (u\cos\theta)\, t} \Longrightarrow \boxed{t = \frac{x}{u\cos\theta}}$

Again, $S_y = u_y t + \frac{1}{2} a_y t^2$

$\Rightarrow y = (u\sin\theta)\, t - \frac{1}{2} g t^2$ ($\because a_y = -g$ between O to A)

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

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

This is the eq^n of trajectory for a projectile fired at an angle 'θ' with horizontal at initial speed 'u'.

(ii) <u>Maximum Height (y_m)</u> → It is the maximum distance travelled by the projectile in vertical direction.

At 'O', $u_y = u\sin\theta$

At 'A', $v_y = 0$

$a_y = -g$

$S_y = y_m$

$$v_y^2 - u_y^2 = 2a_y s_y$$

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

$$\Rightarrow -u^2\sin^2\theta = -2g\, y_m$$

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

(iii) Time of flight (T) :

$T = t_a + t_d$; [t_a = time of ascent, t_d = time of dessent)

$t_a = t_d$

$$\Rightarrow \boxed{T = 2t_a = 2t_d}$$

At A;
t = time of ascent (t_a)
$u_y = u\sin\theta$ & $v_y = 0$
$a_y = -g$

$$\Rightarrow v_y = u_y + a_y t \Rightarrow 0 = u\sin\theta - g t_a$$

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

Now, $T = 2t_a = \dfrac{2u\sin\theta}{g}$

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

(iv) Horizontal range (X) :- It is the distance travelled by the projectile in the horizontal direction.

At B; $S_x = X$, $t = T$

$u_x = u\cos\theta$; $a_x = 0$

$$S_x = u_x t + \frac{1}{2}\cancel{a_x}^{0} t^2$$

$$\Rightarrow X = (u\cos\theta)T = u\cos\theta \times \frac{2u\sin\theta}{g}$$

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

Condition for maximum horizontal range :-

Range will be maximum if "$\sin 2\theta$" is maximum, ie, one.

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

$$2\theta = 90^\circ \text{ or } \boxed{\theta = 45^\circ}$$

$$\boxed{X_{max} = \frac{u^2}{g}}$$

=0=

(Engg. Physics IH 2a) Assignment - 4 (Unit - 5 & 6) Brach - CIVIL & Electrical Date - 12/01/2023

(1) 2 Marks Questions →

(i) What are Ultrasonics?
(ii) State Newton's law of gravitation.
(iii) Write down two applications of Ultrasonics.
(iv) The gravitational force between two objects is F. If masses of both the objects are halved without altering the distance between them, then what will be the change in gravitational force?
(v) Define weight. Write down its unit.
(vi) What is the relation between wavelength and frequency of a wave?
(vii) Define Universal Gravitational Constant (G).
(viii) Define Simple Harmonic Motion (SHM).

(2) 5 Marks Questions →

(i) State and explain Kepler's laws of Planetary motion.
(ii) Compare longitudinal waves with transverse waves.
(iii) Explain the variation of acceleration due to gravity (g) with (a) Altitude, (b) Depth.
(iv) Distinguish between mass and weight.
(v) Discuss properties of ultrasonics.
(vi) State and explain Newton's laws of gravitation.
(vii) Derive a relation between g & G.

(3) 10 Marks Questions →

(i) Find expressions for displacement, velocity and acceleration of a particle executing SHM.

(1) (a) Sound of frequency greater than the upper limit of audible range (generally 20,000 cs^{-1}) is termed as ultrasonics.

Ultrasonic wave may have a range from 2×10^4 to $10^9 cs^{-1}$.

(b) 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 inversely as the square of the distance between them.

Mathematically, $\boxed{F = G\frac{M_1 M_2}{R^2}}$

(c) Two applications of Ultrasonics :

(i) Thickness gauging → The process of echo sounding can also be used to measure the thickness of rolled sheets in rolling mills.

(ii) Fuel gauging → Ultrasonics have also been employed to make an idea about the fuel present in rockets.

(d) The gravitational force between two objects is F.

The masses of both the objects are halved without altering the distance between them.

$$F = G\frac{M_1 M_2}{R^2}$$

Now, $M_1' = \frac{M_1}{2}$ & $M_2' = \frac{M_2}{2}$ & $R' = R$

$$F' = G\frac{M_1'M_2'}{(R')^2} = G\frac{\frac{M_1}{2}\times\frac{M_2}{2}}{R^2}$$

$$= \frac{1}{4}G\frac{M_1M_2}{R^2} = \frac{F}{4}$$

Therefore, the gravitational force will become one forth of F, i.e, $\frac{F}{4}$.

(e) Weight is defined as the force with which the body is attracted to earth.

Mathematically, Weight = Mass x accl^n due to gravity

$$\Rightarrow \boxed{W = mg}.$$

Its unit is kgf or kgwt or N.

(f) Relation between wavelength and frequency of a wave :

The velocity of a wave is given as :

$$\text{velocity} = \frac{\text{wavelength}}{\text{Time period}} = \text{wavelength} \times \text{frequency}$$

$$\Rightarrow v = \lambda \times \nu \quad \text{or} \quad \lambda = \frac{v}{\nu}$$

Where, v = velocity of wave
λ = wavelength of wave
ν = frequency of wave

(g) From Newton's law of Gravitation,

$$F = G \frac{M_1 M_2}{R^2}$$

Let, $M_1 = M_2 = 1$ unit & $R = 1$ unit

$\Rightarrow F = G$ or $\boxed{G = F}$

Hence, the Universal Gravitational Constant (G) may be defined as the gravitational force between two bodies of unit masses separated by a distance of 1 unit.

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

Mathematically, $\boxed{F = -ky}$ — ①

where, k = force constant
y = displacement from mean position.

Again, $F = m \frac{d^2y}{dt^2} = -ky$

$$\Rightarrow \boxed{\frac{d^2y}{dt^2} = -\frac{k}{m} y} \quad \text{— ②}$$

The above eq^n-② is called differential equation of S.H.M.

(2)(a) Kepler's Laws of Planetary Motion ⇒

(i) Law of elliptical orbits → A planet moves around the sun in an elliptical orbit with sun situated at one of its foci.

(ii) 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)

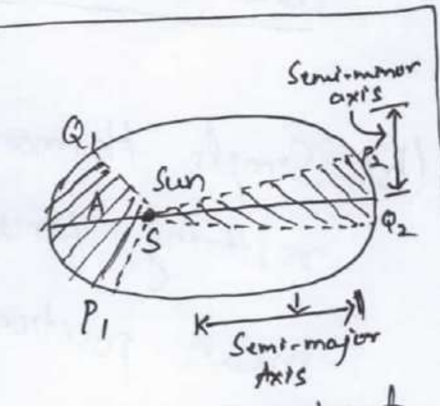


Fig. 1 : Rotation of a planet around the sun

Let 't' be the time taken by the planet to go from P_1 to Q_1 so that the line SP_1 traverses an area P_1SQ_1 (Fig. 1). While going from P_2 to Q_2, the planet moves in such a way that

$$\boxed{\text{Area } P_2SQ_2 = \text{Area } P_1SQ_1}$$

(iii) Law of Time periods → "The Harmonic Laws"

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

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

(2)(b) Transverse wave	Longitudinal wave
(1) Vibrations of the particles of medium are normal to the direction of wave propagation.	(1) Vibrations of the particles are parallel to the direction of propagation of wave.
(2) Crests and throughs are formed during its propagation.	(2) Compression 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) Medium through which such a wave travels possesses shear modulus and inertia.	(4) Medium through which such wave travels possesses compressibility & inertia.
(5) It travels through solids & shallow pool of liquid but not through gases.	(5) It travels through solid, liquid and gas.

