

9th - 03-5 integrated Task

①

Refractive index of glass $\mu_g = \frac{3}{2}$

Time taken by light to travel in glass $t_g = ?$

Time taken by light to travel in air $t_a = 4 \text{ sec}$

Refractive index of air $\mu_a = 1$

\therefore Given distance travelled by the light in air and glass

Same

$$x_{\text{air}} = x_{\text{glass}}$$

$$\Rightarrow v_a t_a = v_g t_g$$

But Velocity $\propto \frac{1}{\mu}$

$$\therefore \Rightarrow \mu_g t_a = \mu_a t_g$$

$$\frac{v_a}{v_g} = \frac{\mu_g}{\mu_a}$$

$$\Rightarrow \frac{3}{2} \times 4 = 1 \times t_g$$

$$\Rightarrow t_g = 6 \text{ sec.}$$

②

Given wavelength of light $\lambda = 6000 \text{ \AA}$

Refractive index of air $\mu_a = 1.0003$

Let the thickness of air column t

We know that no. of wavelengths $n = \frac{t}{\lambda}$

$$\text{For air } n_{\text{air}} = \frac{t_a}{\lambda_a} \Rightarrow t_a = n_{\text{air}} \lambda_a$$

$$\text{For vacuum } n_v = \frac{t_v}{\lambda_v} \Rightarrow t_v = n_v \lambda_v$$

$$\text{Given } n_a = 1 + n_v \quad [t_a = t_v]$$

$$\Rightarrow \frac{t_a}{\lambda_a} = 1 + \frac{t_v}{\lambda_v}$$

$$\frac{t_a}{\lambda_a} - \frac{t_v}{\lambda_v} = 1$$

$$\Rightarrow t \left[\frac{1}{\lambda_a} - \frac{1}{\lambda_v} \right] = 1$$

$$\Rightarrow t \left[\frac{\mu_a}{\lambda_v} - \frac{1}{\lambda_v} \right] = 1$$

$$\Rightarrow \frac{t}{\lambda_v} (\mu_a - 1) = 1$$

$$\Rightarrow t = \frac{\lambda_v}{\mu_a - 1} = \frac{6000 \times 10^{-10}}{1.0003 - 1} = \frac{6 \times 10^{-7}}{0.0003} = \frac{6 \times 10^{-7}}{3 \times 10^{-4}} = 2 \text{ mm}$$

we know $\mu \propto \frac{1}{\lambda}$

$$\Rightarrow \frac{\mu_v}{\mu_a} = \frac{\lambda_a}{\lambda_v}$$

$$\Rightarrow \lambda_a = \lambda_v \frac{\mu_v}{\mu_a}$$

$$= \frac{\lambda_v}{\mu_a} \quad [\mu_v = 1]$$

(3)

let the two medias are A and B.

Given $\frac{\text{Distance travelled by a light in A}}{\text{Distance travelled by a light in B}} = \frac{2}{3}$

\Rightarrow distance \propto velocity $\propto \frac{1}{\mu}$.

$$\therefore \frac{d_A}{d_B} = \frac{\mu_B}{\mu_A}$$

$$\Rightarrow \frac{\mu_B}{\mu_A} = \frac{2}{3}$$

$$\Rightarrow \frac{\mu_A}{\mu_B} = \frac{3}{2}$$

④

Thickness of slab $t_s = 4 \text{ cm}$

Thickness of water $t_w = 5 \text{ cm}$

Refractive index of water $\mu_w = \frac{4}{3}$

$$\text{No. of waves} = \frac{\text{Thickness of medium}}{\text{wavelength of light}}$$

