CTEVT, DIPLOMA, QUESTION & SOLUTION

⇐ **SECOND EDITION** ⇒

Engineering Physics-I

(for Diploma I Yrs. I Part)

First Semester

(Engineering All)

By

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S.No	Exam Year,	Month
1.	2076	Falgun Regular/Back
2.	2078	Bharda Regular/Back
3.	2079	Ashad Regular (2021 New)
4.	2080	Baishakh Back (Old)
5.	2080	Baishakh Regular (2021 New)
6.	2080/81	Chaitra Regular (2021 New)

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Engineering Physic I__(Engg. All) 1st Sem

(2076) Question Paper Solution.

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1) State and prove principle of conservation of linear momention.

➢ The principle of conservation of linear momentum states that, "If no external force act the initial momentum on a colliding system of bodies is equal to the final momentum".

Verification of the principle from the laws of motion

Let two bodies 'A' and 'B' of masses m_1 and m_2 moving in a same straight path from opposite directions collided.

If initial velocities before collision are u_1 and u_2, suppose after collision they move in same directions with the velocities v_1 and v_2. Therefore,

Initial momentum of A $= m_1 u_1$

Final momentum of A $= m_1 v_1$

Initial momentum of B $= m_2(-u_2) = -m_2 u_2$

Final momentum of B $= m_2 v_2$

$\therefore$ Change in momentum of A $= m_1 v_1 - m_1 u_1$

Change in momentum of B $= m_2 v_2 - (-m_2 u_2)$

$= m_2 v_2 + m_2 u_2$

According to the third law of motion, the force exerted by 'A' on 'B' is equal and opposite to the reaction exerted by 'B' on 'A'. Again, the time 't' during which the force acted on 'B' is equal to the time for which the reaction acted on A. Hence, impulse $F \cdot t$ on 'B' is equal and opposite to the magnitude of the impulse $R \cdot t$ on 'A'.

$$i.e., \quad F \cdot t = -R \cdot t \quad \cdots\cdots\cdots\cdots \quad (i)$$

From Newton's second law of motion; we have,

$$F \cdot t = \text{Change in momentum}$$

For particle A;

$$-R \cdot t = -(m_1 v_1 - m_1 u_1) = m_1 u_1 - m_1 v_1$$

Similarly, For particle B

$$F \cdot t = m_2 v_2 + m_2 u_2$$

Substituting the values of $R \cdot t$ and $F \cdot t$ in equation (i); we get,

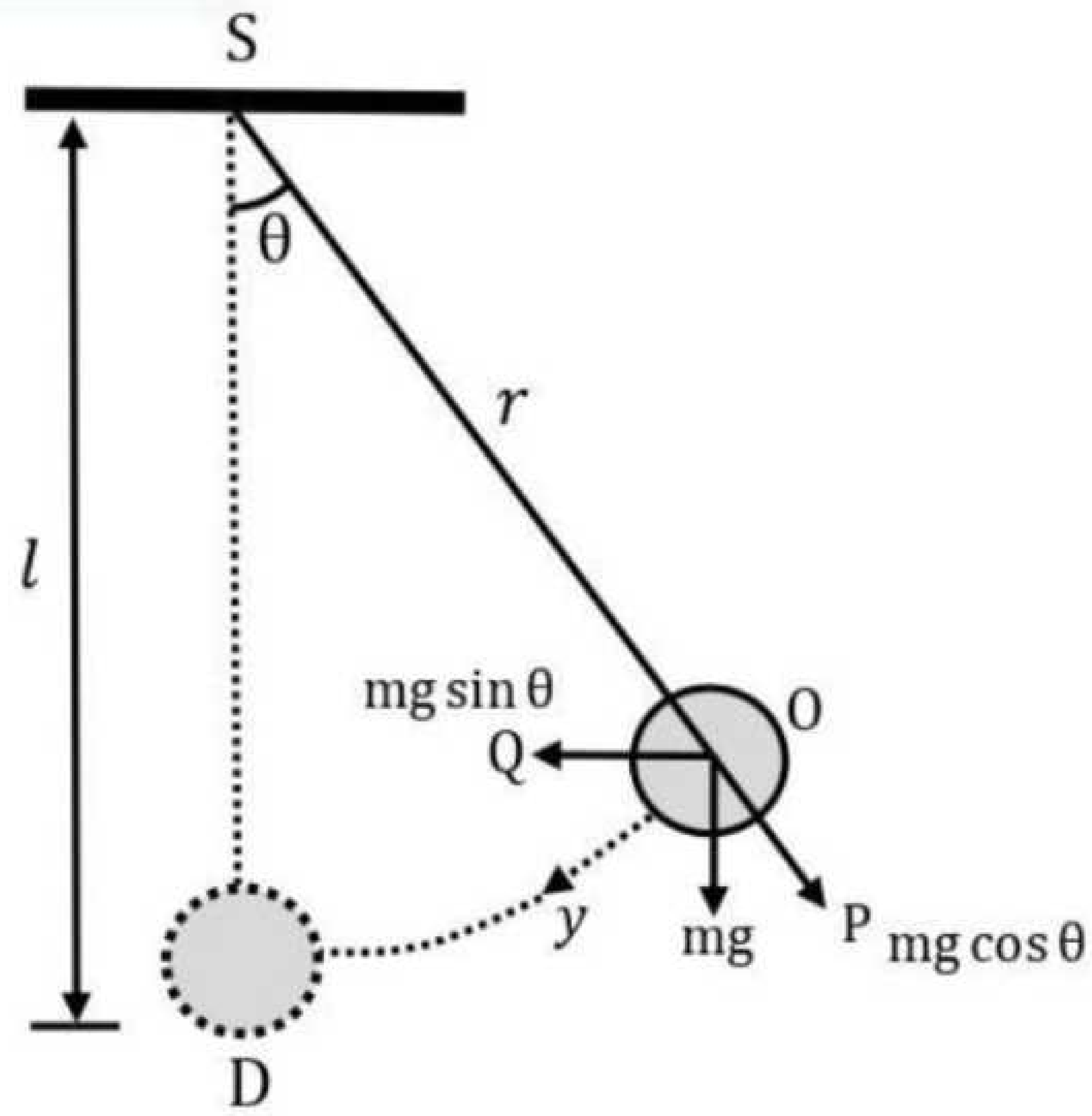
$$m_1 u_1 - m_1 v_1 = m_2 v_2 + m_2 u_2$$
$$m_1 u_1 - m_2 u_2 = m_1 v_1 + m_2 v_2$$

i.e., Total initial momentum = Total final momentum

This is according to the principle of conservation of linear momentum. Hence, principle is verified and followed according to laws of motion.

2) What is simple pendulum? Show that the motion of simple pendulum is simple harmonic and hence find its time period.

- A heavy bob suspended from a light, extensible and string forms a simple pendulum. When pendulum bob is taken to one side and let free it moves to and fro. Let the angle made by the string with vertical is less than 4° then the motion of the pendulum will be in simple harmonic motion It can be shown as follow.



Suppose the bob is displaced making an angle θ from its mean position to 'O' and released. Then, weight (mg) acts vertically downwards as shown.

Resolving mg into two components mg sin θ along OQ and mg cos θ along OP. The component mg cos θ balances the tension 'T' in the string and mg sin θ provides necessary forces to return bob to its mean or original position.

$\therefore$ Force acting on the bob $= -\,mg\sin\theta$

or, $ma = -mg\sin\theta$

$\therefore \quad a = -g\sin\theta$

When θ is very small then sin θ ≈ θ

$$\therefore \quad a = -\frac{a}{g} \qquad \cdots\cdots\cdots\cdots \ (i)$$

Also,

$$\theta = \frac{\text{Arc OD}}{l} = \frac{y}{l}$$

Substituting the value of θ in the equation (*i*); we get,

$$a = -g\frac{y}{l} \qquad \cdots\cdots\cdots\cdots \ (ii)$$

Since, $\frac{g}{l}$ is constant quantity, hence,

$$\mathbf{a \propto -\,y}$$

i.e., the acceleration 'a' is directly proportional to the displacement 'y'. –ve sign indicate directed toward mean position. Hence, motion of simple pendulum must be in S.H.M.

Time period

For a particle in S. H. M the acceleration $'a'$ is;

$$a = -\omega^2 y \quad \cdots\cdots\cdots\cdots \quad (iii)$$

Now, comparing equations (ii) and (iii); we get

$$\omega^2 = \frac{g}{l}$$

$$\therefore \ \omega = \sqrt{\frac{g}{l}}$$

Again, time period $'T'$ for particle is S. H. M. is given by;

$$T = \frac{2\pi}{\omega}$$

$$\therefore \ \text{Time period (T)} = 2\pi\sqrt{\frac{l}{g}}$$

This is the required reaction for the time period of simple pendulum.

3) Define minimum deviation produced by prism. Hence derive the relation $\mu = \dfrac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\frac{A}{2}}$.

- **Minimum deviation to a prism**

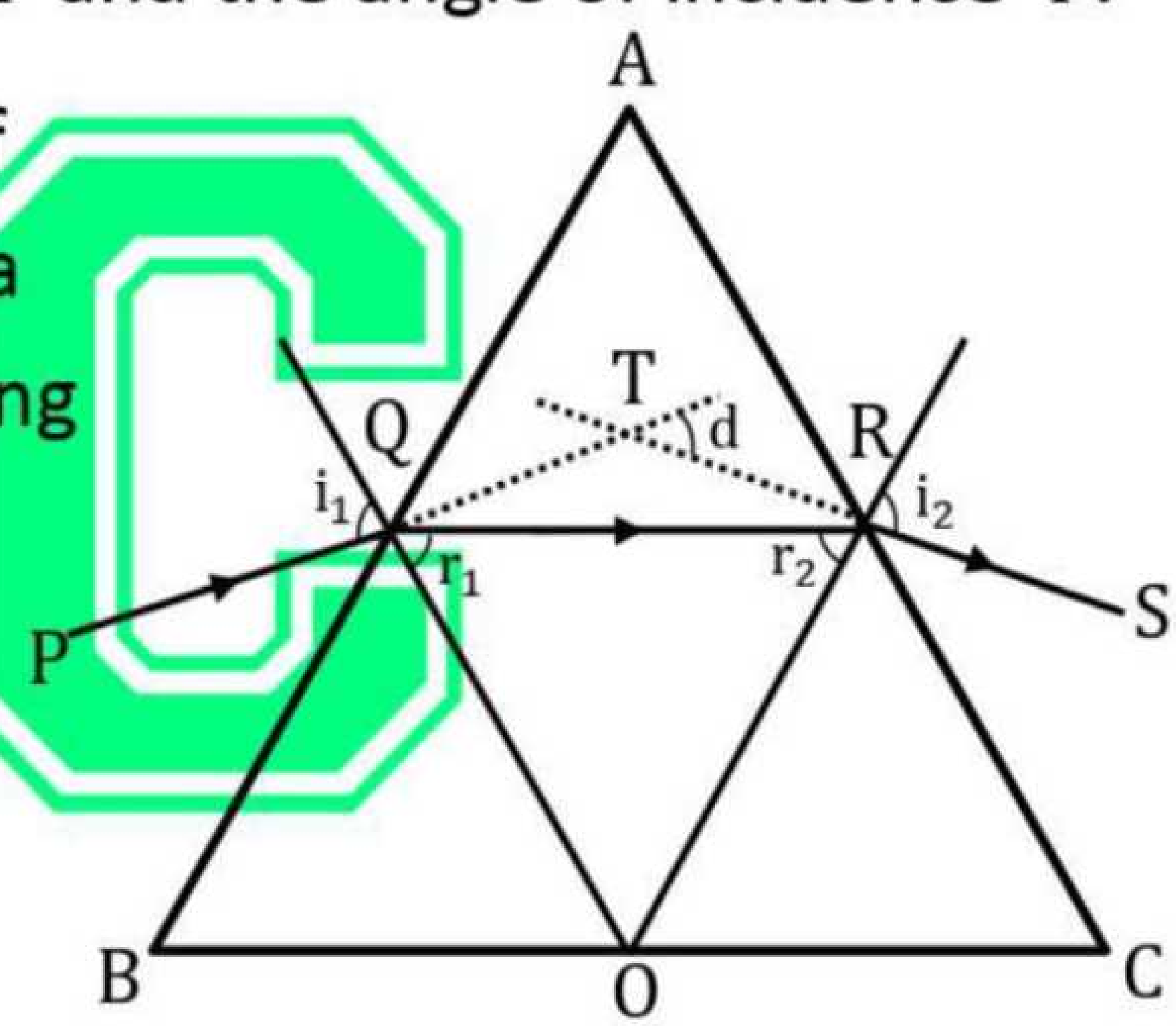
When light ray is made to strike on a prism then ray of light will emerges out as shown in the figure. The angle between incident ray and the emergent ray produces is the angle of deviation. It is represented by the letter 'δ'. The deviation from a prism depends on the angles of incidence and emergence. For a prism there is a stationary value for minimum deviation. The deviation becomes minimum when the light ray traverses prism symmetrically. In this condition the angles of incidence and emergence are equal and the angle of deviation produced by a prism becomes minimum and is called angle of minimum deviation. The relation between the minimum deviation δ_m, the angle of the prism 'i', and the refractive index 'μ' is given by**;**

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

➢ Expression for minimum deviation

When light ray passes through a refracting surface of prism the light ray is deviated. The amount of deviation produced by the prism depends upon the angle of prism 'A', the refractive index 'n' and the angle of incidence 'i'.

Suppose ABC is the section of a prism of material having refractive index 'μ'. Let a ray of light PQ is incident on the refracting face AB of the prism at point 'Q'. According to the law of refraction, it will refract along QR again suffers refraction at point 'R' on the second refracting surface AC and emerges out from the prism along RS. Produce SR to meet PQ in point 'T' then PQ , QR and RS will be incident ray, refracted ray and emergent ray respectively.



From quadrilateral ARO and AQR; we have,

$\measuredangle AQO + \measuredangle ARO = 180° \cdots\cdots\cdots (\boldsymbol{i})$

and, $\measuredangle AQR + \measuredangle QAR + \measuredangle ARQ = 180° \cdots\cdots\cdots (\boldsymbol{ii})$

Subtracting equation $(\boldsymbol{ii})$ from $(\boldsymbol{i})$; we get;

$$(\measuredangle AQO - \measuredangle AQR + (\measuredangle ARO - \measuredangle ARQ) - \measuredangle QAR = 0$$

or, $\measuredangle OQR + \measuredangle OAQ = \measuredangle QAR$

or, $r_1 + r_2 = A$ ………………… (iii)

But, $d = x + x' = (i_1 - r_1) + (i_2 - r_2)$

$= i_1 + i_2 - (r_1 + r_2)$

$= i_1 + i_2 - A$ ………… (iv)

But, for deviation 'd' to be minimum,

$i_1 = i_2$ *and* $r_1 = r_2$

Hence, from equation (iii), putting $r_1 = r_2 = r$; we get,

$A = 2r$

or, $r = \frac{A}{2}$

Again, from equation (iv); We get,

$2i = \delta_m + A$ **[taking $\delta = \delta_m$ for minimum deviation]**

or, $i = \frac{\delta_m + A}{2}$

∴ Refractive index $(\mu) = \frac{\sin i}{\sin r}$

$$\therefore \quad \mu = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}$$

This is the required expression.

4) Prove $\alpha = \beta/_2 = \gamma/_3$, where symbols have their usual meanings.

Coefficient of linear expansion

- It is defined as the increase in length per unit length per unit degree rise in temperature of the substance. It is represented by the symbol α and the unit is $°C^{-1}$ or K^{-1}.

i.e., $$\alpha = \frac{\text{Increase in length}}{\text{Original length} \times \text{Rise in temperature}} = \frac{l_t - l_0}{l_0(t - t_0)}$$

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

Coefficient of superficial expansion

- It is defined as the increase in area per unit area per unit degree rise in temperature of the substance. It is represented by the symbol **β** and the unit of β is $°C^{-1}$ or K^{-1}.

i.e., $$\beta = \frac{\text{Increase in area}}{\text{Original area} \times \text{Rise in temperature}} = \frac{A_t - A_0}{A_0(t - t_0)}$$

$$A_t = A_0(1 + \beta t)$$

Coefficient of cubic expansion

- The increase in volume per unit original volume per unit degree rise in temperature of the substance is called Coefficient of cubic expansion. It is represented by the symbol **γ** and the unit is $°C^{-1}$ or K^{-1}.

i.e., $$\gamma = \frac{\text{Increase in volume}}{\text{Original volume} \times \text{Rise in temperature}} = \frac{V_t - V_0}{V_0(t - t_0)}$$

$$V_t = V_0(1 + \gamma t)$$

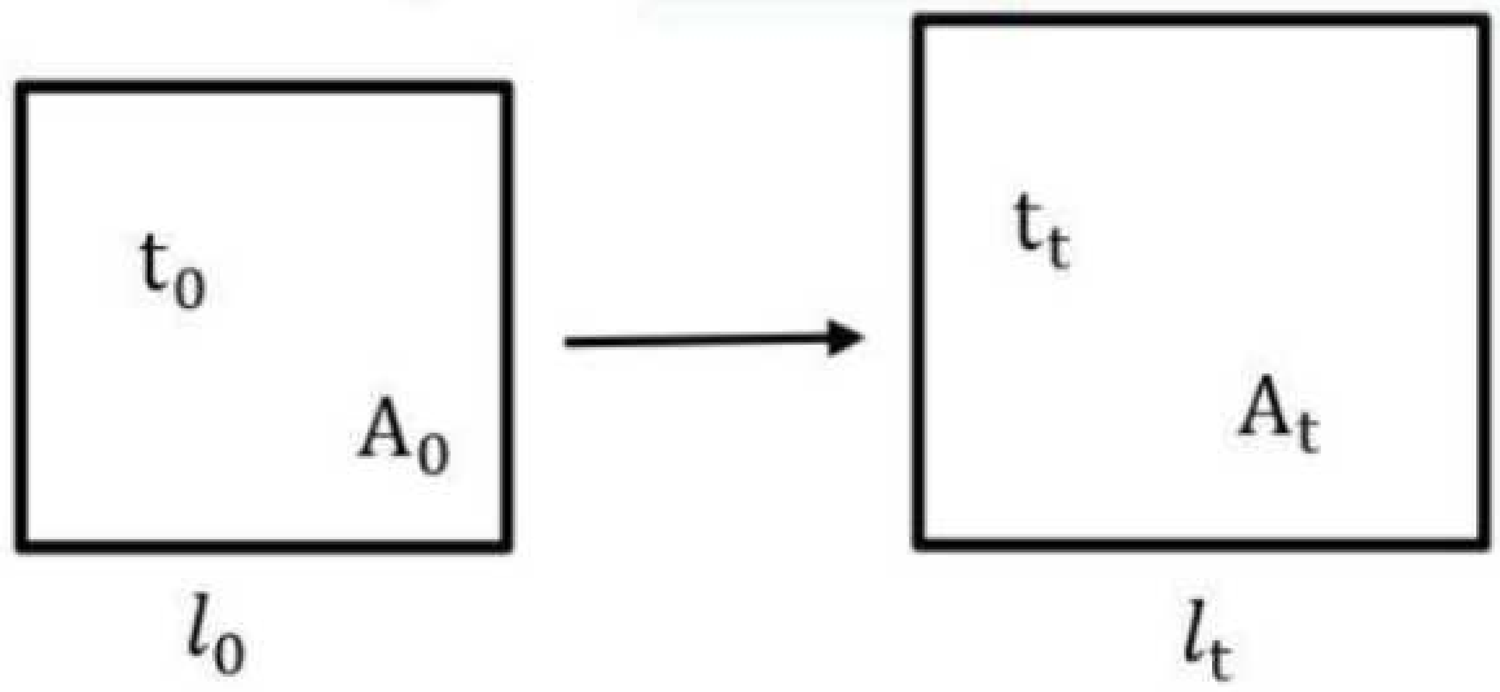
Relation between α and β

- Consider a square having sides l_0 at 0°C. Let the sides of the square increases to l_t when the temperature increases to t°C. Then, we get,

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

Also,

Area of square at 0°C $(A_0) = l_0^2$



and, Area of square at t°C (A_t) $= l_t^2 = l_0^2\,(1+\ \alpha t)^2 = A_0(1+2\alpha t+\alpha^2 t^2)$

Since, the value of α is very small, so, $\alpha^2 t^2$ will be very small. Thus, the terms containing $\alpha^2 t^2$ is neglected.

$$\therefore A_t = A_0\,(1+2\alpha t) \qquad \cdots\cdots\cdots (i)$$

But, from definition of the coefficient of superficial expansion; we have,

$$\therefore A_t = A_0\,(1+\beta t) \qquad \cdots\cdots\cdots (ii)$$

Comparing the relation (*i*) and (*ii*); we get,

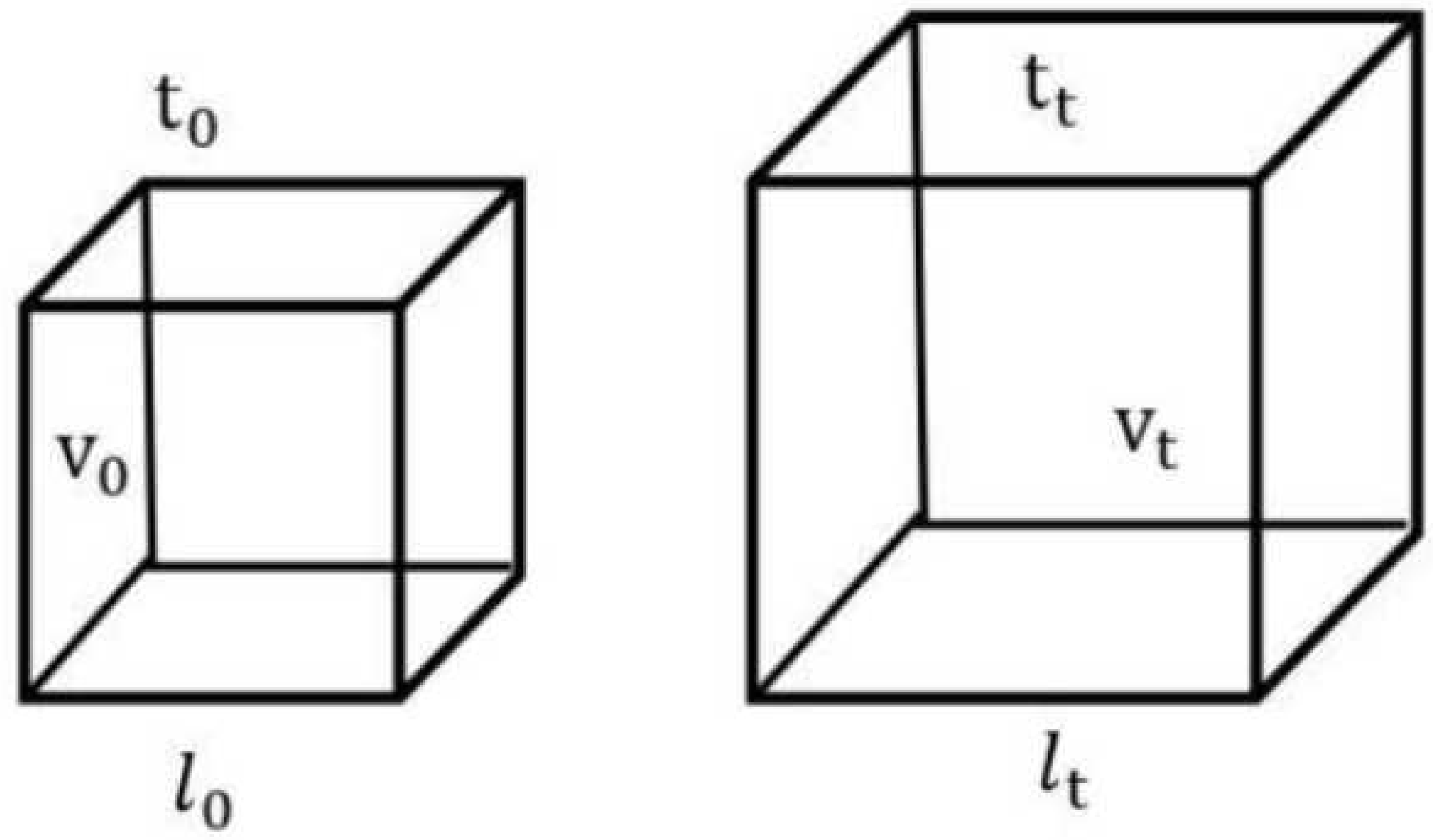
$$\beta = 2\alpha$$

$$\frac{\beta}{2} = \alpha \qquad \cdots\cdots\cdots (iii)$$

Relation between α and γ

- Consider a cube having sides l_0 at 0°C. If temperature of the increases from 0°C to t°C, then the sides of the cube increase to 'L' then, we have,

$$L = l_0\,(1+\alpha t)$$



Also,

$\therefore$ Volume of Cube at 0°C (V_0) $= l_0^2$

And, Volume of Cube at t°C (V_t) $= L^3 = l_0^3(1+\alpha t)^3$

$$= V_0(1 + 3\alpha t + 3\alpha^2 t^2 + \alpha^3 t^3)$$

Since, the value of α is very small, so higher power of α will be very small. Thus, the terms containing higher power of α can be neglected.

$$\therefore V_t = V_0\,(1 + 3\alpha t) \qquad \cdots\cdots\cdots (iv)$$

But, from definition of the coefficient of cubical expansion; we have,

$$\therefore V_t = V_0\,(1 + \gamma t) \qquad \cdots\cdots\cdots (v)$$

Comparing the relation (iv) and (v); we get,

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

$$\frac{\gamma}{3} = \alpha \qquad \cdots\cdots\cdots (vi)$$

From equations (iii) &(vi), we gets,

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

Hence,

$$\boldsymbol{\alpha = \frac{\beta}{2} = \frac{\gamma}{3}}$$

5) State Newton's first and second law of motion. show that Newton's first law is the special case of Newton's second law of motion.

➢ Newton's laws of motion are stated as :

First law :

➢ An object at rest always tends to remain at rest and an object in motion always tends to remain in motion with constant speed along the same direction until acted upon by an external agent (force).

Second Law :

➢ The rate of change of momentum of a body is directly proportional to the impressed force and takes place along the direction of the impressed force.

Newton′s first law as a special case of second law of motion

➢ Since, Newton′s second law of motion gives the equation as $F = ma$.
If net force 'F' acting on the mass is zero; then,

$$ma = 0$$

As $m \neq 0$,

$$\therefore a = 0$$

For this, either $v = \text{Constant}$

or, $a = \frac{d\,(constant)}{dt} = 0 \quad \left[\because a = \frac{dv}{dt}\right]$

This means the body moves with constant velocity (uniform velocity with no acceleration) or it will be at rest which is the statement of the first law.

6) Show that g decreases with increase in height.

➢ The acceleration produced by gravity is called acceleration due to gravity and is denoted by 'g' The value of 'g' is constant at the same place, but varies with distance from the centre of the earth above its surface.

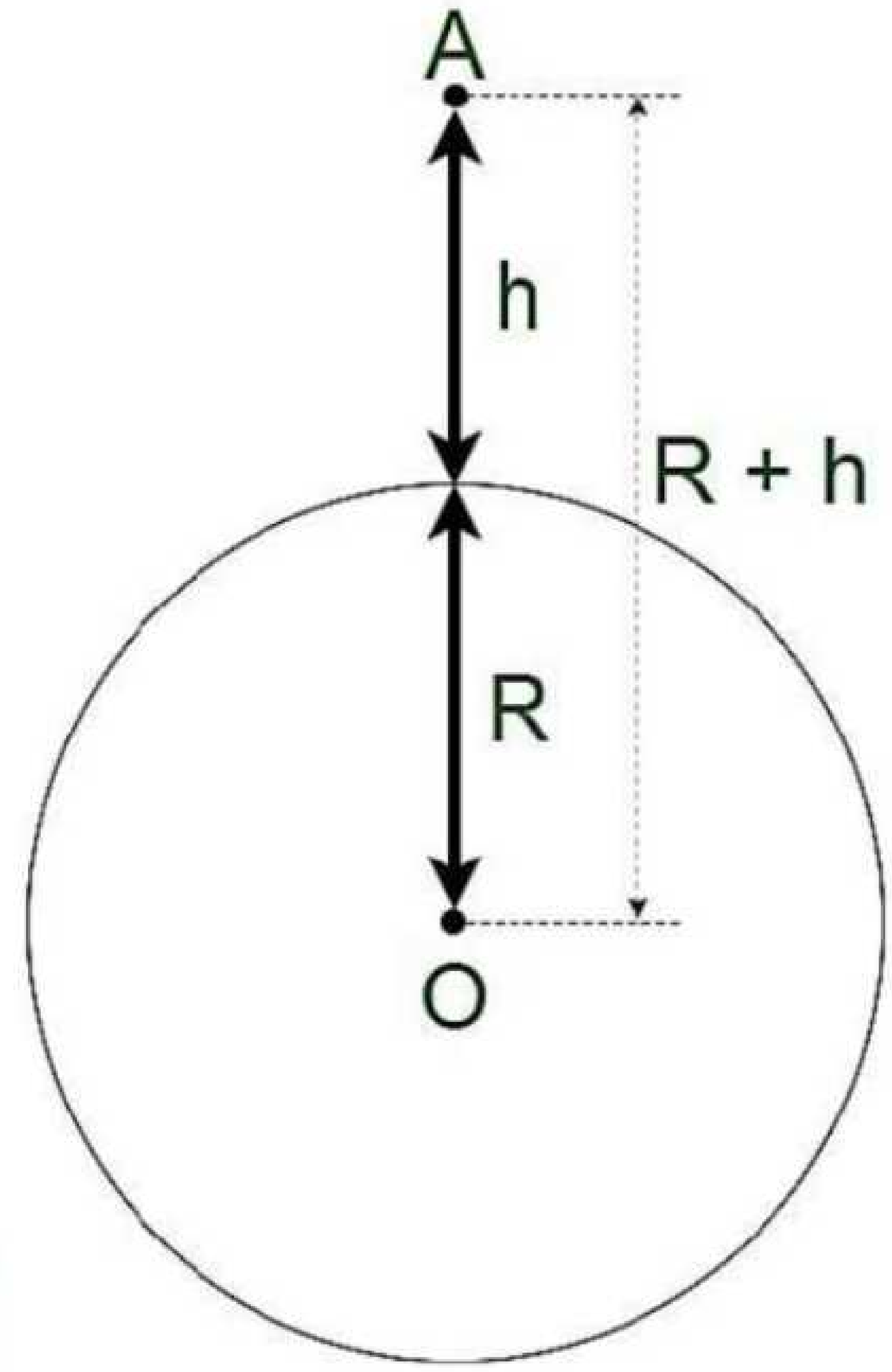
❖ Height above the earth's surface

➢ Consider a body at a height h above the surface of the earth. Let the radius of the earth is 'R' and its mass is 'M'. The body is at a distance $(R + h)$ from the center of the earth. If g_h is the value of acceleration due to gravity at that point, then,

$$g_h = \frac{GM}{(R+h)^2} \qquad \cdots\cdots\cdots (i)$$

But acceleration due to gravity at the earth's Surface

$$g = \frac{GM}{R^2} \qquad \cdots\cdots\cdots (ii)$$



Dividing equation (i) by (ii); we get,

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

Since, 'R' is constant.
Then,

$$g_h \propto \frac{1}{(R+h)^2} \qquad \cdots\cdots\cdots (iii)$$

The acceleration due to **gravity decreases** as move **height above the surface of the earth**.

7) State and explain Stefan's law of black body radiation.

- *Stefan's law states that*, "heat radiation radiated per second per unit area of a black body is directly proportional to the fourth power of its absolute temperature".

$$i.e, \quad E \propto T^4$$
$$or, \quad E = \sigma T^4$$

Where, 'E' is the energy radiated per sec per unit area.

'T' is the temperature in absolute scale.

'σ' is Stefan's constant and is equal to $5.7 \times 10^{-8}\ W\,m^{-2}K^{-4}$.

But, the law holds true when;

i) Radiating body is a perfect black body and
ii) It receives no heat from surroundings.

If a black body is at temperature 'T' and is enclosed inside an enclosure having temperature T_0, then the radiation energy radiated by black body per second per unit area 'E' is related as follow;

$$\text{If } T > T_0; \text{ the relation is,}$$

$$E = \sigma (T^4 - T_0^4)$$

$$\text{If } T_0 > T; \text{ then,}$$

$$E = \sigma (T_0^4 - T^4)$$

But, if the body is not perfect black body the relation becomes;

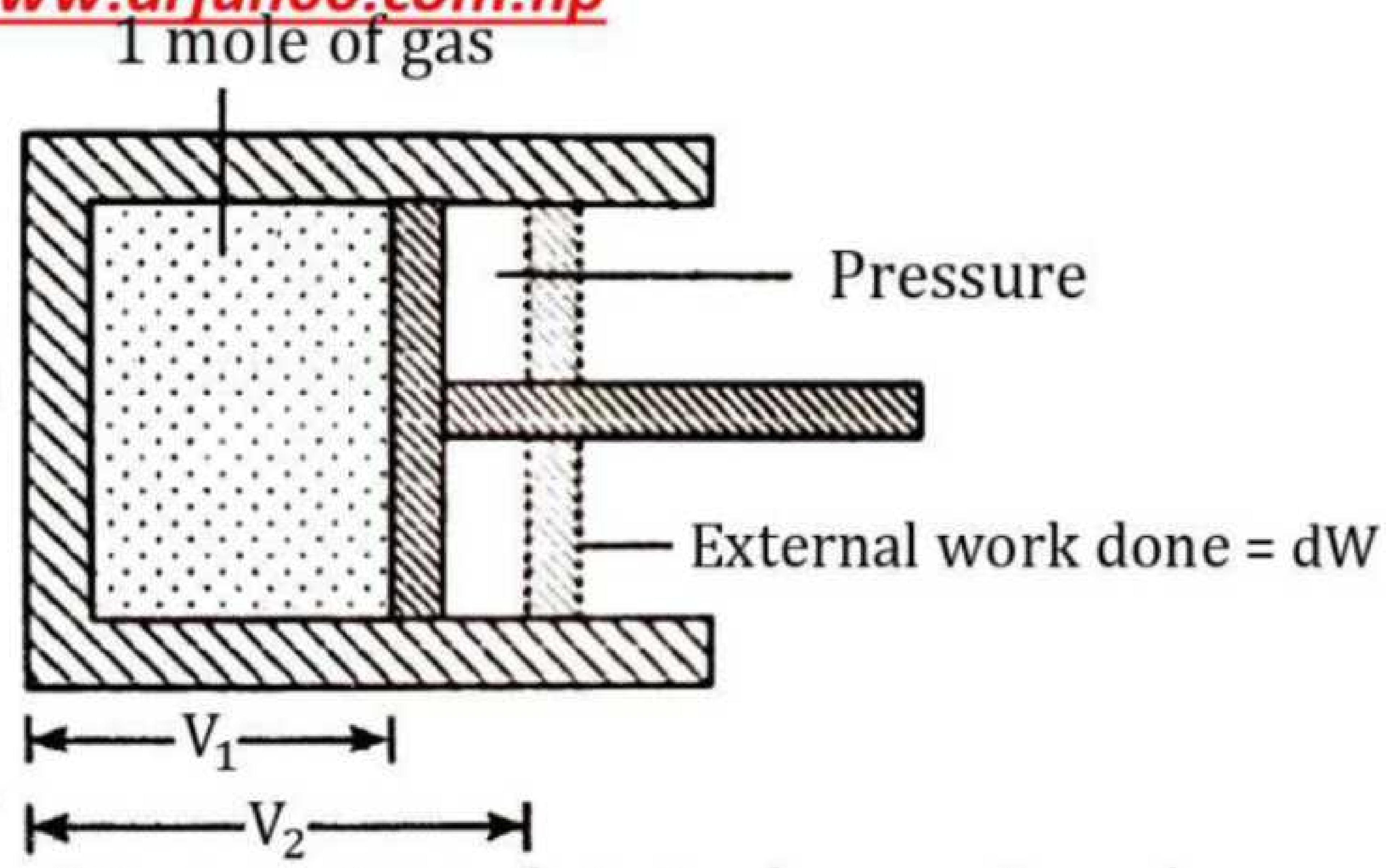
$$E = \sigma e (T^4 - T_0^4)$$

Where, 'e' is known as radiation emissivity of the surface and is different for different materials.

8) Show that $C_P - C_V = R$; where symbols have their usual meanings.

➢ At constant volume, no piston is allowed to move from its initial position. Thus, the heat supplied to the gas cannot perform work. The heat will increase the internal energy raising the temperature through unit degree, which is molar heat capacity at constant volume and represented by C_V. the molar heat capacity at constant pressure is always greater than molar heat capacity at constant volume $i.e.$, $C_P > C_V$. The difference between them is always equal to the amount of work done during expansion at constant pressure.

$$i.e., C_P > C_V = dW$$



- For consider one mole of an ideal gas enclosed Inside a cylinder fitted with smooth piston as Shown in the figure.

During heating at constant Pressure piston has to be kept free. So the gas expands and pushes the piston outward. Let, change in volume due to expansion is dV . The change in volume of gas is from V_1 to V_2,

$i.e., dV = V_2 - V_1$

$$\text{Thus, amount of work done } (dW) = P\, dV = P(V_2 - V_1)$$

$$\text{Since, } C_P - C_V = dW$$

$$\text{or, } C_P - C_V = P(V_2 - V_1) = C_V + PV_2 - PV_1$$

But , we have for one mole of any gas; we have,

$$\therefore \quad PV_1 = RT_1 \qquad \because PV = RT$$

$$\text{and, } PV_2 = RT_2$$

$$\text{and, } PV_2 - PV_1 = R(T_2 - T_1) = R\, dT \qquad \because dT = T_2 - T_1 = 1°C$$

$$\text{Hence, } C_P = C_V + R\, dT$$

$$= C_V + R.1$$

$$\therefore C_P - C_V = R$$

The relation is verified.

9) Define critical angle and total internal reflection of light.

- If the light travels from denser to rear medium then particular angle of incidence in denser medium when angle of refraction becomes 90° is called **critical angle** for the two given media. It is generally represented by 'C'.

- If angle of incidence in denser medium increases more than critical angle then, the ray of light reflected back to the same denser medium without refraction to rarer medium. The reflected ray obeys the laws of reflection. Such phenomenon of reflection without refraction is called **total internal reflection.**

** Additional if Ask

Relation between critical angle and refractive index

- If light travels from denser medium to rarer medium the refractive index 'μ' is given by;

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

$$\text{or,}\quad \frac{1}{\mu} = \frac{\sin i}{\sin r}$$

For critical angle ' i = C '; angle of refraction r = 90°

$$i.e.,\quad \frac{1}{\mu} = \frac{\sin C}{\sin 90°}$$

$$\therefore \quad \boldsymbol{\mu = \frac{1}{\sin C}} \quad \textbf{or,} \quad \boldsymbol{\sin C = \frac{1}{\mu}}$$

i.e., the refractive index (μ) is equal to the reciprocal of sine of the critical angle 'C'.

10) Define lens formula. Derive lens formula for convex lens.

➢ The lens formula is an equation that relates the focal length, object distance, and image distance of a lens. It is expressed as:

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

Where:

- ✓ **f** is the focal length of the lens
- ✓ **u** is the distance of the object from the lens (also called object distance)
- ✓ **v** is the distance of the image from the lens (also called image distance)

Relation between the f, u and v of a convex lens

➢ Consider a convex lens and a point object 'O' is placed at a distance u' from the lens on the principle axis.