(c)(i) Variation of acceleration due to gravity (g) with altitude.

Consider a body of mass 'm' placed on the surface of the earth (Fig. 1(a)). Let M & R denote the mass and radius respectively of the earth. Let 'g' be the value of acceleration due to gravity on the free surface of earth.

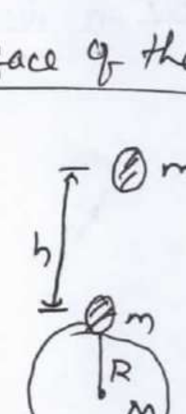


Fig 1.1(a) Effect of altitude on 'g'.

Then, $g = \frac{GM}{R^2}$ ——

At height 'h', let the value of accl^n due to gravity at this height be g'.

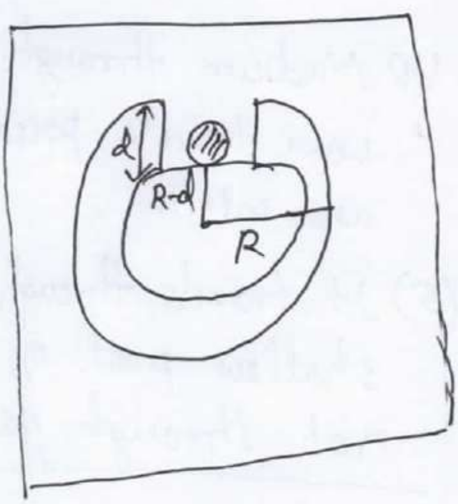
$$g' = \frac{GM}{(R+h)^2}$$ ——

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

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

for $h << R$.

(ii) Variation of 'g' with depth



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

Mass = volume × density

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

$$\boxed{g = \frac{4}{3}\pi G R \rho}$$

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

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

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

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

Eqn (A) & (B) represents the variation of 'g' with altitude & depth respectively.

(d) Mass	Weight
(1) Mass is defined as the amount of substance contained in the body.	(1) Weight is defined as the gravitational force on body due to earth.
(2) Mass is a fundamental quantity.	(2) Weight is a derived quantity.
(3) SI Unit of Mass is kg.	(3) SI Unit of ~~Mass~~ Weight is, N or kgwt or kgf.
(4) Dimensional formula is, $[M^1L^0T^0]$	(4) Dimensional formula is, $[MLT^{-1}]$
(5) Mass is fixed throughout the universe.	(5) Weight varies from place to place in universe.

(e) Properties of Ultrasonics :-

(i) Ultrasonics are longitudenal in nature.

(ii) Propagation of Ultrasonics results in formation of compression and rarefaction through the medium

(iii) These are waves of very high frequency having a range of 2×10^4 to 10^9 Hertz.

(iv) They travel with the speed of sound.

(v) Ultrasonics are highly energetic waves.

(vi) Due to their much smaller wavelength, ultrasonics do not spread that much as audible sound waves do.

(vii) Passage of ultrasonics through a liquid results in a variation of density. Such liquids can be used as diffraction grating.

(f) Newton's law of Gravitation →

"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 inversely as the square of the distance between them".

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

Consider two bodies of masses m_1 & m_2 as shown in fig1. Let r be the distance between their centres. Let F be the magnitude of the force of attraction $\vec{F}$ between them.

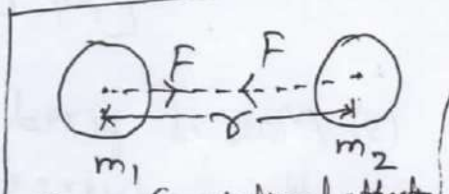


Fig.-1 → Gravitational attraction betn two bodies

According to the law of gravitation,

(i) $F \propto m_1 m_2$

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

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

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

where G = Universal gravitational constant.

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

From eq^n -(1) ; $F = G\frac{1\times1}{1^2} = G$

or $\boxed{G = F}$

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

(g) Relation between 'g' & 'G' ->

Fig. Attraction due to earth

Force between earth and a body near it is called gravity.
The acceleration produced by gravity is called acceleration due to gravity and is denoted by 'g'.

Force with which the body is attracted towards earth is called weight.

Therefore, $F = mg$ —— (1)

From newton's law of gravitation, we have,

$$F = G\frac{Mm}{R^2} \text{ —— (2)}$$

where, G = Universal gravitational constant (G)

M = Mass of earth

m = Mass of the body

R = Radius of earth.

From eq^n (1) & (2), we have,

$$mg = G\frac{Mm}{R^2}$$

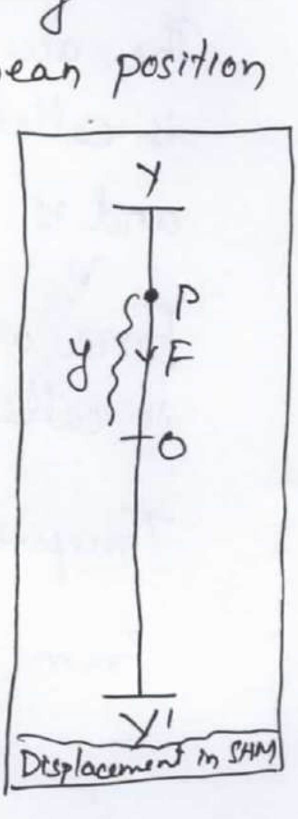
$$\Rightarrow \boxed{g = G\frac{M}{R^2}} \quad \text{---} (3)$$

The above eq^n (3) represents the relation bet^n 'g' & 'G'.

(3) (i) Displacement of a particle executing SHM

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

Mathematically, $F = -ky$ —— (1)



Displacement in SHM

Acceleration 'a' of a body, vibrating in SHM is given by

$$a = \frac{d^2y}{dt^2}$$

Therefore, restoring force F acting on the body is,

$$F = m \times a = m\frac{d^2y}{dt^2} \quad \text{---} (2)$$

From eq^n ① & ②;

$$m\frac{d^2y}{dt^2} = -ky$$

$$\Rightarrow \frac{d^2y}{dt^2} = -\frac{k}{m}y \quad \text{③}$$

Eq^n (3) is called differential eq^n of SHM.

The solution of differential eq^n of SHM is,

$$\boxed{y = r\sin(\omega t + \phi)} \quad \text{Ⓐ}$$

Here, r = Amplitude of SHM

ω = Angular velocity $= \sqrt{\frac{k}{m}}$

ϕ = phase angle.

"Displacement of a particle vibrating in SHM, at any instant, is defined as its distance from the mean position at that instant."