Given that No. of waves in slab = No. of waves in water

$$\Rightarrow \frac{t_s}{\lambda_s} = \frac{t_w}{\lambda_w}$$

$$\Rightarrow \frac{\lambda_w}{\lambda_s} = \frac{t_w}{t_s} \quad \because \text{we know that } \mu \propto \frac{1}{\lambda}$$

$$\Rightarrow \frac{\mu_s}{\mu_w} = \frac{t_w}{t_s} \quad \Rightarrow \frac{\lambda_w}{\lambda_s} = \frac{\mu_s}{\mu_w}$$

$$\Rightarrow \frac{\mu_s}{\mu_w} = \mu_w \times \frac{t_w}{t_s}$$

$$\Rightarrow \mu_s = \frac{4}{3} \times \frac{5}{4}$$

$$\Rightarrow \mu_s = \frac{5}{3}$$

⑤

wavelength of light in vacuum $\lambda_v = 5700 \text{ \AA}$

Refractive index of glass $\mu_g = \frac{3}{2}$

Refractive index of vacuum $\mu_v = 1$

we know that $\mu \propto \frac{1}{\lambda}$

$$\Rightarrow \frac{\lambda_g}{\lambda_v} = \frac{\mu_v}{\mu_g} \Rightarrow \lambda_g = \lambda_v \times \frac{\mu_v}{\mu_g} = \frac{5700 \times 2}{3}$$

$$\Rightarrow \lambda_g = 3800 \text{ \AA}$$

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$$Li = 25^\circ ; Lr = 32^\circ$$

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 25^\circ}{\sin 32^\circ} = \frac{0.4233}{0.551} \approx 0.79$$
$$\approx 0.8$$

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$$Lr = 14^\circ ; \mu = 1.02$$

$$\mu = \frac{\sin i}{\sin r} \Rightarrow \sin i = \mu \sin r$$
$$= 1.02 \times \sin 14^\circ$$
$$= 1.02 \times 0.24$$

$$\sin i = 0.24$$

$$\Rightarrow i = 16.7^\circ$$

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$\mu_i = 1.14$

$$\mu = 1.14$$

$$\sin i = 48^\circ$$

$$r = 39^\circ$$

$$\frac{\mu_r}{\mu_d} = \frac{\sin i}{\sin r}$$

$$\Rightarrow \mu_r = \mu_d \frac{\sin 48^\circ}{\sin 39^\circ}$$

$$= 1.14 \times \frac{0.74}{0.629}$$

$$= 1.346$$

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$$\mu_w = 1.33$$

$$i = 10^\circ$$

$$\mu_a = 1$$

$$\frac{\mu_w}{\mu_a} = \frac{\sin i}{\sin r} \Rightarrow \sin r = \sin i \times \frac{\mu_a}{\mu_w}$$
$$= \sin(10^\circ) \times \frac{1}{1.33}$$

$$= \frac{0.17368}{1.33}$$

$$\sin r = 0.131$$

$$r = 7.5^\circ$$

⑩ The shift produced in the path of the ray is given

⑩

by
$$d = \frac{k}{\cos r} \sin(i-r) \rightarrow (1)$$

Given $i = 60^\circ$: Refractive index of glass slab = $\mu_g = \sqrt{3}$
Thickness $k = \sqrt{3}$ cm

From Snell's law
$$\frac{\mu_g}{\mu_a} = \frac{\sin i}{\sin r}$$

$$\Rightarrow \sqrt{3} = \frac{\sin 60}{\sin r}$$

$$\Rightarrow \sqrt{3} \sin r = \frac{\sqrt{3}}{2} \Rightarrow \sin r = \frac{1}{2}$$

$$\Rightarrow r = 30^\circ$$

∴

From (1)

$$d = \frac{\sqrt{3}}{\cos 30} \sin(60-30)$$

$$= \frac{\sqrt{3}}{\frac{\sqrt{3}}{2}} \times \sin 30$$

$$\Rightarrow 2 \times \frac{1}{2} = 1 \text{ cm}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{c}{\mu_2} = \frac{c}{\mu_1 \mu_2} = \frac{\sin C_2}{\sin C_1}$$

(ii)

Given that real depth $h = 1 \text{ m}$.