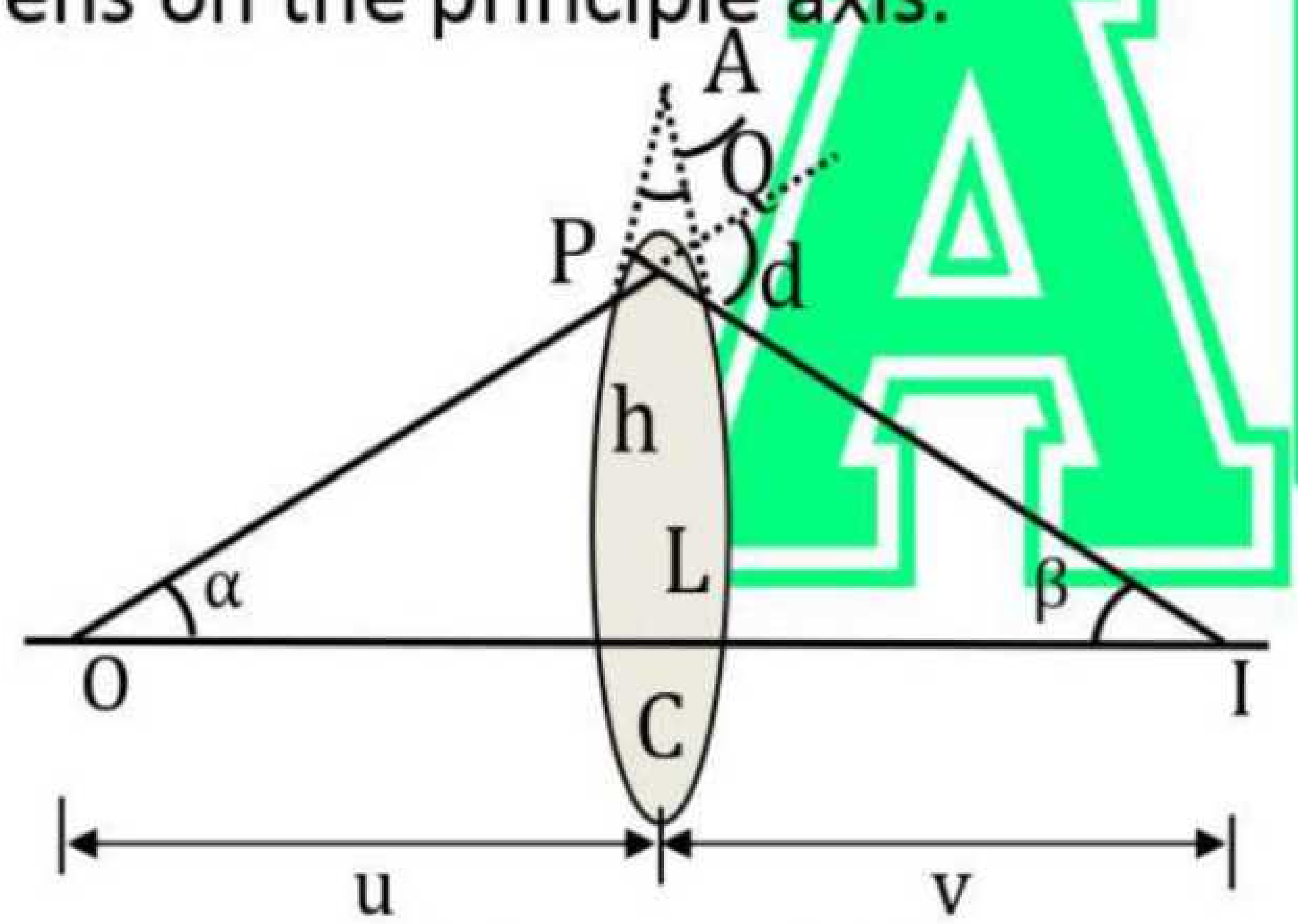


Figure: (1)

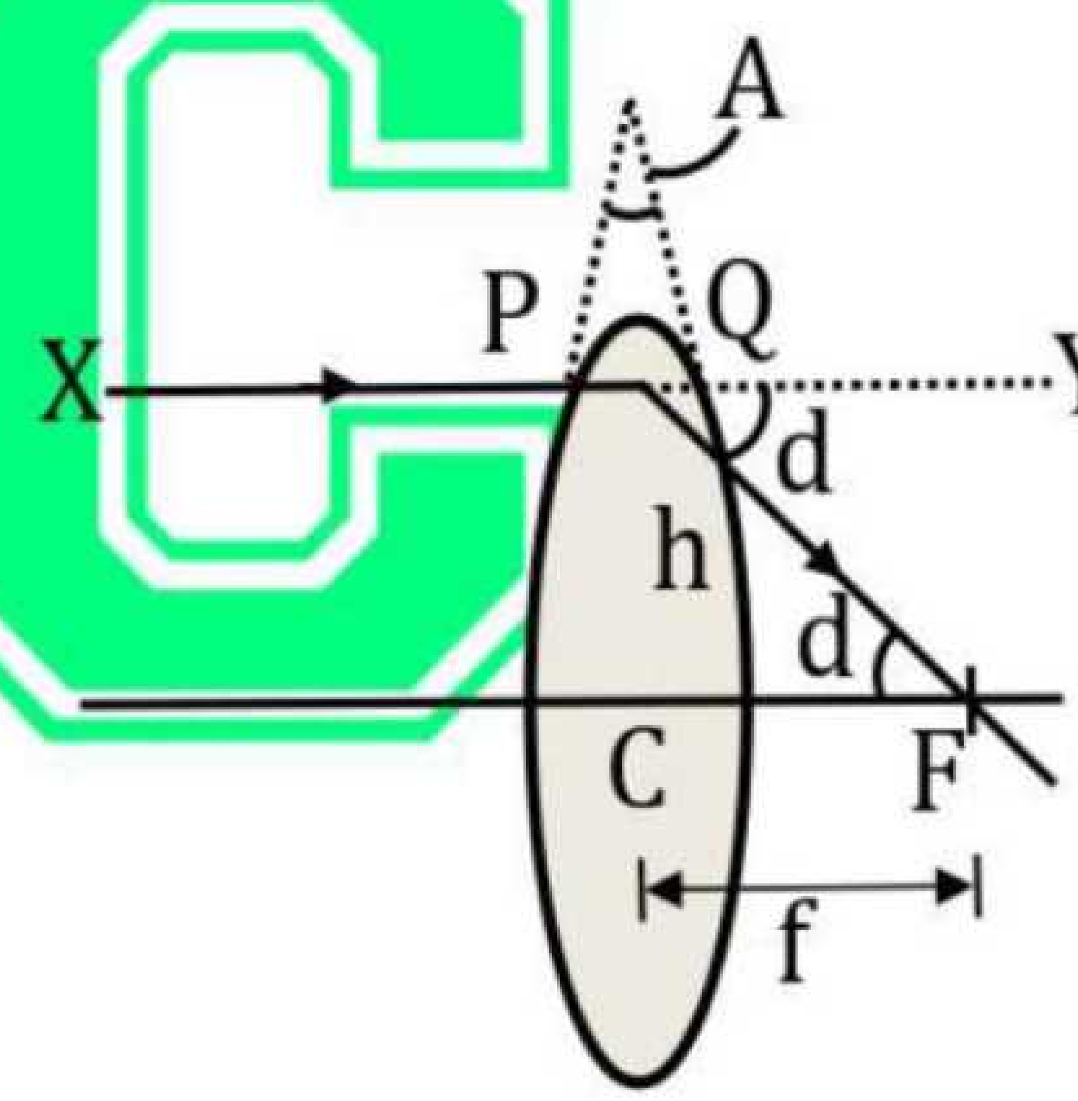


Figure: (2)

➢ A ray OP from object 'O' strikes the lens and refracted along PQ on the lens and then passes through QI. Similarly a ray from 'O' strikes the lens normally and moves straight. Then rays QI and LI meet at 'I'. Hence, 'I' is the image of the point object 'O' in next side of the lens. Let 'h' is the height of the point 'P' from the principle axis and 'α' is the angle made by the incident ray with principle axis and 'β'. the angle made by the ray QI. If 'd' be the angle of deviation produced by the light during refraction.

We have, from the figure,

$$d = \alpha + \beta \qquad \cdots\cdots\cdots(i)$$

From the right angled triangle POL; we have,

$$\tan\alpha = \frac{PL}{OL}$$

If angle 'α' is small , then,

$$\tan\alpha \approx \alpha = \frac{PL}{OL} = \frac{h}{u}$$

Similarly, from triangle PIL; we have,

$$\tan\beta = \frac{PL}{IL} = \frac{h}{v}$$

If 'β' is small then,

$$\tan\beta \approx \beta$$

Now, substituting the values in equation (i); we get,

$$d = \tan\alpha + \tan\beta = \frac{h}{u} + \frac{h}{v}$$

Again, if a parallel ray striking the lens at point 'P' as shown in the figure (2) refracted along the focus 'F'. Then,

$$\tan d = \frac{h}{f}$$

for a small angle of deviation,

$$\tan d \approx d = \frac{h}{f}$$

$$\text{or,} \quad d = \frac{h}{u} + \frac{h}{v}$$

$$\text{or,} \quad \frac{h}{f} = \frac{h}{u} + \frac{h}{v}$$

$$\text{or,} \quad \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

This is the required relation between focal length, object distance and image distance in case of a convex lens.

11) Differentiate among diamagnetic, paramagnetic and ferromagnetic materials.

➢ The differences between diamagnetic, paramagnetic and ferromagnetic are:-

Diamagnetic	Paramagnetic	Ferromagnetic
The net magnetic moment of atoms is zero.	Each atom or molecule has a net non-zero magnetic moment.	Each atom or molecule has a strong spontaneous net magnetic moment.
The intensity of magnetization of a diamagnetic substance is small and negative.	The intensity of magnetization is small and positive.	The intensity of a magnetization is very high and positive.
The magnetic susceptibility of a diamagnetic material is small and negative.	The magnetic susceptibility of a paramagnetic material is small and positive.	The magnetic susceptibility of a Ferro-magnetic material is very large and positive.
The permeability of diamagnetic is less than 1.	The permeability of paramagnetic is nearly equal to unity.	Permeability of ferromagnetic substance is much greater than one ($\mu >> 1$).
For example: copper, silver, gold, water, helium, argon, etc.	For example: platinum, potassium, oxygen, aluminum etc.	For example: alnico, alloy, iron, nickel, cobalt, etc.

12) A slab of mass 10kg is laying on a plane inclined at 30° to the horizontal. Find the least force which will pull the slab upward (μ=0.15).

➢ **Solution:**

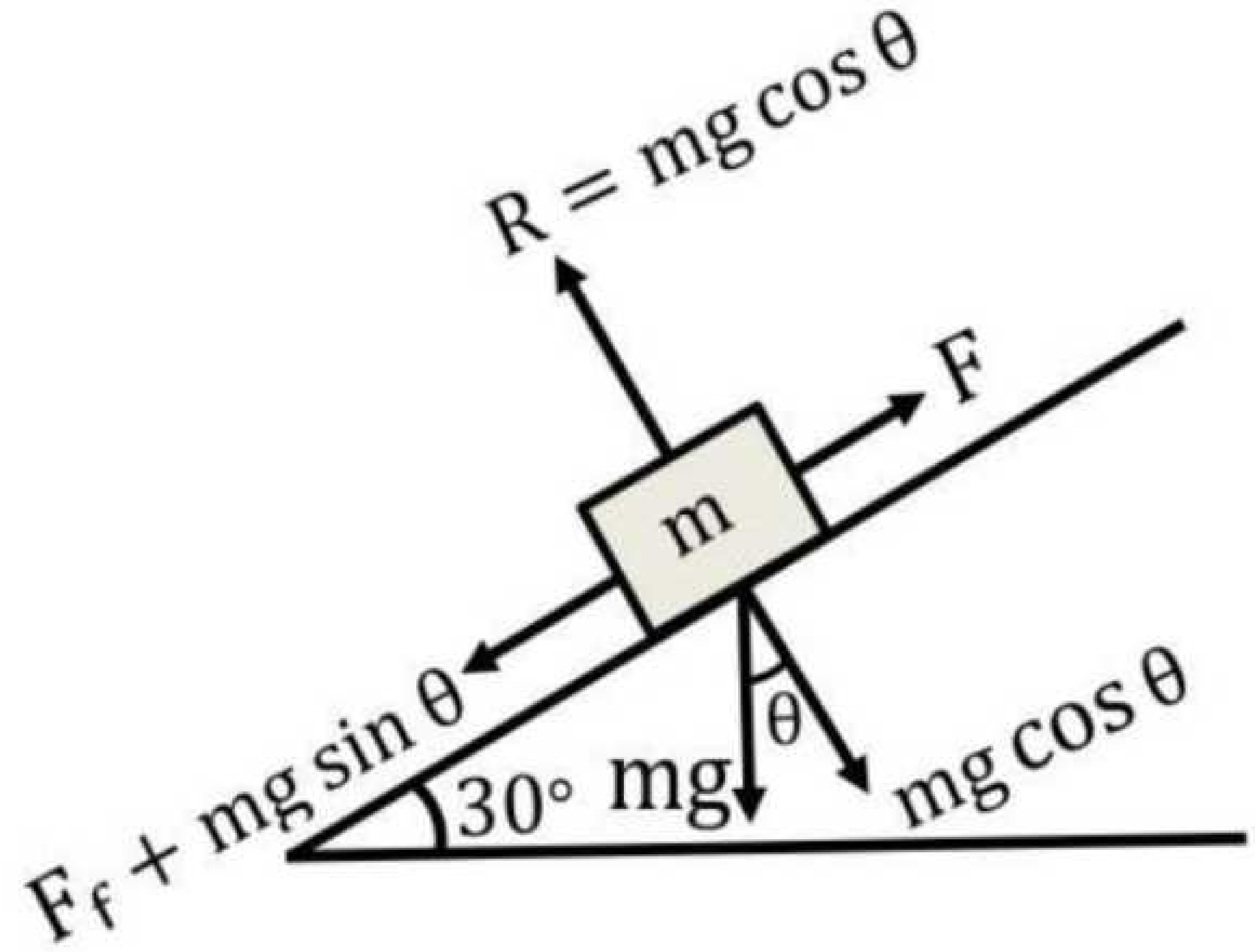


Fig: Iron block on inclined surface

Given that;

Mass of slab (m) = 10 kg

Angle of inclination (θ) = 30°

Coefficient of friction (μ) = 0.15

$g = 9.8\ ms^{-2}$

Least force to pull slab upward (F) = ?

The least force to pull the slab upward on an inclined plane is; (from figure)

$$F = mg\sin\theta + F_f$$

$$= mg\sin\theta + \mu R \qquad [\because F_f = \mu R,\ \text{Frictional force}]$$

$$= mg\sin\theta + \mu mg\cos\theta$$

$$= mg(\sin\theta + \mu\cos\theta)$$

$$= 10 \times 9.8\,(\sin 30° + 0.15\cos 30°)$$

$$= 98 \times 0.63$$

$$\therefore F = 61.73\ N$$

Thus, the least force to pull the slab upward is 61.73 N

13) A constant torque of 200 Nm turns a wheel about its centre. The momen of inertia about this axis is 100 kgm². Find the angular velocity gained in 4 Second used also calculate the kinetic energy gained after 20 revolution.

➢ **Solution:-**

Given that;

Torque $(\tau) = 200$ Nm

Moment of inertia $(I) = 100\ kgm^2$

Time $(t) = 4$ sec.

Number of revolutions $(n) = 20$

Angular velocity $(\omega) = ?$

Kinetic energy gained $(K.E.) = ?$

i) For angular velocity (ω)

We have,

$$\text{Angular acceleration } (\alpha) = \frac{\tau}{I} = \frac{200}{100} = \mathbf{2rads^{-2}}$$

So, the angular velocity gained after 4 sec. is;

$$\begin{aligned}\omega &= \omega_0 + \alpha t \\ &= 0 + 2 \times 4 \\ &= \mathbf{8\ rads^{-1}}\end{aligned}$$

ii) For Kinetic energy gained (K. E.)

We have, angular displacement in 'n' revolution is given by;

$$\theta = 2\pi n = 2\pi \times 20 = 40\pi \text{ rad}$$

So, the angular velocity gained by wheel is;

$$\omega^2 = \omega_0^2 + 2\alpha\theta = 0 + 2 \times 2 \times 40\pi = 160\pi(\text{ rad}s^{-1})^2$$

Thus, the kinetic energy gained after 20 revolutions is;

$$K.E. = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 100 \times 160\pi = \mathbf{25132.7\ J}$$

14) Find the result of mixing 20gm of water at 90°c with 5gm of ice at-10°c. (Sp. heat of ice=0.5 $calg^{-1}{}^\circ C^{-1}$, Sp. heat of water = 1$calg^{-1}{}^\circ C^{-1}$, Latent heat of fusion of ice = 80 $calg^{-1}$).

➢ **Solution:**

Given that;

Mass of water $(m_1) = 20$ gm

Initial temperature of water $(\theta_1) = 90°C$

Mass of ice $(m_2) = 5$ gm

Initial temperature of ice $(\theta_2) = -10°C$

Latent heat of ice $(L_f) = 80$ cal/gm

Specific heat of ice $(S_i) = 0.5$ cal/gm°C − 1

Specific heat of water $(S_w) = 1$ cal/gm°C − 1

Resultant temperature $(\theta) = ?$

From the principle of calorimetry; we can write,

Heat lost by water = Heat gained by ice

$or,\ m_1S_w(\theta_1 - \theta) = m_2S_i[0 - (-\theta_2)] + m_2L_f + m_2S_w(\theta - 0)$

$or,\ 20 \times 1 \times (90 - \theta) = 5 \times 0.5 \times 10 + 5 \times 80 + 5 \times 1 \times \theta$

$or,\ 20(90 - \theta) = 25 + 400 + 5\theta$

$or,\ 25\theta = 1800 - 425$

$or,\ 25\theta = 1375$

$or,\ \theta = 55°C$

Hence, the resultant temperature of mixture of mass 25 gm of water is 55°C.

15) An object is placed 12cm from a concave mirror of radius of curvature 16 cm. Find the position of image and magnification of mirror.

➢ **Solution:**

Given that;

Object distance (u) = 12 cm.

Radius of curvature (r) = 16 cm

So, Focal length (f) $= \frac{r}{2} = \frac{16}{2} = 8\text{cm}$

Image distance (v) $= ?$

Magnification (m) $= ?$

Using mirror formula; we have,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\text{or,} \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\text{or,} \quad \frac{1}{v} = \frac{1}{8} - \frac{1}{12}$$

$$\text{or,} \quad \frac{1}{V} = \frac{3-2}{24} = \frac{1}{24}$$

$$\therefore \mathbf{v = 24\ cm}$$

and, Magnification (m) $= \frac{v}{u} = \frac{24}{12} = \mathbf{2}$

Thus, the position of real image is 24 cm from a concave mirror and its magnification is 2.

16) Find the minimum deviation produced by an equilateral glass prism of refractive index 1.5.

➢ **Solution:**

Given that;

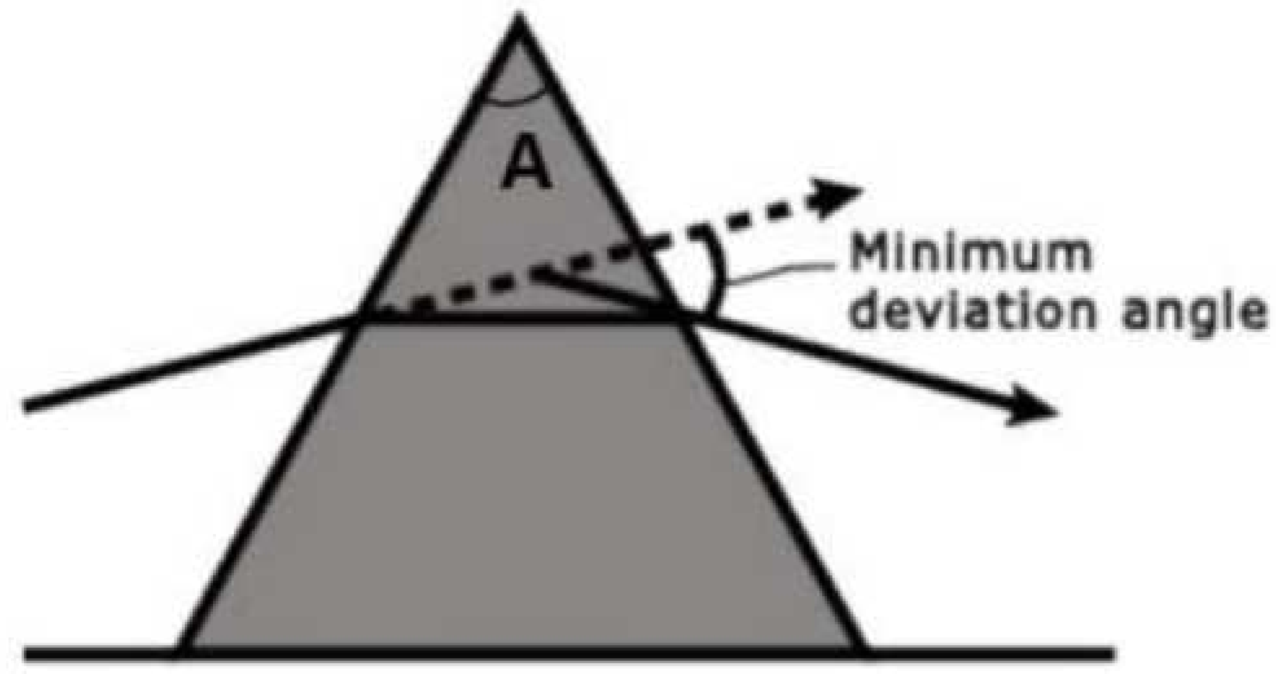
Angle of prism, for equilateral prism (A) $= 60°$

Refractive index (μ) $= 1.5$

Angle of minimum deviation (δ_m) $= ?$

For a minimum deviation of a glass prism; we have,

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



$$\text{or,}\quad 1.5 = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{sin\frac{60°}{2}}$$

$$\text{or,}\quad \mathrm{Sin}\left(30° + \frac{\delta_m}{2}\right) = 1.5\ \sin 30° = 0.75$$

$$\text{or,}\quad 30° + \frac{\delta_m}{2} = \sin^{-1}(0.75) = 48.59°$$

$$\text{or,}\quad \frac{\delta_m}{2} = 48.59° - 30° = 18.59°$$

$$\text{or,}\quad \delta_m = 2 \times 18.59° = 37.2°$$

Thus, the minimum deviation of given prism is 37.2°.

17) A bar magnet 10cm long is placed in the magnetic meridian with its N-pole pointing geographical north. A neutral points observed at a point 15 cm from each pole. Calculate its magnetic moment.

➢ **Solution:**

Given that;

Length of bar magnet $(2l) = 10\text{ cm} = 0.1\text{ m}$

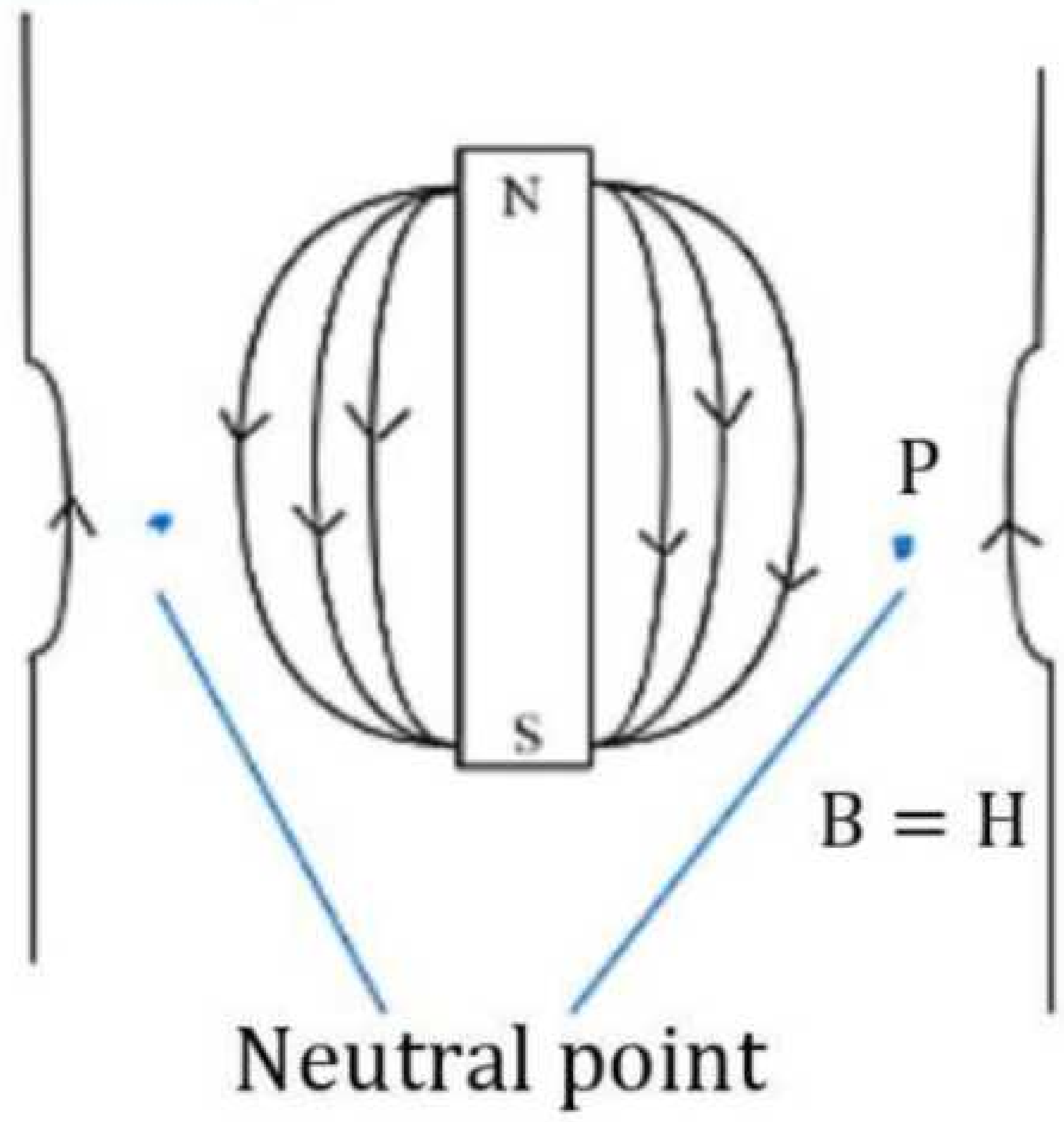
Position of neutral point $\left(\sqrt{d^2 + l^2}\right) = 15\text{ cm} = 0.15\text{ m}$

Horizontal component $(H) = 0.34 \times 10^{-1}\text{ T}$

Magnetic moment $(M) = ?$

For N – pole pointing north, the neutral point lies on the equatorial line; so,

$$\mathbf{B = H}$$



$$\text{or, } \frac{\mu_0}{4\pi} \times \frac{M}{(d^2 + l^2)^{\frac{3}{2}}} = H$$

$$\text{or, } \frac{4\pi \times 10^{-4}}{4\pi} \times \frac{M}{(0.15)^3} = 0.34 \times 10^{-4}$$

$$\text{or, } M = \frac{(0.15)^3 \times 0.34 \times 10^{-4}}{10^{-7}} = 1.15 \text{ Am}^2$$

Hence, the magnetic moment of the given bar magnet is $\mathbf{1.15\ Am^2}$.

18) The total intensity of earth's magnetic field at a place where the angle of dip 30° is 37×10^{-6} T. Find the horizontal and vertical components.

- **Solution:**

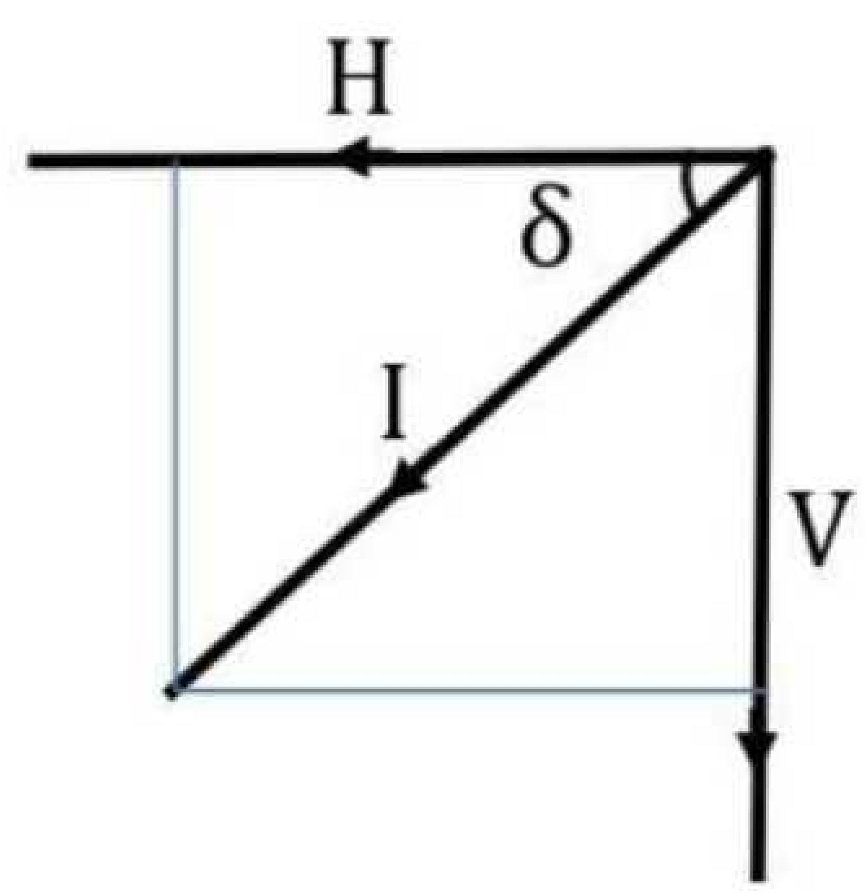
Given that;

Angle of dip (δ) = 30°

Total intensity of the earth's magnetic field (I) = 37×10^{-6} T

Horizontal component (H) =?

Vertical component (V) =?



We have, from figure

$$\text{Horizontal component (H)} = I \cos \delta$$

$$= 37 \times 10^{-6} \times \cos 30°$$

$$= \mathbf{3.20 \times 10^{-5} T}$$

Similarly,

$$\text{Vertically component (V)} = I \sin \delta$$
$$= 37 \times 10^{-6} \times \sin 30°$$
$$= 1.85 \times 10^{-5} \text{T}$$

–The End –

**** "If you find a mistake in Question/Answer, Kindly take a Screenshot and email to info@arjun00.com.np "**

Engineering Physic I__(Engg. All) 1^{st} Sem

(2078) Question Paper Solution.

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1) State parallelogram law of vector addition. Derive the expression for magnitude and direction of resultant vector.

➢ ***Parallelogram law of vector :*** "It state that If two vectors acting simultaneously at a point are represented both in magnitude and direction by two adjacent sides of a parallelogram drawn from a point, then the diagonal of the parallelogram passing through that point represents the resultant both in magnitude and direction."

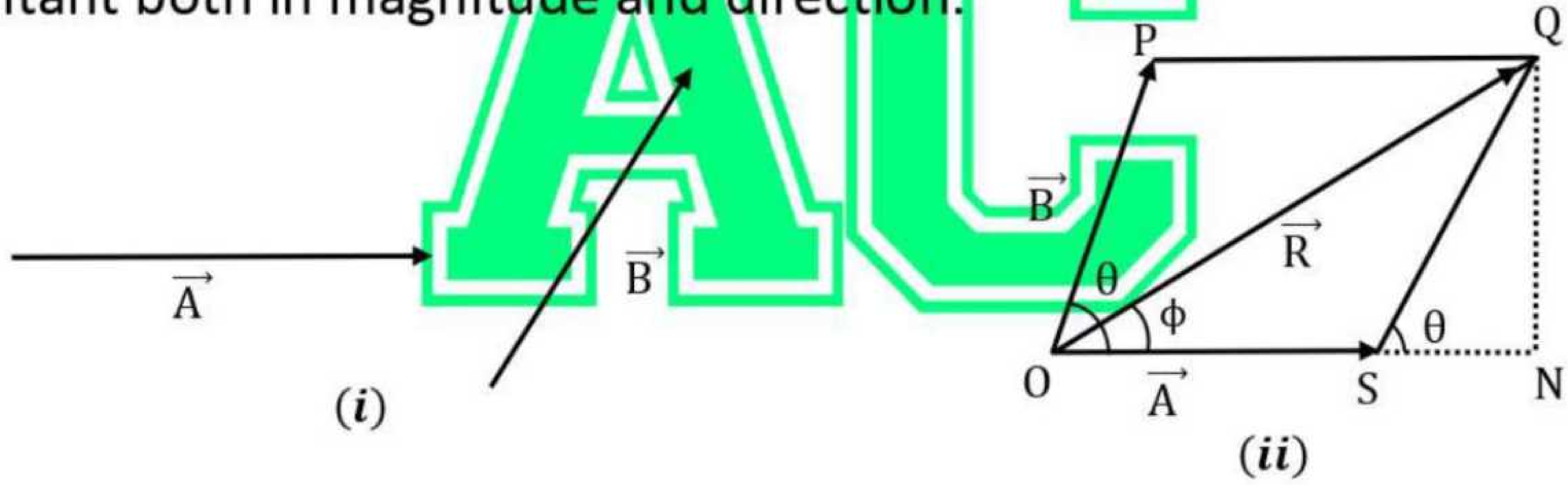


Fig: Parallelogram law of vectors

In the shown figure, $\vec{A}$ and $\vec{B}$ are represented by the sides of parallelogram OPQS and If resultant $\vec{R}$ is represented by diagonal OQ such that $\vec{R} = \vec{A} + \vec{B}$

Magnitude of $\vec{R}$: To calculate the magnitude of the resultant vector $\vec{R}$, Let us draw a perpendicular at N form Q when OS is produced. Let the angle between vectors $\vec{A}$ and $\vec{B}$ be θ.

In ΔONQ,

$$OQ^2 = ON^2 + NQ^2$$

$$or,\ \ OQ^2 = (OS + SN)^2 + NQ^2 \qquad \cdots\cdots\cdots\cdots (i)$$

$$\sin\theta = \frac{NQ}{QS} = \frac{NQ}{B}$$

$$or,\ \ NQ = B\sin\theta$$

$$\text{and}\ \ \cos\theta = \frac{SN}{QS} = \frac{SN}{B}$$

$$or,\ \ SN = B\cos\theta$$

From Equation (*i*)

$$OQ^2 = (OS + SN)^2 + NQ^2$$

$$or,\ \ R^2 = (OS + B\cos\theta)^2 + (B\sin\theta)^2$$

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

$$or,\ \ R^2 = A^2 + 2AB\cos\theta + B^2\cos^2\theta + B^2\sin^2\theta$$

$$or,\ \ R^2 = A^2 + 2AB\cos\theta + B^2$$

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

This is the magnitude of the resultant vector.

Direction of $\vec{R}$: Let the angle made by the resultant $\vec{R}$ with the vector $\vec{A}$ be ϕ.

In ΔONQ,

$$\tan\phi = \frac{QN}{ON} = \frac{QN}{OS + SN}$$

$$or,\ \ \tan\phi = \frac{B\sin\theta}{A + B\cos\theta}$$

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

This is the direction of the resultant vector.

OR) What is simple pendulum? Show that the motion of simple pendulum is simple harmonic and hence find its time period.

➢ **Refer to the solution 2076 of Q. No 2 on page 4.**

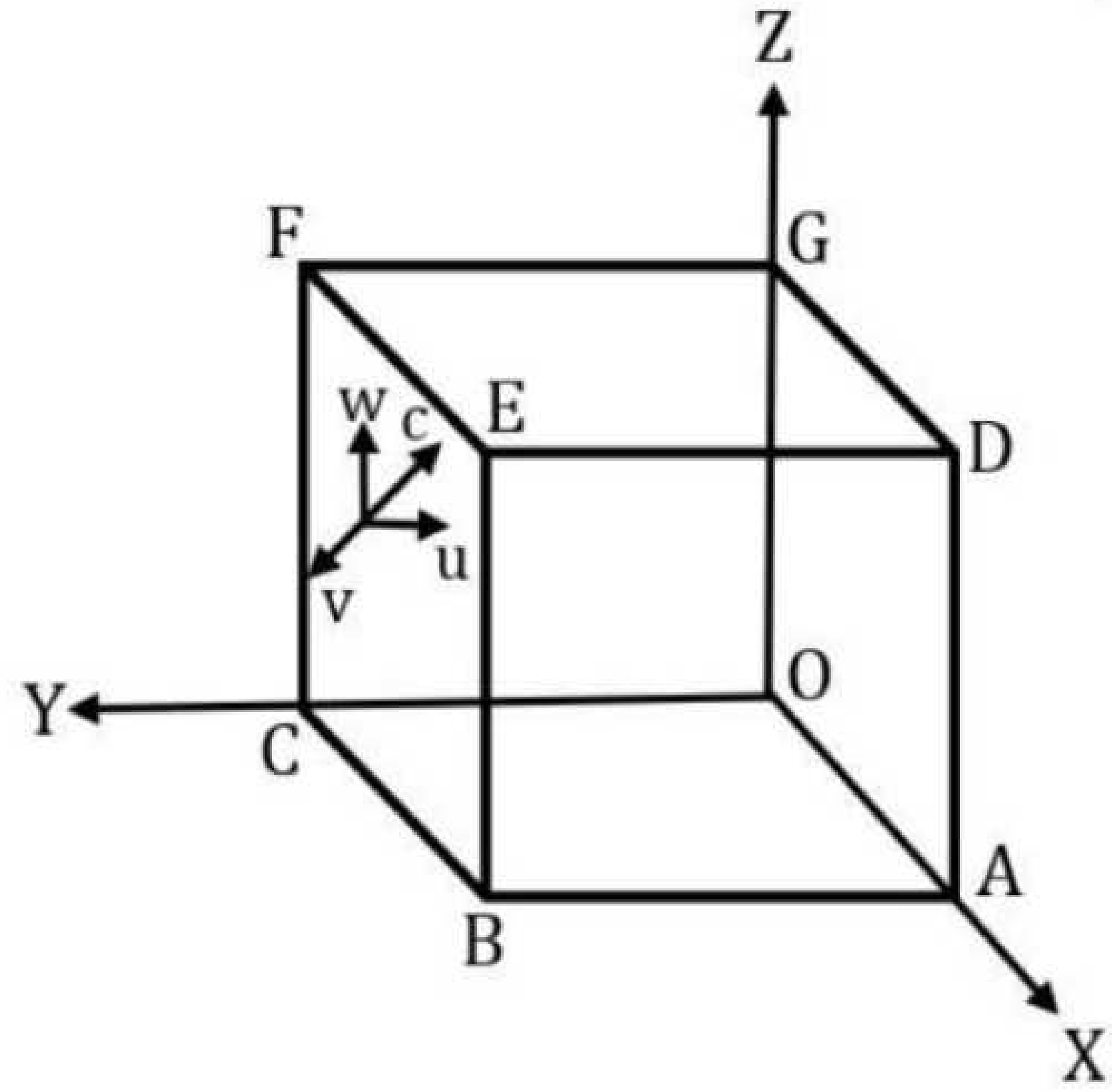
2) Stating the postulate of kinetic theory of gas. derive the relation $p = \frac{1}{3}\rho c^2$, where the symbols have their usual meanings.

➢ **The postulates of kinetic theory of gases are:**

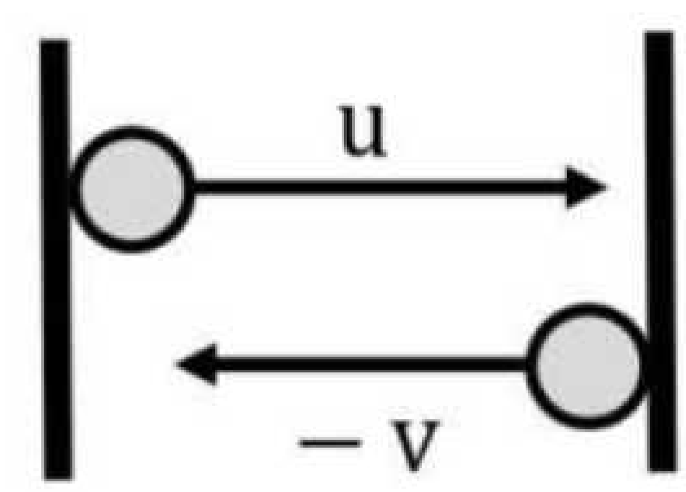
- ✓ Every system of gas consists of large numbers of small particles called molecules.
- ✓ Molecules of a gas are alike but different from other gas molecules.
- ✓ The molecules of gases are continuously in motion with random velocity.
- ✓ The volume of a gas molecule is negligibly small with respect to the container.
- ✓ All the collisions are perfectly elastic in nature.
- ✓ The molecules do not exert any force except during collisions and duration of collisions is negligibly small.
- ✓ Molecules travel straight path between two collisions and distance covered during two collisions is called the free path of the molecule.

❖ Expression for the pressure exerted by an ideal gas

➢ Consider a system of gas enclosed inside a cubical vessel of sides 'l'. Let the edges OA, OG and OC of the vessel are parallel to x, y and $z - axis$.



(a)



(b)

If 'N' is the number of gas molecules inside the vessel and 'm' is the mass of each gas molecule. 'N' molecules of gases are moving with velocities $c_1, c_2, \ldots\ldots c_n$ respectively. The velocity c_1 of a gas molecule can be resolved into three components, u_1, v_1 and w_1 along x, y and $z-$axis respectively. Then,

$$c_1^2 = u_1^2 + v_1^2 + w_1^2$$

Similarly, for other gas molecules have similar values given by;

$$c_2^2 = u_2^2 + v_2^2 + w_2^2$$

$$c_3^2 = u_3^2 + v_3^2 + w_3^2$$

....

$$c_N^2 = u_N^2 + v_N^2 + w_N^2$$

Consider collision of a single molecule with the wall ABED as shown in the figure (b). The molecules strike the wall with momentum mu_1. As the collision is perfectly elastic the molecules rebound with same velocity in opposite direction. Thus, momentum of molecules after rebound is $-mu_1$.