(ii) Velocity of a particle executing SHM

SHM can be represented as a projection of uniform circular motion.

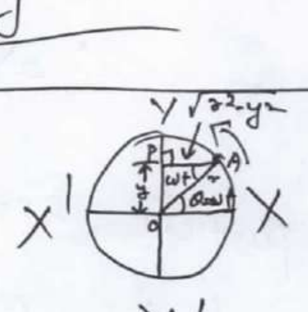


Fig. SHM as projection of uniform circular motion.

Let, v = linear velocity of particle A

V = Velocity of particle executing SHM at point P

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

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

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

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

$\Rightarrow \boxed{V = \omega \sqrt{r^2 - y^2}}$ —— (B)

Eqⁿ (B) gives the velocity of a particle executing SHM at pt. 'P'.

At mean position; $y = 0$

$\Rightarrow V = \omega r = v$ (Max^m velocity)

At extreme positions, $y = \pm r$

$\Rightarrow V = 0$

A particle executing SHM, passes with max^m velocity through the mean position and is at rest at the extreme positions.

(iii) Acceleration of a particle executing SHM

Acceleration 'a' is given as,

$$a = \frac{dv}{dt} = \frac{d}{dt}(r\omega\cos\omega t) = -r\omega^2 \sin\omega t$$

$$= -(\omega^2) \cdot r\sin\omega t$$

$$\Rightarrow \boxed{a = -\omega^2 y} \quad \text{(c)}$$

At mean position; $y = 0$

$$\Rightarrow a = 0$$

At extreme position; $y = \pm r$

$$\Rightarrow a = \pm\omega^2 r \quad (\text{Max}^m \text{ acceleration})$$

A particle executing SHM; has zero acceleration while passing through mean position and has maximum acceleration while at extreme positions.

Th 2a- Engg. Physics

Assignment-5
(Unit-7&8)

Date-05/02/2023

(1) 2 Mark Questions →

(a) Define Specific Heat.
(b) State laws of reflection.
(c) Write down the SI unit & Dimension of Specific Heat.
(d) What are the conditions for minimum deviation when a ray of light passes through a prism?
(e) Express 1 Joule into erg.
(f) Define Joule's mechanical equivalent of heat.
(g) State any two differences between heat and temperature.
(h) Define Critical angle.
(i) What is Refractive Index? state its unit.
(j) What is Fiber Optics?
(k) Define Latent Heat.
(l) Write down two applications of optical fibre.
(m) State laws of refraction.
(n) Write two properties of optical fibre.

(2) 5 Mark Questions →

(a) Define critical angle and total internal reflection with a diagram.
(b) How much heat is needed to convert 0.005 kg of ice at 0°C to water at 10°C?
(c) Draw the full page ray diagram of Refraction through glass prism.

[P.T.O.]

(2)
(d) State and explain 1st law of Thermodynamics.

(e) A 500 gm cube of lead is heated from 25°C to 75°C. How much energy was required to heat the lead? Sp. Heat of lead is 0.129 J/(g.°C).

(f) Establish the relationship between refractive index and critical angle of a medium.

3) 10 Mark questions →

(a) Calculate the total amount of heat required to convert 2.5 kg of ice from −30°C to a steam at 200°C.

(b) Establish the relation between α, β & γ. A copper wire has a length of 2m at 0°C. Find its length at 100°C. Given, $\alpha = 1.7 \times 10^{-5}$ °C^{-1}.

(c) How much heat is required to convert 10 gm of ice at −5°C to steam at 100°C?

(d) How much steam at 100°C will melt 3.2 kg of ice at −10°C? Given that the specific heat capacity of ice = 0.5 kcal kg^{-1} °C^{-1}, Sp. latent heat of steam = 540 kcal kg^{-1}, Specific latent heat of ice = 80 kcal kg^{-1}.

Th2a. Engg. Physics

Assignment - 5
(Unit-7 & 8)

(1) (a) Specific heat of a substance is defined as the amount of heat required to raise the temperature of a unit mass of substance through $1^\circ C$ without changing its state.
Mathematically, $Q = ms\Delta\theta$

(b) Laws of reflection :-
(i) The incident ray, the reflected ray and the normal to the interface at the point of incidence all lie in one plane.
(ii) The angle of incidence (i) = the angle of reflection (r)

(c) We have, $Q = ms\Delta t$
$\Rightarrow s = \dfrac{Q}{m\Delta t}$

SI unit of Specific heat is, Cal $kg^{-1}\,{}^\circ C^{-1}$

The Dimensional formula is, $[S] = \left[\dfrac{Q}{m\Delta t}\right] = \left[\dfrac{ML^2T^{-2}}{M\,K}\right]$
$= [M^0L^2T^{-2}K^{-1}]$

Dimensions of specific heat are; 0 in M, 2 in L, -2 in T and -1 in temp. (K)

(d) For minimum deviation when a ray of light passes through a prism;
(i) $\angle r_1 = \angle r_2 = \angle r = \dfrac{A}{2}$
(ii) $\angle i = \angle e$
(iii) The ray of light passes symmetrically through prism and is parallel to the base of the prism.

(e) 1 Joule = $\underline{10^7}$ erg.
Dimension of Joule, $[M^1L^2T^{-2}]$

$$1 \text{ Joule} = 1 \text{ kg} \times 1 \text{ m}^2 \times 1 \text{ s}^{-2}$$
$$= 1000 \text{ gm} \times 100^2 \text{ cm}^2 \times 1 \text{ s}^{-1}$$
$$= 10^7 (\text{gm} \times \text{cm}^2 \times \text{s}^{-1})$$
$$= 10^7 \text{ erg}$$

(f) <u>Joule's mechanical equivalent of heat</u>

If an amount of work 'W' results in the production of an amount 'H' of heat

$$W \propto H$$
$$\Rightarrow W = JH$$

Where, J = Joule's mechanical equivalent of heat

If $H = 1$, $W = J$

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

$$J = \frac{W}{H} = 4.2 \text{ J cal}^{-1}$$

(g)

Heat	Temperature
(1) Heat is a form of energy.	(1) Temperature is the measure of heat energy.
(2) It is a derived physical quantity.	(2) It is a fundamental physical quantity.
(3) SI Unit is calorie (cal)	(3) SI unit is kelvin (K)
(4) Dimensional formula: $[M^1L^2T^{-2}]$	(4) D.F. : $[K^1]$

(h) 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°.

Mathematically, $^{1}\mu_2 = \frac{1}{\sin C}$

(i) Refractive index of a medium is a characteristic of medium which determines its behaviour to propagation of light. It is a measure of the optical density of the medium. Refractive index is a constant and hence unitless.

(j) Fiber optics refers to the technology that transmits information as light pulses along a glass or plastic fiber.

(k) Latent heat is defined as the amount of heat or energy absorbed or released during change of phase (physical state) that occurs without changing its temperature.

(l) Applications of optical fibre →

(i) Used for data transmission in high-level data security fields of military.

(ii) Used for imaging in hard to reach places in automobiles.

(iii) Used to transmit high-definition television signals in broadcasting.