$$\begin{aligned} \text{Apparent depth} &= \text{Real depth} - \text{shift} \\ &= 1 - 0.1 = 0.9 \text{ m} \end{aligned}$$

we know that Refractive index $\mu = \frac{\text{Real depth}}{\text{apparent depth}}$

$$\Rightarrow \mu = \frac{1}{0.9} = \frac{10}{9}$$

λ_0

$$\Rightarrow c = 5m^{-1} \left[\frac{\lambda}{\lambda_0} \right]$$

(13)

we know that when we view from underwater

$$u = \frac{\text{apparent height}}{\text{real height}}$$

Apparent height from surface = $36 - 12 = 24$ m.

$$u = \frac{4}{3}$$

$$\therefore \frac{4}{3} = \frac{24}{\text{real height}}$$

$$\Rightarrow \text{Real height} = 24 \times \frac{3}{4} = 18 \text{ m.}$$

Given ${}^a\mu_{gly} = 1.04$; ${}^a\mu_{dia} = 2.04$.

(17)

(17)

velocity of light in air $c = 3 \times 10^8$ m/s

\therefore we know that velocity $\propto \frac{1}{\mu}$

\therefore Refractive index of glycerine with respect to air

$${}^a\mu_{gly} = \frac{\mu_a}{\mu_{gly}} = \frac{v_{gly}}{c}$$

$$\text{velocity in glycerine} \Rightarrow v_{gly} = c \times \frac{\mu_a}{\mu_{gly}} = 3 \times 10^8 \times \frac{1}{1.04}$$

$$\Rightarrow v_{gly} = 2.8846 \times 10^8 \text{ m/s}$$

$${}^{11}{}^{14} \text{ velocity of light in diamond} = c \times \frac{\mu_a}{\mu_{dia}} = 3 \times 10^8 \times \frac{1}{2.04}$$

$$v_{dia} = 1.4706 \times 10^8 \text{ m/s}$$

Refractive index of diamond with respect to glycerine

$${}^{gly}\mu_d = \frac{\mu_{gly}}{\mu_{dia}} = \frac{1.04}{2.04} = 0.5098$$

Refractive index of glycerine with respect to diamond

$${}^d\mu_{gly} = \frac{\mu_d}{\mu_{gly}} = \frac{2.04}{1.04} = 1.9615$$

18

we know that NO. of waves = $\frac{\text{Thickness of the medium}}{\text{wavelength of light}}$

Thickness of glass slab $t_g = 4 \text{ cm}$.

Thickness of water $t_w = 5 \text{ cm}$.

Refractive index of water $\mu_w = \frac{4}{3}$; $\mu_g = ?$

Given

NO. of waves in glass slab = NO. of waves in water

$$\Rightarrow \frac{t_g}{\lambda_g} = \frac{t_w}{\lambda_w}$$

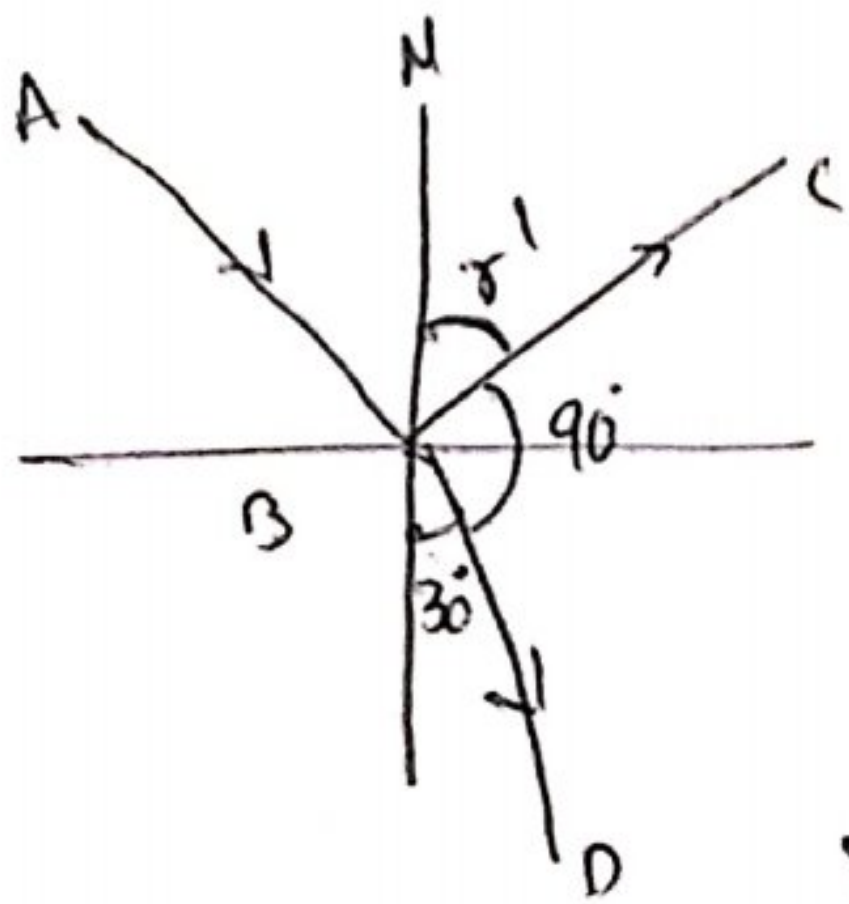
$$\Rightarrow t_g = \frac{\lambda_g}{\lambda_w} t_w \quad [\because \lambda \propto \frac{1}{\mu}]$$