Change in momentum $= mu_1 - (-mu_1) = 2mu_1$

In order to strike the same face again the molecule has to cover the distance $2l$. Therefore, time 't' between successive collisions is given by;

$$\mathbf{S} = \mathbf{ut}$$

$$\text{or,} \quad 2l = u_1 t$$

$$\text{or,} \quad t = \frac{2l}{u_1}$$

$$\therefore \text{Change in momentum of first molecule along x} - \text{axis} = \frac{2mu_1}{t}$$

$$= \frac{2mu_1}{\frac{2l}{u_1}}$$

$$= \frac{mu_1^2}{l}$$

$i.e.$, Average force exerted by single molecule in the wall ABED $= \dfrac{mu_1^2}{l}$

Hence,

$$\text{Total force (F)} = \frac{mu_1^2}{l} + \frac{mu_2^2}{l} + \ldots\ldots\ldots\ldots + \frac{mu_N^2}{l}$$

$\therefore$ Pressure P_X on the same wall due to N − molecules is;

$$P_X = \frac{F_X}{l^2} = \frac{m}{l^3}\left(u_1^2 + u_2^2 + \ldots\ldots\ldots\ldots + u_N^2\right)$$

$$\text{Similarly,} \quad P_Y = \frac{F_Y}{l^2} = \frac{m}{l^3}\left(v_1^2 + v_2^2 + \ldots\ldots\ldots\ldots + v_N^2\right)$$

$$\text{and,} \quad P_Z = \frac{F_Z}{l^2} = \frac{m}{l^3}\left(w_1^2 + w_2^2 + \ldots\ldots\ldots\ldots + w_N^2\right)$$

The average pressure 'P' due to N − molecules on the vessel is given by;

$$\mathbf{P} = \frac{\mathbf{P_X + P_Y + P_Z}}{\mathbf{3l^3}}$$

$$= \frac{m}{3l^3}[(u_1^2 + u_2^2 + \cdots + u_N^2) + (v_1^2 + v_2^2 + \cdots + v_N^2) + (w_1^2 + w_2^2 + \cdots + w_N^2)]$$

$$= \frac{m}{3l^3}[(u_1^2 + v_1^2 + w_1^2) + (u_2^2 + v_2^2 + w_2^2) + \ldots\ldots]$$

$$= \frac{m}{3l^3}[(c_1^2 + c_2^2 + \ldots + c_N^2)]$$

$$= \frac{m}{3V}[(c_1^2 + c_2^2 + \ldots + c_N^2)] \quad [\because l^3 = V] \qquad \cdots\cdots\cdots (i)$$

Let 'c' is the root mean square velocity. Then,

$$c^2 = \frac{c_1^2 + c_2^2 + \ldots\ldots + c_N^2}{N}$$

$$\therefore \; c_1^2 + c_2^2 + \cdots + c_N^2 = Nc^2$$

Now, substituting the value of $c_1^2 + c_2^2 + \cdots + c_N^2$ in relation (i); we get,

$$P = \frac{mNc^2}{3V} = \frac{\mathbf{1}}{\mathbf{3}}\boldsymbol{\rho c^2}$$

where, $\rho = \frac{\text{total mass of gases}}{\text{total volume}} = \frac{mN}{V}$

3) Define magnetic field intensity. Derive magnetic field intensity of bar magnet at a point on equatorial line.

- *The strength of a magnetic field at a point is called the* **magnetic field intensity**. It is defined as the force per unit north pole acting on any pole, placed at that point.

❖ Magnetic field intensity of bar magnet at a point on equatorial line

➢ Suppose a point 'P' is on the equatorial line of the bar magnet. The equatorial line of the magnet is a line perpendicular to the axis of the magnet, which bisects the magnet. Led 'd' be the distance of the point 'P' from the centre of the magnet. 'P' is at equal distance 'r' from each pole, where $r = (d^2 + l^2)^{1/2}$.

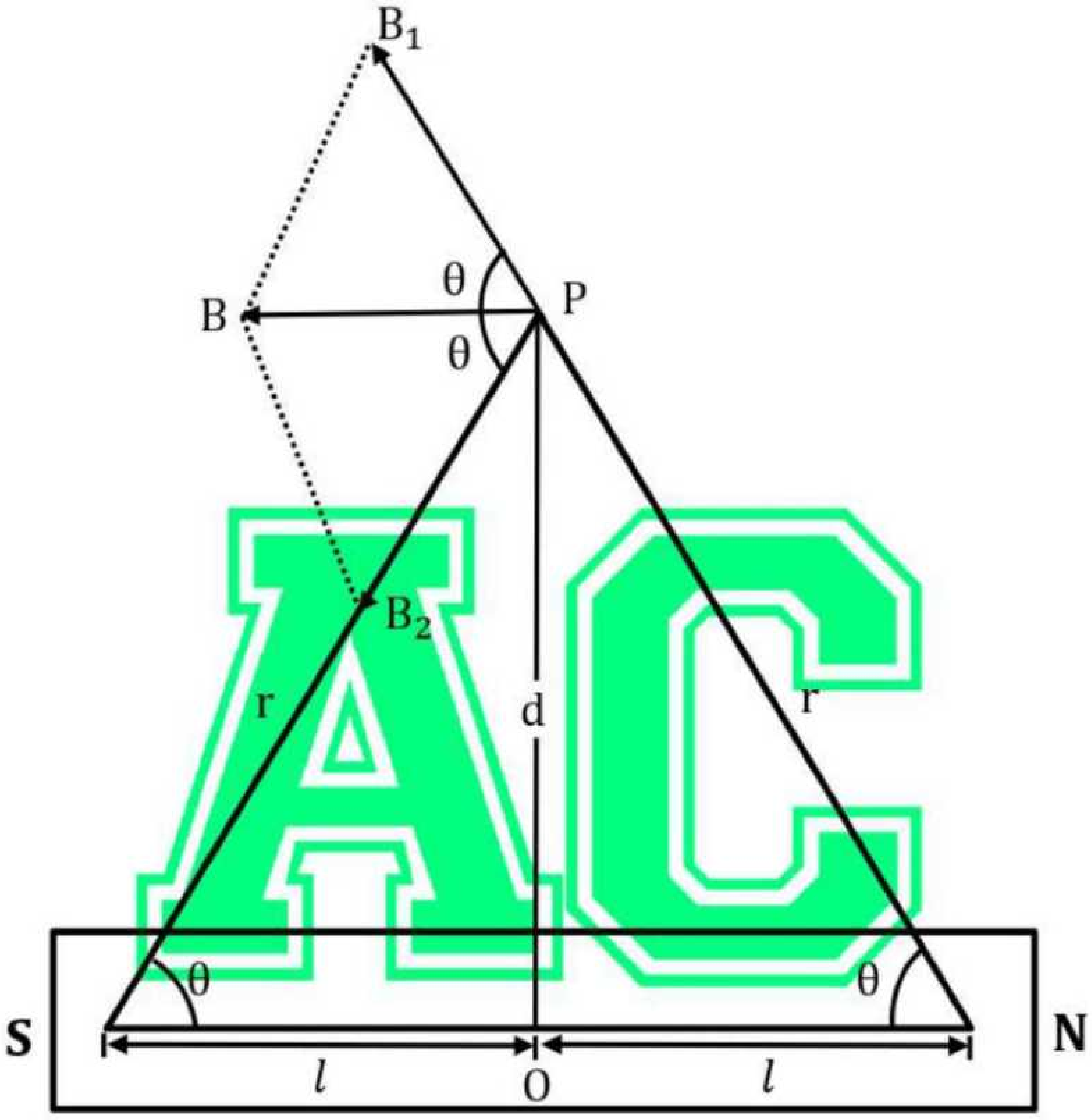


Figure: *Magnetic field intensity at a point on the equatorial axis of bar magnet.*

The magnetic field intensity B_1 at P due to the north pole is

$$B_1 = \frac{\mu_0}{4\pi}\frac{m}{r^2} = \frac{\mu_0}{4\pi}\frac{m}{(d^2 + l^2)}$$

directed away from N-pole. The magnetic field B_2 at P due to S-pole is

$$B_2 = \frac{\mu_0}{4\pi}\frac{m}{r^2} = \frac{\mu_0}{4\pi}\frac{m}{(d^2 + l^2)}$$

directed towards S − pole. These fields have different directions, but the same magnitude as shown in the Figure. Let angle $\angle PSO = \theta$ and by symmetry, angle $\angle PNO = \theta$. The angle between B_1 and B_2 is then 2θ. Using parallelogram law of vectors, the resultant magnetic field, B at P is given by

$$B^2 = {B_1}^2 + {B_2}^2 + 2B_1B_2\cos\theta$$

Since, $B_1 = B_2$ in magnitude, so

$$B^2 = {B_1}^2(2 + 2\cos 2\theta)$$

$$B^2 = 2\,{B_1}^2(1 + \cos 2\theta)$$

$$B^2 = 4\,{B_1}^2\cos^2\theta \Rightarrow B = 2B_1\cos\theta$$

From the Figure, we have, $\cos\theta = \frac{1}{\sqrt{(d^2 + l^2)}}$

And then

$$B = 2B_1\cos\theta$$

$$= 2\frac{\mu_0}{4\pi}\frac{m}{(d^2 + l^2)}\frac{l}{\sqrt{(d^2 + l^2)}}$$

$$= \frac{\mu_0}{4\pi}\frac{2m\,l}{(d^2 + l^2)^{\frac{3}{2}}}$$

$$\boldsymbol{B = \frac{\mu_0}{4\pi}\frac{M}{(d^2 + l^2)^{\frac{3}{2}}}}$$

Which is required expression of magnetic field intensity of bar magnet at a point on equatorial line.

4) Define g. How does g vary with depth?

➢ The acceleration produced by gravity is called acceleration due to gravity and is denoted by 'g' The value of 'g' is constant at the same place, but varies with distance from the centre of the earth above its surface.

❖Varation of g with depth:

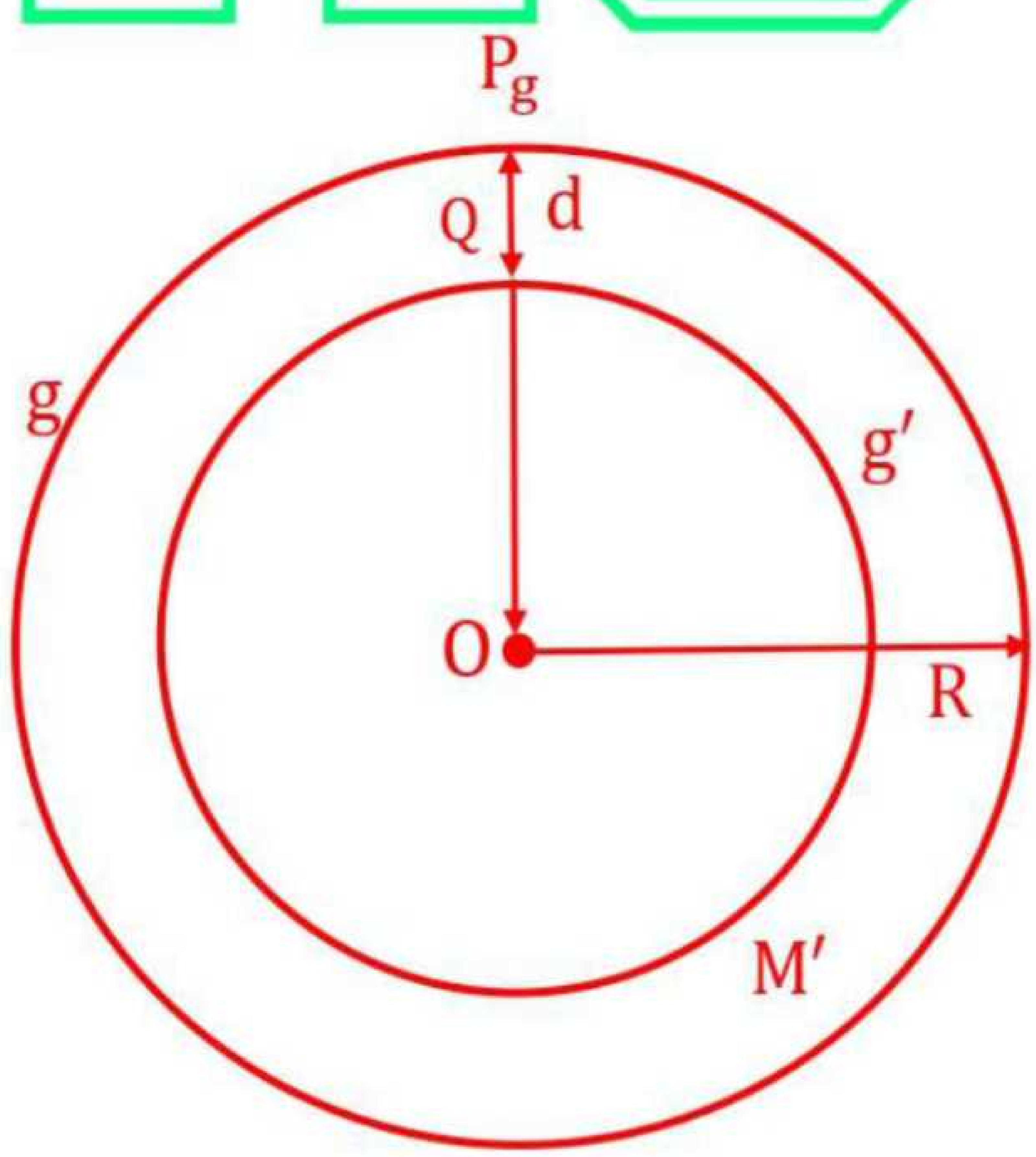
➢ Let g and g′ be the values of acceleration due to gravity on the surface of earth and at a depth 'd ' of the surface of earth.

The acceleration due to gravity at the surface of earth,

$$g = \frac{GM}{R^2} \qquad \cdots\cdots\cdots (1)$$

Where 'M' is mass of earth and 'R' be the radius of earth. At a depth 'd' below the earth's surface, acceleration due to gravity is given by

$$g' = \frac{GM'}{(R-d)^2} \qquad \cdots\cdots\cdots (2)$$



Where 'M′ ' is mass of earth having radius (R − d). Taking earth to be perfectly spherical, then

$$M = \frac{4}{3}\pi R^3 \rho \qquad \cdots\cdots\cdots (3)$$

Where 'ρ' is density of earth.

$$\text{and } M' = \frac{4}{3}\pi (R-d)^3 \rho \qquad \cdots\cdots\cdots (4)$$

Using equation (3) and (4) in equation (1) and (2)

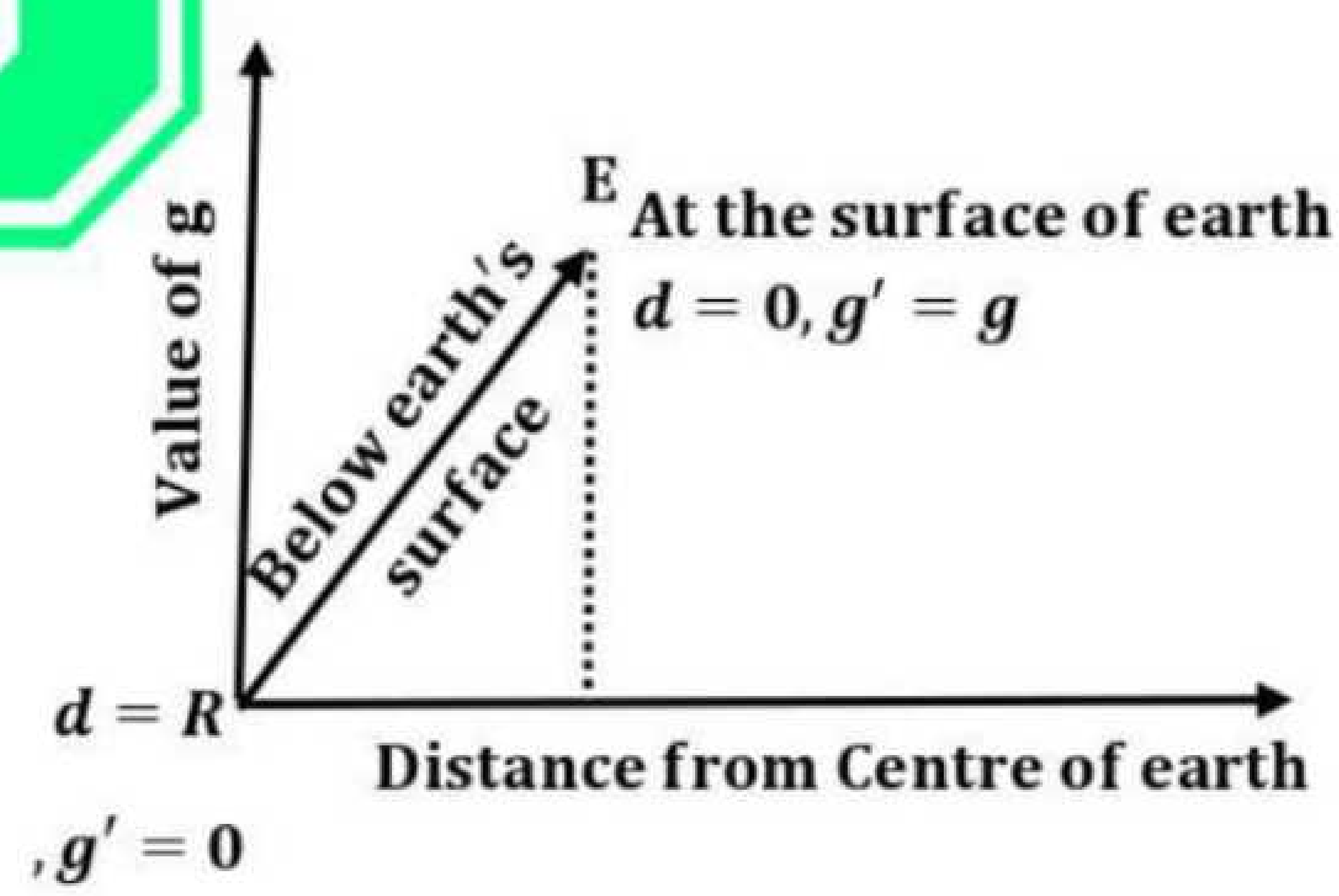
$$g = \frac{G}{R^2}\frac{4}{3}\pi R^3 \rho = \frac{4}{3}\pi G R \rho \qquad \cdots\cdots\cdots (5)$$

$$\text{and } g' = \frac{G}{(R-d)^2}\frac{4}{3}\pi (R-d)^3 \rho \qquad \cdots\cdots\cdots (6)$$

Dividing equation (4)by (5)we get,

$$\frac{g'}{g} = \frac{\frac{4}{3}\pi G (R-d)\rho}{\frac{4}{3}\pi G R\rho} = \frac{R-d}{R} = 1 - \frac{d}{R}$$

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



Which is the required *expression* for the variation of acceleration due gravity with depth. The above expression shows that the value of acceleration due to **gravity decreases** with **increasing the value of depth** and **zero** at the centre of earth ***i.e., at* d = R**.

5) Define moment of inertia. Obtain the expression for rotational kinetic energy of a rigid body.

- The moment of inertia is defined as the sum of the products of the masses and the square of the distance of the different particles of the body from the axis of rotation. It is represented by 'I'.

Mathematically,

$$\mathbf{I} = \sum \mathbf{mr^2}$$

It is the measure of an object's resistance to a change in the object's angular acceleration due to the action of a torque.
The kinetic energy of a rotational motion is;

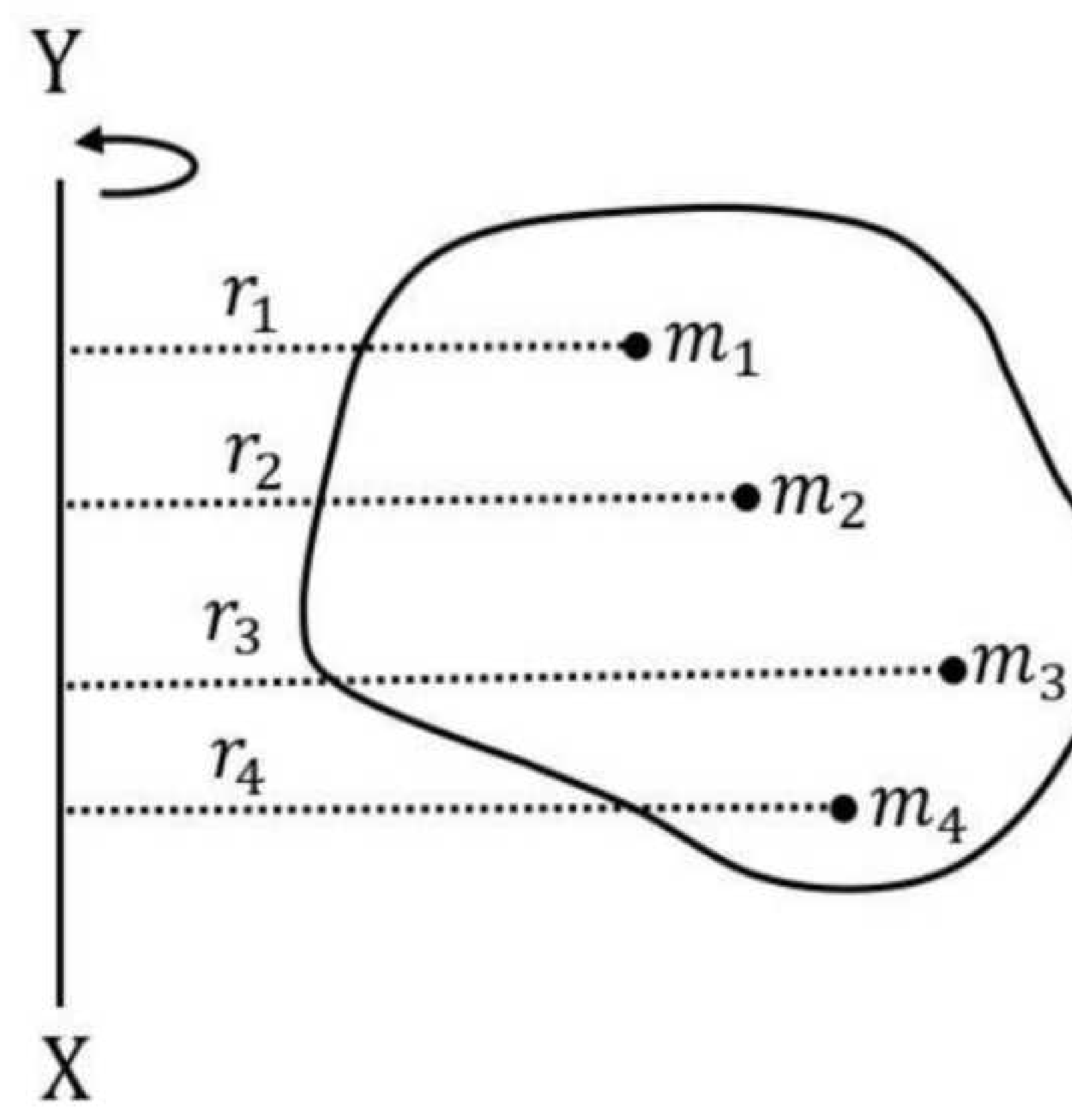
$$\frac{1}{2} I\omega^2$$

The kinetic energy of a body in linear motion is;

$$\frac{1}{2} mv^2$$

Relation between moment of inertia and rotational kinetic energy

- Suppose a body rotates about an axis XY with an angular velocity 'ω'. If a body contains large number of particles, the particles on it also have the same angular velocity 'ω', but as particles are at different distances from the axis of rotation, their linear velocities will be different. Suppose a linear velocities of the particles of masses m_1, m_2 ,.........at distances r_1, r_2 from the axis of rotation are v_1, v_2 and v_3 etc.



Then, kinetic energy of the particles is;

$$\frac{1}{2}m_1v_1^2, \frac{1}{2}m_2v_2^2, \text{.................}$$

Total kinetic energy of the body is equal to the sum of the kinetic energies of various particles and is given by;

$$\text{Total kinetic energy} = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + \text{.................}$$

Since, $v_1 = \omega r_1$ and $v_2 = \omega r_2$ and so on.

$$\text{Total kinetic energy} = \frac{1}{2}m_1\omega^2r_1^2 + \frac{1}{2}m_2\omega^2r_2^2 + \text{.................}$$

$$= \frac{1}{2}(\sum mr^2)\omega^2 = \frac{1}{2}I\,\omega^2 \qquad [\because \; I = \sum mr^2 \;]$$

Kinetic energy of rotation $= \frac{1}{2}I\omega^2$

This is the required relation.

6) What is thermal conductivity? Derive formula for thermal conductivity.

- The thermal conductivity is defined as, "the amount of heat that flows normally per second across the two opposite faces of a unit cube in the steady state when they are maintained at a temperature difference of one degree centigrade."

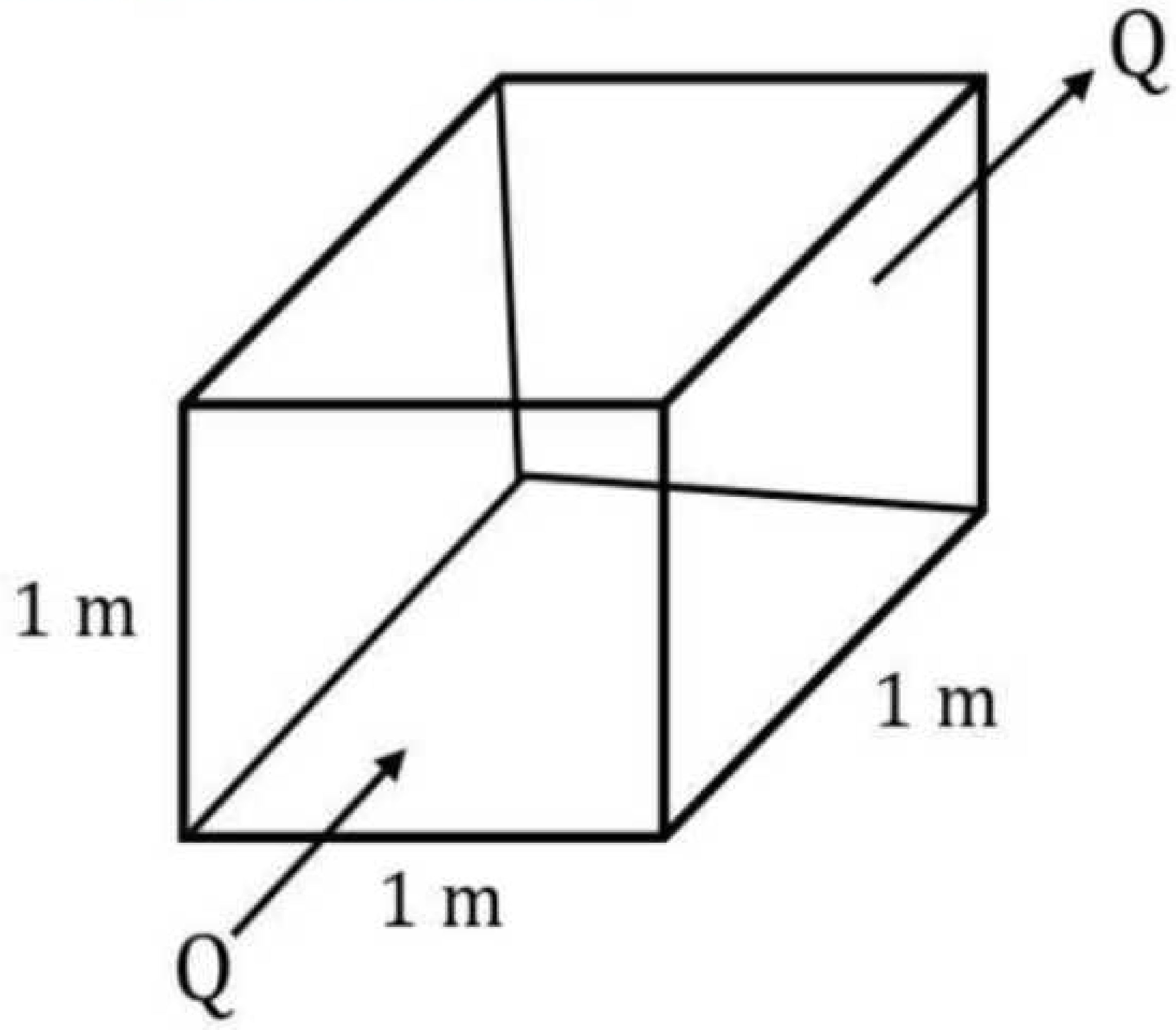
❖ Expression for formula for thermal conductivity.

- The quantity of heat Q flowing across two opposite faces of a conductor maintained at a constant high and low temperature depends;
  - i) directly on the cross sectional area A
  - ii) temperature difference $(\theta_2 - \theta_1)$ between its two ends
  - iii) time 't' for which the heat is allowed to flow
  - iv) inversely to the distance between two ends

$$i.e., Q \propto \frac{A(\theta_2 - \theta_1)}{l}$$

$$\text{or,} \quad Q = \frac{KA(\theta_2 - \theta_1)t}{l}$$

$$\therefore \quad K = \frac{Q \times l}{A(\theta_2 - \theta_1)t}$$



Where, K is a constant called the thermal conductivity of a conductor.

7) Show that $C_P - C_V = R$; where symbols have their usual meanings.

➢ **Refer to the solution 2076 of Q. No 8 on page 14.**

8) Derive the mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ for convex mirror, where symbols have their usual meanings.

Mirror formula for convex mirror

➢ Suppose a real object 'O' lies in front of convex mirror. Its virtual image 'I' is formed behind the mirror as shown in the figure.

Here,
OP = Object distance
IP = Image distance
FP = Focal length

As CA produced externally bisects $\measuredangle$OAQ; we can write,

$$\frac{OA}{IA} = \frac{OC}{IC}$$

Since, the aperture of a mirror is being small; we can write,

$$OA \approx OP$$

and, $IA \approx IP$

$$\therefore \quad \frac{OP}{IP} = \frac{OC}{IC} \quad \cdots\cdots\cdots (i)$$

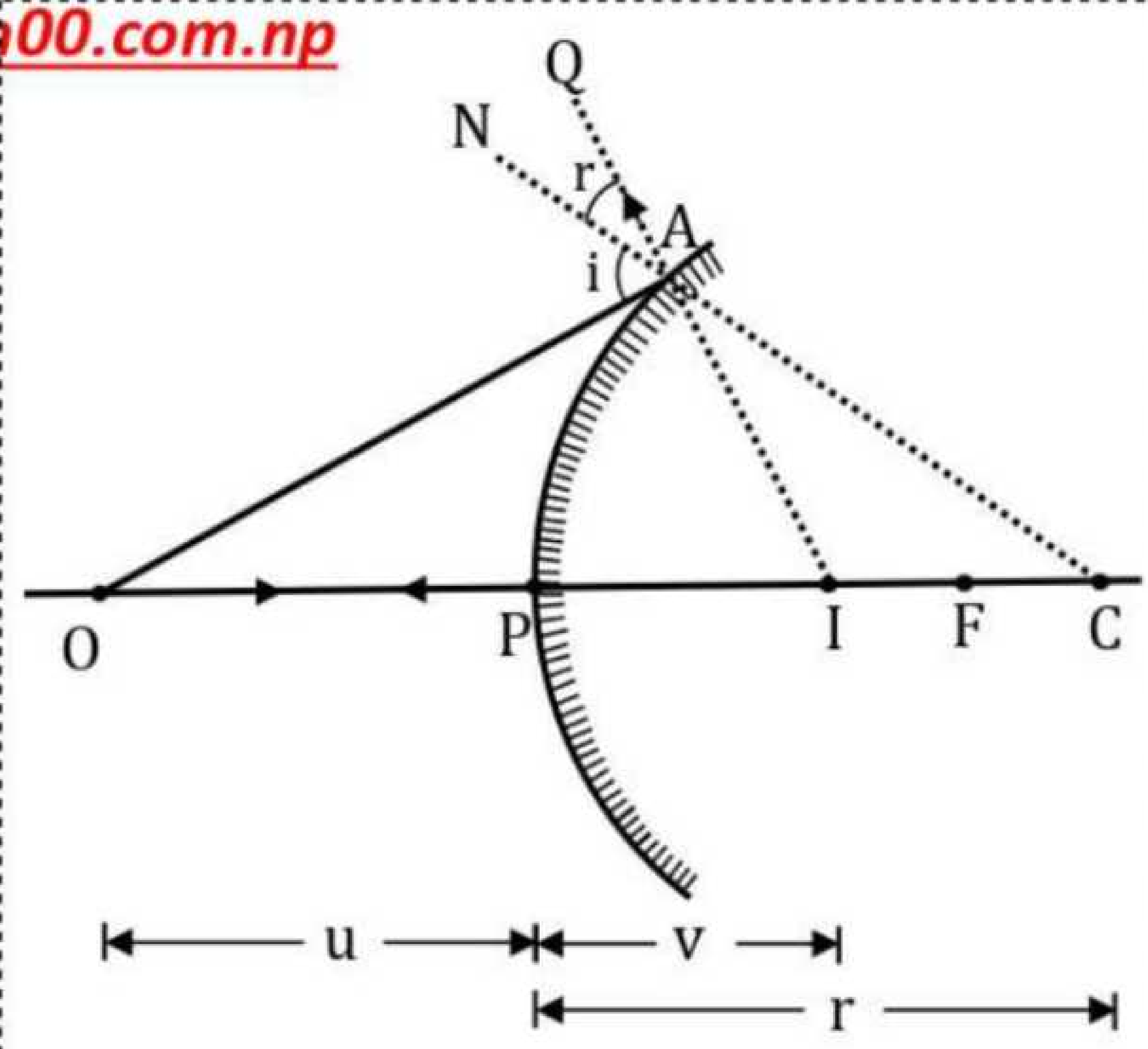


Figure : Virtual image formed by convex mirror

But, $OC = OP + P$

and, $IC = CP - IP$

With these values, equation (*i*) becomes;

$$\frac{OP}{IP} = \frac{OC + CP}{CP - IP} \quad \cdots\cdots\cdots (ii)$$

Applying sign convention for the convex mirror; we have,

$OP = +u$ [∵ real object distance]
$IP = -v$ [∵ virtual object distance]
and, $CP = -r$ [∵ radius of curvature of the convex mirror]

Then, equation (*ii*) becomes;

$$\frac{u}{-v} = \frac{u + (-r)}{-r - (-v)}$$

or, $$\frac{u}{-v} = \frac{u - r}{r - v}$$

or, $uv - ur = -uv + vr$

or, $ur + vr = 2uv$

On dividing both sides by **uvr**; we get,

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{r}$$

Using $\mathbf{r = 2f}$, we get

$$\mathbf{\frac{1}{u} + \frac{1}{v} = \frac{1}{f}}$$

This is the mirror formula for the convex mirror.

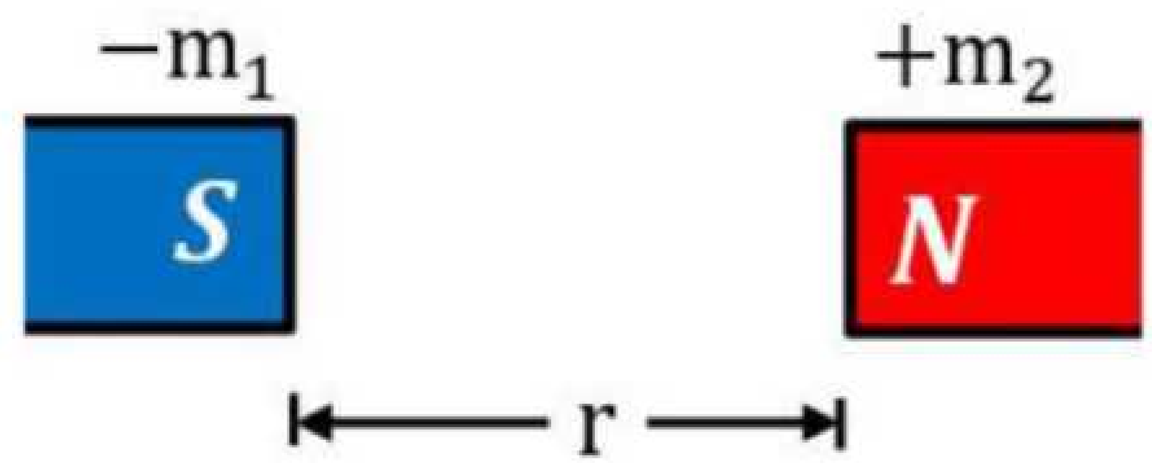
9) State and explain coulomb's law in magnetism.

➢ The *Coulomb's law of magnetism states that* "the attractive or repulsive force between any two poles of the magnets is directly proportional to the product of the pole strength of the poles and inversely proportional to the square of the distance between them".

Let two poles of magnets having pole strengths ; m_1 and m_2 are separated by distance 'r', then,

$$F \propto m_1 m_2 \quad \cdots\cdots\cdots (i)$$

$$and, \; F \propto \frac{1}{r^2} \quad \cdots\cdots\cdots (ii)$$



Combining equation (i) and (ii); we get,

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

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

Where, K is a constant and $K = \frac{\mu}{4\pi}$.

Here, μ is a constant called permeability of the medium between the poles.

$$\therefore F = \frac{\mu}{4\pi} \cdot \frac{m_1 m_2}{r^2}$$

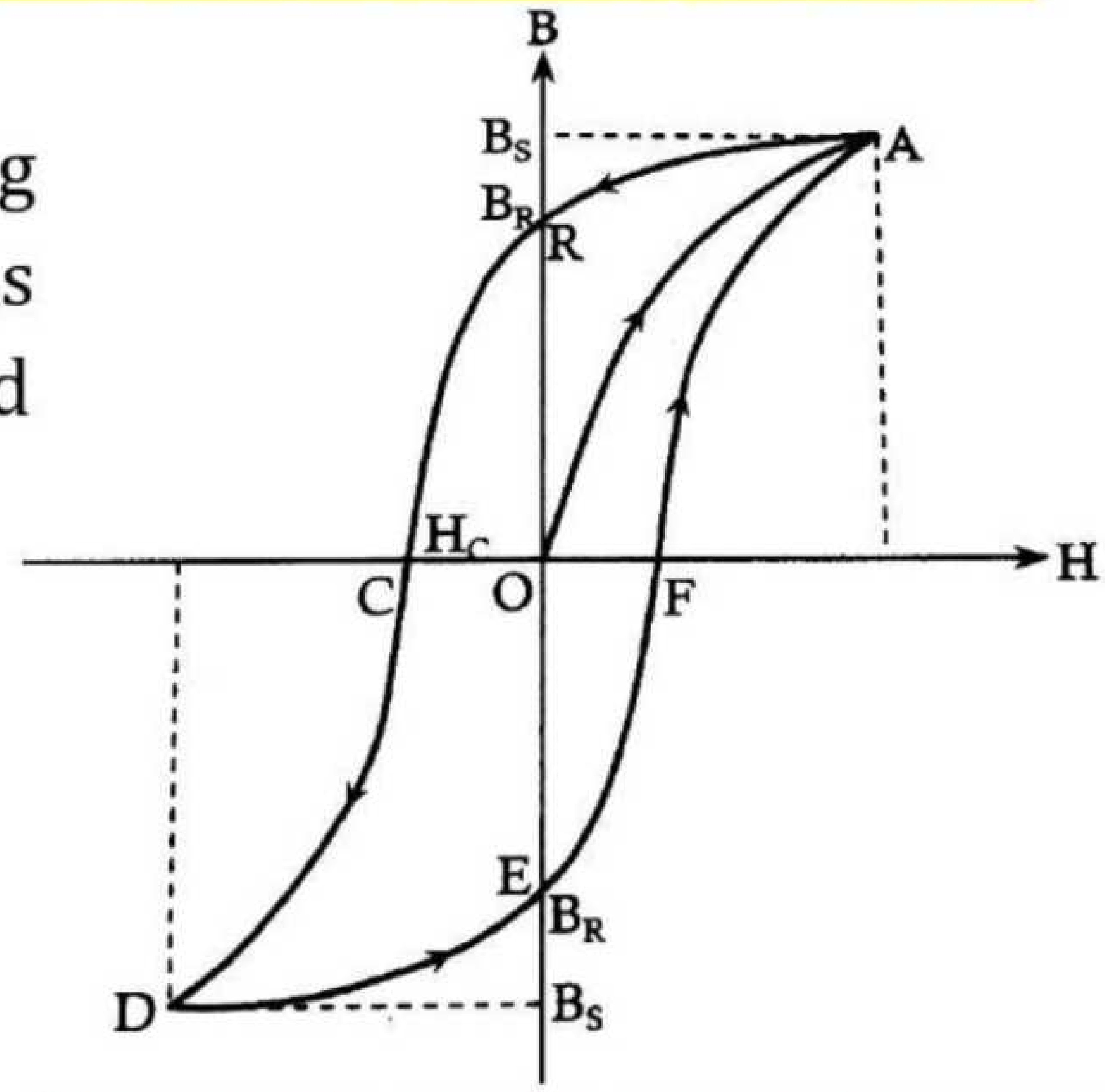
For vacuum; it is represented by μ_0

The value of $\boldsymbol{\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}}$.