(m) Laws of refraction →

(i) The incident ray, the refracted ray and the normal to the interface at the point of incidence all lie in the single plane and it is perpendicular to the interface

(ii) Snell's law →

The sine of the angle of incidence bears a constant ratio with sine of angle of refraction.

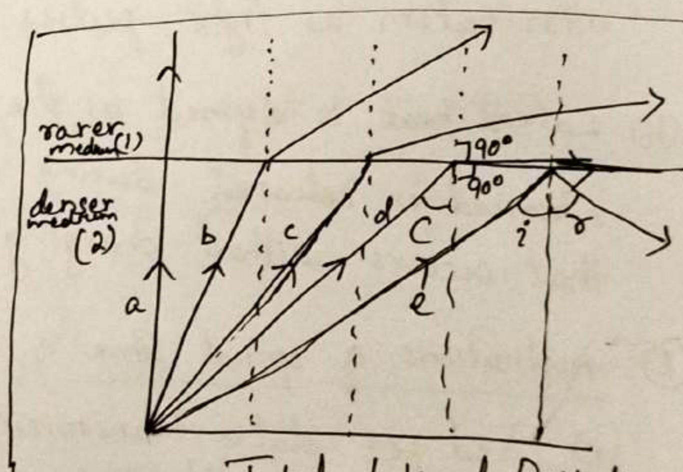
i.e., $\frac{\sin i}{\sin r}$ = constant

(n) Properties of Optical fibre →

(i) It permits data communication at higher speed and at a higher bandwidth (data rates)

(ii) It is a flexible but extremely thin transparent strand of very pure glass. It acts as an waveguide.

(2) (a) 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°.



Total Internal Reflection

If 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.

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

(b) 0.005 kg of ice at $0°C \xrightarrow{H_1}$ water at $0°C$

$\xrightarrow{H_2}$ water at $10°C$

Total heat $H = H_1 + H_2$

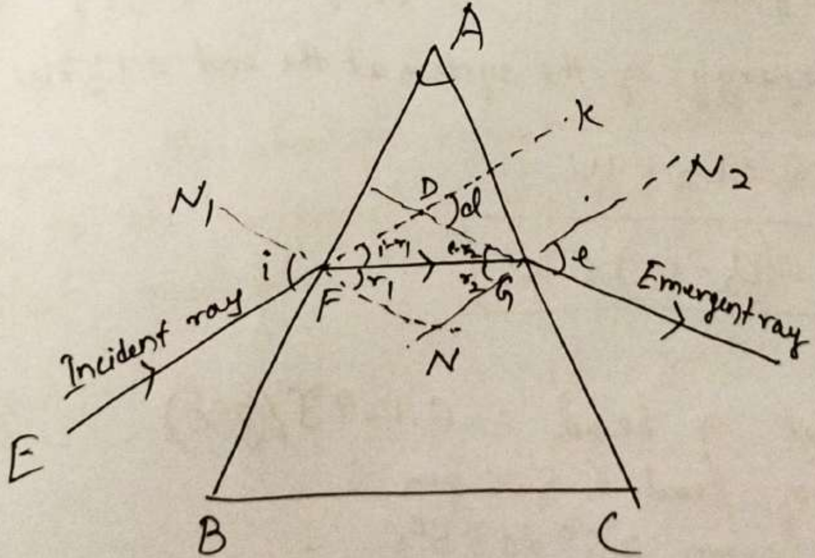
$$H_1 = mL_f = 0.005\ kg \times 80\ cal\ gm^{-1}$$
$$= 5\ gm \times 80\ cal/gm$$
$$= 400\ cal$$

$$H_2 = ms\Delta\theta = 0.005\ kg \times 1\ cal\ gm^{-1}\,°C^{-1} \times 10°C$$
$$= 5 \times 1 \times 10\ cal$$
$$= 50\ cal.$$

Total heat, $H = 450$ cal

Therefore, 450 cal of heat is needed to convert 0.005 kg of ice at $0°C$ to water at $10°C$.

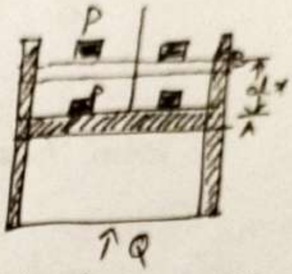
(c)



Refraction through a prism

(d) <u>First law of Thermodynamics</u> →

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



Heating of a gas at constant pressure

Mathematically, $\boxed{dQ = dU + dW}$

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.

If 'U_1' is the initial energy of the system,

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

After gaining heat the gas tends to expand, pushing the piston from A to B.

If 'U_2' is final internal energy of the system,

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

$\Rightarrow U_1 + Q = U_2 + W$

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

(e) Sp. heat of lead $= 0.129\ J/(g°C)$

mass of lead $= 500\ gm$

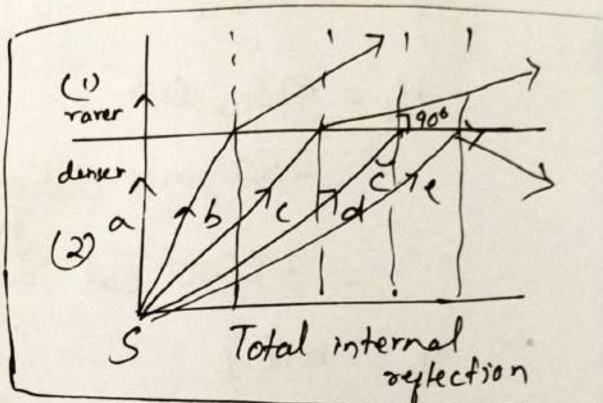
heated from $25°$ to $75°C$.

$\Rightarrow Q = ms\Delta\theta = 500\ gm \times 0.129\ J\ g^{-1}\ °C^{-1} \times 50°C$

$= 3225\ J = 3.225\ kJ$

Therefore, 3.225 kJ heat energy required to heat the 500gm lead from 25°C to 75°C

(b) Consider refraction of ray 'd'. Since, the ray goes from medium 2 to medium 1.



$$^2\mu_1 = \frac{\sin c}{\sin 90^0} = \frac{\sin c}{1} = \sin c$$

$$\rightarrow \ ^1\mu_2 = \frac{1}{^2\mu_1} = \frac{1}{\sin c}$$

In case, the first medium is air or vacuum.

$$^1\mu_2 = \mu$$

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

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

(3) (a) 2.5 kg of ice at −30°C
$\downarrow H1$
" ice at 0° C
$\downarrow H2$
" water at 0° C
$\downarrow H3$
" water at 100°C
$\downarrow H4$
steam at 100°C
$\downarrow H5$
2.5kg of steam at 200°C

$$\boxed{H = H_1 + H_2 + H_3 + H_4 + H_5}$$

We know; $S_{water} = 1\ cal/(gm\,°c)$

$S_{ice} = 0.5\ cal/(gm°c) = S_{steam}$

$L_f = 80\ cal/gm$; $L_v = 540\ cal/gm$

$H_1 = m S_{ice} \Delta\theta$

$= 2500gm \times 0.5 \frac{cal}{gm°c} \times 30°C$

$= 37500\ cal = 37.5\ kcal$

$H_2 = m L_f$

$= 2500gm \times 80\ cal/gm$

$= 200000\ cal = 200\ kcal$

$H_3 = m S_{water} \Delta\theta$

$= 2500\ gm \times \frac{1\ cal}{gm°c} \times 100°C$

$= 250000\ cal = 250\ kcal$

$H_4 = m L_v = 2500 gm \times 540 \frac{cal}{gm}$

$= 1350000\ cal = 1350\ kcal$

$H_5 = m S_{steam} \Delta\theta = 2500 gm \times 0.5 \frac{cal}{gm°c} \times 100°c$