$$\Rightarrow t_g = \frac{\mu_w}{\mu_g} t_w$$

$$\Rightarrow \mu_g = \mu_w \times \frac{t_w}{t_g} = \frac{4}{3} \times \frac{5}{4} = \frac{5}{3}$$

19

19



Given angle between Refracted ray and Reflected ray is 90°

Angle of refraction = $30^\circ = r$

r' is Angle of reflection.

From fig $r' + 90^\circ + 30^\circ = 180^\circ \Rightarrow r' = 60^\circ$

we know that Angle of incidence = $r' = 60^\circ$.

(20)

Given $\mu_1 = \mu_2$ if the refractive indices for the two media are same, then no refraction (or) bending takes place

$\mu_1 > \mu_2 \Rightarrow$ If light travels from 1st medium [denser] to 2nd medium [rarer] it bends away from normal.

$\mu_1 < \mu_2 \Rightarrow$ If light travels from 1st medium [rarer] to 2nd medium [denser], it bends towards normal.

Task

jee main level

(1) we know that optical path $\Delta x = c \times t$
 $\Rightarrow \mu d = c \times t$

where 'd' \rightarrow distance travelled (or) thickness of medium
't' \rightarrow time taken = 10^{-9} sec.

Refractive index $\mu = 1.5$.

$$\therefore \Rightarrow 1.5 \times d = 3 \times 10^8 \times 10^{-9}$$

$$\Rightarrow d = \frac{3}{1.5} \times 10^{-1} \Rightarrow \frac{30}{15} \times 10^{-1} = 2 \times 10^{-1}$$

$$\Rightarrow d = 0.2 \text{ m}$$

②

Time taken by the light in air $t_a = 9 \times 10^{-6}$ sec.

Refractive index of air $\mu_a = 1$.

Refractive index of water $\mu_w = \frac{4}{3}$.

Given that
distance travelled by light in air = distance
travelled by light in water

$$\therefore \mu_w t_a = \mu_a t_w$$

$$\Rightarrow \frac{4}{3} \times 9 \times 10^{-6} = 1 \times t_w$$

$$\Rightarrow 12 \times 10^{-6} = t_w \Rightarrow t_w = 12 \mu\text{sec.}$$

③

Refractive index of slab = $\mu_g = \frac{3}{2}$.