The relation for the attractive or repulsive force between poles in vacuum;

$$\mathbf{F = \frac{\mu}{4\pi} \cdot \frac{m_1 m_2}{r^2}}$$

10) What is magnetic hysteresis? Explain it with hysteresis curve.



Hysteresis loop of ferromagnetic material

- Hysteresis is the lag of intensity of Magnetization behind the magnetizing field. Take a ferromagnetic material as an iron rod and apply an external field B_0 to it by placing it into a Solenoid.

  Let us compare the field B in the material to the magnetic intensity $H\left(=\frac{B_0}{\mu_0}\right)$. When, H is increased from zero, the magnetization and hence, the total field B in the material increases along the curve OA and reaches tot the maximum value B_s at A as shown in figure.

  Now, the rod is saturated and further increases in H will not change B. This occurs when all the magnetic domain in the rod align with H. When the H is brought back to zero, the field B does not retrace its original path but instead follows the curve AB and the material remain magnetized with a value of B_R. When H_c is reversed, the magnetic moments in the material reorient unit B reaches to zero at point C on further increasing the intensity, the sample reaches to the saturation at D in opposite direction and on returning H to zero, the material is permanently magnetized at E.

  When the field is increased in original direction, curve DEFA is traced. This behavior is called hysteresis and the closed curve ARCDEFA is called the hysteresis loop. The loop shows that magnetization of the material lags behind the magnetizing field B_0 or H when it is taken through a complete magnetization cycle.

11) An iron block of mass 10kg. rests on a wooden plane at 30° to the horizontal. It is found that the least force parallel to the plane which causes the block to slide up is 100N, calculate the co-efficient of sliding friction between wood and iron. $(\mathbf{g = 10ms^{-2}})$

➢ **Solution:**

Given that;

Mass of slab $(m) = 10$ kg

Angle of inclination $(\theta) = 30°$

$g = 10\ ms^{-2}$

Pulling force $(F) = 100N$

Coefficient of friction $(\mu) = ?$

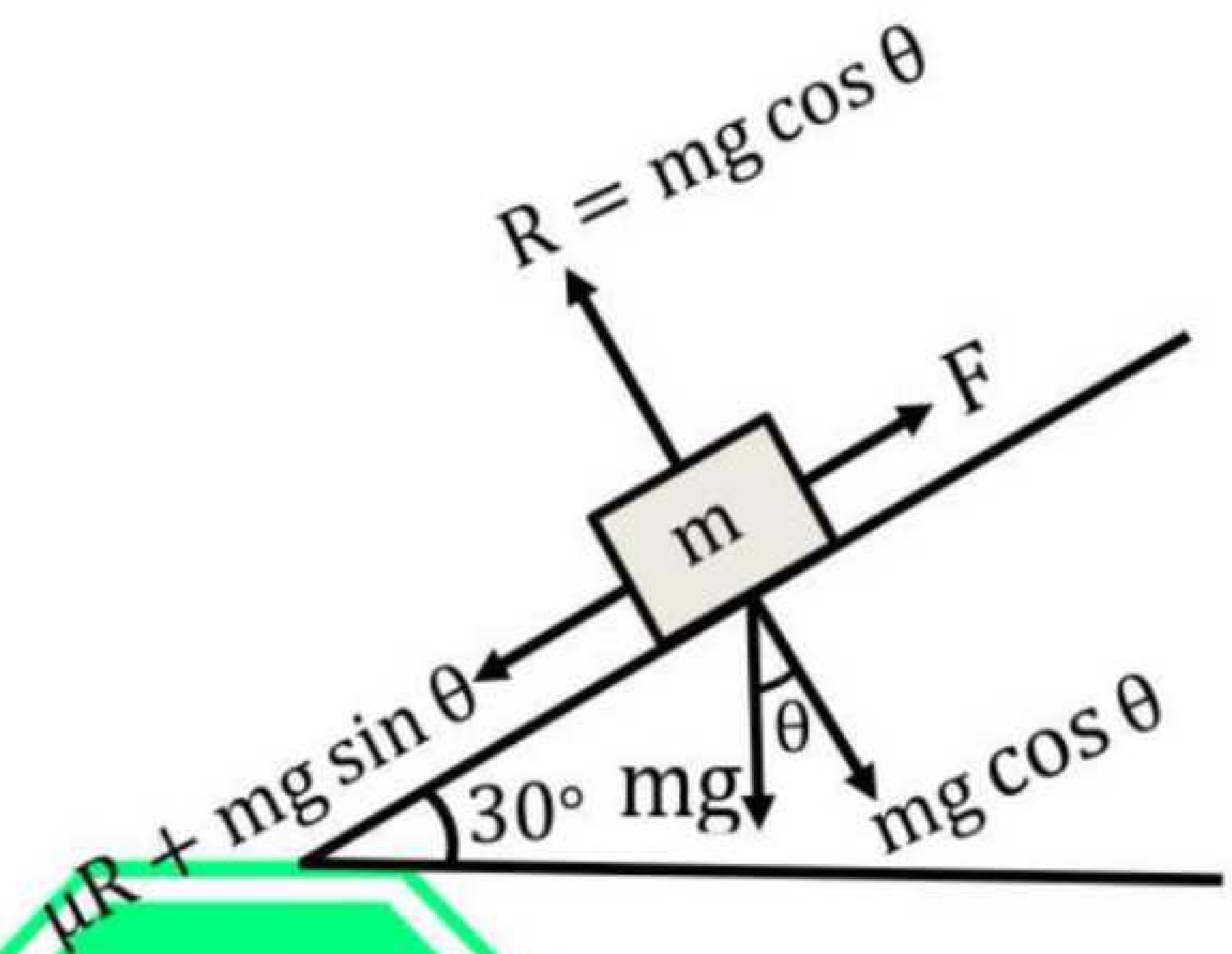


Fig: Iron block on inclined surface

From the figure; we have,

$$F = mg\sin\theta + \mu R$$

$$F = mg\sin\theta + \mu\, mg\cos\theta$$

$$\text{or, } 100 = mg(\sin\theta + \mu\cos\theta)$$

$$\text{or, } 100 = 10 \times 10(\sin 30° + \mu\cos 30°)$$

$$\text{or, } 1 = \sin 30° + \mu\cos 30°$$

$$\text{or, } 0.5 = \mu\cos 30°$$

$$\text{or, } \mu = \frac{0.5}{\cos 30°}$$

$$\therefore \quad \mu = 0.577$$

Thus, The Coefficient of friction $(\mu) = 0.577$.

12) A motorcycle rider going with a velocity of 60 km/hr around a curve with radius of 50m must lean at an angle to the vertical, find the angle at which he leans.

➢ **Solution:-**

Given that,

Velocity(v) = 60 km/hr = 16.67 m/sec.

Radius (r) = 50 m

Angle (θ) = ?

We have,

$$\tan\theta = \frac{v^2}{rg}$$

$$or,\ \tan\theta = \frac{(16.67)^2}{50 \times 10}$$

$$or,\ \theta = tan^{-1}\ (0.555)$$

$$or,\ \theta = 29.03°$$

∴ **He leans at θ = 29.03° with vertical.**

13) Calculate the amount of heat required to convert 1 kg of ice at -5°c to water at 100°c. Given, specific heat capacity of ice = 2100 J/ kg K, specific heat capacity of water = 4200 J/kg K and specific latent heat of fusion of ice = 3.34×10^5 J/kg.

➢ **Solution:-**

Given that,

Mass of ice (m_i) = 1kg

Temperature of ice (θ_1) = −5℃

Specific heat capacity of ice (S_i) = 2100 J /kgK

Specific heat capacity of water (S_w) = 4200 J /kgK

Latent heat capacity of ice (L_f) = 3.34×10^5 J /kg

We know that;

Amount of heat required to change 1 kg of ice at $-5°C$ to $0°C$;

$$\mathbf{Q_1} = m_i\, S_i\, (\theta_2 - \theta_1) = 1 \times 2100\,[0 - (-5)\,] = \mathbf{10500\ J}$$

Amount of heat required to convert ice at 0°C to water at 0°C is;

$$\mathbf{Q_2} = m_i\, S_i = 1 \times 3.34 \times 10^5 = \mathbf{3.34 \times 10^5\ J}$$

Amount of heat required to convert water at 0°C to water at 100°C is;

$$\mathbf{Q_3} = m_i\, S_i\, (\theta_2 - \theta_1) = 1 \times 4200\,(100 - 0) = \mathbf{420000\ J}$$

$[\because\ m_w = (m_i)]$

$$\textbf{Total amount of heat required} = \mathbf{Q_1 + Q_2 + Q_3}$$
$$= 10500 + 3.34 \times 10^5 + 420000$$
$$= 764500\ \text{J}$$

$\therefore$ **Total amount of heat required is 764500 J**

14) A glass flask of volume 800cm^3 is just filled with mercury at $10°\text{c}$. How much mercury will overflow when the temperature of system is raised to $80°\text{c}$? (The coefficient of linear expansion of glass is $4 \times 10^{-6}\ °\text{C}^{-1}$ and coefficient of cubical expansion of mercury is $1.8\ \times \times\ 10^{-6}\ °\text{C}^{-1}$.

➢ **Solution:**

Given that;

Initial volume of glass flask $(V_g) = 800$ cm3

Initial volume of mercury $(V_m) = 800$ cm3

Initial temperature $(\theta_1) = 10°C$

Final temperature $(\theta_2) = 80°C$

Coefficient of linear expansion of glass $(\alpha_g) = 4 \times 10^{-6}\ °C^{-1}$

Coefficient of cubical expansion of mercury $(\gamma_m) = 1.8 \times 10^{-5}\ °C^{-1}$

We know that;

Coefficient of cubical expansion of glass (γ_m) $= 3\alpha_g$

$= 3 \times 4 \times 10^{-6}$

$= 1.2 \times 10^{-5}\ °C^{-1}$

Also,

Increase in volume of glass flask (ΔV_g) $= V_g\gamma_g\Delta\theta$

$= 800 \times 1.2 \times 10^{-5} \times (80 - 10)$

$= 0.672\ cm^3$

Similarly;

Increase in volume of mercury (ΔV_m) $= V_m\gamma_m\Delta\theta$

$= 800 \times 1.8 \times 10^{-5} \times (80 - 10)$

$= 1.008\ cm^3$

Hence,

Amount of mercury that overflows $= \Delta V_m - \Delta V_g$

$= 1.008 - 0.672$

$= \mathbf{0.336 cm^3}$

15) The refractive index of diamond is 2.47. Calculate the speed of light in diamond.

➢ **Solution:**

Given that;

Refractive index of diamond (μ) $= 2.47$

Speed of light in diamond (v) =?

But, we know that the velocity of light in air (vacuum)(c) $= 3 \times 10^8$ m/sec.

Now, using $\boldsymbol{\mu = \frac{c}{v}}$ we have,

$$or,\ v = \frac{c}{v} = \frac{3 \times 10^8}{2.47} = 1.21 \times 10^8 \text{ m/sec.}$$

Hence, the speed of light in diamond is $\mathbf{1.21 \times 10^8}$ m/sec

16) Find the angle of prism if angle of minimum deviation is 38°and refractive index is 1.6.

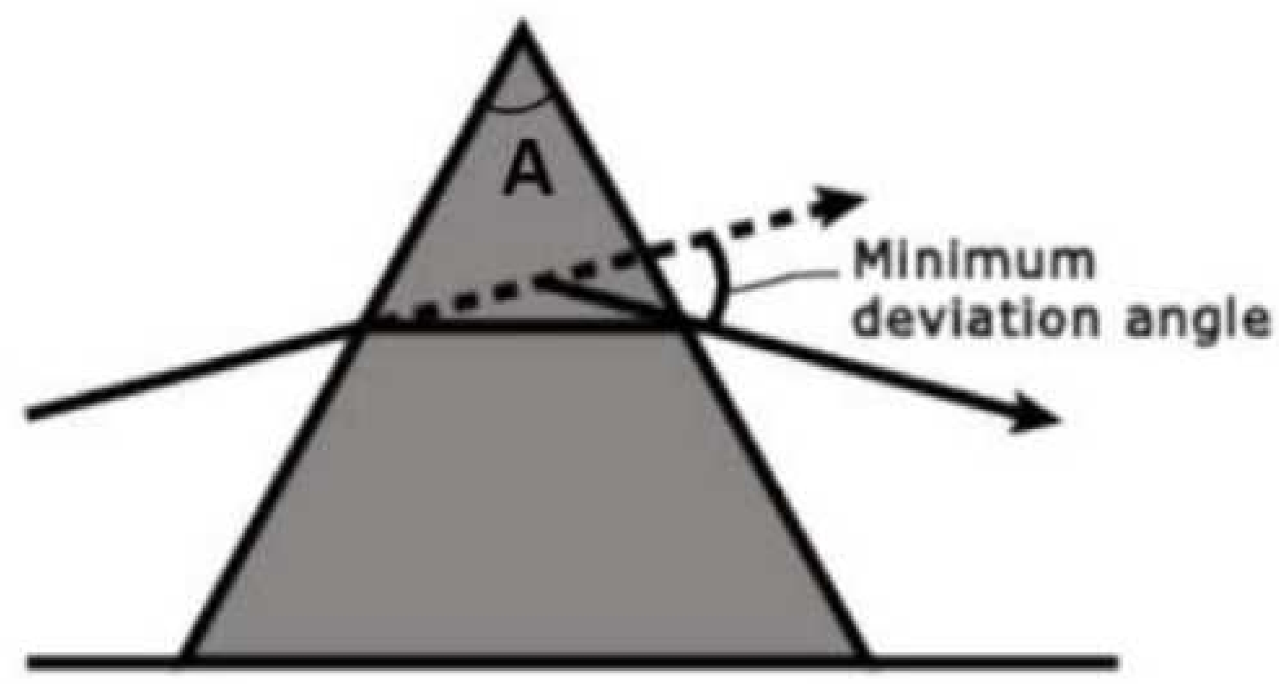
➢ **Solution:**

Given that;

Angle of minimum deviation $(\delta_m) = 38°$

Refractive index $(\mu) = 1.6$

Angle of prism (A) =?



We have,

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

or, $\quad 1.6\sin\left(\frac{A}{2}\right) = \sin\left(\frac{A+38°}{2}\right)$

or, $\quad 1.6\sin\left(\frac{A}{2}\right) = \sin\left(\frac{A}{2}\right)\cos\left(\frac{38°}{2}\right) + \cos\left(\frac{A}{2}\right)\sin\left(\frac{38°}{2}\right)$

$[\because$ using $\sin(A+B) = \sin A\cos B + \cos A\sin B]$

or, $\quad 1.6\sin\left(\frac{A}{2}\right) = \sin\left(\frac{A}{2}\right)\cos 19° + \cos\left(\frac{A}{2}\right)\sin 19°$

or, $\quad \sin\left(\frac{A}{2}\right) \times [1.6 - 0.945] = \cos\left(\frac{A}{2}\right) \times 0.325$

or, $\quad \frac{\sin\left(\frac{A}{2}\right)}{\cos\left(\frac{A}{2}\right)} = \frac{0.325}{0.655}$

or, $\quad \tan\left(\frac{A}{2}\right) = 0.496$

or, $\quad \frac{A}{2} = \tan^{-1}(0.496)$

or, $\quad \frac{A}{2} = 26.38°$

$\therefore$ **Angle of prism (A) = 52.76°**

17) A bar magnet of magnetic length 10cm has a magnetic moment of $1.2\ \text{Am}^2$. Calculate the magnetic intensity at a point 20cm from each pole. ($\mu_0 = 4\pi \times 10^{-7}\text{TmA}^{-1}$).

➢ **Solution:**

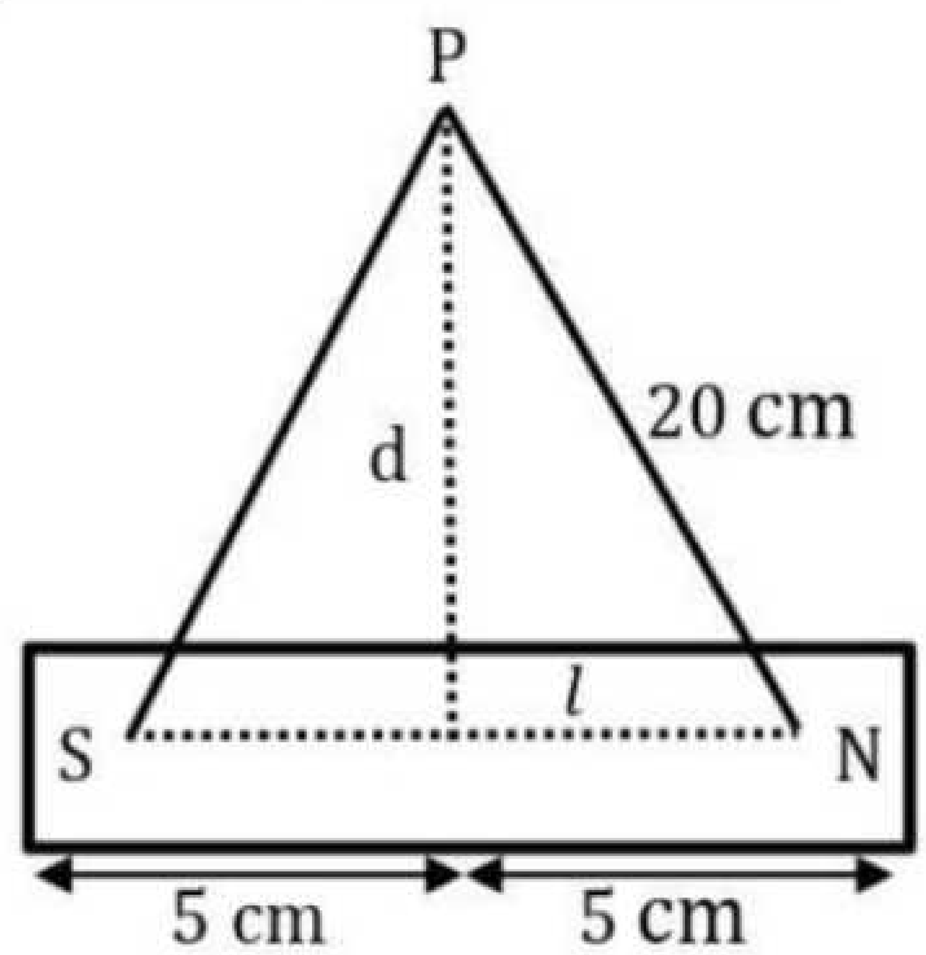
Given that;
Length of bar magnet $(2l) = 10\text{ cm} = 0.1\text{ m}$
Magnetic moment $(\text{M}) = 1.2\ \text{Am}^2$
$\mu_0 = 4\pi \times 10^{-7}\text{TmA}^{-1}$
Distance from each pole $(\sqrt{d^2 + l^2}) = 20\text{cm} = 0.2\text{m}$
Magnetic field intensity (B) =?

The value of magnetic field intensity on the equatorial line is

$$B = \frac{\mu_0}{4\pi} \times \frac{M}{(d^2 + l^2)^{\frac{3}{2}}}$$

$$= \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{12}{(0.2)^3}$$

$$= \mathbf{1.5 \times 10^{-5}\ T}$$



18) The horizontal component of earth's magnetic field is 3.4×10^{-5} T and angle of true dip is $30°$. find the total magnetic flux density of earth and the vertical component.

➢ **Solution:-**

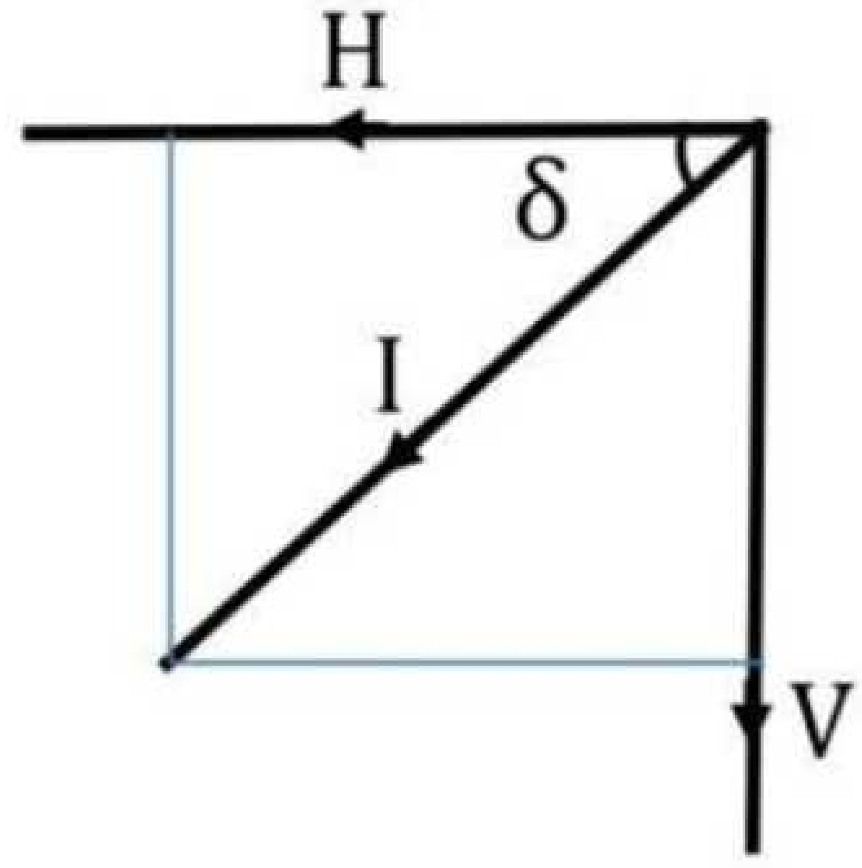
Given that;
Horizontal component of earth's magnetic field $(\text{H}) = 3.4 \times 10^{-5}\text{T}$
Angle of dip $(\delta) = 30°$
Total intensity (I) =?
Vertical component (V) =?

For total intensity of earth's magnetic field; we have,

from figure, $H = I \cos\delta$

$$\therefore I = \frac{H}{\cos\delta} = \frac{3.4 \times 10^{-5}}{\cos 30°} = \mathbf{3.925 \times 10^{-5}\ T}$$

and, for vertical component of earth's magnetic field;



we have, $\tan\delta = \frac{V}{H}$

or, $V = H \tan\delta$

or, $V = 3.4 \times 10^{-5} \tan 30°$

$\therefore\ V = 1.962 \times 10^{-5}$ T

Hence, the value of total magnetic intensity of earth's magnetic field is 3.925×10^{-5} T and vertical component is 1.962×10^{-5} T

–The End –

1) State the principle of conservation of linear momentum. Show that principle follows Newton's laws of motion.

➢ **Refer to the solution 2076 of Q. No 1 on page 3.**

2) What is satellite? Derive the expression for orbital velocity of and artificial Satellite and hence derive its time period.

➢ **Satellite** is heavenly body which revolves round the earth in its own orbit. Type of Satellite : Natural & Artificial Satellite.
For example, the moon is a satellite because it orbits Earth.

Expression for orbital velocity

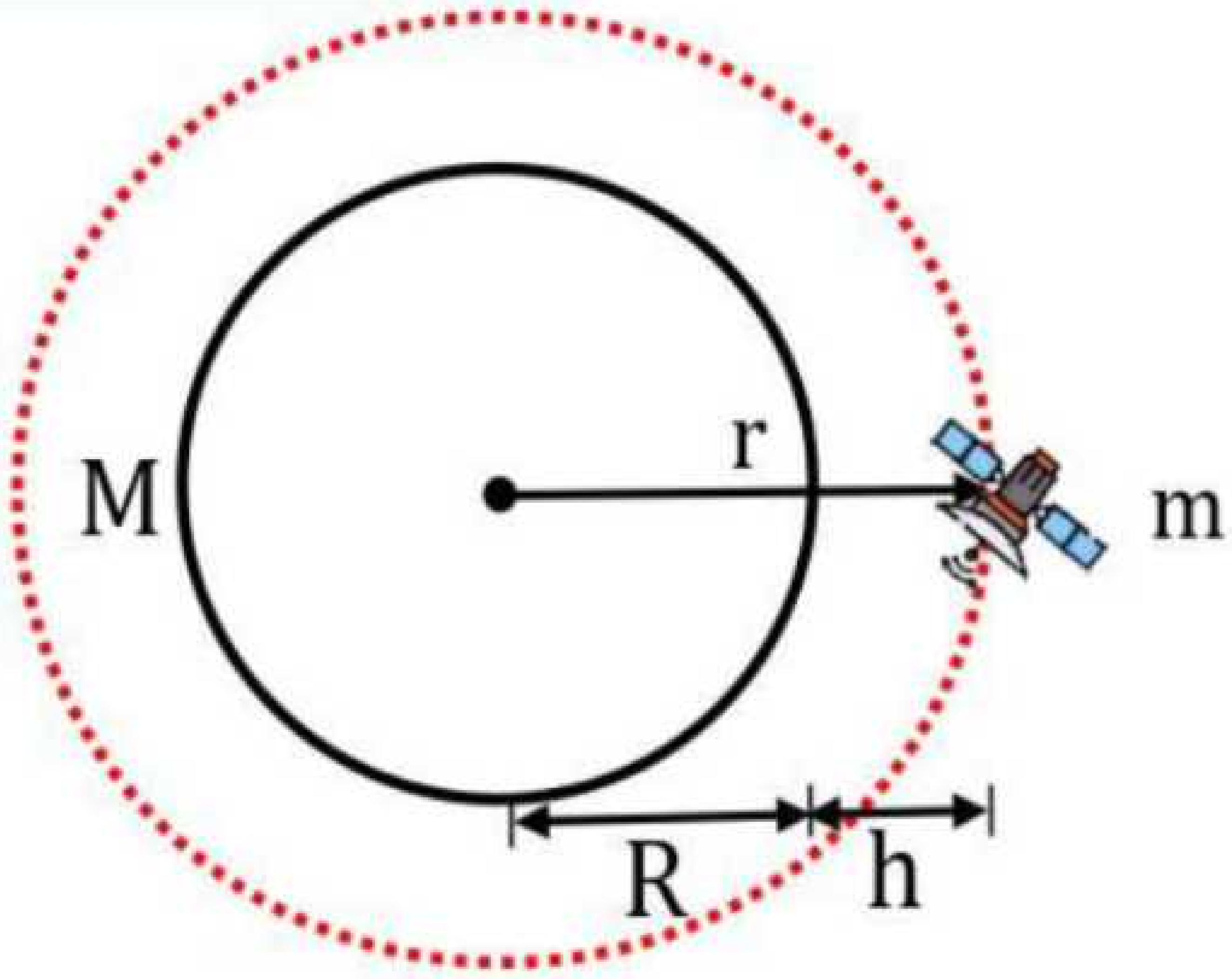
➢ Let a satellite of mass m moves around the earth in an orbit of radius $'r = R + h'$. If 'M' is the mass of the earth, then to orbit around the earth necessary centripetal force is provided by gravitational force between the earth and the satellite.

$i.e.,$ centripetal force $=$ gravitational force between earth & satellite

$$or, \quad \frac{mv^2}{r} = \frac{GMm}{r^2}$$

or, $v^2 = \frac{GM}{r}$

or, $v = \sqrt{\frac{GM}{r}}$



The orbital velocity in independent of mass of satellite. It depends on Mass (M) and radius (R) of planet around which it revolves.

❖Time Period

➢ The time taken by satellite to complete one revolution around earth is called time period of satellite. It is denoted by T.

$$T = \frac{\text{Circumference of orbit}}{\text{Orbital Velocity}}$$

$$T = \frac{2\pi r}{v}$$

On Substituting $v = \sqrt{\frac{GM}{r}}$

$$T = \frac{2\pi r}{\sqrt{\frac{GM}{r}}}$$

$$= 2\pi\sqrt{\frac{(r)^3}{GM}} \qquad \textit{, where } \mathbf{r = R + h}$$

Hence, Which is Required Expression For Time period for satellite

3) Stating the postulate of kinetic theory of gas. Derive an expression for the pressure exerted by the gas contained box.

➢ **Refer to the solution 2078 of Q. No 2 on page 29.**

4) What is power of lens? Derive lens maker's formula for convex lens.

➢ Power of a lens is its ability to converge or diverge the light rays after passing through it. Power of a lens is equal to reciprocal of the focal length of the lens.

i.e., Power (p) $= \frac{1}{f}$, where f is in meter, P is in Diopter.

❖ Expression for lens maker′s formula for convex lens

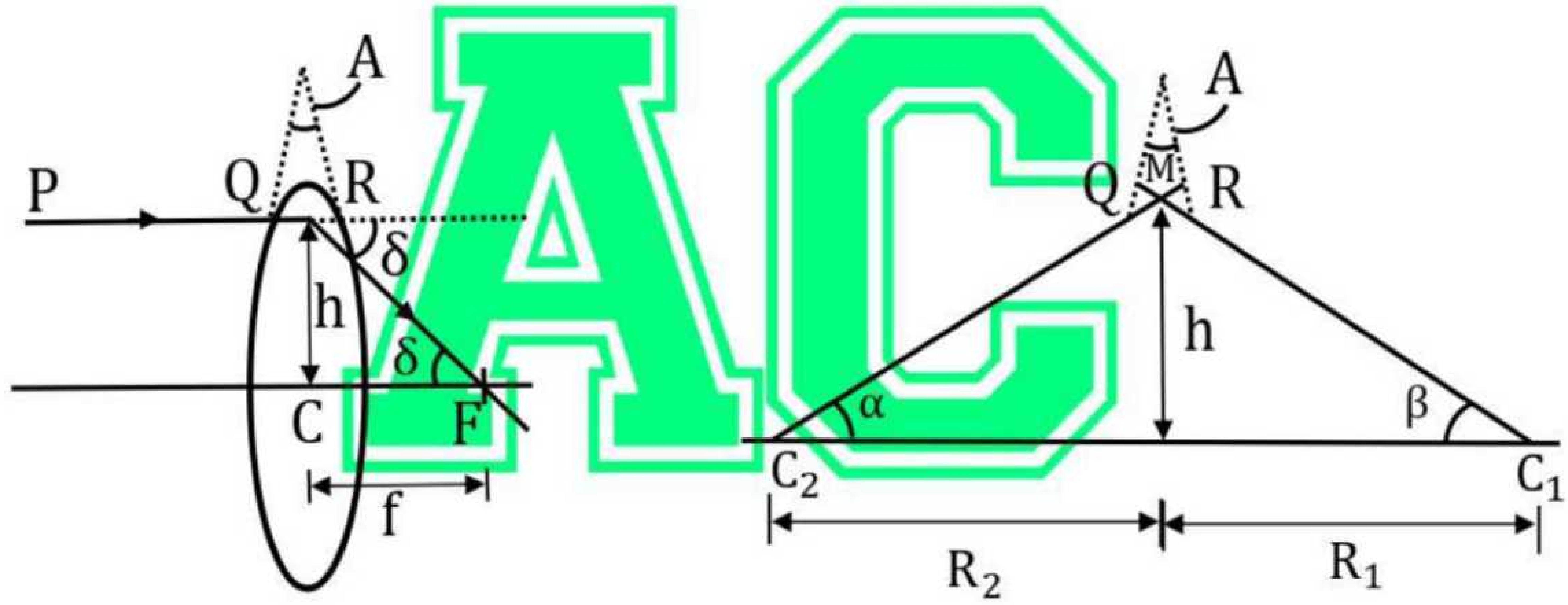


***Figure*: (1)** ***Figure*: (2)**

➢ Let us consider the lens as portion of a small angled prism as shown in the figure. If a ray PQ parallel to the principle axis strikes the lens at 'Q' and is refracted to the focus 'F'. If 'h' is the height of 'Q' from centre 'O' of the lens. If 'δ' is deviation produced, then, from the figure (1); we have,

$$\tan\delta = \frac{h}{f}$$

Since, lens is thin, so,

$$\tan\delta = \delta$$

$$\text{or,} \quad \delta = \frac{h}{f} \qquad \cdots\cdots\cdots\cdots (i)$$

We know for small angle prism the deviation produced is;

$$\delta = A(\mu - 1) \qquad \cdots\cdots\cdots\cdots (ii)$$

Where, A is the angle of prism.

From equation (i) and (ii); we get

$$\frac{h}{f} = A(\mu - 1) \qquad \cdots\cdots\cdots\cdots (iii)$$

Let, C_1 Q and C_2 R be the normal on 'Q' and 'R' as shown in the figure (2) on two faces of the lens. Then; we get,

$$\measuredangle QMC_2 = A = \alpha + \beta = \frac{h}{R_1} + \frac{h}{R_2}$$

Substituting the value of A in the relation (iii); we get,

$$\frac{h}{f} = \left(\frac{h}{R_1} + \frac{h}{R_2}\right)(\mu - 1)$$

$$or, \quad \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Which is the required lens maker's formula.

5) Write the differences between scalar and vector product.

➢ The difference between scalar and vector product are given below:-

Scalar	Vector
If the product of two vectors is a scalar quantity then it is known as ***scalar multiplication*** of two vectors.	If the product of two vectors is a vector quantity, then it is known as ***vector multiplication*** of two vectors.
It is also known as ***scalar product*** or dot product.	It is also known as ***vector product*** or cross product.
Scalar product gives the magnitude of two vectors.	Vector product gives magnitude as well as direction.
If A and B be two vectors inclined at an angle θ to each other, then its scalar product is given by; $\overrightarrow{A}.\overrightarrow{B} = AB\cos\theta$	If A and B be two vectors inclined at an angle θ to each other, then its cross product is given by; $\overrightarrow{A} \times \overrightarrow{B} = AB\sin\theta\,\hat{n}$; where, $\hat{n}$ is unit vector perpendicular to the plane of $\overrightarrow{A}$ and $\overrightarrow{B}$.
For example; Work done, W by a force, $\overrightarrow{F}$ in moving a body through displacement $\overrightarrow{S}$ is a scalar product. $W = \overrightarrow{F}.\overrightarrow{S} = FS\cos\theta$	***For example;*** Torque due to a force is the cross product of force perpendicular distance. $\overrightarrow{\tau} = \overrightarrow{r} \times \overrightarrow{F}$

6) State principle of conservation of angular momentum. How momentum related to torque acting on a body?

- The principle of conservation of angular momentum states that, "If no external torque acts on a system, the total angular momentum of the system remains conserved".

i. e., $I\omega = \text{Constant}$

❖ Expression for momentum related to torque acting on a body.

We have,

$$L = I\omega$$

Now, differentiating the relation; we get,

$$\frac{dL}{dt} = \frac{d}{dt}(I\omega)$$

For a fixed axis of rotation; 'I' remains unchanged, hence,

$$\frac{dL}{dt} = I\frac{d\omega}{dt} \qquad \text{But,} \quad \frac{d\omega}{dt} = \alpha = \text{angular acceleration of body}$$

$$\therefore \frac{dL}{dt} = I\alpha$$

Again, we know that, $\tau = I\alpha$

$$\therefore \frac{dL}{dt} = \tau$$

The torque is equal the rate of change of angular momentum of the body

7) Derive the relation between coefficient of linear and superficial expansion of soild.

Relation between α and β

- **Refer to the solution 2076 of Q. No 4 on page 9.**

8) What is black body? Explain Stefan's law of black body radiation.

- A body which absorbs heat radiations of all wavelengths that falls on it is called black body. Black body when it is heated, it emits radiation which is called ***black body radiation***.

- 2nd Part: **Refer to the solution 2076 of Q. No 7 on page 13.**

9) What is critical angle? Show that $Sin\ C = \frac{1}{\mu}$ where, C is the critical angel and μ is the refractive index of medium.

- **Refer to the solution 2076 of Q. No 9 on page 16.**

10) Derive the mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ for convex mirror, where symbols have their usual meanings.

- **Refer to the solution 2078 of Q. No 8 on page 39.**

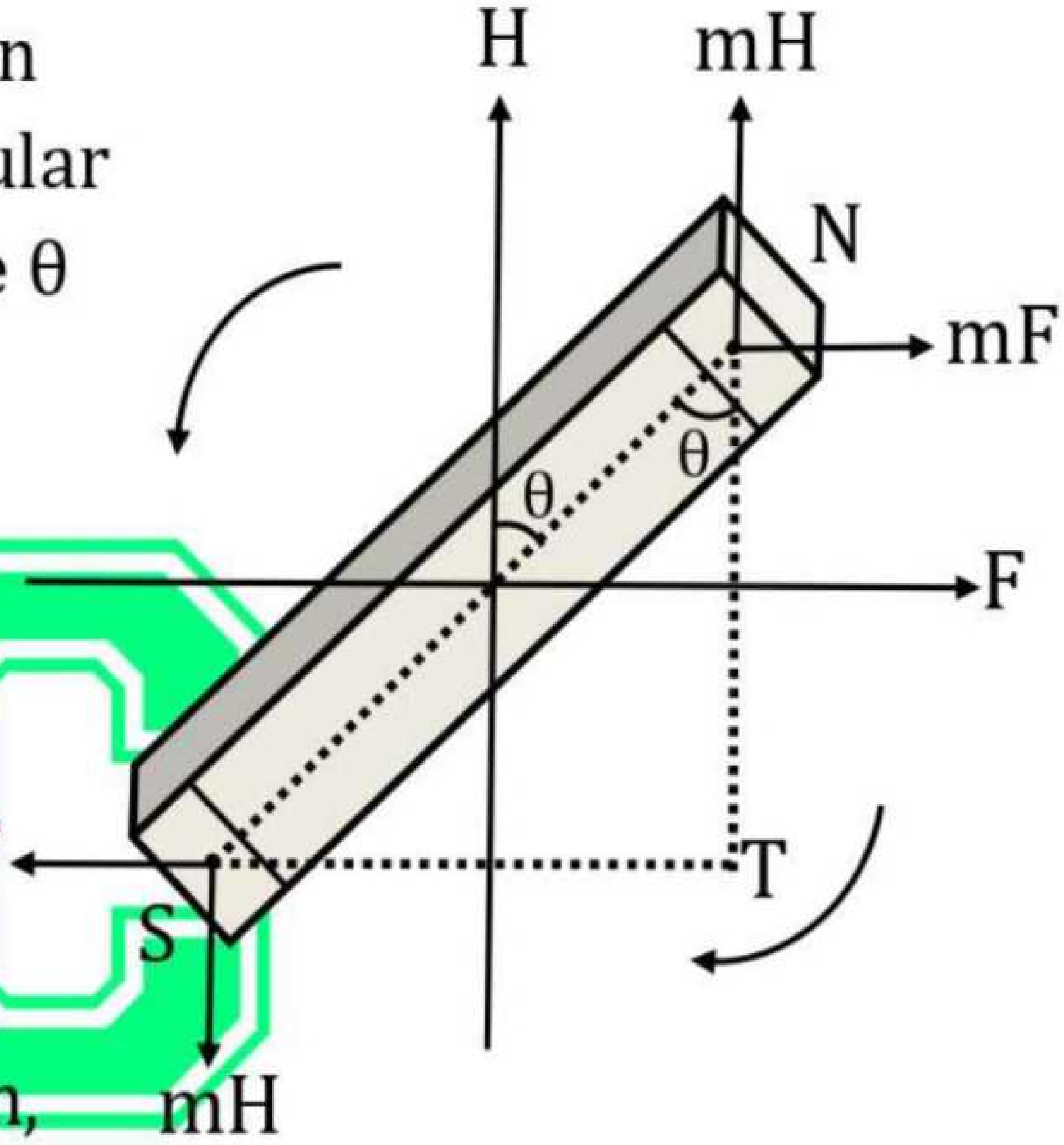
11) State and derive tangent law in magnetism.

- The tangent law states that, if a magnetic needle is suspended freely to two mutually perpendicular magnetic fields 'F' and 'H', then it rests along the resultant of these two fields, such that;

$$F = H \tan\theta$$

Where, θ is the angle made by the axis of the needle with field 'H'.

- Let, a magnet NS be suspended in between two magnetic fields 'H' and 'F' perpendicular to each other and come to rest at an angle θ with the field 'H'. Then clearly, forces mH and mF, due to the fields 'H' and 'F' respectively act upon the two poles of the magnet in the directions shown.



The moment of the couple due to field H = mH × ST tends to rotate the magnet in the anti-clockwise direction,

and moment of the couple, due to field F = mF × NT tending to rotate the magnet in the clockwise direction.
From the principle of moments; we get,

$$mF \times NT = mH \times ST$$

or, $$F = H\frac{ST}{NT} = H\ \tan\theta$$

or, $$F = H\ \tan\theta$$

Since, 'H' is constant for the place.

$$\mathbf{F \propto \tan\theta}$$

This is the tangent law.