$= 125000\ cal = 125\ kcal$

Now, $H = H_1 + H_2 + H_3 + H_4 + H_5$

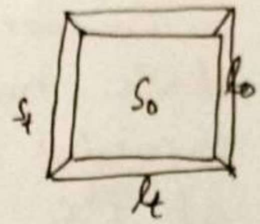
$= 37.5kcal + 200kcal + 250kcal + 1350kcal + 125kcal$

$= 1962.5\ kcal$

Therefore, 1962.5kcal of heat required to convert 2.5 kg of ice from $-30°C$ to a steam at $200°c$

(b) Relation between α, β & γ

(i) Relation between α & β :-



Consider a square of length l_0 & area S_0 at $0^\circ C$.
It is heated through $t^\circ C$ so that the expanded length is l_t and area is S_t at $t^\circ C$.

We have, $l_t = l_0(1+\alpha t)$ — (1)

$S_t = S_0(1+\beta t)$ — (2)

where, α = Coefficient of linear expansion
β = Coefficient of cubical expansion

As, $S_0 = l_0^2$ & $S_t = l_t^2$, from eqn-(2),

$$S_t = S_0(1+\beta t)$$

$$\Rightarrow l_t^2 = l_0^2(1+\beta t)$$

$$\Rightarrow [l_0(1+\alpha t)]^2 = l_0^2(1+\beta t) \quad \text{[from eq}^n\text{-(1)]}$$

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

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

As α is small (of the order 10^{-5}); α^2 can be neglected.

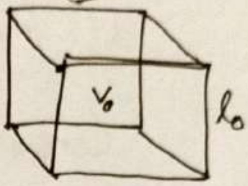
$$\Rightarrow 2\alpha t = \beta t$$

$$\Rightarrow \boxed{\beta = 2\alpha} \text{ — (A)}$$

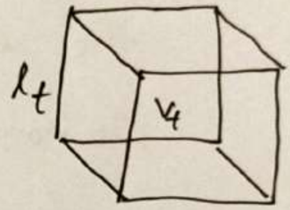
$$\text{or } \boxed{\alpha = \frac{\beta}{2}} \text{ —}$$

(iii) Relation between α & γ :

(0°C)



(t°C)



Consider a cube of length l_0 & volume V_0 at 0°C, heated through t°C such that the expanded length be l_t and volume be V_t at t°C.

We have; $l_t = l_0(1+\alpha t)$ — (1)

$V_t = V_0(1+\gamma t)$ — (2)

As, $l_t^3 = V_t$ & $l_0^3 = V_0$, from eqn (2);

$$l_t^3 = l_0^3(1+\gamma t)$$

$$\Rightarrow [l_0(1+\alpha t)]^3 = l_0^3(1+\gamma t) \quad [\text{from eq}^n (1)]$$

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

$$\Rightarrow \cancel{1}+\cancel{\alpha^3 t^3}+3\alpha t+\cancel{3\alpha^2 t^2} = \cancel{1}+\gamma t$$

As α is small ; α^2 & α^3 can be neglected.

$$\Rightarrow 3\alpha t = \gamma t$$

$$\Rightarrow \boxed{\gamma = 3\alpha} \text{ — (B)}$$

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

From eqn (A) & (B) ;

$$\boxed{\alpha = \frac{\beta}{2} = \frac{\gamma}{3}} \text{ or } \boxed{6\alpha = 3\beta = 2\gamma}$$

The above is the relation between α, β & γ.

3(b) A copper wire has a length of 2m at 0°C.

$\alpha = 1.7 \times 10^{-5} /°C$

$l_t = l_0(1+\alpha t)$

$= 2m(1+1.7\times10^{-5}\times100)$

$= 2m(1+1.7\times10^{-3})$

$= 2m(1+0.0017)$

$= 2m \times 1.0017$

$= 2.0034\,m$

Hence, Length of copper wire at 100°C is 2.0034 m.

(c) 10gm of ice at $-5°C$

$\downarrow H_1$

" ice at 0°C

$\downarrow H_2$

" water at 0°C

$\downarrow H_3$

" water at 100°C

$\downarrow H_4$

" steam at 100°C

$S_{water} = 1 \frac{cal}{gm°C}$

$S_{ice} = 0.5 \frac{cal}{gm°C}$

$S_{steam} = 0.5 \frac{cal}{gm°C}$

$L_f = 80 \frac{cal}{gm}$

$L_v = 540 \frac{cal}{gm}$

$\Rightarrow H = H_1 + H_2 + H_3 + H_4$

Now, $H_1 = m S_{ice} \Delta\theta = 10gm \times 0.5 \frac{cal}{gm°C} \times 5°C$

or $\boxed{H_1 = 25\,cal}$ —

$H_2 = mL_f = 10gm \times 80 \frac{cal}{gm} = 800\,cal$ —

or $\boxed{H_2 = 800 \text{ cal}}$

$H_3 = m s_{water} \Delta\theta$

$= 10 \text{ gm} \times 1 \frac{\text{cal}}{\text{gm}^\circ\text{C}} \times 100^\circ\text{C}$

or $\boxed{H_3 = 1000 \text{ cal}}$

$H_4 = m L_v$

$= 10 \text{ gm} \times 540 \frac{\text{cal}}{\text{gm}}$

or $\boxed{H_4 = 5400 \text{ cal}}$

$H = H_1 + H_2 + H_3 + H_4$

$= 25 \text{ cal} + 800 \text{ cal} + 1000 \text{ cal} + 5400 \text{ cal}$

$= 7225 \text{ cal} = 7.225 \text{ kcal}$

Hence 7.225 kcal heat is required to convert 10gm of ice at $-5^\circ C$ to steam at $100^\circ C$.

(d) Let, Energy required to melt 3.2kg of ice at $-10^\circ C = H_{abs}$

Energy released from x kg of steam $= H_{rel}$

We have, $\boxed{H_{abs} = H_{rel}}$

Now, 3.2 kg of ice at $-10^\circ C$

$\downarrow H_1$

ice at $0^\circ C$

$\downarrow H_2$

water at $0^\circ C$

$\boxed{H_{abs} = H_1 + H_2}$

Similarly: x kg of steam at $100°C$

$$\downarrow -H_3$$

" water at $100°C$

$$\downarrow -H_4$$

" water at $0°C$

$$\boxed{H_{rel} = H_3 + H_4}$$

$$H_1 = m S_{ice} \Delta\theta = 3.2\,kg \times 0.5 \frac{kcal}{kg°C} \times 10°C$$

$$= 16\ kcal$$

$$H_2 = mL_f = 3.2\,kg \times 80 \frac{kcal}{kg}$$

$$= 256\ kcal$$

$$\Rightarrow \boxed{H_{abs} = 272\ kcal}$$

$$H_3 = mL_v = x\,kg \times 540 \frac{kcal}{kg} = (540x)\,kcal$$

$$H_4 = m S_{steam} \Delta\theta$$

$$= x\,kg \times 0.5 \frac{kcal}{kg°C} \times 100°C$$

$$= (50x)\,kcal$$

$$\Rightarrow \boxed{H_{rel} = (590x)\ kcal}$$

Now, $272\,kcal = (590x)\,kcal$

$$\Rightarrow x = 0.46$$

Therefore, 0.46 kg of steam at 100°C will melt 3.2 kg of ice at -10°C.