Thickness of glass = $d_g = 90$ cm ; time taken in glass = $t_1 = t_g$

Refractive index of water = $\mu_w = \frac{4}{3}$; time taken in water = $t_2 = t_w$

Given

we know that path length = $c \times t = \mu d$

$$\Rightarrow t = \frac{\mu d}{c} \Rightarrow t_g = \mu_g \frac{d}{c}$$

$$\text{and } t_w = \mu_w \frac{d}{c}$$

$$\therefore t_g - t_w = (\mu_g - \mu_w) \frac{d}{c}$$

$$= \left(\frac{3}{2} - \frac{4}{3} \right) \times \frac{90 \times 30}{3 \times 10^{10}}$$

$$\Rightarrow \frac{9-8}{6} \times 30 \times 10^{-10}$$

$$\Rightarrow \frac{1}{6} \times 30 \times 10^{-10} = 5 \times 10^{-10} \text{ sec.}$$

5

The refractive index of glass $\mu_g = 1.5 = \frac{3}{2}$

$$\lambda_a = 6000 \text{ \AA}$$

Velocity of light in air ~~is~~ $c = 3 \times 10^8 \text{ m/s}$

we know that $\mu \propto \frac{1}{\lambda}$

$$\Rightarrow \frac{\lambda_g}{\lambda_a} = \frac{\mu_a}{\mu_g}$$

$$\begin{aligned} \Rightarrow \lambda_g &= \lambda_a \times \frac{\mu_a}{\mu_g} = 6000 \times \frac{1}{\frac{3}{2}} \\ &= 6000 \times \frac{2}{3} \\ &= 4000 \text{ \AA} \end{aligned}$$

6

Distance travelled by the light in a medium

is called path length $\Delta x = \mu d = c t$

\therefore time taken by the light $t = \frac{\mu d}{c}$

Here $d = x$ $\therefore t = \frac{\mu x}{c}$

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Refractive index of glass $\mu_g = \frac{3}{2}$

Refractive index of water $\mu_w = \frac{4}{3}$

\therefore Refractive index of glass with respect to water

$$\begin{aligned} \mu_{g/w} &= \frac{\mu_g}{\mu_w} = \frac{\frac{3}{2}}{\frac{4}{3}} = \frac{3}{2} \times \frac{3}{4} = \frac{9}{8} \\ \mu_{g/w} &= \frac{\mu_g}{\mu_w} = \frac{3}{\frac{4}{3}} = \frac{9}{8} \end{aligned}$$

8

Speed of light in glass $v_g = 2 \times 10^8 \text{ m/s}$

Speed of light in liquid $v_L = 2.5 \times 10^8 \text{ m/s}$

Refractive index of glass $\mu_g = 1.5 = \frac{3}{2}$

We know that $\mu \propto \frac{1}{v}$

$$\Rightarrow \frac{\mu_L}{\mu_g} = \frac{v_g}{v_L}$$

$$\Rightarrow \mu_L = \mu_g \times \frac{v_g}{v_L}$$
$$= \frac{3}{2} \times \frac{2 \times 10^8}{2.5 \times 10^8}$$

$$\mu_L = \frac{3}{2.5} = \frac{30}{25} = \frac{6}{5} = 1.2$$

9

Given wavelength of light in air $\lambda_a = 7200 \text{ \AA}$

Refractive index of air $\mu_a = 1$

Refractive index of glass $\mu_g = 1.5 = \frac{3}{2}$

We know that $\lambda \propto \frac{1}{\mu}$

$$\Rightarrow \frac{\lambda_g}{\lambda_a} = \frac{\mu_a}{\mu_g}$$

$$\Rightarrow \lambda_g = \lambda_a \times \frac{\mu_a}{\mu_g}$$
$$= 7200 \times \frac{1}{\frac{3}{2}} = 7200 \times \frac{2}{3}$$

$$= 2400 \times 2$$

$$\lambda_g = 4800 \text{ \AA}$$

10

Given thickness of window = 4 mm
= 4×10^{-3} m.