12) Explain the domain theory of ferromagnetism.

- This theory was proposed by Weiss in 1907. It explains the hysteresis and the properties of ferromagnetic materials.

Postulates of domain theory:

- ✓ A ferromagnetic material is divided into a large number of small region called domains (0.1 to 1 of area)
- ✓ In each domain the magnetic moments are in same direction.
- ✓ But the magnetic moment varies from domain to domain and the net magnetization is zero.
- ✓ In the absence external magnetic field all the magnetic moments are in different direction.
- ✓ When a magnetic field is applied there are two process takes place:

❖ By the motion of Domain walls :

- When a small amount of magnetic field is applied, the dipoles in the domains are aligned parallel to the applied magnetic field. It increases domain area by the motion of domain walls.

❖ By the rotation of Domains:

- If the applied magnetic field is further increased, the domains are rotated parallel to the field direction by the rotation of domains.

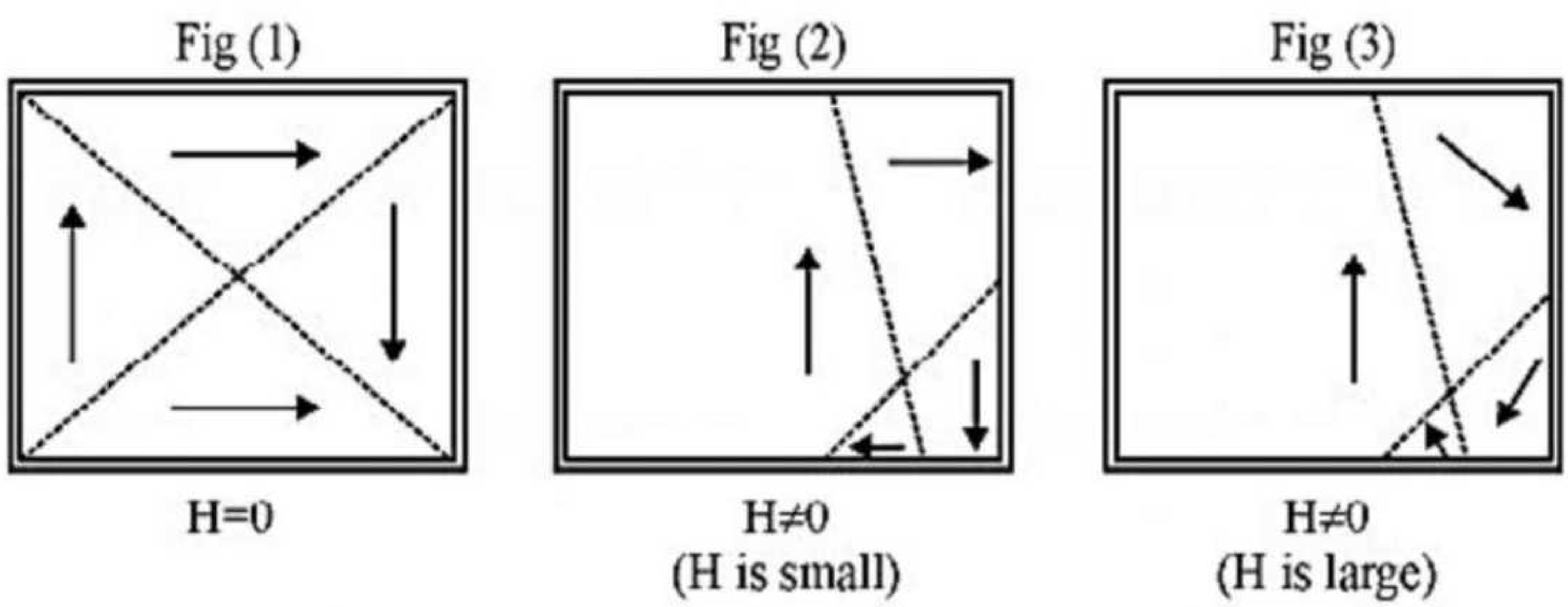


Fig: Domain theory of ferromagnetism

When the field B_0 is removed the boundaries of domain do not recover their original position and the material is not completely demagnetized but some magnetism still remains.

13) A slab of mass 10kg is laying on a plane inclined at 30° to the horizontal. Find the least force which will pull the slab upward. Given Coefficient of friction is 0.2 and $g = 9.8ms^{-2}$

➢ **Solution:**

Given that;

Mass of slab $(m) = 10$ kg

Angle of inclination $(\theta) = 30°$

Coefficient of friction $(\mu) = 0.2$

$g = 9.8\ ms^{-2}$

Least force to pull slab upward $(F) = ?$

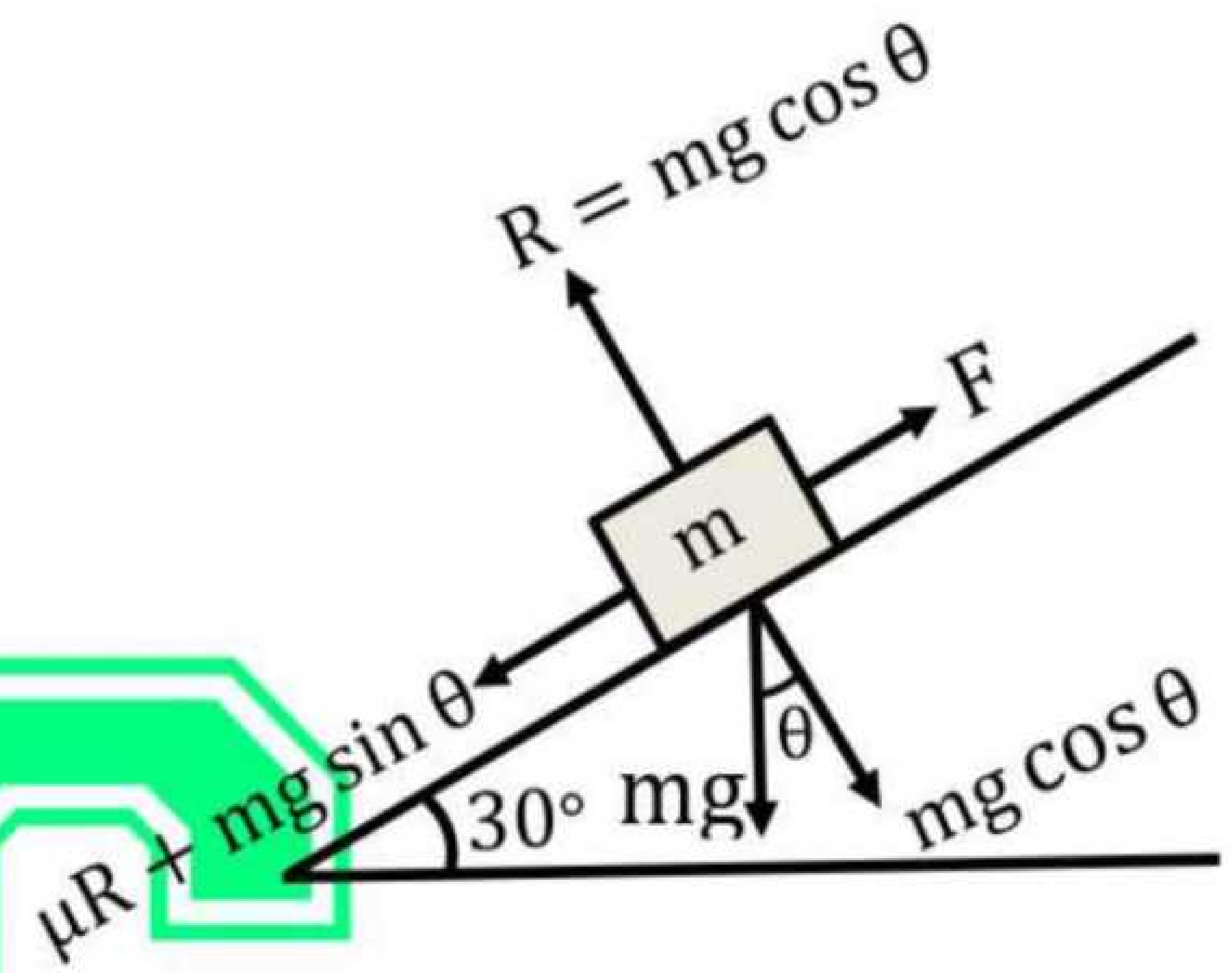


Fig: Iron block on inclined surface

The least force to pull the slab upward on an inclined plane is; (from figure)

$$F = mg\sin\theta + F_f$$

$$= mg\sin\theta + \mu R \qquad [\because F_f = \mu R, \text{Frictional force}]$$

$$= mg\sin\theta + \mu mg\cos\theta$$

$$= mg(\sin\theta + \mu\cos\theta)$$

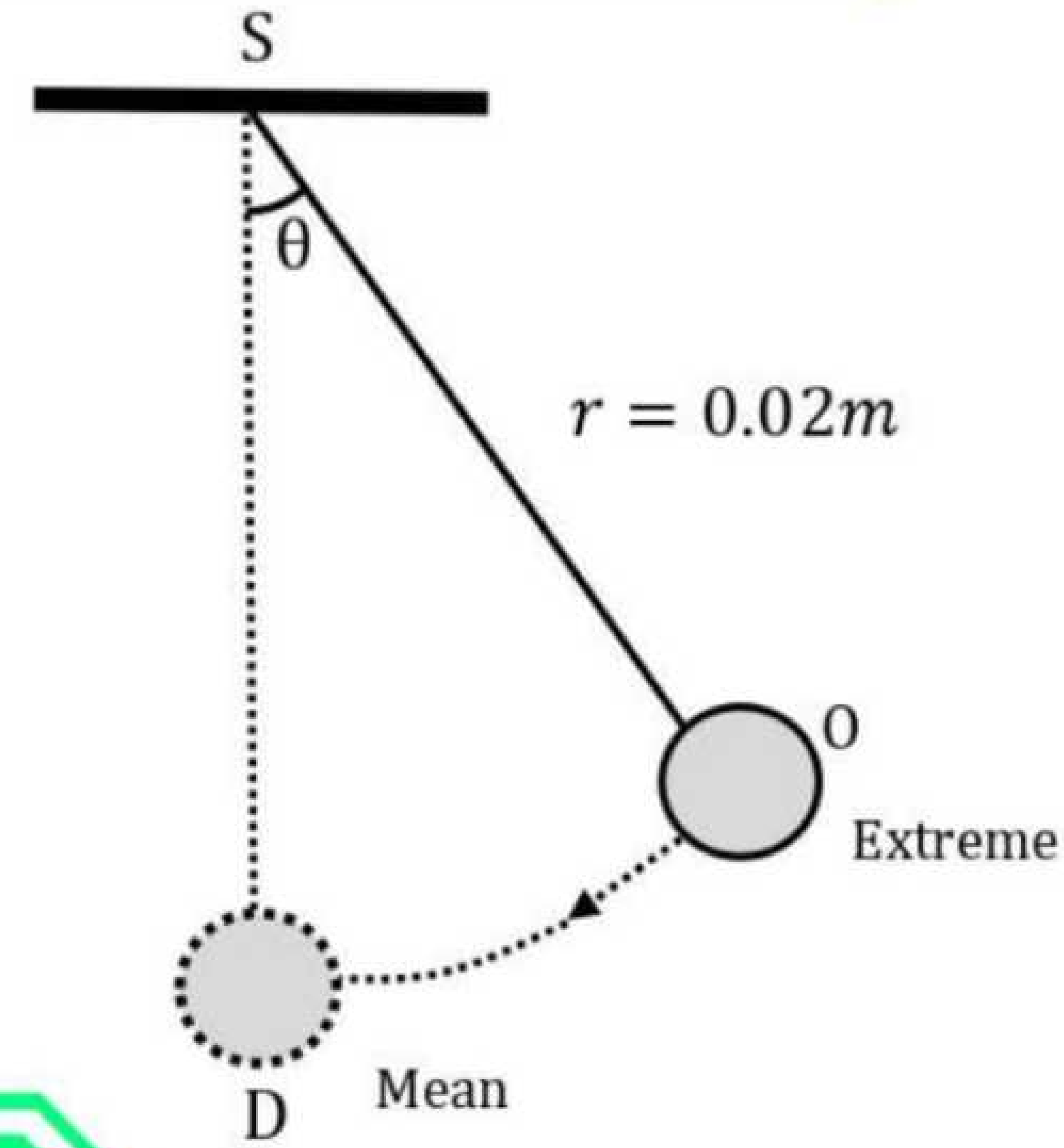
$$= 10 \times 9.8\,(\sin 30° + 0.2\cos 30°)$$

$$= 98 \times 0.67$$

$$\therefore F = 65.97\ N$$

Thus, the least force to pull the slab upward is 65.97 N

14) An object moving with S.H.M. has amplitude of 0.02 m and frequency 20 Hz. Calculate:
(a) the period of oscillation
(b) the velocity and acceleration at mean position and extreme position.



➢ **Solution:**

Given that;
Amplitude (r) = 0.02 m
Frequency (f) = 20 Hz

We have,

a) Time period (T)

$$T = \frac{1}{f} = \frac{1}{20} = 0.05 \text{ sec.}$$

b) At mean position; we have

Maximum velocity$(V_{max}) = \boldsymbol{\omega r} = 2\pi fr = 2\pi \times 20 \times 2.02 = \mathbf{2.51\ ms^{-1}}$

Minimum acceleration$(a_{min}) = 0$ $\quad [\because a = -\omega^2 y \text{ and } y = 0]$

At extreme position; we have

Maximum velocity$(V_{max}) = 0$ $\quad \left[\because v = -\omega\sqrt{r^2 - y^2} \text{ and } r = y\right]$

Maximum acceleration$(a_{max}) = \boldsymbol{\omega^2 r}$

$$= (2\pi f)^2 r$$

$$= 4\pi^2 f^2 r$$

$$= 4 \times (3.14)^2 \times (20)^2 \times 0.02$$

$$= \mathbf{315.50\ ms^{-2}}$$

15) A glass flask of volume $400\ \text{cm}^3$ is just filled with mercury at $0°\text{C}$. How much does the mercury will overflow when the temperature of the system raised to $80°\text{C}$? Given: Coefficient of cubical expansion of glass is $1.2 \times 10^{-5}\,°\text{C}^{-1}$ and that of mercury is $1.8 \times 10^{-5}\,°\text{C}^{-1}$.

- **Solution:**

Given that;

Initial volume of glass flask $(V_g) = 400\ \text{cm}^3 = 400 \times 10^{-6}\ \text{m}^3$

Initial volume of mercury $(V_m) = 400\ \text{cm}^3 = 400 \times 10^{-6}\ \text{m}^3$

Initial temperature $(\theta_1) = 0°\text{C}$

Initial temperature $(\theta_2) = 80°\text{C}$

Coefficient of cubical expansion of glass $(\gamma_g) = 1.2 \times 10^{-5}\,°\text{C}^{-1}$

Coefficient of cubical expansion of mercury $(\gamma_m) = 1.8 \times 10^{-5}\,°\text{C}^{-1}$

We have,

Increase in volume of glass flask $(\Delta V_g) = \mathbf{V_g \times \gamma_g \times \Delta\theta}$

$= 400 \times 10^{-6} \times 1.2 \times 10^{-5} \times 80$

$= \mathbf{3.84 \times 10^{-7} m^3}$

Now,

Increase in volume of mercury $(\Delta \mathbf{V_m}) = \mathbf{V_m \times \gamma_m \times \Delta\theta}$

$= 400 \times 10^{-6} \times 1.8 \times 10^{-5} \times 80$

$= \mathbf{5.76 \times 10^{-7} m^3}$

Hence,

Amount of mercury that overflows $= \mathbf{\Delta V_m - \Delta V_g}$

$= 5.76 \times 10^{-7} - 3.84 \times 10^{-7}$

$= \mathbf{1.92 \times 10^{-7} m^3}$

17) How much heat is required to convert 10 g of ice at $-10°C$ into steam at $100°$? (Specific heat capacity of ice $= 0.5$ cal $g^{-1}°C^{-1}$.

➢ **Solution:**

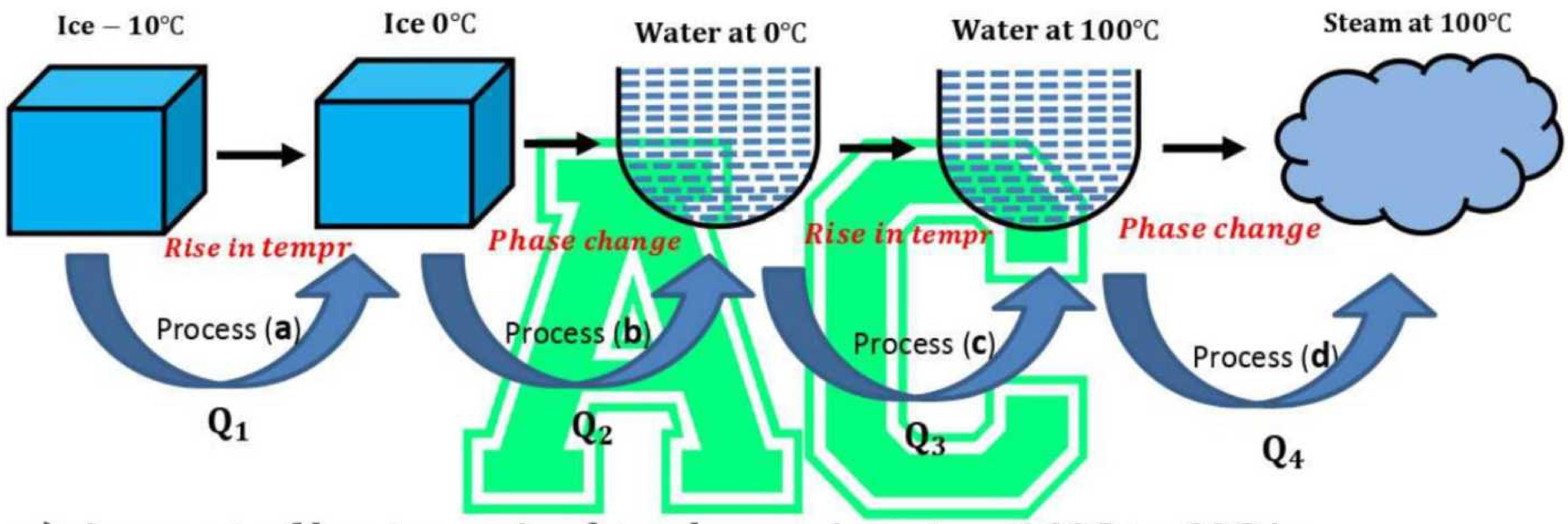
Given that;

Mass of ice (m) = 10 g

Specific heat capacity of ice = 0.5 $calg^{-1}°C^{-1}$

Temperature of ice (t) = − 10 °C

To convert ice at − 10°C to steam at 100°C heat will be gained be ice in following steps.



a) Amount of heat required to change ice at − 10°C to 0°C is;

$$Q_1 = ms_i(0 - t) = 10 \times 0.5[0 - (-10)] = \mathbf{50\ cal}$$

b) Amount of heat required to change ice at 0°C to water at 0°C is;

$$Q_2 = mL_f = 10 \times 80 = \mathbf{800\ cal} \quad [\because \textit{Latent heat of fusion}(L_f) = 80\ cal/g]$$

c) Amount of heat required to change water 0°C to 100°C is;

$$Q_3 = ms_w(100 - 0) = 10 \times 1 \times 100 = \mathbf{1000\ cal}$$

d) Amount of heat required to change water at 100°C to steam at 100°C is;

$$Q_4 = mL_v = 10 \times 540 = \mathbf{5400\ cal}$$

$[\because \textit{Latent heat of vaporization } (L_v) = 540\ cal/g]$

$\therefore$ Total amount of heat required $= Q_1 + Q_2 + Q_3 + Q_4$

$$= 50 + 800 + 1000 + 5400 = \mathbf{7250\ cal}$$

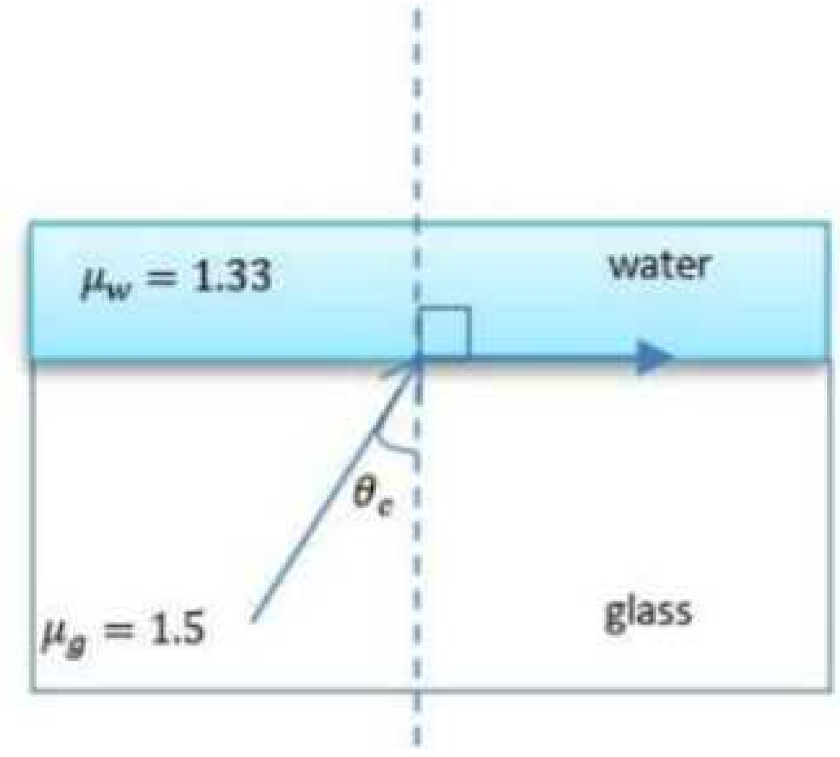
$$= 7250 \times 4.2\ \text{J} = \mathbf{30450\ J} \qquad [\because 1\ \text{cal} = 4.2\text{J}]$$

Therefore, the amount of heat required to convert ice at $-10°C$ to $100°C$ is **30450 Joule**

17) The refractive index of glass and water are 3/2 and 4/3 . respectively. Calculate the critical angle in glass-water interface.

➢ **Solution:**

Given that;



Refractive index of glass $(a^{\mu_g}) = \dfrac{3}{2} = \mathbf{1.5}$

Refractive index of water $(a^{\mu_w}) = \dfrac{4}{3} = \mathbf{1.33}$

From snell's law, $\mu_g\, sin\theta_c = \mu_w \sin 90°$

$\therefore sin\theta_c = \dfrac{a\,\mu_w}{a\,\mu_g} = \dfrac{1}{w\,\mu_g}$

We have,

$\because \mu_{12} = {}_2\mu_1 = \dfrac{\mu_1}{\mu_2}$

$$w^{\mu_g} = \frac{a^{\mu_g}}{a^{\mu_w}} = \frac{1.5}{1.33} = \mathbf{1.1278}$$

$\because {}_2\mu_1 = \dfrac{1}{{}_1\mu_2}$

$\because$ Refractive index of glass w.r.t to water $= W^{\mu_g}$

The critical angle in glass $-$ water interface is given by;

$$\sin\theta_c = \frac{1}{w^{\mu_g}} = \frac{1}{1.127} = \mathbf{0.8866}$$

$$\therefore \quad \theta_c = \sin^{-1}(0.8866) = \mathbf{62.46°}$$

Therefore, the required critical angle in glass $-$ water interface is **62.46°**.

18) A prism of angle 60° is made of glass of refractive index 1.5. Calculate the angle of minimum deviation.

➢ **Solution:**

Given that;

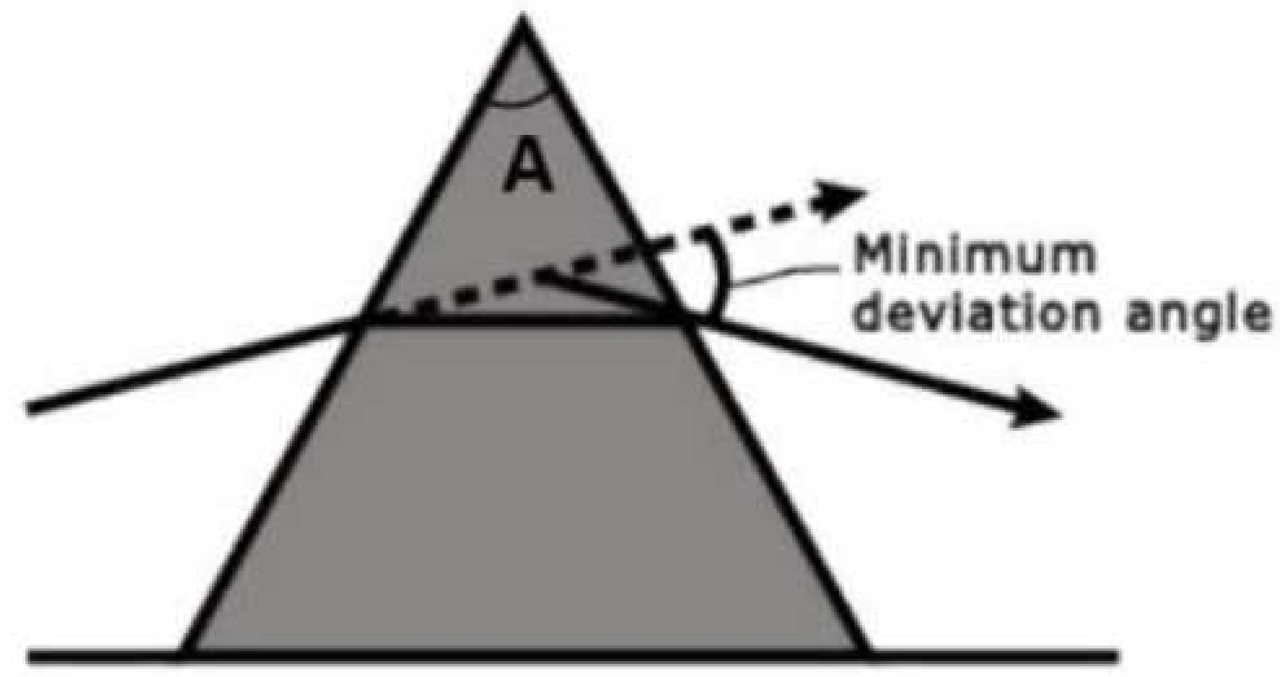
Angle of prism, for equilateral prism $(A) = 60°$

Refractive index $(\mu) = 1.5$

Angle of minimum deviation $(\delta_m) = ?$

For a minimum deviation of a glass prism; we have,

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



$$\text{or,} \quad 1.5 = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{sin\frac{60°}{2}}$$

$$\text{or,} \quad \text{Sin}\left(30° + \frac{\delta_m}{2}\right) = 1.5 \ \sin 30° = 0.75$$

$$\text{or,} \quad 30° + \frac{\delta_m}{2} = \sin^{-1}(0.75) = 48.59°$$

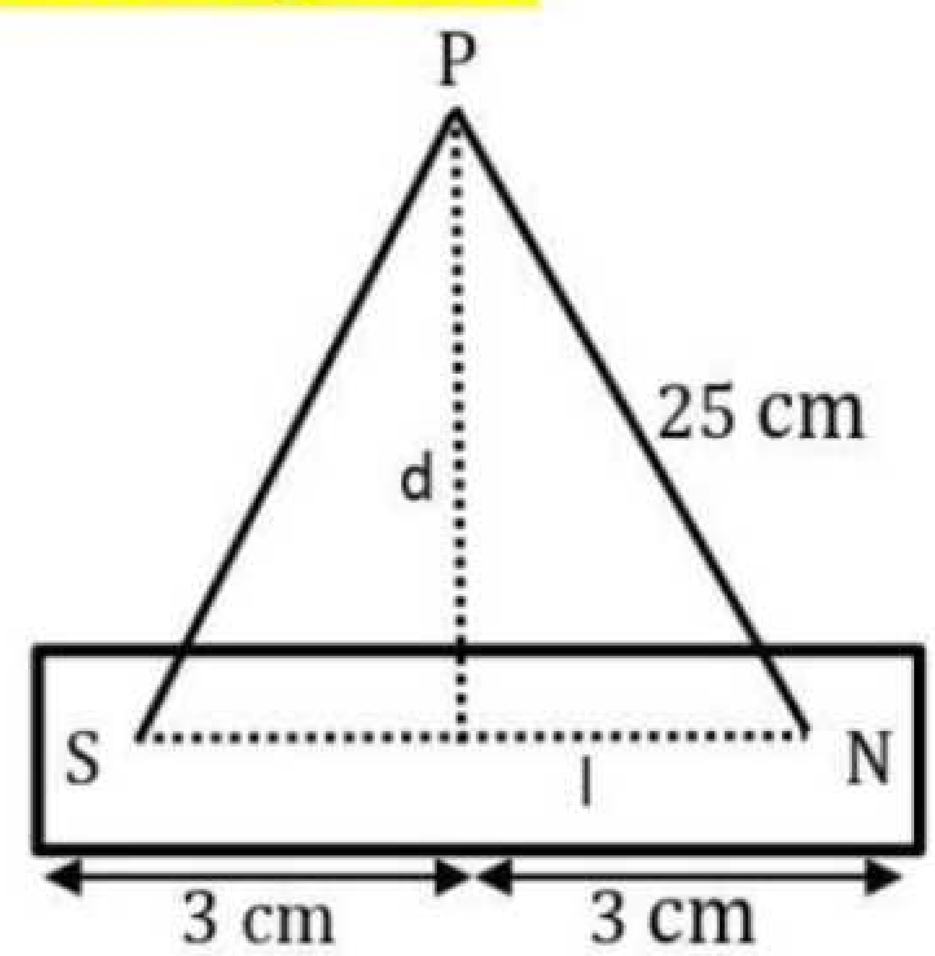
$$\text{or,} \quad \frac{\delta_m}{2} = 48.59° - 30° = 18.59°$$

$$\text{or,} \quad \delta_m = 2 \times 18.59° = 37.2°$$

Thus, the minimum deviation of given prism is 37.2°.

19) A bar magnet 6 cm long is kept its north pole pointing north. A neutral point is found at a distance of 25 cm from each pole. Calculate pole strength of the magnet.

➢ **Solution:**



Given that;

Length of bar magnet $(2l) = 6 \text{ cm} = 0.06 \text{ m}$

or, $\quad l = 0.03 \text{ m}$

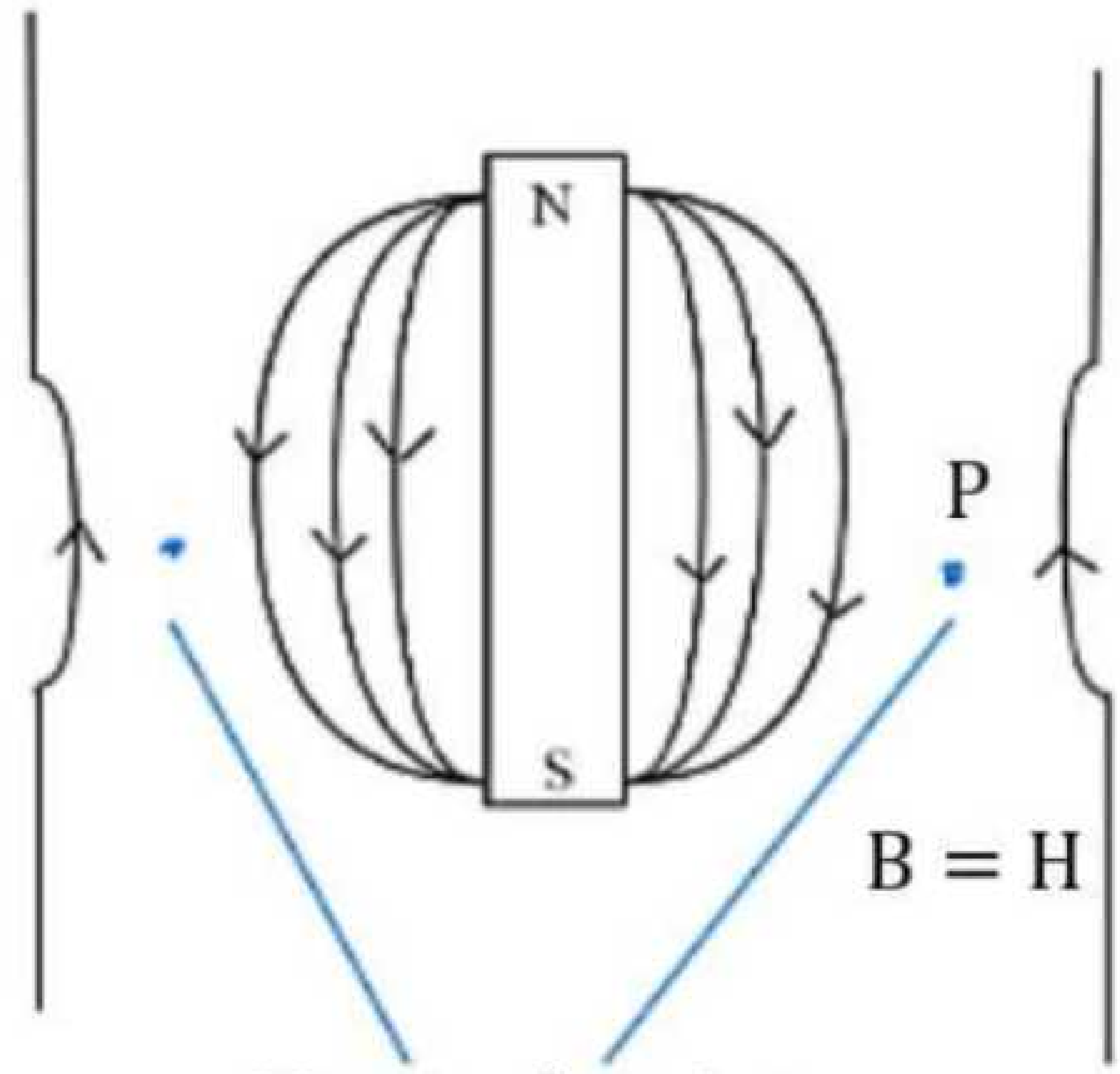
Position of neutral point $\left(\sqrt{d^2 + l^2}\right) = 25 \text{ cm} = 0.25 \text{ m}$

Horizontal component (H) = 0.35×10^{-4} T [missing in question]

Pole strength (M) = ?

We have,

This is the broadside on position of the magnet, at neutral point;



$$\mathbf{B = H}$$

$$\text{or, } \frac{\mu_0}{4\pi} \times \frac{2ml}{(d^2 + l^2)^{\frac{3}{2}}} = H$$

$$\text{or, } \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2 \times 0.03 \times m}{(0.25)^3} = 0.35 \times 10^{-4}$$

$$\text{or, } m = \frac{0.35 \times 10^{-4} \times (0.25)^3}{2 \times 0.03 \times 10^{-7}} = \mathbf{93.12\ Am}$$

Hence, the pole strength of the magnet is 93.12 Am.

–The End –

Engineering Physic I__(Engg. All) 1^{st} Sem

(2080 Old) Question Paper Solution.

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1) State and explain principle of conservation of linear momentum.

➢ **Refer to the solution 2076 of Q. No 1 on page 3.**

Or) What is satellite? Derive the expression for orbital velocity and show that square of time period for satellite is proportional to cube of distance between satellite and earth.

➢ **Refer to the solution 2079 of Q. No 2 on page 50.**

2) Stating the postulates of kinetic theory of gas, derive an expression for the pressure exerted by a gas in a container.

➢ **Refer to the solution 2078 of Q. No 1 on page 29.**

3) Define minimum deviation. What are the conditions for minimum deviation? Derive an expression for refractive index for prism in terms of angle of prism and minimum deviation.

➢ **Refer to the solution 2076 of Q. No 3 on page 6.**

4) Differentiate between scalar multiplication and vector multiplication of two vectors with examples.

➢ **Refer to the solution 2079 of Q. No 5 on page 54.**

5) Define simple pendulum. Show that motion of simple pendulum is simple harmonic motion.

➢ **Refer to the solution 2076 of Q. No 2 on page 4.**

6) What is moment of inertia of a rigid body? Deduce its relation with rotational kinetic energy of the body.

➢ **Refer to the solution 2078 of Q. No 5 on page 37.**

7) Define cubical expansivity. Derive the relation $\gamma = 3\alpha$ where symbols have their usual meaning.

Coefficient of cubic expansion

➢ The increase in volume per unit original volume per unit degree rise in temperature of the substance is called Coefficient of cubic expansion. It is represented by the symbol γ and the unit is $°C^{-1}$ or K^{-1}.

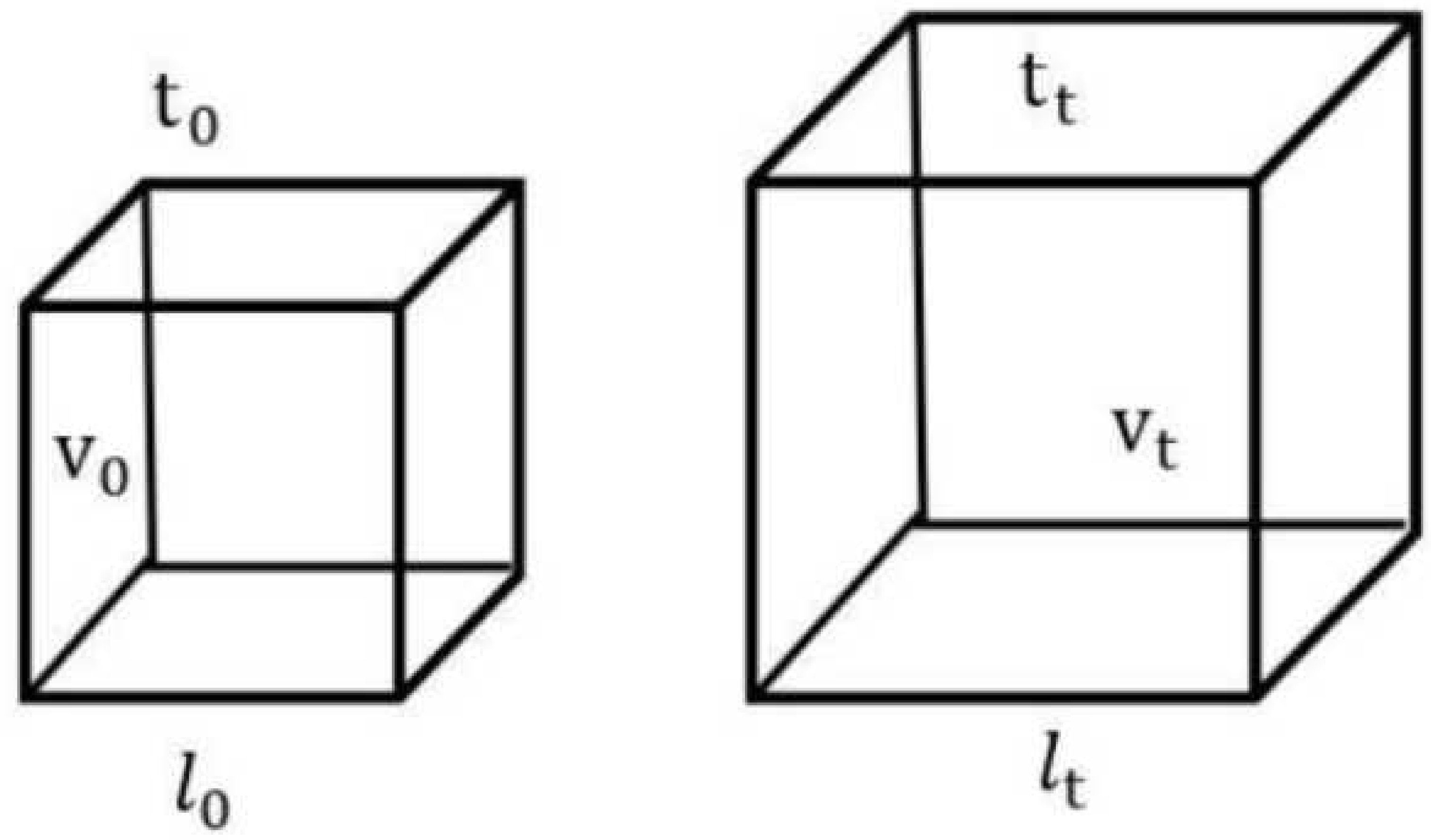
$$i.e., \qquad \gamma = \frac{\text{Increase in volume}}{\text{Original volume} \times \text{Rise in temperature}} = \frac{V_t - V_0}{V_0(t - t_0)}$$

$$V_t = V_0(1 + \gamma t)$$

Relation between α and γ

➢ Consider a cube having sides l_0 at 0°C. If temperature of the increases from 0°C to t°C, then the sides of the cube increase to 'L' then, we have,

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



Also,

$\therefore$ Volume of Cube at 0°C $(V_0) = l_0^2$

and, Volume of Cube at t°C $(V_t) = L^3 = l_0^3\,(1 + \alpha t)^3$

$$= V_0(1 + 3\alpha t + 3\alpha^2 t^2 + \alpha^3 t^3)$$

Since, the value of α is very small, so higher power of α will be very small. Thus, the terms containing higher power of α can be neglected.

$$\therefore V_t = V_0\,(1 + 3\alpha t) \quad \cdots\cdots\cdots (i)$$

But, from definition of the coefficient of cubical expansion; we have,

$$\therefore V_t = V_0\,(1 + \gamma t) \quad \cdots\cdots\cdots (ii)$$

Comparing the relation (i) and (ii); we get,

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

8) State and explain Stefan's law of black body radiation.