(Th.2a Engg Physics) Assignment-6 (Unit-9&10)

(1) 2 Marks Questions →

(a) Define Magnetic Flux Density.

(b) Mention the value of relative permittivity of free space.

(c) Define Unit pole.

(d) Find the equivalent Capacitance if a 2μF capacitor is connected parallel to a 0.5 μF capacitor.

(e) Define Unit charge.

(f) When three capacitors each of 7mF are connected in parallel then find the resultant capacity?

(g) Two capacitors of capacitances C_1 and C_2 are connected in parallel. If a charge Q is given to the assembly the charge gets shared. What is the ratio of the charge on the capacitor C_1 to the charge on the capacitor C_2?

(h) If two capacitors with capacities 2 farad & 3 farad are connected in series connection then, find out the total capacity.

(i) Under what conditions does Ohm's law hold good?

(2) 5 Marks Questions →

(a) The total capacitance of 02 capacitors is 2μF when connected in series and 9μF when connected in parallel. Find out the capacitance of each other.

(b) State & explain (i) KCL, (ii) KVL.

(c) State & explain Coulomb's law in Magnetism.

[P.T.O]

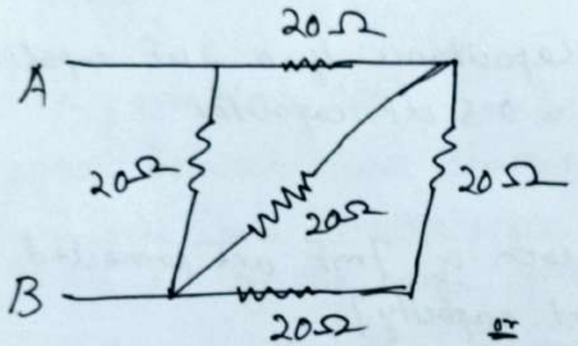
(d) State the properties of magnetic lines of force

(e) State and explain Coulomb's law of electrostatic.

(3) 10 Marks Questions →

(a)(i) State Kirchhoff's laws [4]

(ii) Find the equivalent resistances between A & B [6]



or

(iii) Derive the condition of balance in a Wheatstone Bridge. [6]

(1)

(a) Magnetic flux density (B), 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.

(b) Relative permitivity (ε_r) can be defined as the ratio of the force between two charges separated by some distance apart in free space to the force between the same two charges separated by the same distance apart in that medium.

Mathematically, $\varepsilon_r = \frac{\varepsilon_{medium}}{\varepsilon_0} = \frac{F_{medium}}{F_{vacuum}}$

$\therefore$ Relative permitivity (ε_r) of free space is, 1.

(c) From Coulomb's law of magnetism,

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

$\frac{\mu_0}{4\pi} = 10^{-7}\, WbA^{-1}m^{-1}$

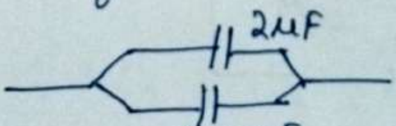
If $F = 10^{-7} N$, $m_1 = m_2 = m$ & $r = 1$,

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

$\Rightarrow m^2 = 1$ or $m = \pm 1$ (unit pole)

A unit pole, in SI 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.

(d)



For parallel connection,

$$C_{eq} = C_1 + C_2 = (2 + 0.5)\ \mu F = 2.5\ \mu F$$

$\therefore$ Equivalent Capacitance $= 2.5\ \mu F$ (Ans)

(e) According to Coulomb's law,

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

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9\ Nm^2C^{-2}$$

Now, if $q_1 = q_2 = q$, $r = 1m$ & $F = 9\times10^9$ newton, then

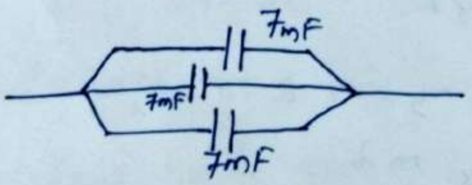
$$9\times10^9 = 9\times10^9 \frac{q^2}{1}$$

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

$$\Rightarrow q^2 = 1 \text{ or } q = \pm 1 \text{ coulomb}$$

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

(f)

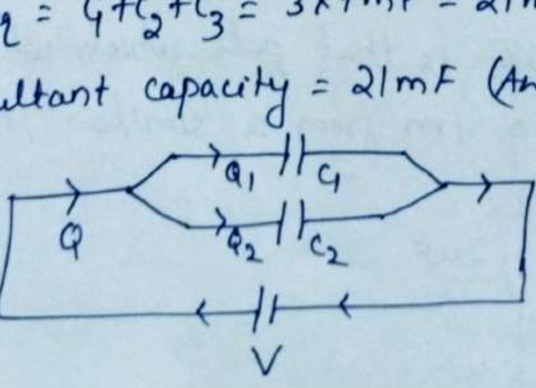


For parallel connection,

$$C_{eq} = C_1 + C_2 + C_3 = 3\times 7mF = 21mF$$

$\therefore$ Resultant capacity $= 21mF$ (Ans)

(g)



Mathematically, $C = \frac{Q}{V}$

$$C_1 = \frac{Q_1}{V} \text{ \& } C_2 = \frac{Q_2}{V}$$

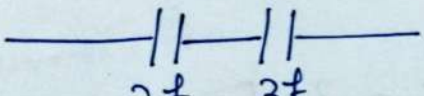
and $Q = Q_1 + Q_2$

$\Rightarrow CV = C_1 V + C_2 V$

$\Rightarrow \boxed{C = C_1 + C_2}$

$\boxed{\frac{Q_1}{Q_2} = \frac{C_1}{C_2}}$ (Ans)

(h)



According to series connection;

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

$\Rightarrow C = \frac{C_1 C_2}{C_1 + C_2} = \frac{2 \times 3}{2+3} f = \frac{6}{5} f = 1.2$ farad

Total capacity $= 1.2$ farad (Ans)

(i) Ohm's law holds good under condition that temperature and other physical conditions ~~must~~ must remain constant.