➢ **Refer to the solution 2076 of Q. No 7 on page 13.**

9) What is total internal reflection? Show that $\sin C = \frac{1}{\mu}$ where, C is critical angle and μ is refractive index.

➢ **Refer to the solution 2076 of Q. No 9 on page 16.**

10) State and derive tangent law in magnetism.

➢ **Refer to the solution 2079 of Q. No 11 on page 57.**

11) A car mass moves 100kg moves up an inclination of 30° at constant speed of 20m/s, calculate the power developed by the engine if the coefficient of friction is 0.2 (g = 9.8m/s²).

➢ **Solution:**

Given that;

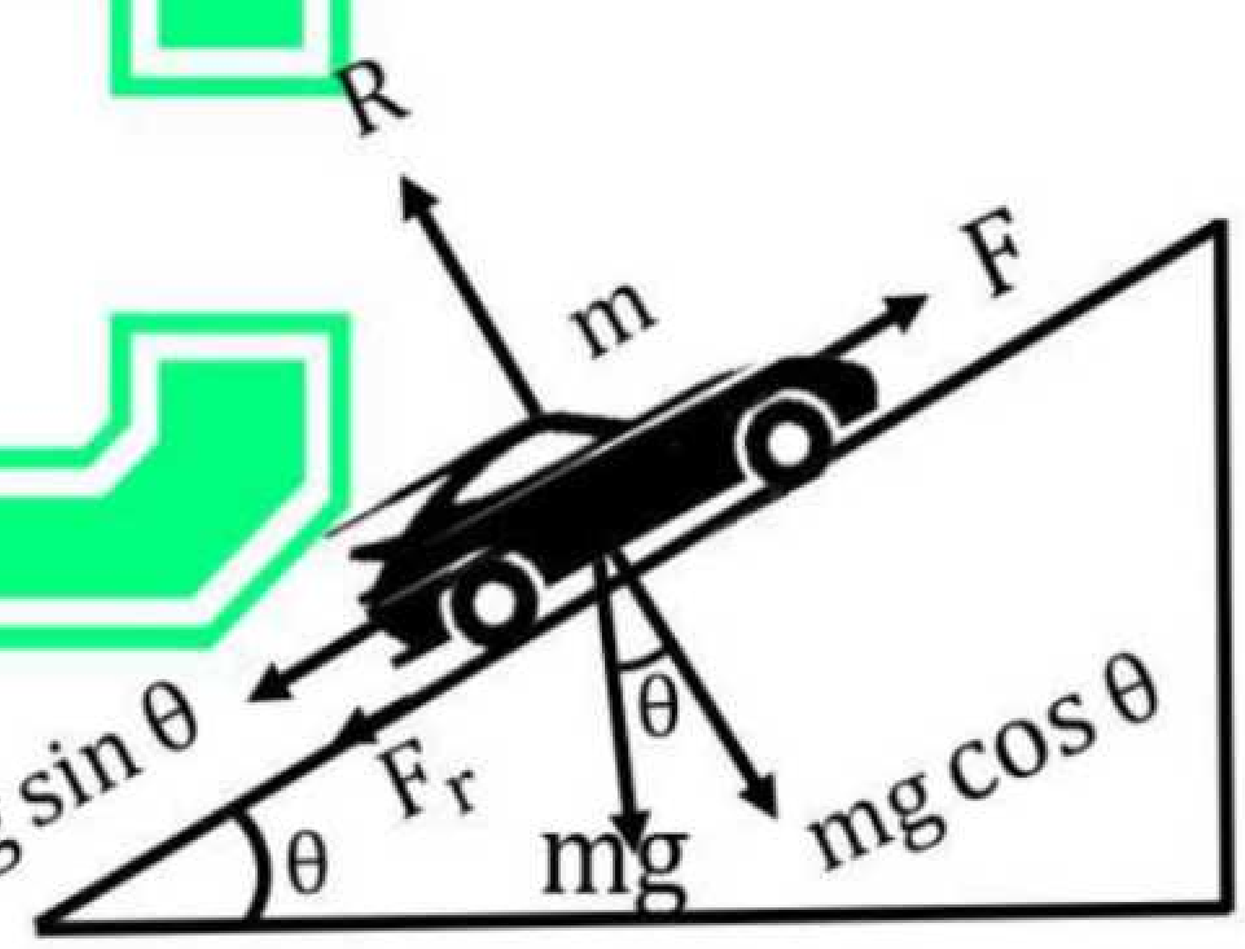
Mass of car (m) = 100 kg

Angle of inclination (θ) = 30°

Velocity of car (v) = 20 m/s

Coefficient of friction (μ) = 0.2

$g = 9.8\ m/s^2$



Here, if the car moves up an inclined plane of inclination angle θ then, power developed by car is given by;

$$\text{Power (P)} = \text{Total upward force} \times \text{Velocity}$$

$$= F \times v$$

$$= (mg\ \sin\theta + F_r) \times v$$

$$= (mg\ \sin\theta + \mu R) \times v$$

Where, F is the frictional force μR

$$= (\text{mg} \ \sin\theta + \mu\text{mg} \ \cos\theta) \times \text{v}$$

$$= \text{mg} \ (\sin\theta + \mu \ \cos\theta) \times \text{v}$$

$$= 100 \times 9.8 \ (\sin 30° + 0.2 \times \cos 30°) \times 20$$

$$= \mathbf{13194.81 \ watts}$$

12) A motor cycle rider going 90Kmhr^{-1} around a curve path with a radius of 100m must lean at an angle to the vertical. Find the angle at which he leans.

➢ **Solution:**

Given that;

Velocity of car $(\text{v}) = 90 \ \text{kmhr}^{-1} = \dfrac{90 \times 1000}{60 \times 60} = \mathbf{25 \ ms^{-1}}$

Radius $(\text{r}) = 100\text{m}$

Angle $(\theta) = ?$

We have,

$$\mathbf{\tan\theta = \frac{v^2}{rg}}$$

$$\text{or,} \quad \theta = \tan^{-1}\left(\frac{\text{v}^2}{\text{rg}}\right)$$

$$= \tan^{-1}\left(\frac{(25)^2}{100 \times 10}\right)$$

$$= \tan^{-1}\left(\frac{(25)^2}{100 \times 10}\right)$$

$$= \tan^{-1}(0.625)$$

$$\therefore \ \boldsymbol{\theta} = \mathbf{32°}$$

13) A metal of mass 100gm at 100°c is dropped into 80gm of water at 20°c contained in a calorimeter of mass 120gm. The final temperature of the calorimeter and its contents rises to 30°c. Determine the specific heat capacity of the metal, specific heat capacity of copper 0.0094 cal/gm°c, specific heat of water=1 cal/gm°c.

➢ **Solution:**

Given that;

Mass of calorimeter$(m_c) = 120$ gm

Mass of water $(m_w) = 80$ gm

Mass of metal ball $(m_m) = 100$ gm

Initial temperature of calorimeter + water $(t_1) = 20\ °C$

Initial temperature of Mixture $(t_2) = 100\ °C$

Final temperature of mixture $(t) = 30°$

Specific heat of water $(s_w) = 1$ Cal $gm^{-1}c^{-1}$

Specific heat of calorimeter $(s_c) = 0.0094$ cal / gmc

Specific heat of metal $(s_m) = ?$

We have,

The specific heat of the solid (metal),

$$S = \frac{M_cS_c(t - t_1) + M_wS_w(t - t_1)}{M_m(t_2 - t)}$$

$$= \frac{120 \times 0.0094 \times (30 - 20) + 80 \times 1 \times (30 - 20)}{100 \times (100 - 30)}$$

$$= \mathbf{0.11589\ cal\ gm^{-1}c^{-1}}$$

$\therefore$ Specific heat of metal$(s_m) = \mathbf{0.11589\ \ cal\ gm^{-1}c^{-1}}$

14. Find the temperature at which the r.m.s. velocity of a gas is half of its value at O°C.

➢ **Solution:**

Given that;

$T_1 = ?$

$T_2 = 0°C = 273k$

$C\ rms_1 = \frac{1}{2}\ C\ rms_2 \qquad \cdots\cdots\cdots (i)$

Since,

$C\ rms \propto \sqrt{T}$

$$\frac{C\ rms_1}{C\ rms_2} = \sqrt{\frac{T_1}{T_2}}$$

$$\frac{1}{2} = \sqrt{\frac{T_1}{T_2}} \qquad \cdots\cdots\cdots\cdots \text{From } (i)$$

Squaring both side,

$$\frac{1}{4} = \frac{T_1}{273}$$

$T_1 = 68.25\ k$

$T_1 = (68.25 - 273)°C$

$= -204.75°C$

$\therefore\ -204.75°C$ at which rms velocity of gas is half of its value at 0°C

15) The image obtained by concave mirror is erect and three times the size of the object. The focal length of mirror is 20cm. calculate the object and image distance.

➢ **Solution:**

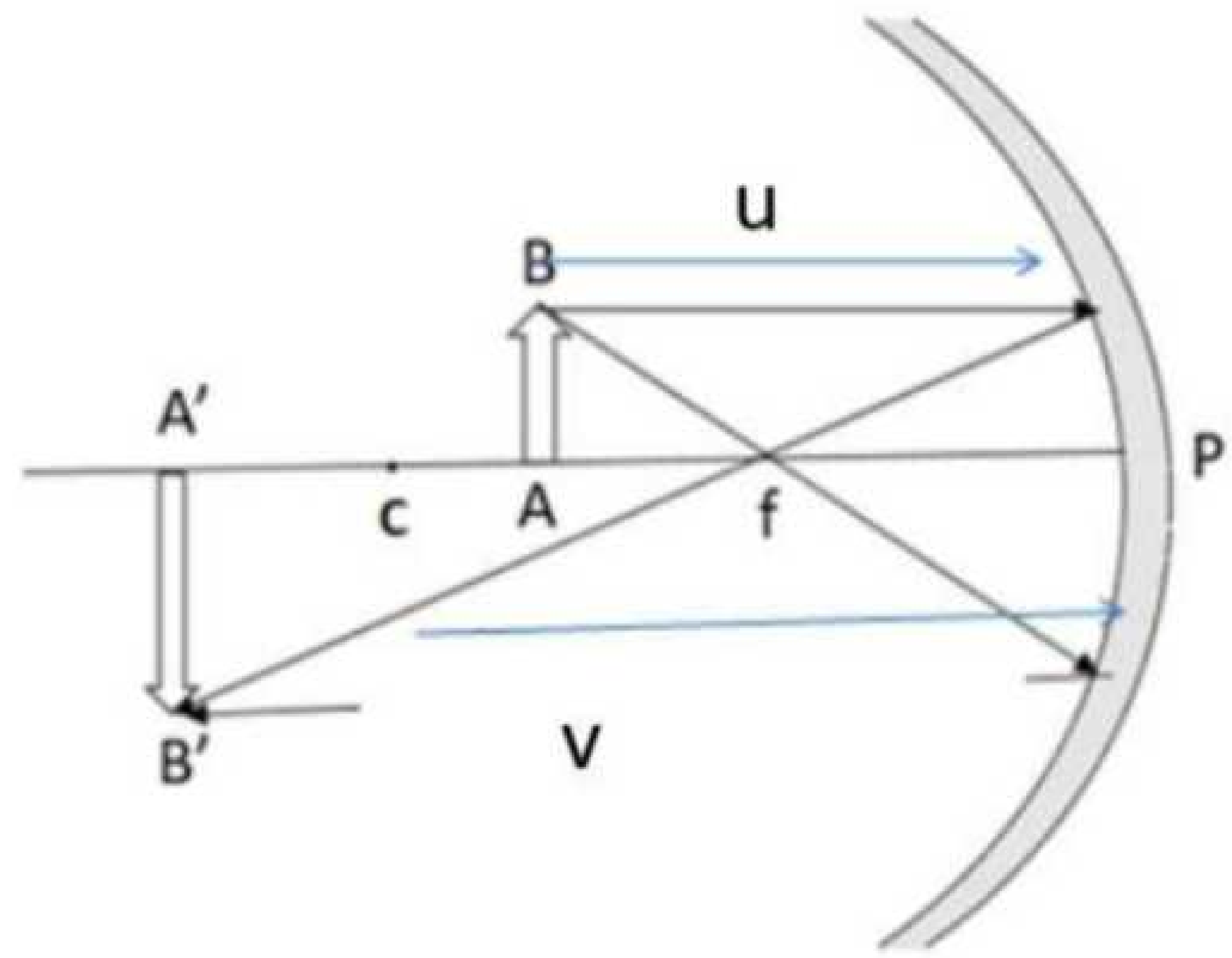
Given that;

Magnification (m) $= \frac{v}{u} = 3$

Focal length (f) $= 20$ cm

Object distance (u) $=?$

Image distance (v) $=?$



We know,

$$m = \frac{v}{u} = 3$$

or, $v = -3u$ (negative sign for virtual and erect image) $\cdots\cdots\cdots (i)$

From general mirror formula; we have,

$$\frac{\mathbf{1}}{\mathbf{f}} = \frac{\mathbf{1}}{\mathbf{u}} + \frac{\mathbf{1}}{\mathbf{v}}$$

$or,\ \frac{1}{20} = \frac{1}{u} + \frac{1}{3u} = \frac{3-1}{3u} = \frac{2}{3u}$

$or,\ 3u = 40$

$\therefore\ u = 13.33$ cm

Again, substituting the value of 'u' in equation (i); we get,

$$v = -3u = -3 \times 13.33 = -40 \text{ cm}$$

Hence, object distance is 13.33 cm and image distance is 40 cm

16) What is the apparent position of an object below a rectangular block of glass 6cm thick if a layer of water 4cm is on top of the glass? Refractive index of glass = 1.5, Refractive index of water = 1.33

➢ **Solution:**

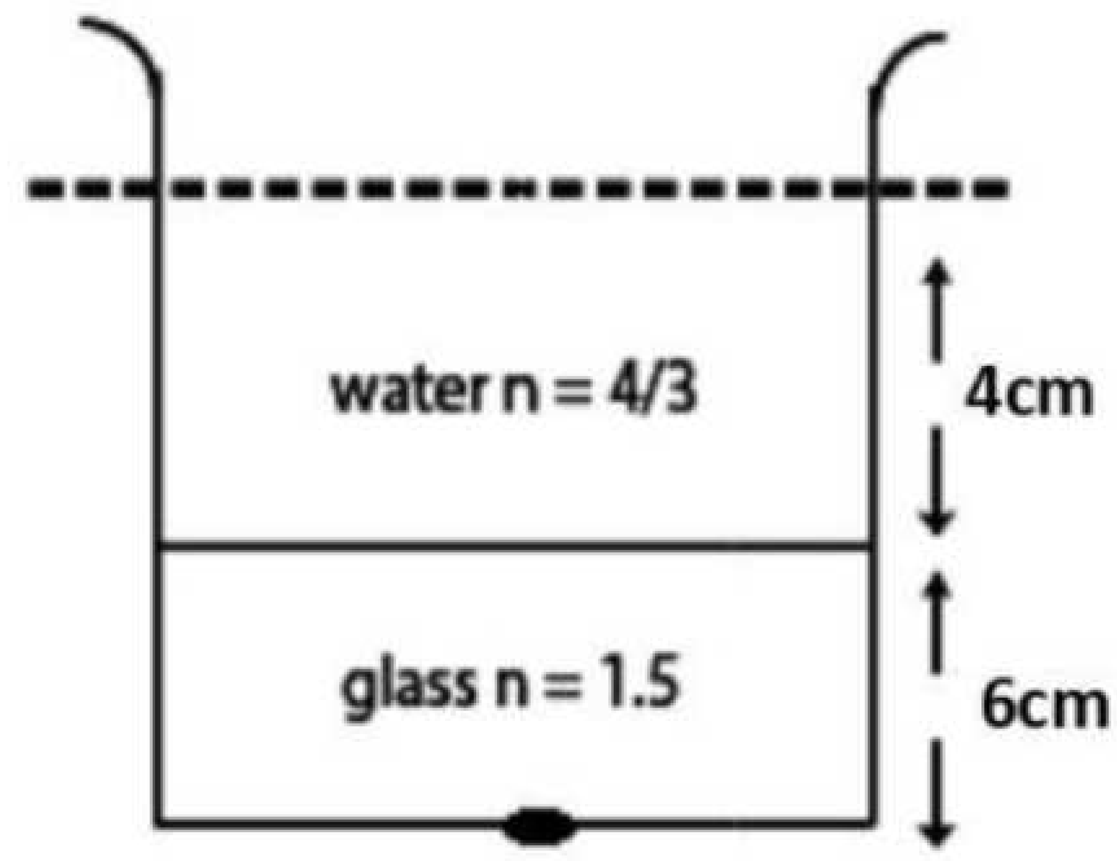
Given that;

Thickness of glass $(t_g) = 6$ cm

Thickness of water $(t_w) = 4$ cm

Refractive index of glass $(a^{\mu_g}) = 1.5$

Refractive index of water $(a^{\mu_w}) = 1.33$



For glass; We have,

$$\text{Displacement } (d_1) = t_g\left(1 - \frac{1}{a^{\mu_g}}\right) = 6\left(1 - \frac{1}{1.5}\right) = \mathbf{2\ cm}$$

For water; We have,

$$\text{Displacement } (d_2) = t_w\left(1 - \frac{1}{a^{\mu_w}}\right) = 4\left(1 - \frac{1}{1.33}\right) = \mathbf{0.99\ cm}$$

$\therefore$ Total displacement $= d_1 + d_2 = 2 + 0.99 = \mathbf{2.99\ cm}$

Thus,

The apparent position of an object is 2.99cm above from the bottom.

17) Calculate the horizontal component of earth magnetic field if the earth's magnetic field at a place where the dip angle is 60° and the vertical component is 3.464×10^{-5} T.

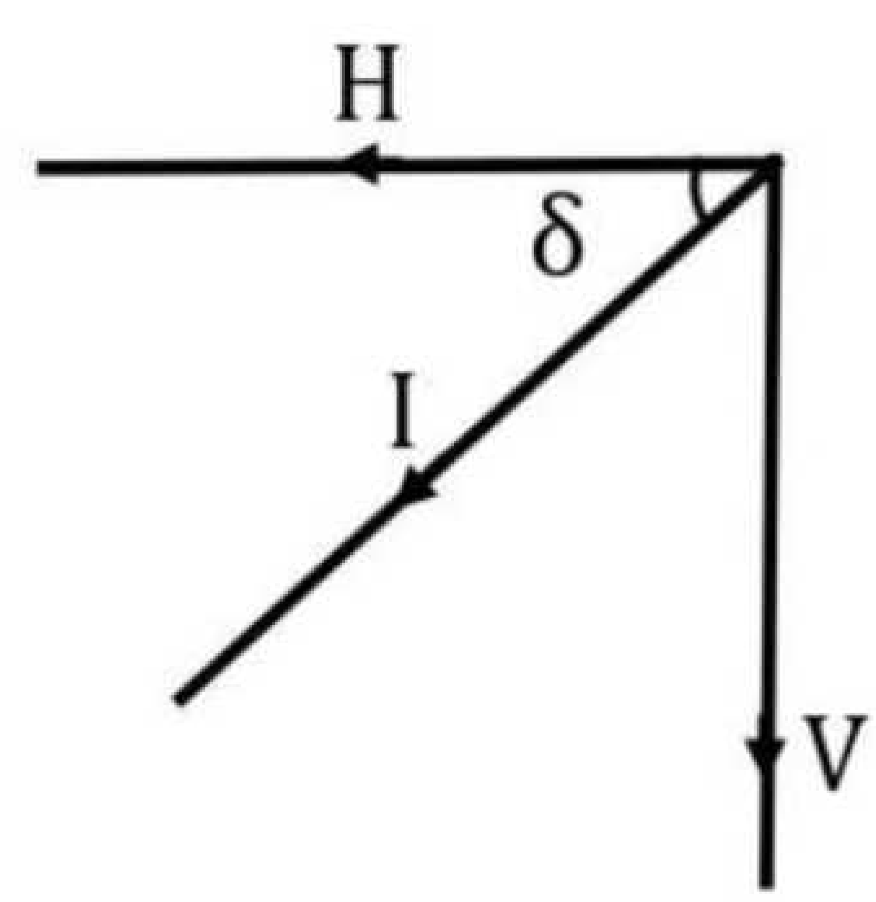
➢ **Solution:**

Given that;

Vertical component (V) $= 3.464 \times 10^{-5}$T

Angle of dip $(\delta) = 60°$

Horizontal Component (H) =?



We know that, from figure,

$$\mathrm{H} = \mathrm{I}\cos\delta \quad \cdots\cdots\cdots\cdots (i)$$

$$\mathrm{V} = \mathrm{I}\sin\delta \quad \cdots\cdots\cdots\cdots (ii)$$

Dividing equation (ii) by (i); we have,

$$\frac{\mathrm{V}}{\mathrm{H}} = \frac{\sin\delta}{\cos\delta}$$

$$or,\ \ \mathrm{H} = \frac{\mathrm{V}}{\tan\delta}$$

$$= \frac{3.464 \times 10^{-5}}{\tan 60°}$$

$$= 1.99 \times 10^{-5}\ \mathrm{T}$$

$$\therefore\ \mathbf{H = 1.99 \times 10^{-5}\ T}$$

–The End –

Engineering Physic I__(Engg. All) 1st Sem

2080 (New) Question Paper Solution.

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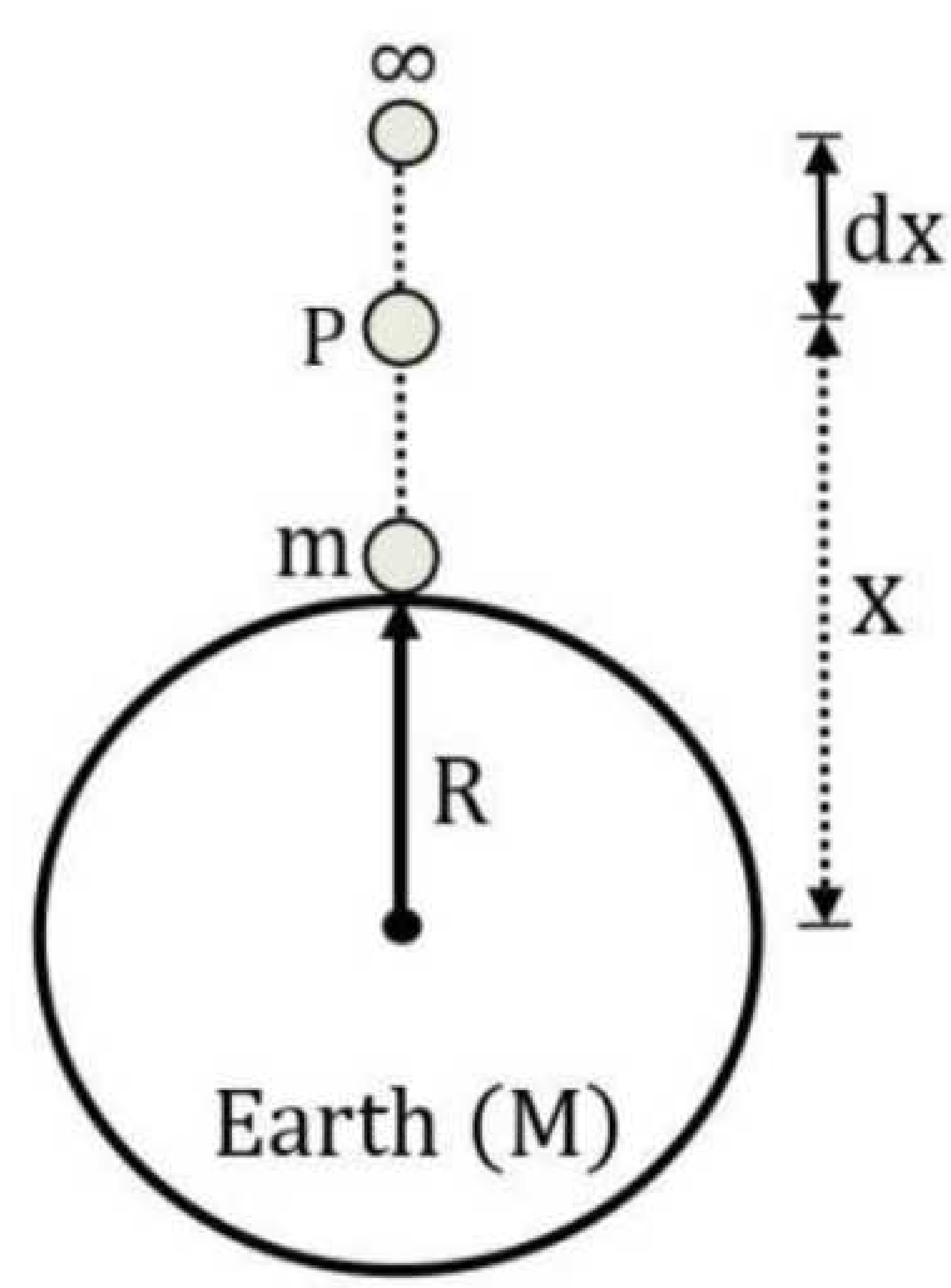
1) State parallelogram law of vector addition. Derive the expression for magnitude and direction of resultant vector.

➢ **Refer to the solution 2078 of Q. No 1 on page 27.**

2) Define escape velocity. Derive an expression for it.

➢ **Escape velocity** is defined as the minimum velocity with which a body is projected in atmosphere such that the body crosses the gravitational field of earth due to which it never returns back to the earth.

Expression for Escape velocity



➢ Let us consider an earth of radius 'R' and mass 'M'. A body of mass 'm' be at P at certain distance 'x' from the centre of earth as shown in the figure.

Then, the gravitational force between earth and that body is given by;

$$F = \frac{GMm}{x^2}$$

Again, let the body is displaced by small distance 'dx' in upward direction then workdone is given by;

$$dw = F \times dx$$

$$= \frac{GMm}{x^2} \times dx$$

But when a body is projected to out of field (or the infinity)from earth surface, then;

$$\text{Workdone (W)} = \int_R^\infty dw = \int_R^\infty \frac{GMm}{x^2} \times dx$$

$$= GMm \int_R^\infty (x^{-2})dx = -GMm\left[\frac{1}{x}\right]_R^\infty = -GMm\left(0 - \frac{1}{R}\right)$$

$$\therefore W = \frac{GMm}{R}$$

Let v_e be escape velocity. Then kinetic energy must be equal to workdone.

$$\therefore \frac{1}{2}mv_e^2 = \frac{GMm}{R}$$

$$or,\ v_e^2 = \frac{2GM}{R}$$

$$or,\ v_e = \sqrt{\frac{2GM}{R}}$$

But, we have; $g = \frac{GM}{R^2} \Rightarrow gR^2 = GM$

$$\therefore \text{Escape velocity } (v_e) = \sqrt{\frac{2gR^2}{R}} = \sqrt{\mathbf{2gR}}$$

Taking, $g = 9.8\ m/s^2$ and Radius of earth $(R) = 6400$ km, we get;

$$\therefore v_e = \sqrt{2gR} = \sqrt{2 \times 9.8 \times 10^{-3} \times 6400} = \mathbf{11.2\ km/sec}$$

Therefore, Escape velocity is constant quantity is equal to 11.2 km/sec

3) State postulate of kinetic theory of gas. Derive an expression for the pressure exerted by gas according to kinetic theory.

- **Refer to the solution 2078 of Q. No 2 on page 29.**

4) Define deviation produced by prism. Derive the relation $\mu = \frac{\sin\frac{(A+\delta m)}{2}}{\sin\frac{A}{2}}$, where the symbols have their usual meaning.

- **Refer to the solution 2076 of Q. No 3 on page 6.**

5) Convert 1 Newton into dyne using dimensional method.

- The newton is unit of force in SI and dyne in CGS system

  Dimensional formula for force $= [MLT^{-2}]$

  Here $a = 1, b = 1$ and $c = -2$ therefore

  Using Dimensional homogeneity,

  $n_1\,[M_1]^a[L_1]^b[T_1]^c = n_2\,[M_2]^a[L_2]^b[T_2]^c$

  We get, $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$

  $$n_2 = 1\left[\frac{1\text{ kg}}{1\text{ g}}\right]^1\left[\frac{1\text{ m}}{1\text{ cm}}\right]^1\left[\frac{1\text{ s}}{1\text{ s}}\right]^{-2}$$

  $$= 1\left[\frac{10^3\text{g}}{1\text{g}}\right]\left[\frac{100\text{ cm}}{1\text{ cm}}\right]\left[\frac{1\text{ s}}{1\text{ s}}\right]^{-2}$$

  $$= 10^5$$

  Using $n_1u_1 = n_2u_2$,

  We get, 1 newton $= 10^5$ dyne

6) Define 'g'. How does 'g' vary with depth?

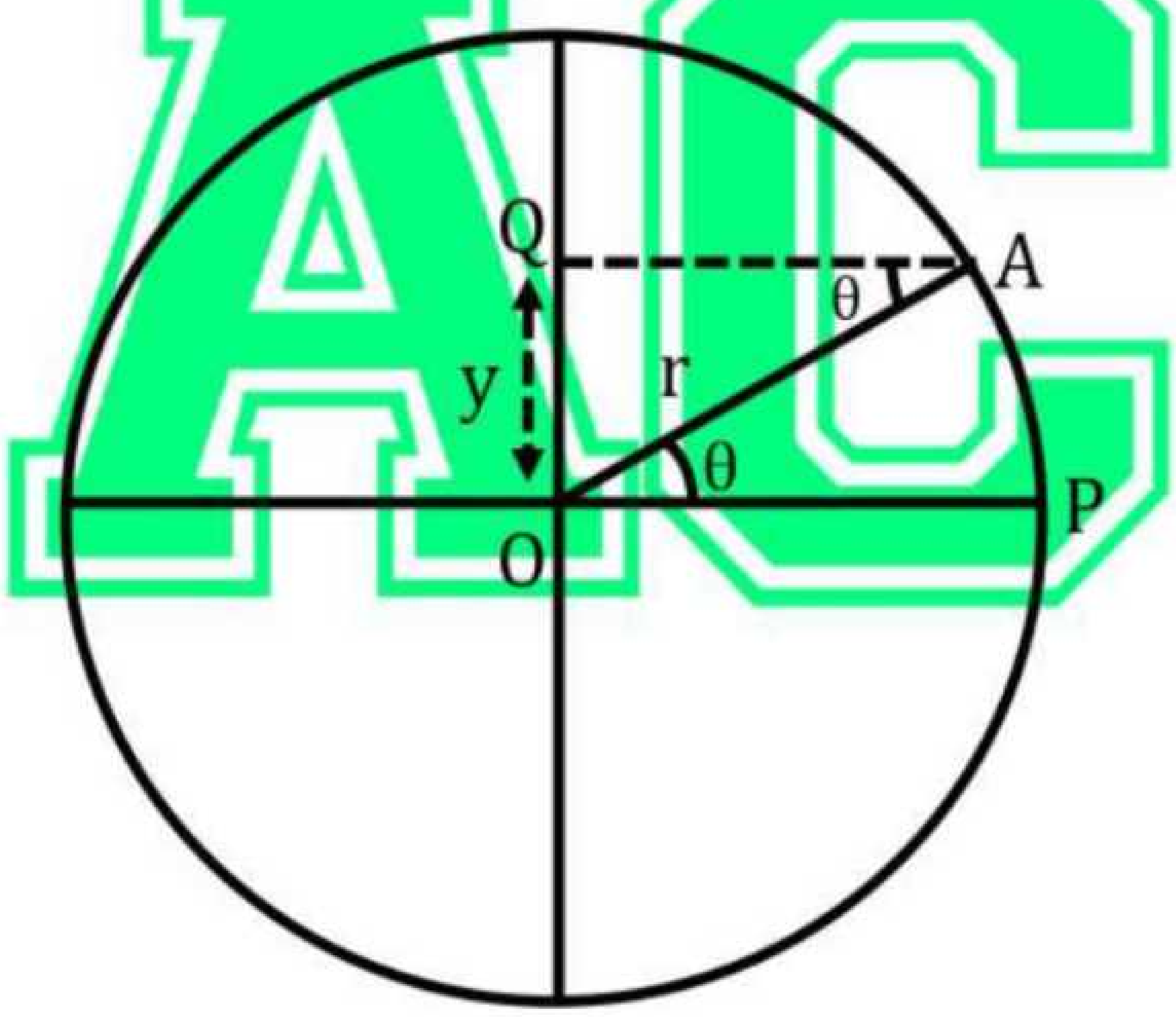
- **Refer to the solution 2078 of Q. No 4 on page 35.**

7) Define a and y. Derive the relation between them.

- The rate of change of velocity of a particle is called acceleration. It is denoted by 'a'.

- The distance traveled by the particle at any time from its initial (mean) position is called displacement of the particle. It is denoted by 'y'.

- Let 'P' be initial Position. After any instant 't' ,particle reaches to 'A'.



In Δ OAQ,

$$\text{Sin}\theta = \frac{OQ}{OA} = \frac{y}{r}$$

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

As angular velocity is angular displacement per unit time, $\omega = \frac{\theta}{t}$

$$\theta = \omega t$$

Hence,

$$y = r\,\omega \sin \omega t \qquad \cdots\cdots\cdots (i)$$

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

$$v = \omega r\,\cos\omega t$$

Again,

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

$$a = \omega r(-\omega)\,\sin\,\omega t$$

$$a = -\omega^2 r\,\sin\omega t$$

$$a = -\omega^2 y \qquad [\text{From } (i)]$$

$i.e.,$ $\boxed{a \propto -y}$

Hence, acceleration is directly proportional to displacement and − ve Indicate that it is always directed toward the mean position.

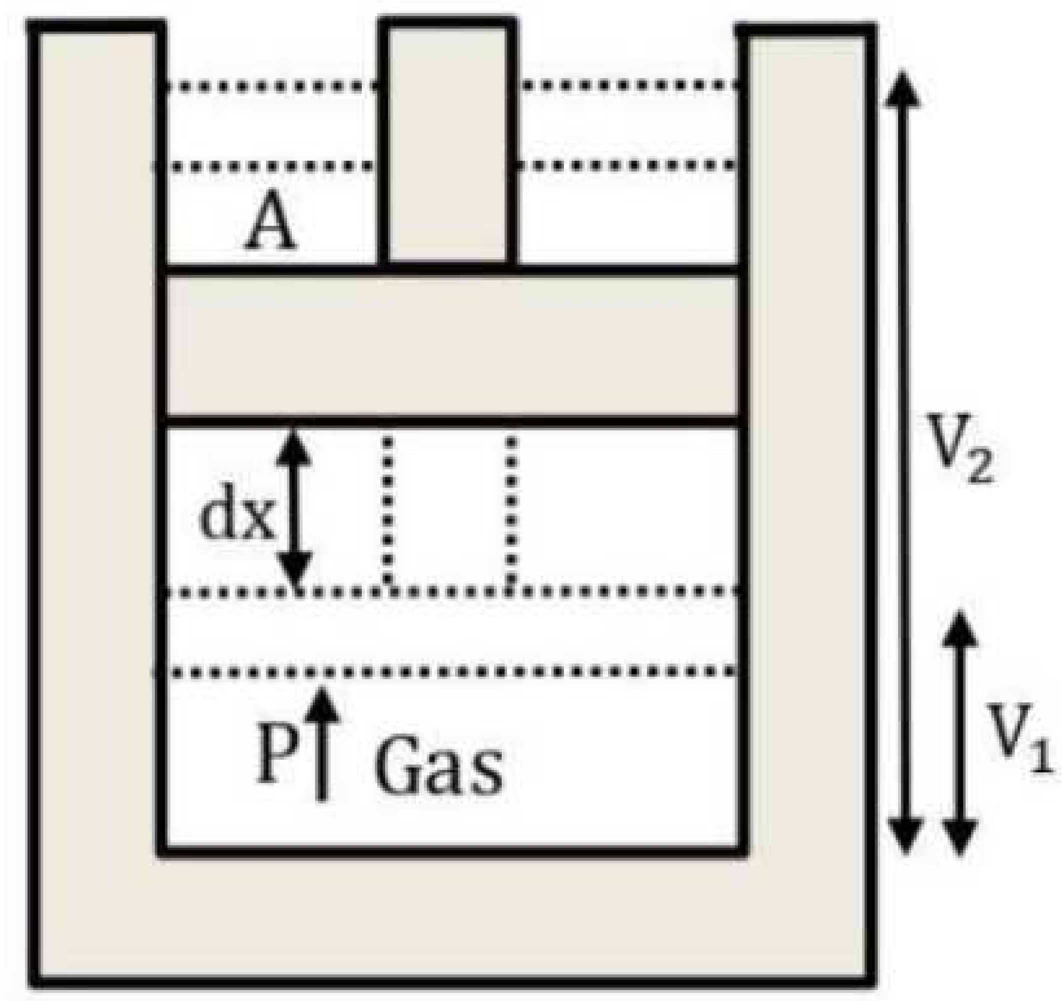
8) Explain isothermal process. Derive an expression for work done during isothermal process.

- The process in which pressure and volume of a system change without any change in its temperature is called an ***isothermal process.*** In such a process, there is a free exchange of heat between the system and its surroundings. During isothermal process: the walls of the cylinder are perfectly conducting so free exchange of heat between the gas and its surroundings makes temperature constant in the isothermal process and the expansion and compression of the system is slow.

  E.g., the boiling of water and melting of ice. The equation of state of isothermal process is PV = constant.

Expression for work done during isothermal process.

- Let us consider one mole of an ideal gas contained in a cylinder having Perfectly conducting walls. when piston move through infinitesimally small distance dx, then small work done dw is given by



$$dW = F \times dx = \frac{F}{A} \times A \times dx = PA\,dx$$

Where 'A' is the area of cross section of the piston.

$$dW = PdV \qquad [\because dV = A\,dx]$$

When gas is allowed to expand from initial state $A\,(P_1, V_1, T_1)$ to final state$B\,(P_2, V_2, T_2)$, the amount of work done is given as

$$W = \int_{V_1}^{V_2} dW = \int_{V_1}^{V_2} PdV \quad \cdots\cdots\cdots (i)$$

For one mole of an ideal gas, we have $PV = RT \Longrightarrow P = \frac{RT}{V}$

For isothermal process, temperature remains constant. Then equation (i) can be written as ,

$$W = \int_{V_1}^{V_2} \frac{RT}{V}\,dV = RT\int_{V_1}^{V_2} \frac{dV}{V} = RT\,[\log_e V_2 - \log_e V_1]$$

$$\therefore W = RT\log_e \frac{V_2}{V_1}$$

$$i.e, \quad W = 2.303\,RT\log_{10}\frac{V_2}{V_1} \qquad \cdots\cdots\cdots (ii)$$

ln terms of pressure change,

$$P_1V_1 = P_2V_2$$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2} \qquad \cdots\cdots\cdots (iii)$$

From equation (ii) & (iii), Work done during isothermal process is given by;

$$W = RT\log_e \frac{P_1}{P_2} = 2.303\ RT\log_{10} \frac{P_1}{P_2}$$

This is the required expression for work done.

9) Define power of lens. Derive equivalent power when two thin lenses are in contact.

- Power of a lens is its ability to converge or diverge the light rays after passing through it. Power of a lens is equal to reciprocal of the focal length of the lens.

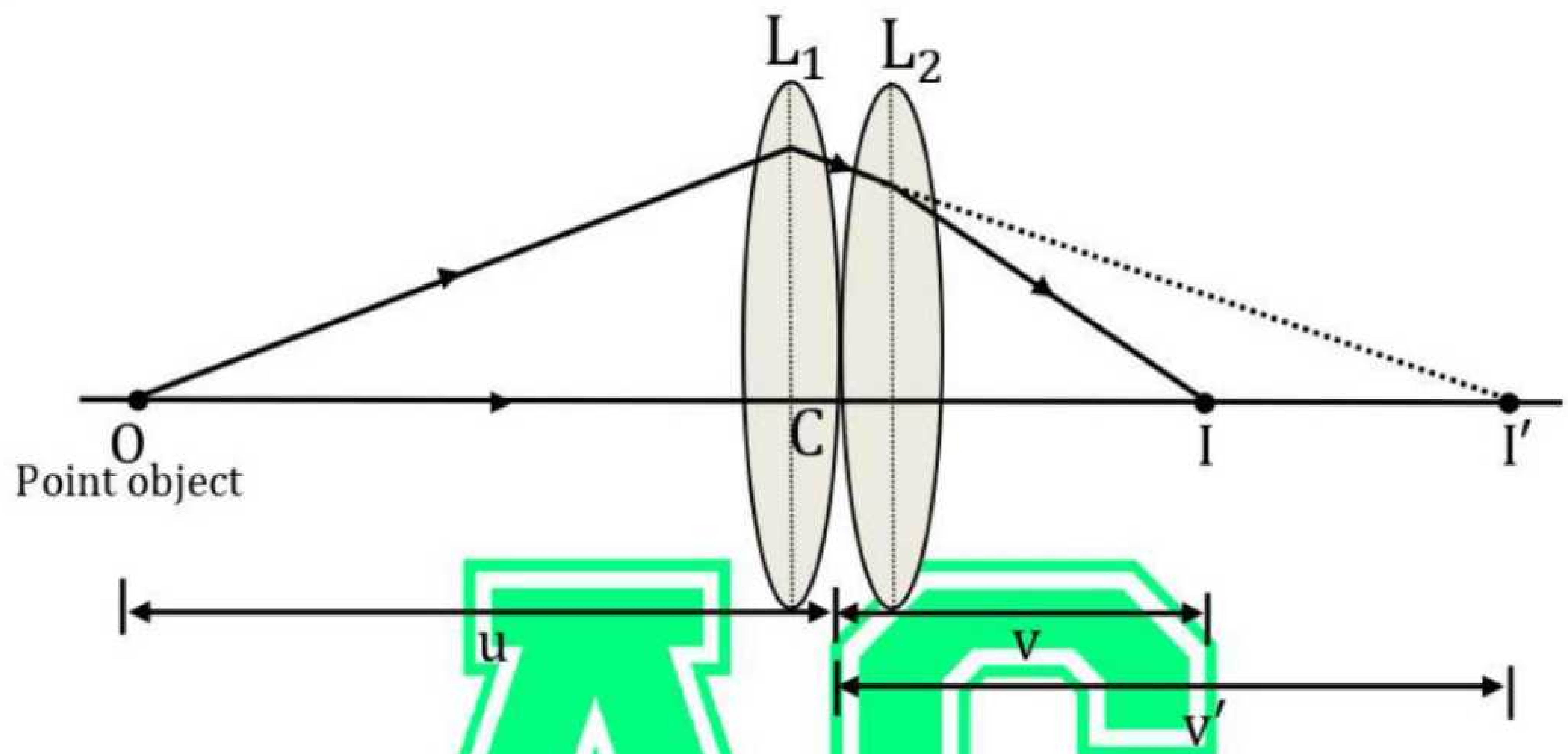
  i.e., Power $(p) = \frac{1}{f}$, where f is in meter, P is in Diopter.

- Let two thin lenses L_1 and L_2 are in contact as shown below. A point object 'O' is kept on the common axis at distance 'P'. The light rays travels refracted from first lens L_1 and forms the image of the object at a distance v'. If 'u' is the object distance and f_1 is the focal length then,

$$\frac{1}{f_1} = \frac{1}{u} + \frac{1}{v'} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (i)$$

For the second lens L_2 the image formed by first lens L_1 acts as a virtual object. Then, lens L_2 forms the real image at 'I' at distance 'v' from the combination. For second lens L_2 the object distance will be $-v'$ as the object 'I' is virtual. Then,

$$\frac{1}{f_2} = \frac{1}{-v'} + \frac{1}{v} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (ii)$$



Now adding equations (i) and (ii); we have

$$\frac{1}{f_1} = \frac{1}{f_2} = \frac{1}{u} + \frac{1}{v'} - \frac{1}{v'} + \frac{1}{v}$$

$$= \frac{1}{u} + \frac{1}{v} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (iii)$$

If the combination, form the image at 'I'. If 'F' is the focal length of the combination, then from the general lens formula; we have,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{F} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (iv)$$

From equation (iii) and (iv); we have,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

i. e., the reciprocal of the combined focal length is equal to the algebraic sum of the reciprocals of the focal length of the individual lenses.

10) Show that when a mirror is rotated by some angle, the reflected ray will rotate double the angle.

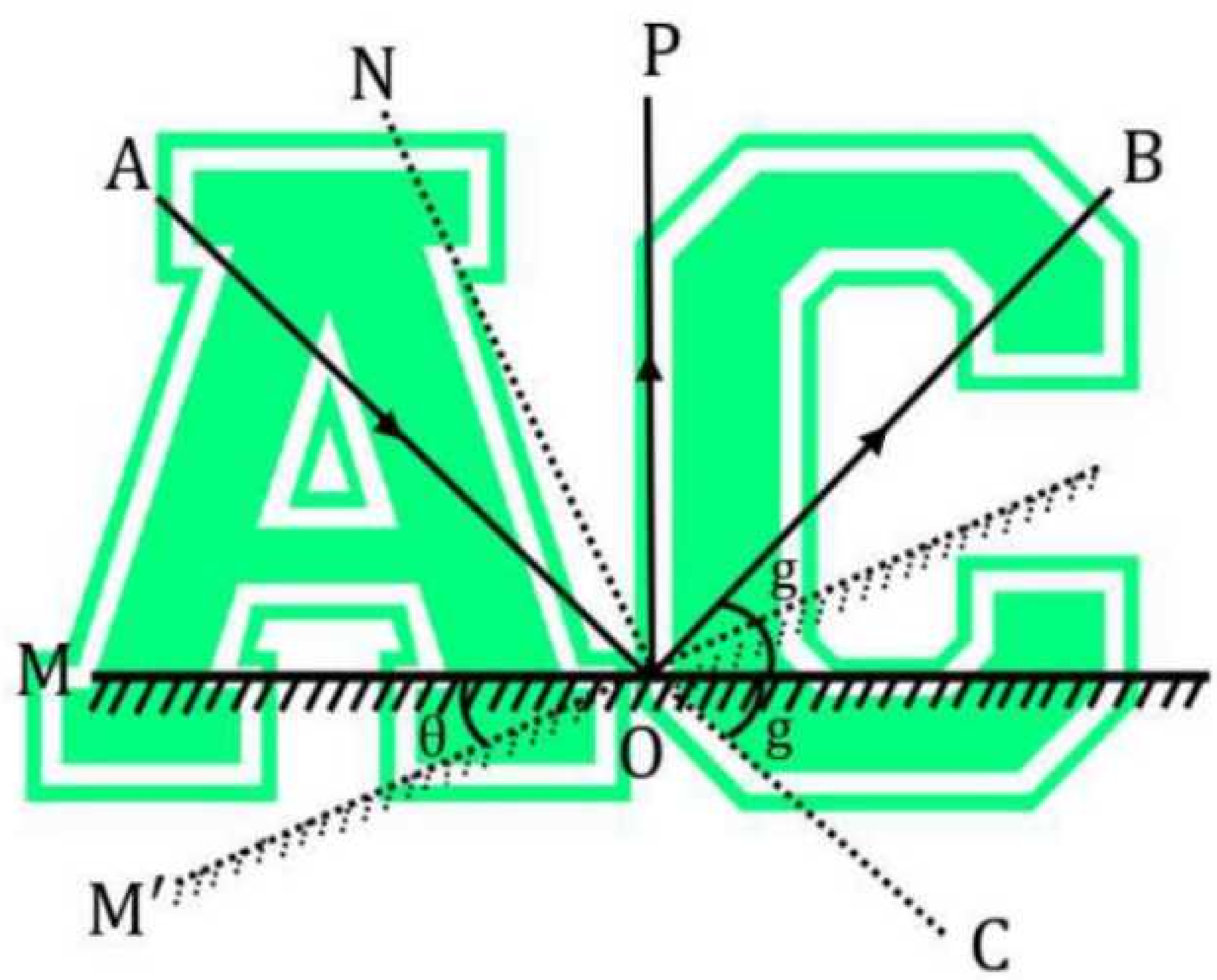
➢ Let AO is an incident ray strikes a mirror at point 'O' and is reflected along OB. Then angle of deviation related with glancing angle 'g' as;

$$\measuredangle BOC = 2g$$

Now, the mirror is rotated through an angle θ keeping the incident ray unchanged or fixed to a position M′ But, the reflected ray is now shifted from OB to OP. Thus, new glancing angle changes to $(\theta + g)$

Now, the new angle of deviation is given by;

$$\measuredangle POC = 2(g + \theta)$$



The rotation of reflected ray is ∡BOP and is given by;

$$\begin{aligned} \measuredangle BOP &= \measuredangle POC - \measuredangle BOC \\ &= 2(g + \theta) - 2g \\ &= 2\theta \end{aligned}$$

The result shows that of the direction of the incident ray is kept fixed, the angle of rotation of the reflected ray is double the angle of rotation of mirror.

11) What is magnetic hysteresis? Explain it with hysteresis curve.

➢ **Refer to the solution 2078 of Q. No 10 on page 42.**

12) State and derive tangent law in magnetism.

➢ **Refer to the solution 2079 of Q. No 11 on page 57.**

13) A bullet of mass 300 g is fired with velocity 720 kmhr^{-1} by making 60° to the vertical. Find (a) maximum horizontal range (b) maximum height attained (c) time to reach maximum height.

➢ **Solution:**

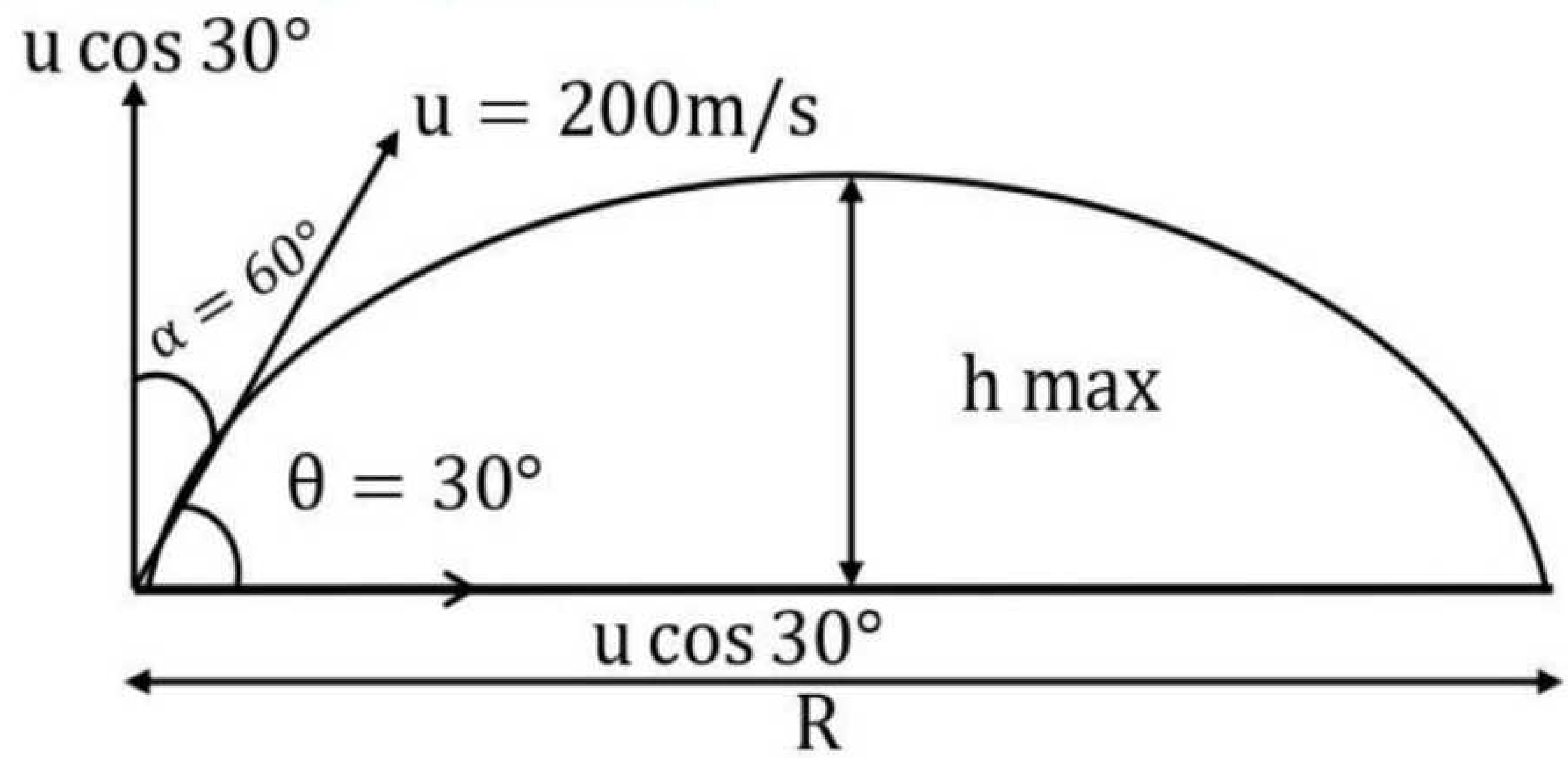
Given that;

Mass $= 300\text{g}$

Velocity $(u) = 720 \text{ km hr}^{-1} = \dfrac{720 \times 100}{60 \times 60} = 200 \text{ m/s}$

$\alpha = 60°$ to vertical

$\theta = 90 - 60 = 30°$ to horizontal



We have,

To find:

(a) Maximum horizontal range (R) =?

(b) (b) Maximum height attained (h_{max}) =?

(c) Time to reach maximum height. *i.e.* time of ascent (t_a) =?

$u_y = u \sin 30$, $u_x = u \cos 30$

For vertical motion,

$$V^2 = {u_y}^2 - 2gs$$

At h_{max}, final velocity is zero, $V = 0$, $S = h_{max}$,

$$V^2 = {U_y}^2 - 2gs \text{ , using vertical motion}$$

$$0 = u^2 \sin^2 30 - 2g\, h_{max}$$

$$h_{max} = \frac{u^2 \sin^2 30}{2g}$$

$$= \frac{200^2 \times \sin^2 30}{2 \times 9.81}$$

$$= 509.68\, m$$

$\therefore$ **(b) maximum height attained $(h_{max}) = 509.68\, m$**

(a) maximum horizontal range (R) =?

$$S = ut + \frac{1}{2} a_x t^2, \text{ using horizontal motion}, a_x = 0$$

$$R = u_x . T \quad \text{where T is Time of fight}$$

$$= u \cos\theta \times \frac{2u\sin\theta}{g} \qquad \left[\because \; T = \frac{2u\sin\theta}{g}\right] \cdots\cdots\cdots (i)$$

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

$$= \frac{200^2 \times \sin(2 \times 30)}{9.81}$$

$$= 3531.19 \text{ m}$$

$\therefore$ **(a) maximum horizontal range (R) = 3531.19 m**

c) time to reach maximum height.

i. e. time of ascent $(t_a) = ?$

Since, Time of fight is sum of time of ascent and decent,

i. e. $T = t_a + t_d$

We know that, $t_a = t_d$ (Time of ascent & time of decent are equal)

$$\Rightarrow T = 2t_a$$

$$t_a = \frac{T}{2} = \frac{2\,u\,\sin\theta}{2\,g} \qquad [\text{ from equation } (i)]$$

$$= \frac{u\,\sin\theta}{g}$$

$$t_a = \frac{200\times\sin 30}{9.81}$$

$$= 10.193\text{ sec}$$

$\therefore$ Time of ascent *i.e.* Time to reach maximum height = **10.193 sec**

14) A motor cycle rider going with a velocity of 60 km/hr. around a curve with a radius 50 m must lean at angle to the vertical. Find the angle at which he lean.

➢ **Solution:**

Given that;

Velocity of car (v) = 60 km/hr = **16.67 m/s**

Radius (r) = 50m

Angle $(\theta) = ?$

We have,

$$\tan\theta = \frac{v^2}{rg}$$

or, $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$

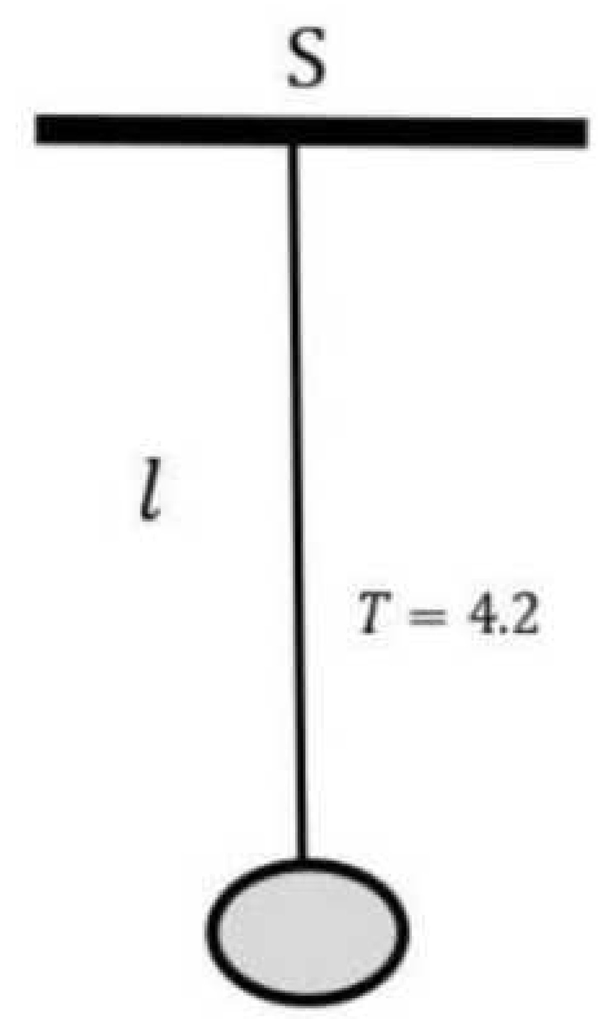
$= \tan^{-1}\left(\frac{(16.67)^2}{50 \times 10}\right)$

$= \tan^{-1}\left(\frac{277.88}{500}\right)$

$= \tan^{-1}(0.555)$

$\therefore$ **angle $\boldsymbol{\theta} = 29.03°$ *at which he leans***

15) A simple pendulum has period of 4.2 s. When the pendulum is shortened by 1 m, the period is 3.7 s. Calculate the acceleration due to gravity and original length of pendulum.



case (i)

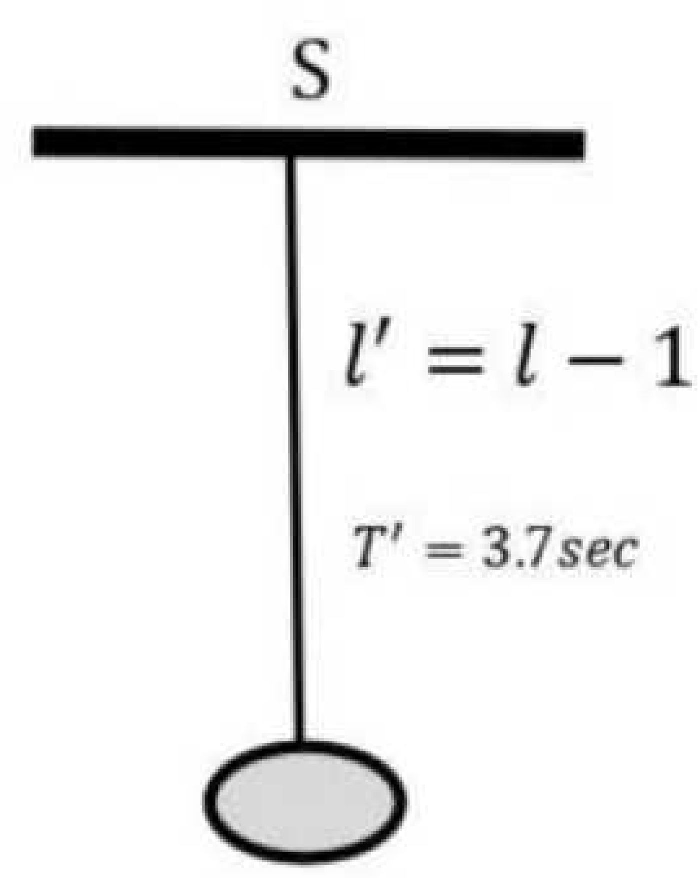
➢ **Solution:** *case(i)*

Let 'l' be length of simple pendulum So,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

From (i) T = 4.2 sec with $'\mathbf{l}'$ Length & $'g'$ be gravity.

$$4.2 = 2\pi\sqrt{\frac{l}{g}} \quad \cdots\cdots\cdots (i)$$



case (ii)

case(ii), When the length is shortened by 1 m

$i.e., l' = (l - 1)m$, Then $T' = 3.7$ sec

$$T' = 2\pi\sqrt{\frac{l'}{g}}$$

$$3.7 = 2\pi\sqrt{\frac{l-1}{g}} \quad \cdots\cdots\cdots (ii)$$

Dividing (ii) by (i),

$$\frac{3.7}{4.2} = \frac{2\pi\sqrt{\frac{l-1}{g}}}{2\pi\sqrt{\frac{l}{g}}}$$

$$\frac{3.7}{4.2} = \sqrt{\frac{l-1}{l}}$$

Squaring both side

$$\left(\frac{3.7}{4.2}\right)^2 = \left(\sqrt{\frac{l-1}{l}}\right)^2$$

$$\left(\frac{3.7}{4.2}\right)^2 = \frac{l-1}{l}$$

$$\frac{1}{l} = 1 - \left(\frac{3.7}{4.2}\right)^2$$

$$\frac{1}{l} = \frac{395}{1764}$$

$$l = 4.465\ m$$

Original length of pendulum $= 4.465\ m$

From equation (i)

$$4.2 = 2\pi\sqrt{\frac{4.465}{g}}$$

$$\frac{4.2}{2\pi} = \sqrt{\frac{4.465}{g}}$$

Squaring both Side,

$$\left(\frac{4.2}{2\pi}\right)^2 = \left(\sqrt{\frac{4.465}{g}}\right)^2$$

$$\left(\frac{4.2}{2\pi}\right)^2 = \frac{4.465}{g}$$

$$0.446 = \frac{4.465}{g}$$

$$g = \frac{4.465}{0.446}$$

$$\boldsymbol{g = 10.01\, m/s^2}$$

16) A copper ball of weight 400 gm is transferred from furnace to 1000 gm of water at 20°C. The temperature of water rises to 50°C. What is the original temperature of ball?

➢ **Solution:**

Given that;

Mass of copper ball $(m_c) = 400 \text{ gm} = 0.4\text{kg}$

Mass of the water used $(m_w) = 1000 \text{ gm} = 1 \text{ kg}$

Mass of metal ball $(m_m) = 100 \text{ gm}$

Initial temperature of water $(t_1) = 20\ °C$

Temperature of Mixture $(t_2) = 50\ °C$

Specific heat capacity of water $(s_w) = 4.2 \times 10^3\ Jkg^{-1}K^{-1}$

Specific heat capacity of copper $(s_c) = 400\ Jkg^{-1}K^{-1}$

Initial temperature of the copper ball $(t) =?$

Heat lost by copper ball to decrease temperature from t°C to 50°C is,

$$= m_c s_c (t - t_2) = 0.4 \times 400(t - 50) = \mathbf{160(t - 50)}$$

Similarly,

Heat gained by 1 kg to water to increase temperature from 20°C to 50°C is,

$$= m_w s_w (t_2 - t_1) = 1 \times 4200(50 - 20) = \mathbf{126000\ Joule}$$

Now, from principal of calorimeter, we have,

Heat lost = Heat gained

$or,\ 160(t - 50) = 126000$

$or,\ 160\,t - 8000 = 126000$

$\therefore\ t = 837.5℃$

Hence, Temperature of the copper ball is 837.5 ℃

17) A Carnot engine absorbs 1000 J of heat from a reservoir at 127°C and rejects 600 J of heat during each cycle. Calculate the temperature of sink.

➢ **Solution:**

Given that;

Heat taken from reservoir $(Q_1) = 1000$ Joule

Heat rejected $(Q_2) = 600$ Joule

Temperature of reservoir $(T_1) = 127℃ = 127 + 273 = 400k$

Temperature of sink $(T_2) = ?$

We know,

Thermal efficiency (η)of a carnot engine is given by;

$$\eta = 1 - \frac{Q_2}{Q_1} \quad \cdots\cdots\cdots (i)$$

and $$\eta = 1 - \frac{T_2}{T_1} \quad \cdots\cdots\cdots (ii)$$

By equating equation (i) and (ii) we get,

$$\frac{T_2}{T_1} = \frac{Q_2}{Q_1}$$

$$T_2 = \frac{Q_2 T_1}{Q_1}$$

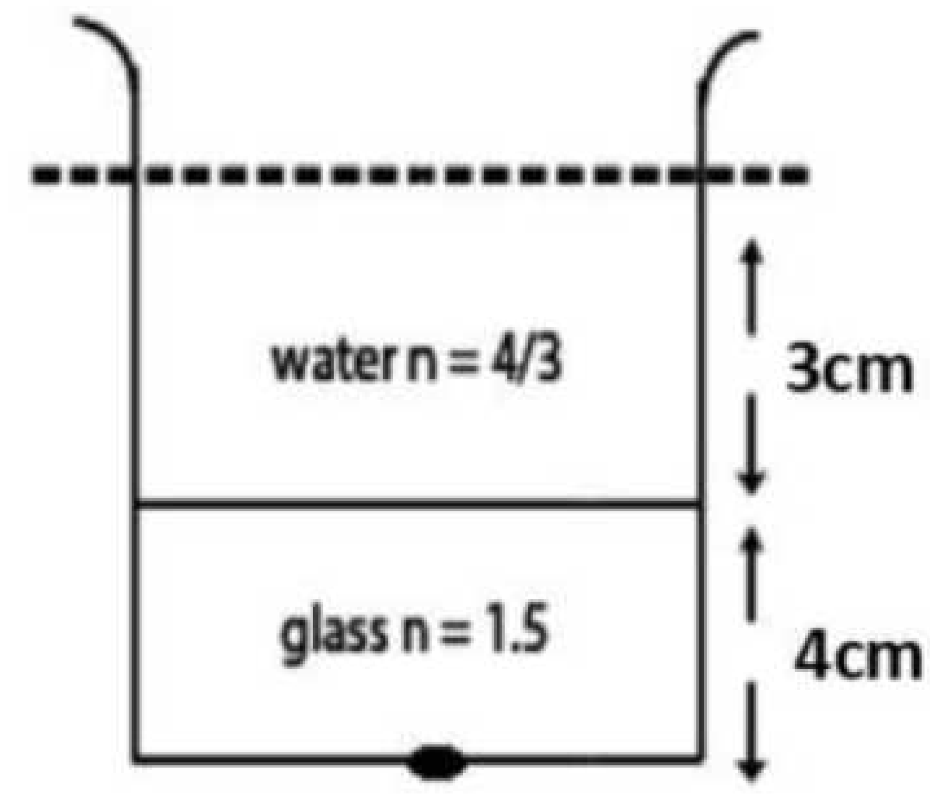
$$= \frac{600 \times 400}{1000}$$

$$\therefore T_2 = 240\ K$$

Hence, Temperature of sink $(T_2) = 240K$

18. What is the apparent position of an object below a rectangular block of glass 4 cm thick if a layer of water 3 cm thick is on the top of the glass? (Refractive indices of glass and water are 3/2 and 4/3 respectively).

➢ **Solution:**



Given that;

Thickness of glass $(t_g) = 4$ cm

Thickness of water $(t_w) = 3$ cm

Refractive index of glass $({}_a\mu_g) = \frac{3}{2} = 1.5$

Refractive index of water $({}_a\mu_w) = \frac{4}{3} = 1.33$

For glass; We have,

$$\text{Displacement } (d_1) = t_g\left(1 - \frac{1}{{}_a\mu_g}\right) = 4\left(1 - \frac{1}{1.5}\right) = \mathbf{1.33\ cm}$$

For water; We have,

$$\text{Displacement } (d_2) = t_w\left(1 - \frac{1}{{}_a\mu_w}\right) = 3\left(1 - \frac{1}{1.33}\right) = \mathbf{0.74\ cm}$$

$$\therefore \text{Total displacement} = d_1 + d_2 = 1.33 + 0.74 = \mathbf{2.07\ cm}$$

Thus,

The apparent position of an object is 2.07cm above from the bottom.

19) A concave mirror produces a real image 3 times as big as the object placed on its principle axis. If the distance between the object and image is 16 cm, what is the focal length of the mirror.

➢ **Solution:**

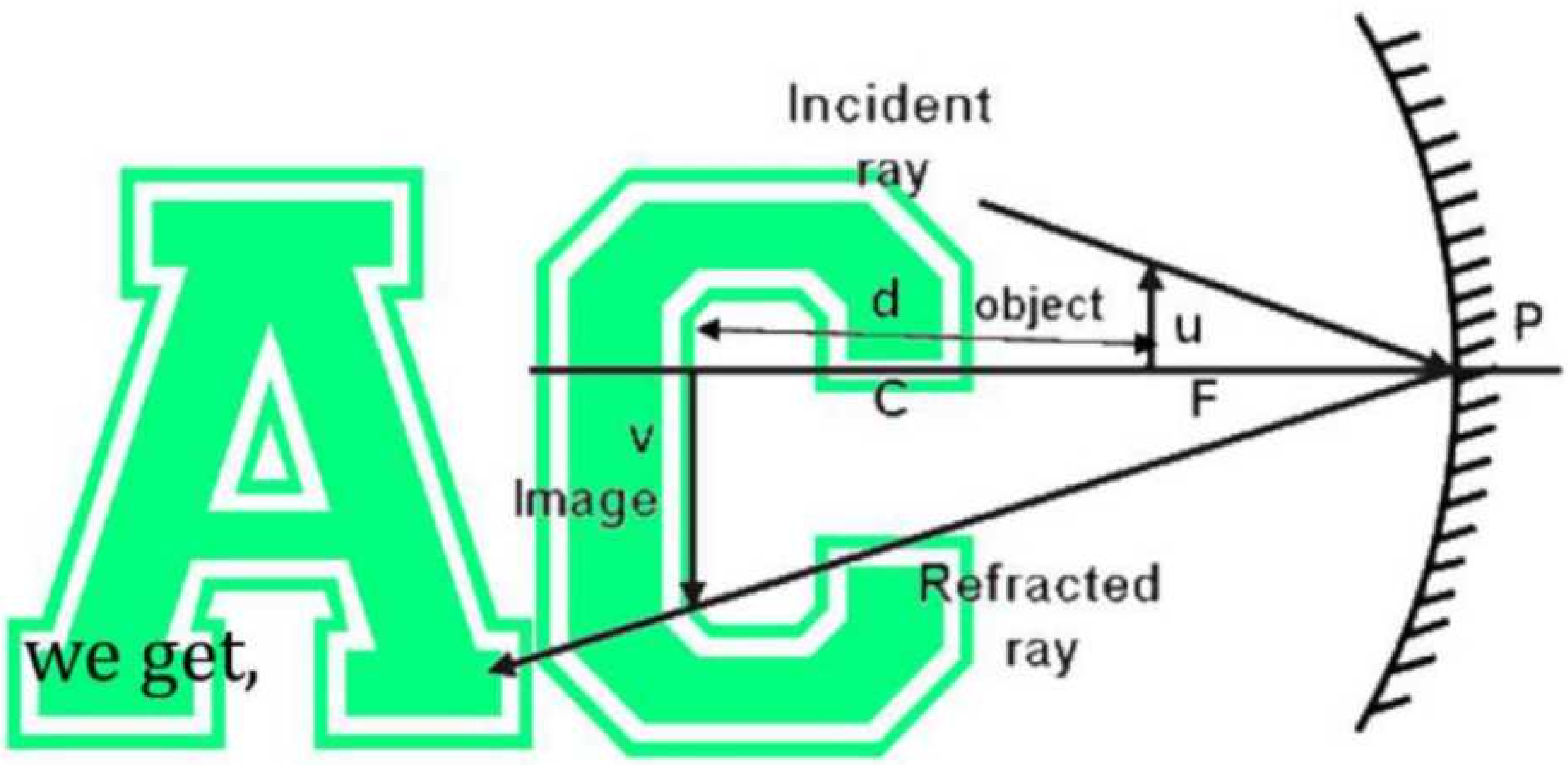
Given that; Magnification $(\mathrm{m}) = 3$

Since, Concave mirror produces a real image. So image is Inverted so, it lies on same side

Object and image distance $(\mathrm{d}) = \mathrm{v} - \mathrm{u} = 16\ \mathrm{cm} \quad \cdots\cdots (i)$

Focal length $(\mathrm{f}) = ?$

Now, we have,



$$\mathrm{m} = \frac{\mathrm{v}}{\mathrm{u}}$$

$$\text{or, } 3 = \frac{\mathrm{v}}{\mathrm{u}}$$

$$\text{or, } \mathrm{v} = 3\mathrm{u}$$

From the relation (i); we get,

$$\mathrm{v} - \mathrm{u} = 16$$

$$\text{or, } 3\mathrm{u} - \mathrm{u} = 16$$

$$\text{or, } 2\mathrm{u} = 16\ \mathrm{cm}$$

$$\mathrm{u} = 8\ \mathrm{cm}$$

and $\mathrm{v} = 3 \times 8 = 24\mathrm{cm}$ Since, u , v is left to pole so, both are negative

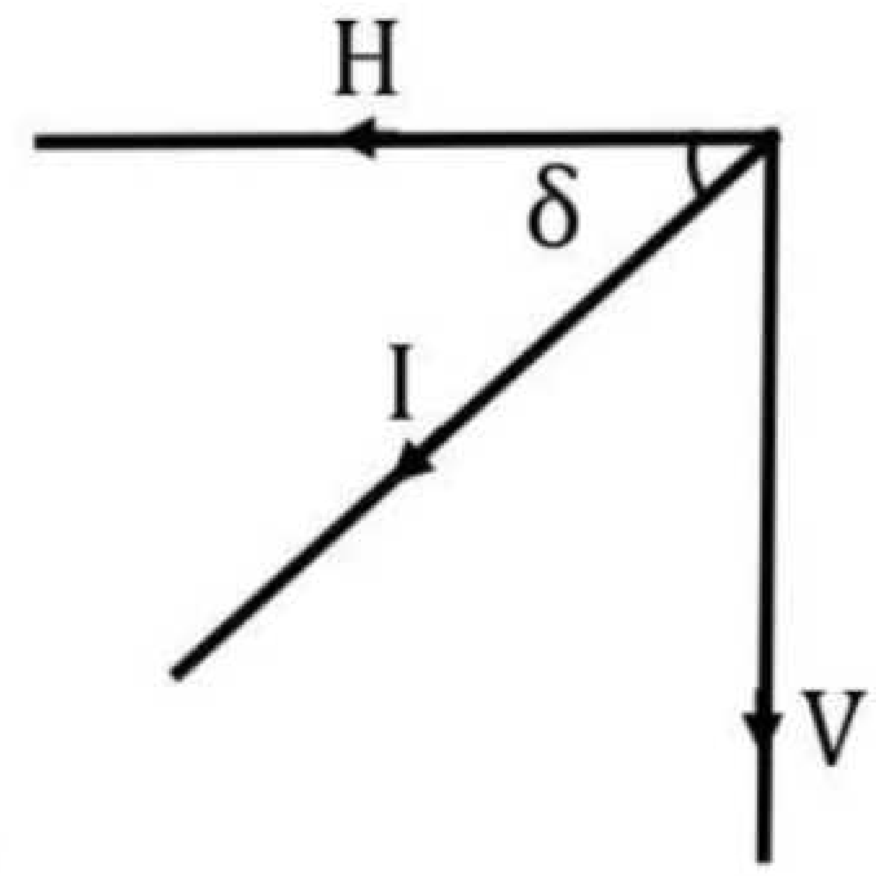
Hence, $$\frac{1}{\mathrm{f}} = \frac{1}{\mathrm{u}} + \frac{1}{\mathrm{v}} = \frac{1}{-8} + \frac{1}{-24} = \frac{-24 - 8}{8 \times 24} = -\frac{1}{6}$$

or, $\therefore \mathbf{f} = -\mathbf{6cm}$ **i. e , f is also left to pole**

Therefore, the focal length of the mirror is 6 cm.

20) The horizontal component of earth's magnetic field at a place is 0.3 gauss and angle of dip is 30°. Find the vertical component and total intensity of earth's magnetic field is tesla.

➢ **Solution:**



Given that;

Earth's magnetic field $(I) = 0.3\ G = 0.3 \times 10^{-4} T$

Angle of dip $(\delta) = 30°$

Now, from geometry,

$$\begin{aligned}\text{Horizontal component (H)} &= I\cos\delta \\ &= 0.3 \times 10^{-4} \times \cos 30° \\ &= \mathbf{2.59 \times 10^{-5} T}\end{aligned}$$

Similarly;

$$\begin{aligned}\text{Vertical component (V)} &= I\sin\delta \\ &= 0.3 \times 10^{-4} \times \sin 30° \\ &= \mathbf{1.5 \times 10^{-5} T}\end{aligned}$$

–The End –

Engineering Physic I__(Engg. All) 1^{st} Sem

2080/81 (New) Question Paper Solution.

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1) State triangle law of vector addition. Derive the expression for magnitude and direction of resultant vector.

➢ **Triangle law of vector**: It state that "*If two sides of a triangle completely represent two vectors both in magnitude and direction taken in same order, then the third side taken in opposite order represents the resultant of the two vectors both in magnitude and direction.*"

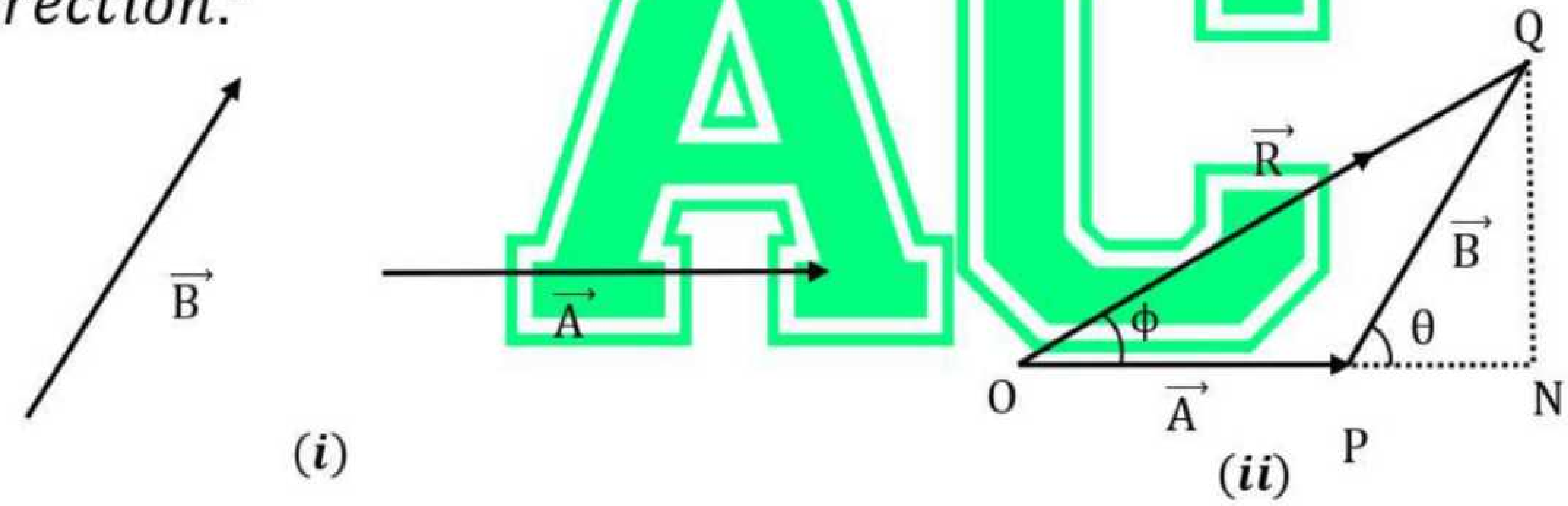


Fig: **Triangle law of vectors**

Let there be two vectors $\vec{A}$ and $\vec{B}$ acting on a particle simultaneously represented both magnitudes and direction by the sides OP and PQ of a triangle OPQ. Let θ be the angle between them. Then, according to the triangle law of vectors, the side OQ represents their resultant $\vec{R}$ which makes an angle ϕ with the vector $\vec{A}$. So, the resultant vector is $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$

Magnitude of $\vec{R}$: Let us drop a perpendicular at N form Q when OP is produced to ON.