(2) (a) $\frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C_{eq}}$ (series)

$\Rightarrow C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 2\mu F$ —— (1)

For parallel, $C_1 + C_2 = C_{eq} = 9\mu F$ —— (2)

$$C_1 C_2 = 18\,(\mu F)^2$$

$$C_1 - C_2 = \sqrt{(C_1+C_2)^2 - 4C_1C_2}$$

$$= \sqrt{81 - 72}$$

$$\Rightarrow C_1 - C_2 = 3\,\mu F$$

$$(C_1+C_2) + (C_1 - C_2) = 9\,\mu F + 3\,\mu F$$

$$\Rightarrow 2C_1 = 12\,\mu F$$

$$\Rightarrow C_1 = 6\,\mu F$$

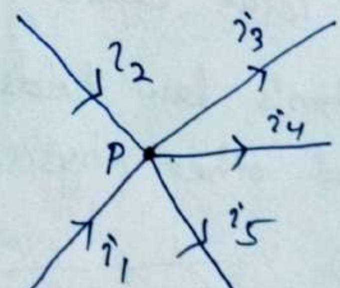
$$C_2 = C_1 - 3\,\mu F = 3\,\mu F$$

$\therefore$ $C_1 = 6\,\mu F$ and $C_2 = 3\,\mu F$ (Ans)

(b) Kirchhoff's Current Law (KCL)

It states that the algebraic sum of currents meeting at a point is zero.

Consider a number of wires connected at a point P. Currents i_1, i_2, i_3, i_4 & i_5 flow through these wires in the directions shown in the figure.



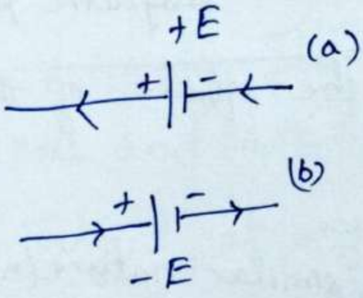
Currents meeting at a point

According to Kirchhoff's law of current (KCL)

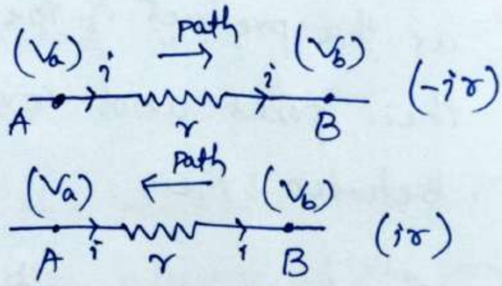
$$i_1 + i_2 - i_3 - i_4 - i_5 = 0 \Rightarrow \boxed{\sum i = 0}$$

Kirchhoff's Voltage Law (KVL) →

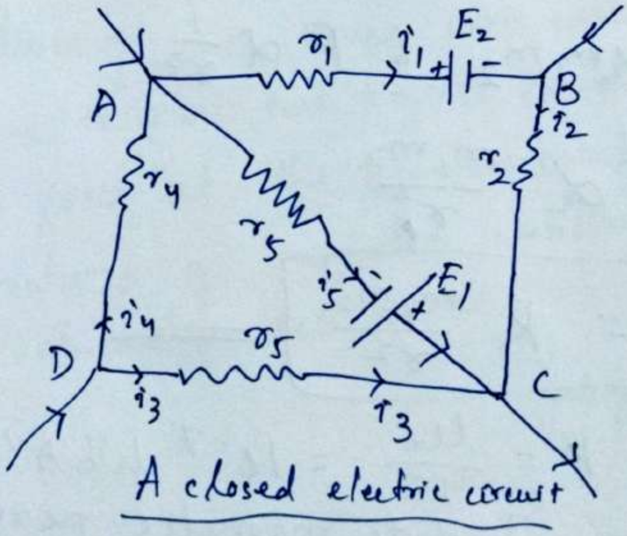
It states that, in a closed electric circuit, the algebraic sum of e.m.f. is equal to the algebraic sum of the products of the resistances and the currents flowing through them.



Sign convention for source of e.m.f.



Sign convention for 'ir'



A closed electric circuit

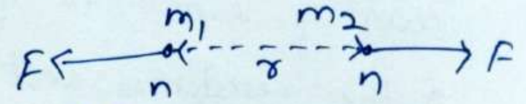
For ABC; $i_1 r_1 + i_2 r_2 - i_5 r_5 = E_1 - E_2$

For ACD; $i_5 r_5 - i_3 r_3 - i_4 r_4 = E_1$

$$\Rightarrow \boxed{\Sigma ir = \Sigma E}$$

(c) Coulomb's law in Magnetism:

The magnitude of the force between two magnetic poles (supposed isolated) varies directly as the product of the strengths their poles and inversely as the square of the distance between them.



(Force between two magnetic poles)

Consider two magnetic poles of similar nature (n) of strengths m_1 & m_2 separated a distance 'r' from each other (figure). The force (of repulsion) between them.

$$F \propto m_1 m_2 \quad \& \quad F \propto \frac{1}{r^2}$$

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

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

In SI; $K = \frac{\mu_0}{4\pi} = 10^{-7}\ Wb\,A^{-1}m^{-1}$

μ_0 = absolute magnetic permeability.

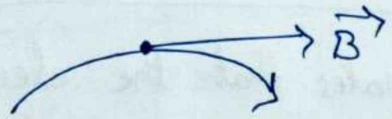
$$\Rightarrow \boxed{F = \frac{\mu_0}{4\pi} \times \frac{m_1 m_2}{r^2}}$$

(d) 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 ->

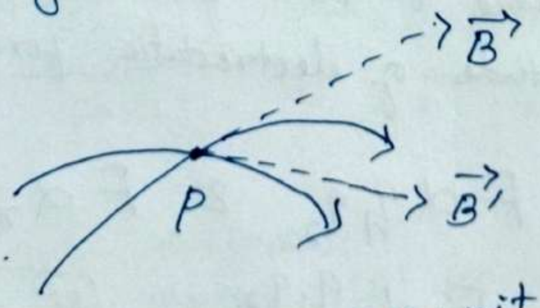
(i) Lines of force are directed away from a north pole and are directed towards a south pole.

(ii) Tangent, at any point, to the magnetic lines of force gives the direction of magnetic intensity at the point.



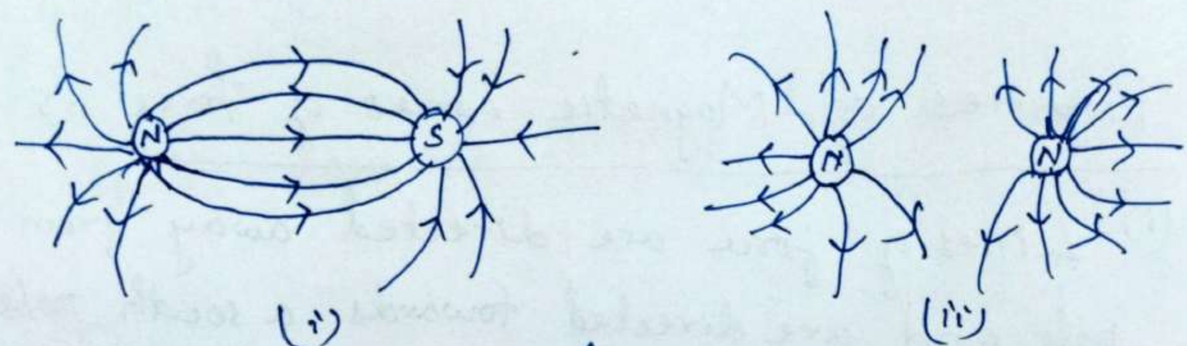
Direction of Magnetic intensity at a point

(iii) Two lines of force never cross each other. If the two lines were to cross, two tangents could be drawn to the lines of force at the common point meaning thereby two directions of magnetic intensity at that point, which is obviously not possible.