In ΔONQ,

$$OQ^2 = ON^2 + NQ^2$$

$$or,\ \ OQ^2 = (OP + PN)^2 + NQ^2 \qquad \cdots\cdots\cdots (i)$$

In ΔPNQ,

$$\cos\theta = \frac{PN}{PQ} = \frac{PN}{B}$$

$$or,\ \ PN = B\cos\theta$$

$$\text{and}\ \ \sin\theta = \frac{QN}{PQ} = \frac{QN}{B}$$

$$or,\ \ QN = B\sin\theta$$

From Equation (i)

$$OQ^2 = (OP + PN)^2 + NQ^2$$

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

$$or,\ \ R^2 = A^2 + 2AB\cos\theta + B^2\cos^2\theta + B^2\sin^2\theta$$

$$or,\ \ R^2 = A^2 + 2AB\cos\theta + B^2$$

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

This is the magnitude of the resultant vector.

Direction of $\vec{R}$: As the resultant $\vec{R}$ makes an angle ϕ with $\vec{A}$, then

In ΔONQ,

$$\tan\phi = \frac{QN}{ON} = \frac{QN}{OP + PN}$$

$$or,\ \ \tan\phi = \frac{B\sin\theta}{A + B\cos\theta}$$

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

This is the direction of the resultant vector.

2) Define collision. Explain how Newton's laws of motion lead to conservation of linear momentum for the system of colliding bodies.

- ***Collision*** is defined as the mutual interaction between two particles for relatively short interval of time as a result of which the energy and momentum of interacting particles change. There are two types of collision; elastic and inelastic collision.
- 2nd Part: **Refer to the solution 2076 of Q. No 1 on page 3.**

3) Define specific heat capacity. Explain the experiment that determine the specific heat capacity of solid by the method of mixture.

- The amount of heat energy required to increase the temperature of unit mass of a substance by 1°C is called its ***specific heat capacity.*** The unit of specific heat capacity is J/Kg°C. It is denoted by S and given by :

$$S = \frac{\text{Amount of heat (Q)}}{\text{Mass(m)} \times \text{Temp. diff} (\Delta\theta)} = \frac{Q}{m\,\Delta\theta}$$

❖ **Determination of specific heat capacity of a solid by the method of mixture**:

- Let us consider a solid of mass m_s and its specific heat capacity is S_s. The solid is heated to the temperature T_2 and dropped in a calorimeter with water at initial temperature T_1. Suppose m_c and S_c are the mass and specific heat capacity of calorimeter respectively and m_w is the mass of water taken in calorimeter and S_w specific heat capacity of water. When the solid is dropped into water, the temperature of water increased and temperature of solid decreased. By stiring water, it can reach to a constant temperature. The final constant temperature T is noted.

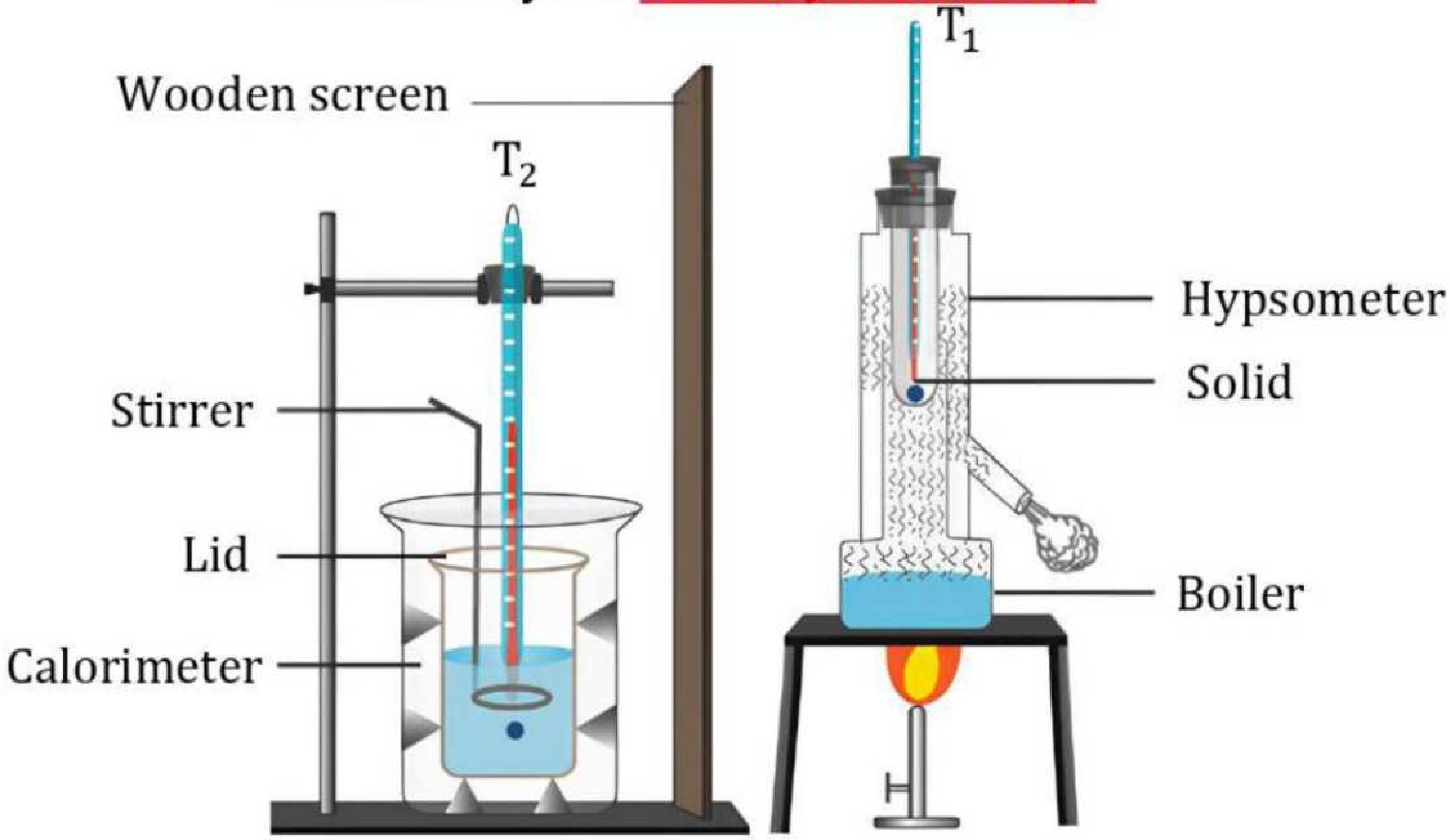


***Fig*: Determination of specific heat of solid by the method of mixture**

Now, Heat lost by the body when its temperature fall from T_2 to T

$$T = m_s\, S_s\, (T_2 - T)$$

Heat gained by calorimeter and water system

$$= m_c\, S_c(T - T_1) + m_w\, S_w(T - T_1)$$

$$= (m_c\, S_c + m_w\, S_w) + (T - T_1)$$

Now, According to principle of calorimetry,

Heat lost by hot body = heat gained by calorimeter & water system

$$m_s\, S_s\, (T_2 - T) = (m_c\, S_c + m_w\, S_w) + (T - T_1)$$

$$\therefore \quad S_s = \frac{(m_c\, S_c + m_w\, S_w) + (T - T_1)}{m_s(T_2 - T)}$$

Therefore, The specific heat capacity of solid can be calculated by using above expression.

4) What is power of lens? Prove that $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ where symbols has their usual meanings.

➢ **Refer to the solution 2079 of Q. No 4 on page 53.**

5) The escape velocity of the body is $V_e = \sqrt{2gR}$. Check the correctness of the formula using dimension.

➢ **Given Equation:**

$$V_e = \sqrt{2gR}$$

Dimensions of escape velocity $(V_e) = [M^0L^1T^{-1}]$
Dimensions of Acceleration due to Gravity $(g) = [M^0L^1T^{-2}]$
Dimensions of Radius $(R) = [M^0L^1T^0]$

So,

$$V_e = \sqrt{2gR}$$

$$[M^0L^1T^{-1}] = \sqrt{[M^0L^1T^{-2}] \times [M^0L^1T^0]} \quad [\because 2 \text{ is dimensionless}]$$

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

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

$$\Rightarrow \textbf{LHS} = \textbf{RHS}$$

So, the formula is dimensionally correct.

6) Define gravity. How does 'g' vary with depth from the surface of earth?

➢ **Refer to the solution 2078 of Q. No 4 on page 35.**

7) Define torque and angular momentum. Derive the relation between them.

- The product of one of the force and shortest distance between two forces which always have turning effect is called ***torque***. It is also called moment of couple. It is represented by (τ)and given by:

  Torque (τ) = force (F) $\times$ perpendicular distance (r)

- ***Angular momentum*** is defined as the product of linear momentum and distance between the object and axis of rotation. It is represented by (L) and given by :

  L = lines momentum $\times$ perpendicular distance from the axis of rotation.

Relation between torque and angular momentum.

- Refer to the solution 2079 of Q. No 6 on page 55.

8) Show that the coefficient of cubical expansion of solid is thrice the coefficient of linear expansion.

- **Refer to the solution 2080 (old) of Q. No 7 on page 67.**

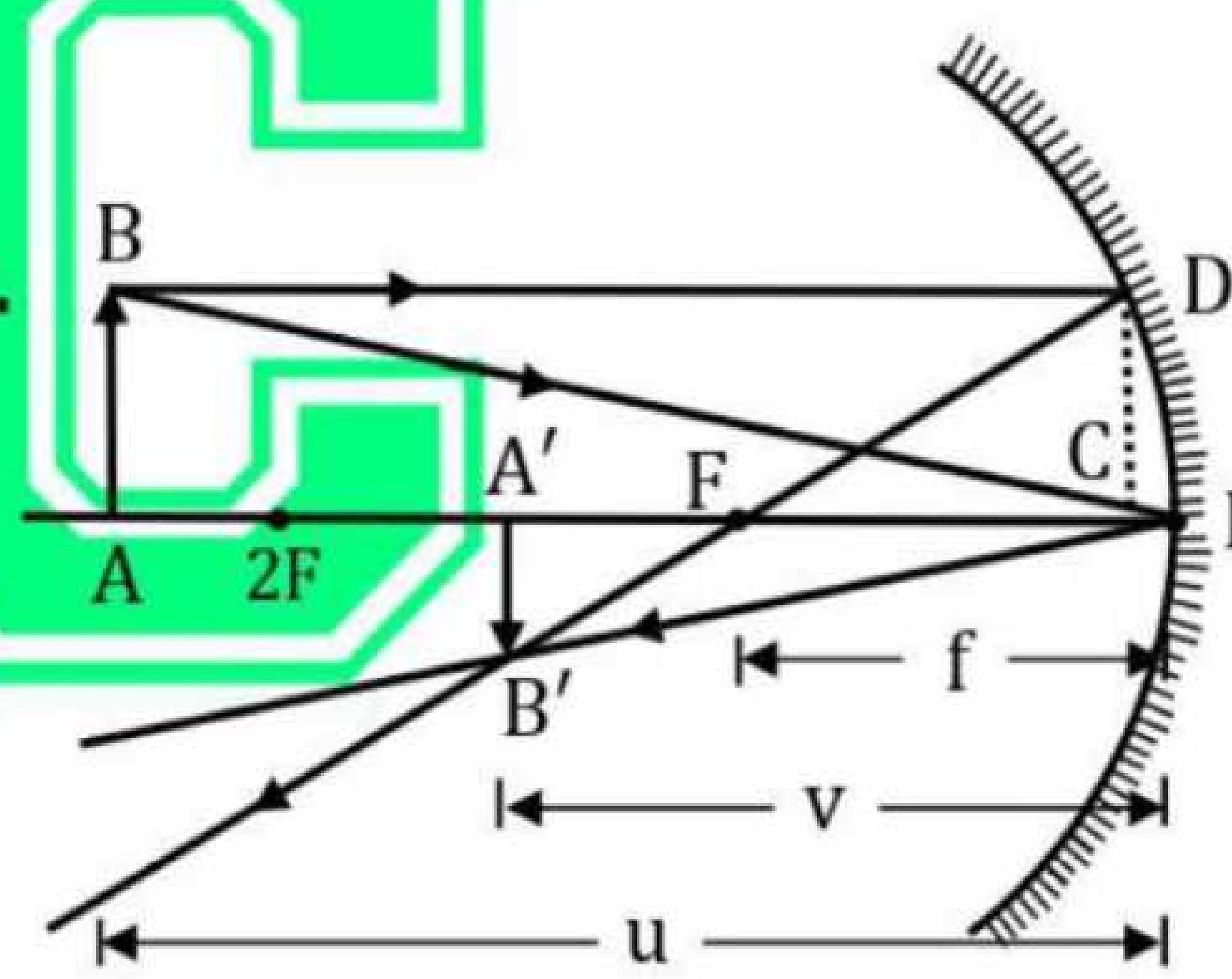
9) What do you mean by isothermal process? Derive an expression for work done by gas during Isothermal process.

- **Refer to the solution 2080 (New) of Q. No 8 on page 80.**

10) Define mirror formula. Derive the mirror formula for concave mirror when image formed is real.

- The relationship between focal length of mirror with object distance and image distance is called ***mirror formula***.
- Consider a concave mirror of focal length f which has to relate with object distance u and image distance v. Let AB be an object placed normally on the principal axis of the mirror. The rays of light from the object AB, after reflection from concave mirror meet at point B'. So A'B' is the real image of the object AB. If the aperture of the mirror is small, the point P *i.e* pole of the mirror coincides with point C. Since Δ's ABC and A'B'C are similar, so their corresponding sides are proportional.

$$\frac{AB}{A'B'} = \frac{CA}{CA'} \qquad \cdots\cdots\cdots(i)$$



Similarly Δ's CDF and A'B'F are similar.

$$\therefore \frac{CD}{A'B'} = \frac{CF}{FA'}$$

But CD=AB

$$\therefore \frac{AB}{A'B'} = \frac{CF}{FA'} \qquad \cdots\cdots\cdots(ii)$$

Form equation (i) & (ii), we have,

$$\frac{CA}{CA'} = \frac{CF}{FA'}$$

or, $$\frac{CA}{CA'} = \frac{CF}{CA' - CF}$$

or, $$\frac{u}{v} = \frac{f}{v - f}$$

$$\left[\begin{array}{l} \text{Where, CA} = \text{u is object distance taken + ve for real object} \\ \text{CA}' = \text{v is image distance taken + ve for real image} \\ \text{CF} = \text{f is focal length taken + ve for concave mirror} \end{array}\right]$$

or, $uv - uf = vf$

or, $uv = uf + vf$

Dividing both sides by uv

$$\frac{uv}{uv} = \frac{uf}{uv} + \frac{vf}{uv}$$

or, $1 = \frac{f}{v} + \frac{f}{u}$

or, $1 = f\left(\frac{1}{v} + \frac{1}{u}\right)$

$\therefore \quad \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, which is mirror formula

The nature of image is **inverted**, real and different size according to position of object.

11) State and establish the Coulomb's law of magnetism.

➢ **Refer to the solution 2078 of Q. No 9 on page 41.**

12) Distinguish between diamagnetic, paramagnetic and ferromagnetic material.

➢ **Refer to the solution 2076 of Q. No 11 on page 19.**

13) A motor cycle rider going with a velocity of 60 km/hr. around a curve with a radius 50 m must lean at angle to the vertical. Find the angle at which he lean. $(\mathbf{g = 9.8\ m/s^2})$

- **Solution:**

Velocity (v) $= 60\text{km/hr} = 60 \times \frac{1000\text{ m}}{60 \times 60\text{ sec}} = \mathbf{16.67 m/s}$

Radius (r) $= 50\text{m}$

Accleration due to gravity(g) $= 9.8\ \text{m/s}^2$

To find : Angle at he lean $(\theta) = ?$

We have,

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

$$= \tan^{-1}\left(\frac{(16.67)^2}{50 \times 9.8}\right)$$

$$= \tan^{-1}(0.5671)$$

$$\therefore \boldsymbol{\theta = 29.558°}$$

Hence, Angle at he lean , $\theta = 29.558°$ with vertical

14) A simple pendulum is oscillating at the rate of 30 times per minute. Find the time period and length of pendulum. $[\mathbf{g = 9.8\ m/s^2}]$

- **Solution:**

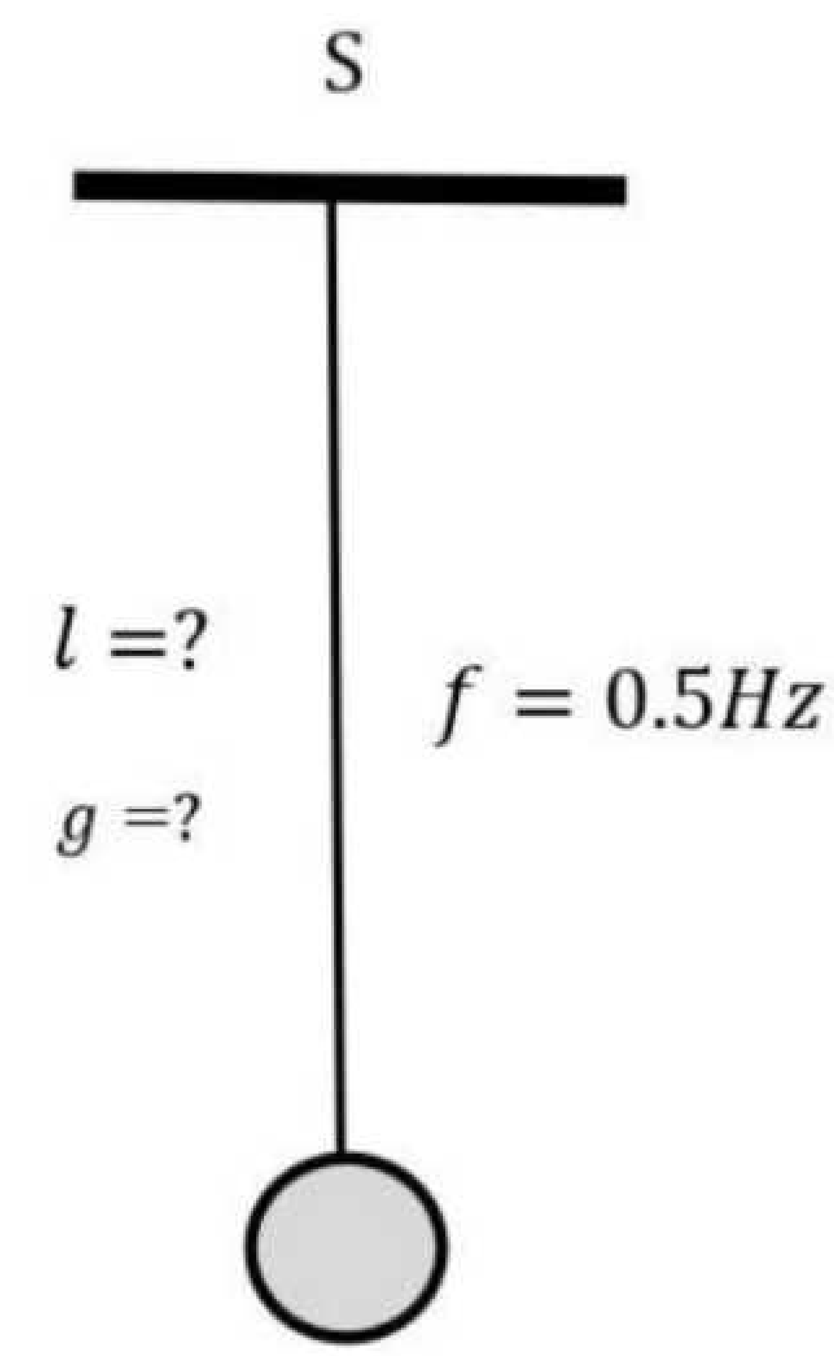
By Question,

Pendulum osciating at rate of 30 times per minute

$\boldsymbol{i.e},$ Frequency(f) $= \frac{30}{60}$ per sec $= 0.5\ \text{s}^{-1} = \mathbf{0.5 Hz}$

Hence, Time period (T) $= \frac{1}{f} = \frac{1}{0.5} = \mathbf{2\ sec}$

Acceration due to gravity(g) $= \mathbf{9.8\ m/s^2}$



Let 'l' be length of simple pendulum So,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$2 = 2\pi\sqrt{\frac{l}{9.8}}$$

Squaring both side, we get,

$$4 = 4\pi^2 \times \frac{l}{9.8}$$

$$\Rightarrow l = \frac{9.8}{\pi^2} = 0.999\ m \approx \mathbf{1m}$$

Hence, Time period of pendulum is 2 sec and length = 1m

15) What is result of mixing 20 gram of water at 90° with 10 gram of ice at −10°C? [Specific heat of ice = 2100 J $kg^{-1}°C^{-1}$, Specific heat of water = 4200 J $kg^{-1}°C^{-1}$, Latent heat of fusion of ice = 3.36×10^5 J kg^{-1}].

➢ **Solution: Given that;**

Mass of water $(m_1) = 20\ gm = \frac{20}{1000} kg = 0.02\ kg$

Initial temperature of water $(\theta_1) = 90°C$

Mass of ice $(m_2) = 10\ gm = \frac{10}{1000} kg = 0.01\ kg$

Initial temperature of ice $(\theta_2) = -10°C$

Latent heat of ice $(L_f) = 3.36 \times 10^5$ J/kg

Specific heat of ice $(S_i) = 2100$ J/kg °C^{-1}

Specific heat of water $(S_w) = 4200$ J/kg °C^{-1}

Resultant temperature $(\theta) = ?$

From the principle of calorimetry; we can write,

Heat lost by water = Heat gained by ice

or, $m_1 S_w(\theta_1 - \theta) = m_2 S_i[0 - (-\theta_2)] + m_2 L_f + m_2 S_w(\theta - 0)$

or, $0.02 \times 4200 \times (90 - \theta) = 0.01 \times 2100 \times 10 + 0.01 \times 3.36 \times 10^5 +$
$0.01 \times 4200 \times \theta$

or, $84(90 - \theta) = 210 + 3360 + 42\theta$

or, $7560 - 84\theta = 3570 + 42\theta$

or, $126\theta = 3990$

or, $\theta = 31.67°C$

Hence, Resultant temperature of mixture of mass 20 gm of water is 31.67°C.

16) Find the rate of heat flow through a glass window of area $200\ cm^2$ and thickness 5 mm if the temperature inside room is 18 °C and outside the room is 40°C. (Thermal conductivity of glass is $1.38\ Wm^{-1}K^{-1}$).

➢ **Solution:**

Given that;

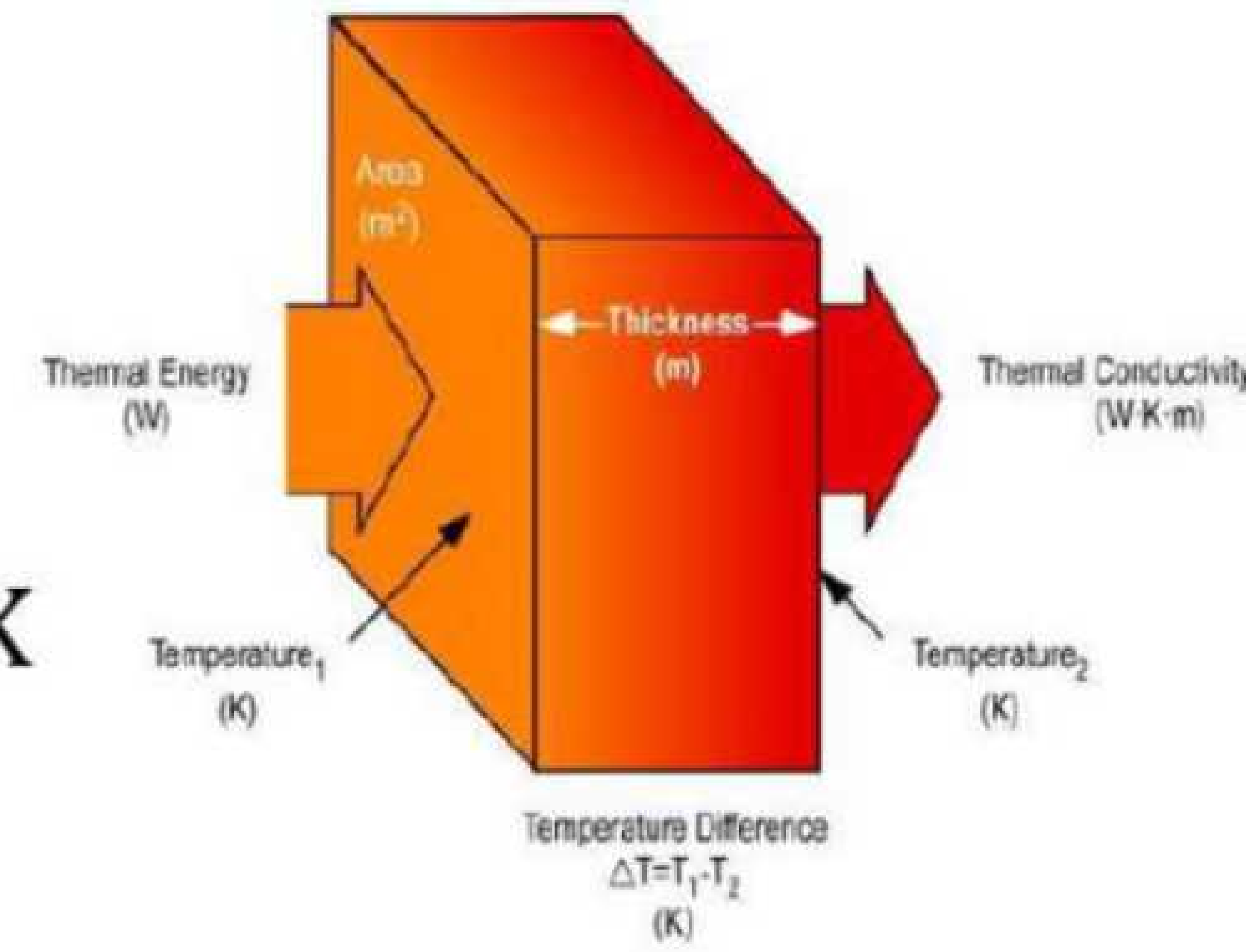
Area of Glass window (A) $= 200\text{cm}^2 = 0.02\text{m}^2$

Thickness of glass window (l) $= 5\text{mm} = 0.005\text{m}$

Inside temperature of room(θ_1) $= 18°\text{C} = 291°\text{K}$

Outside temperature of room(θ_2) $= 40°\text{C} = 313°\text{K}$

Thermal Conductivity of glass $= 1.38\ \text{Wm}^{-1}\text{K}^{-1}$



To find: Rate of Heat flow: $\frac{dQ}{dt} = ?$

We have thermal conductivity formula, $Q = \frac{KA(\theta_2 - \theta_1)t}{l}$

Differentiating Q w.r.t time 't'

$$\frac{dQ}{dt} = \frac{KA(\theta_2 - \theta_1)}{l} \times 1$$

$$\frac{dQ}{dt} = \frac{1.38 \times 0.02(313 - 291)}{0.005}$$

$$\therefore \frac{\mathbf{dQ}}{\mathbf{dt}} = \mathbf{121.44\ Watt}$$

17) A convex mirror has radius of curvature 40 cm. An object is placed 16 cm in front of the mirror. Find the position where image is formed. Also, determine magnification and nature of image.

➢ **Solution:**

Given that;

Object distance (u) $= -16$ cm.

Radius of curvature (r) $= +40$ cm

So, Focal length (f) $= \frac{r}{2} = \frac{40}{2} = 20\text{cm}$

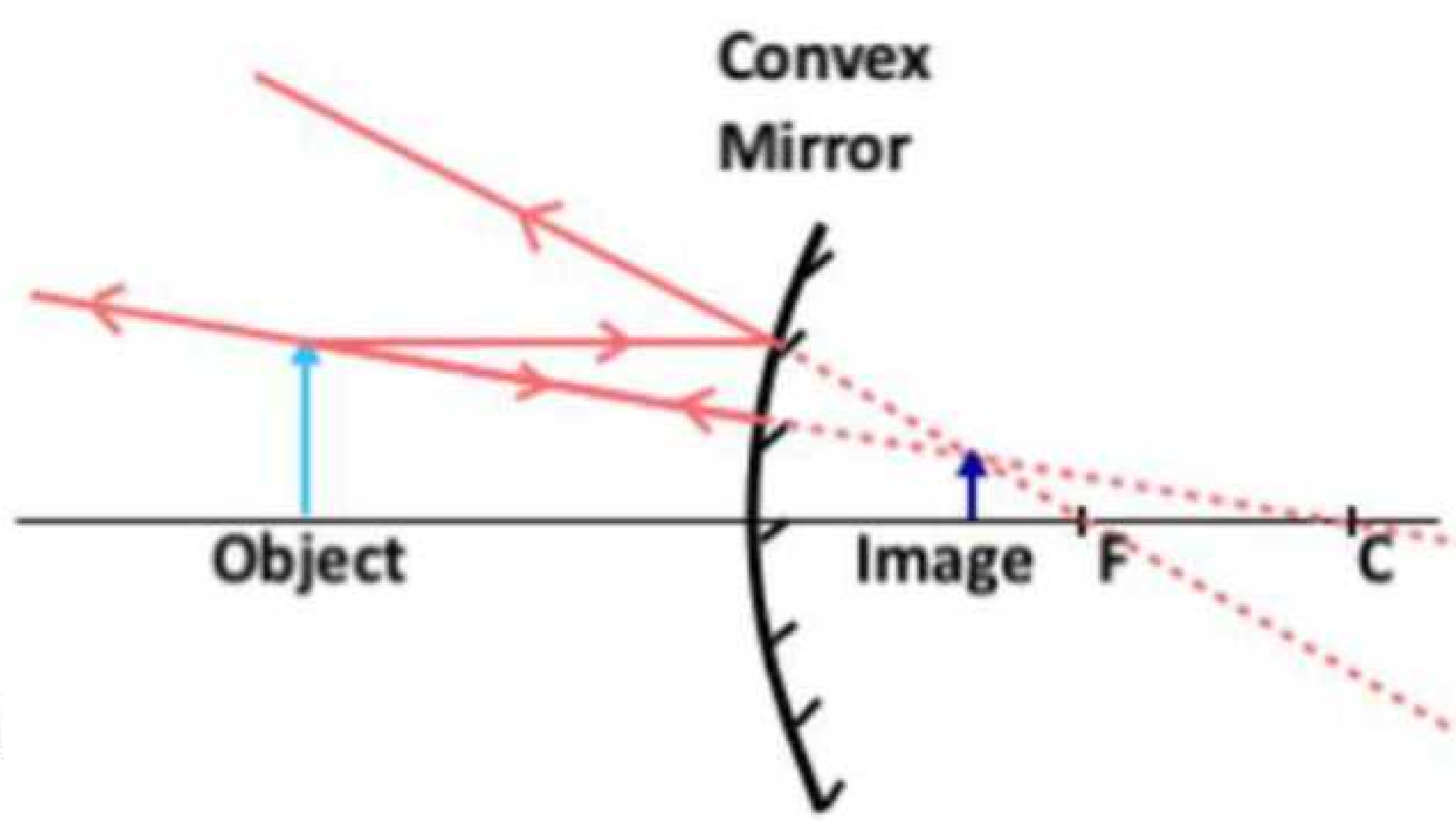


Image distance (v) = ?

Magnification (m) = ?

Using mirror formula; we have,

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

$$\text{or,}\quad \frac{1}{v}=\frac{1}{f}-\frac{1}{u}$$

$$\text{or,}\quad \frac{1}{v}=\frac{1}{20}-\frac{1}{16}$$

$$\text{or,}\quad \frac{1}{V}=\frac{20+16}{20\times 16}=\frac{36}{320}=\frac{9}{80}$$

$$\therefore \mathbf{v}=\frac{\mathbf{80}}{\mathbf{9}}=\mathbf{8.89\ cm}\ (\mathbf{real})$$

$$\text{and,}\quad \text{Magnification (m)}=-\frac{v}{u}=\frac{8.89}{-(-16)}=+\mathbf{0.55}$$

Thus, the position of real image is 8.89 cm from a concave mirror and its magnification is + 0.55.
Nature of image is **Virtual image and Erect**

18) The angle of minimum deviation produced by prism of refractive index 1.33 is $23.4°$. Calculate the angle of prism.

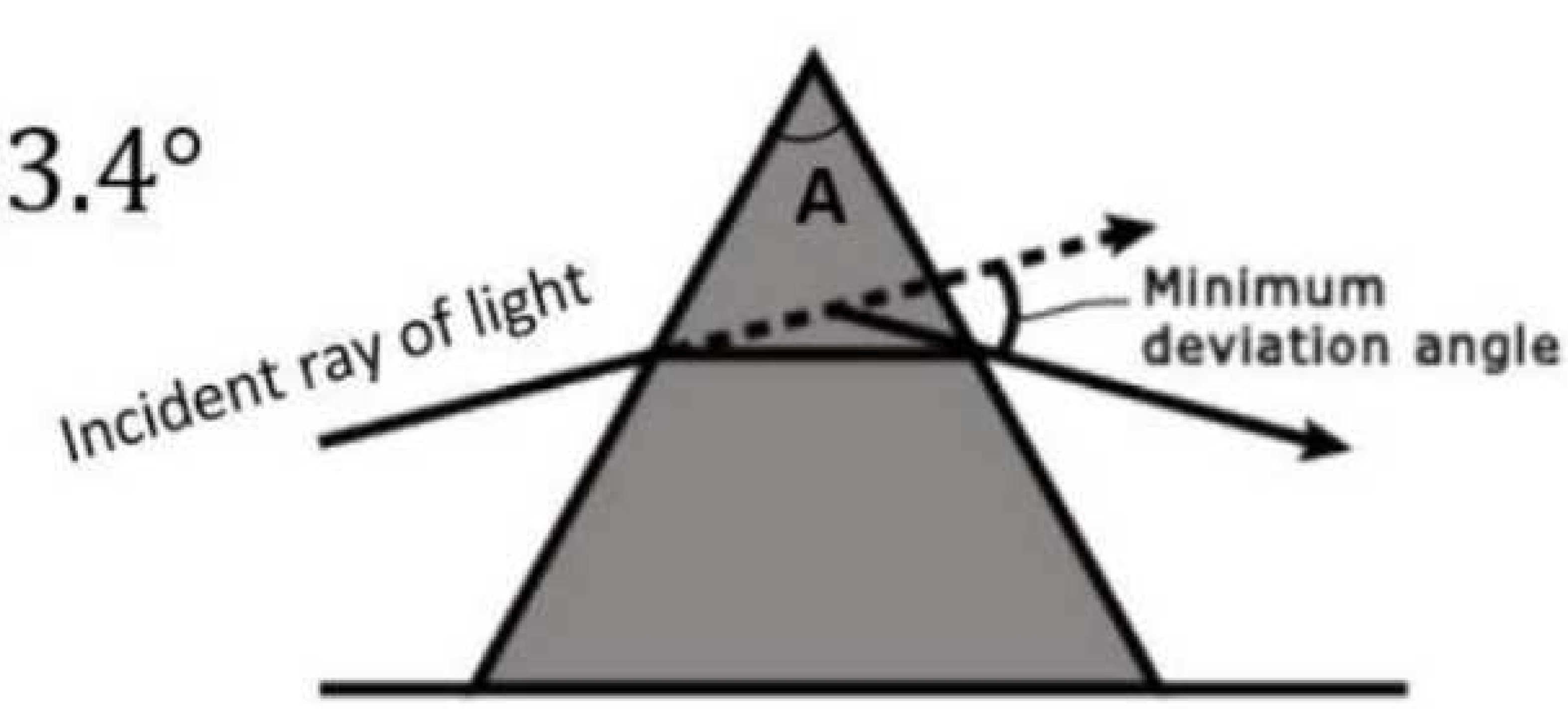
➢ **Solution:**

Given that;

Angle of minimum deviation (δ_m) = 23.4°

Refractive index (μ) = 1.33

Angle of prism(A) =?



We have,

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

or, $1.33 \sin\left(\frac{A}{2}\right) = \sin\left(\frac{A + 23.4°}{2}\right)$

or, $1.33 \sin\left(\frac{A}{2}\right) = \sin\left(\frac{A}{2}\right) \cos\left(\frac{23.4°}{2}\right) + \cos\left(\frac{A}{2}\right) \sin\left(\frac{23.4°}{2}\right)$

[$\because$ using $\sin(A + B) = \sin A \cos B + \cos A \sin B$]

or, $1.33 \sin\left(\frac{A}{2}\right) = \sin\left(\frac{A}{2}\right) \cos 11.7° = \cos\left(\frac{A}{2}\right) \sin 11.7°$

or, $\sin\left(\frac{A}{2}\right) \times [1.33 - 0.979] = \cos\left(\frac{A}{2}\right) \times 0.203$

or, $\sin\left(\frac{A}{2}\right) \times 0.351 = \cos\left(\frac{A}{2}\right) \times 0.203$

or, $\frac{\sin\left(\frac{A}{2}\right)}{\cos\left(\frac{A}{2}\right)} = \frac{0.203}{0.351}$

or, $\tan\left(\frac{A}{2}\right) = 0.5783$

or, $\frac{A}{2} = \tan^{-1}(0.5783)$

or, $\frac{A}{2} = 30.04°$

$\therefore$ **Angle of prism (A) = 60.085°**

19) The horizontal component of earth's magnetic field is 3.4×10^{-5}T and angle of true dip is $30°$. Find the total magnetic flux density of earth and vertical component of earth's magnetic field.

➢ **Solution:-**

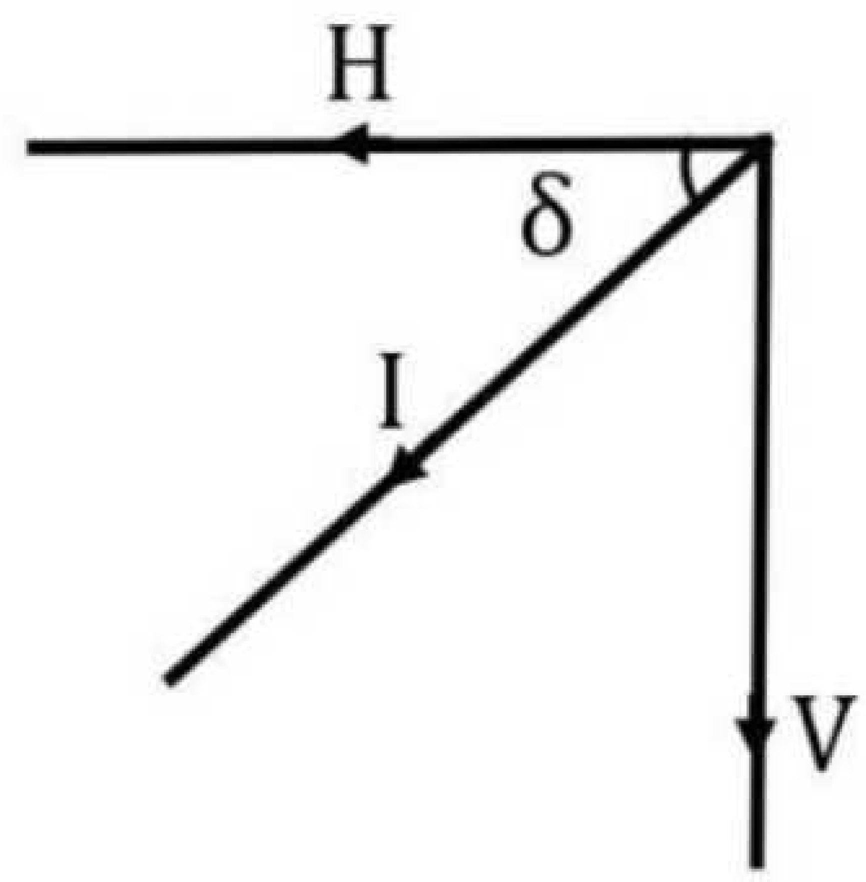
Given that;

Horizontal component of earth's magnetic field (H) $= 3.4 \times 10^{-5}$T

Angle of dip (δ) $= 30°$

Total intensity (I) =?

Vertical component (V) =?



We know that,

$$H = I\cos\delta \cdots\cdots\cdots (i)$$

$$V = I\sin\delta \cdots\cdots\cdots (ii)$$

Dividing equation (ii) by (i); we have,

$$\frac{V}{H} = \frac{\sin\delta}{\cos\delta}$$

$$or,\ V = H.\tan\delta$$

$$= 3.4 \times 10^{-5} \times \tan 30°$$

$$= 1.962 \times 10^{-5}\ T$$

$$\therefore\ \mathbf{V = 1.962 \times 10^{-5}\ T}$$

Also, from (i),

$$\mathbf{H = I\cos\delta}$$

$$I = \frac{H}{\cos\delta}$$

$$= \frac{3.4 \times 10^{-5}}{\cos 30^\circ}$$

$$= \mathbf{3.925 \times 10^{-5}\ T}$$

Hence, the value of total magnetic intensity of earth's magnetic field is 3.925×10^{-5} T and vertical component is 1.962×10^{-5} T

–The End –