(iv) The number of lines of force per unit area (area being perpendicular to lines) is proportional to magnitude of strength of field (magnetic intensity) at that point.

Thus, more concentration of lines represents stronger magnetic field.

(c) 

Magnetic lines of force

(2) Coulomb's law in Electrostatics :-

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

Suppose two point charges q_1 & q_2 are situated at a distance 'r' from each other in some medium (let vacuum). The magnitude of electrostatic force F is ;

$$F \propto q_1 q_2 \quad \& \quad F \propto \frac{1}{r^2}$$

where, ε_0 = permittivity of free space (vacuum)

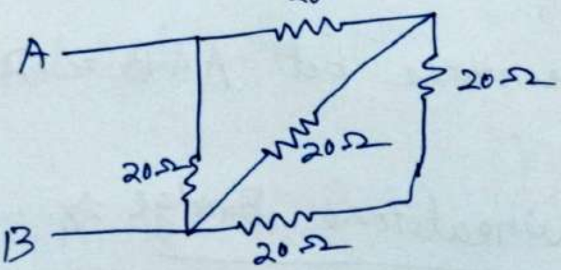
$= 8.854 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

$$\Rightarrow \boxed{\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}\ N m^2 C^{-2}}$$

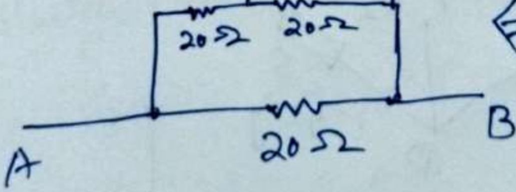
Coulomb's law is strictly true for point charges only.

(3) (a) (i) Answer of question number 2(b).

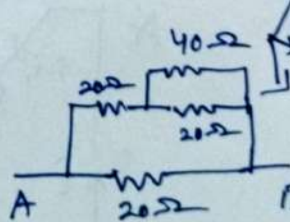
(ii)



$\Updownarrow$



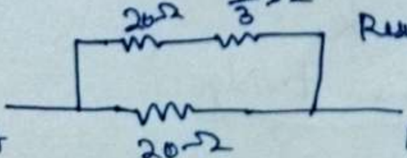
$\Leftrightarrow$



(20Ω & 20Ω) are in series

Resultant $= 20\Omega + 20\Omega = 40\Omega$

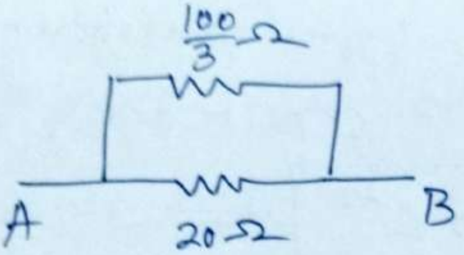
$\Leftrightarrow$



20Ω // 40Ω

Resultant $= \frac{20 \times 40}{20+40} = \frac{800}{60} = \frac{40}{3}\Omega$

$\Leftrightarrow$



20Ω & $\frac{40}{3}\Omega$ are in series

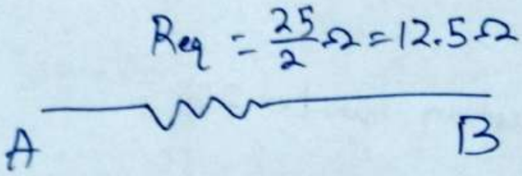
Resultant $= 20 + \frac{40}{3} = \frac{100}{3}\Omega$

$\frac{100}{3}\Omega \parallel 20\Omega \Rightarrow$ Resultant $= \dfrac{20 \times \frac{100}{3}}{20 + \frac{100}{3}}$

$= \dfrac{2000}{160} = \dfrac{25}{2}\Omega$

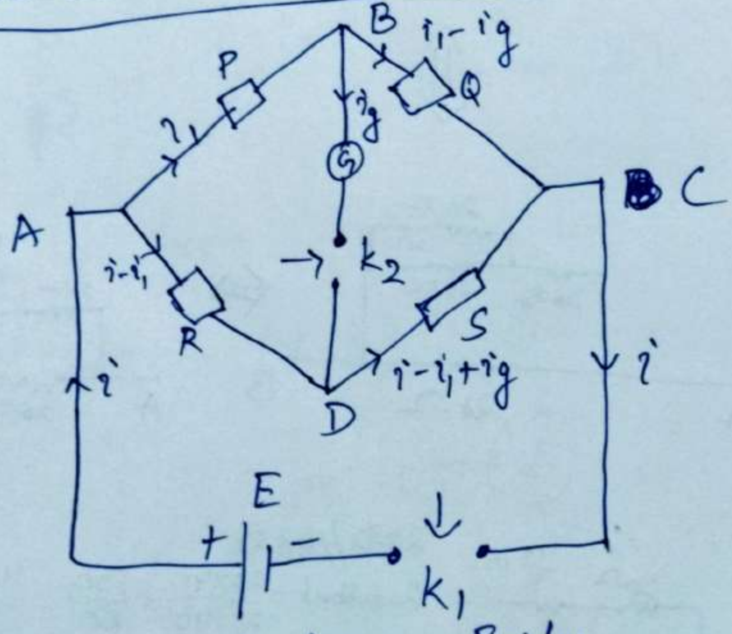
$= 12.5\Omega$

$\Leftrightarrow$



$\therefore$ Equivalence resistance bet A & B $= 12.5\Omega$

(iii) Balanced Wheatstone Bridge $\Rightarrow$



Wheatstone Bridge

The wheatstone bridge is said to be balanced (11)
if P, Q, R & S are so adjusted that the galvanometer shows no deflection.

Applying KVL to mesh ABD,

$$i_1 P + i_g G - (i - i_1) R = 0 \quad \text{---} (1)$$

Similarly applying KVL to mesh BCD,

$$(i_1 - i_g) Q - (i - i_1 + i_g) S - i_g G = 0 \quad \text{---} (2)$$

For balanced wheatstone bridge ; $i_g = 0$.

$$\Rightarrow i_1 P - (i - i_1) R = 0 \quad [\text{from eq}^n \text{ (1)}]$$

$$\Rightarrow \frac{P}{R} = \frac{i - i_1}{i_1} \quad \text{---} (3)$$

Simillarly from eq^n (2);

$$i_1 Q - (i - i_1) S = 0$$

$$\Rightarrow \frac{Q}{S} = \frac{i - i_1}{i_1} \quad \text{---} (4)$$

From eq^n (3) & (4) we have,

$$\boxed{\frac{P}{R} = \frac{Q}{S}}$$

or, $$\boxed{\frac{P}{Q} = \frac{R}{S}}$$

This is the required condition for the bridge to be balanced and gives the principle of Wheatstone bridge.

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