Refractive index of glass $\mu_g = 1.5 = \frac{3}{2}$

∴ distance travelled by the light = $\mu d = ct$

$$\Rightarrow t = \frac{\mu d}{c}$$

$$\Rightarrow t = \frac{1.5 \times 4 \times 10^{-3}}{3 \times 10^8} = \frac{6 \times 10^{-3}}{3} = 2 \times 10^{-11} \text{ s}$$

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Thickness of glass slab $d_g = 4 \text{ cm}$

Thickness of water $d_w = 5 \text{ cm}$

Refractive index of water $\mu_w = \frac{4}{3}$

Given that no. of waves in a glass slab = no. of waves in water

$$\Rightarrow \mu_g d_g = \mu_w d_w$$

$$\Rightarrow \mu_g \times 4 = \frac{4}{3} \times 5$$

$$\Rightarrow \mu_g = \frac{5}{3}$$

(12)

Thickness of glass slab $d_g = 8 \text{ cm}$

Thickness of water $d_w = 10 \text{ cm}$

Refractive index of water $\mu_w = \frac{4}{3}$

Given no. of waves in glass = no. of waves in water

$$\Rightarrow \mu_g d_g = \mu_w d_w$$

$$\Rightarrow \mu_g \times 8 = \frac{4}{3} \times 10$$

$$\Rightarrow \mu_g = \frac{5}{3}$$

(13)

Thickness of glass slab $t = 4 \text{ cm}$

Refractive index of glass $\mu_g = \sqrt{3}$

Angle of incidence $i = 60^\circ$

From Snell's law $\mu_g = \frac{\sin i}{\sin r}$

$$\Rightarrow \sqrt{3} = \frac{\sin 60^\circ}{\sin r}$$

$$\Rightarrow \sin r \sqrt{3} = \frac{\sqrt{3}}{2} \Rightarrow \sin r = \frac{1}{2} \\ \Rightarrow r = 30^\circ$$

$$\text{Lateral displacement} = \frac{t}{\cos r} \sin(i-r)$$

$$\Rightarrow \frac{4}{\cos 30^\circ} \sin 30^\circ = \frac{4}{\frac{\sqrt{3}}{2}} \times \frac{1}{2}$$

$$\Rightarrow \frac{4}{\sqrt{3}} \text{ cm.}$$

(10)

(17)

Velocity of light in water $>$ velocity of light in glass

Because Refractive index of water $\mu_w = \frac{4}{3} = 1.33$

Refractive index of glass $\mu_g = \frac{3}{2} = 1.5$

clearly $\mu_w < \mu_g$ and we know that $v \propto \frac{1}{\mu}$

due to this speed changes

(18)

Given Refractive index of glass with respect to water

$$\mu_{g/w} = \frac{9}{8} \rightarrow (1)$$

wavelength of light in glass is $\lambda_g = 4000 \text{ \AA}$

From (1)

$$\frac{\mu_g}{\mu_w} = \frac{9}{8}$$

we know that $\mu \propto \frac{1}{\lambda}$

$$\Rightarrow \frac{\lambda_w}{\lambda_g} = \frac{9}{8}$$

$$\frac{\mu_g}{\mu_w} = \frac{\lambda_w}{\lambda_g}$$

$$\Rightarrow \lambda_w = \frac{9}{8} \times \lambda_g = \frac{9}{8} \times 4000$$

$$\Rightarrow \lambda_w = 4500 \text{ \AA}$$

(19)

Given optical path length of light in glass and liquid are same. i.e)

$$\Delta x = \mu d = \text{constant}$$

$$\Rightarrow \mu_g d_g = \mu_L d_L$$

$$\Rightarrow (1.5) \times 4 = \mu_L \times 4 \times 3$$

$$\Rightarrow \mu_L = \frac{4}{3}$$

(20)

Given Refractive index of denser medium with respect to rarer medium $\mu_r \mu_d = \frac{\mu_d}{\mu_r} = 1.125 \rightarrow (1)$

$$v_r - v_d = 0.25 \times 10^8 \text{ m/s} \rightarrow (2)$$

we know that $\mu \propto \frac{1}{v} \Rightarrow \frac{\mu_d}{\mu_r} = \frac{v_r}{v_d}$

$$\Rightarrow 1.125 = \frac{v_r}{v_d} \Rightarrow v_r = 1.125 v_d$$

sub v_r value in (2) we get

$$\Rightarrow 1.125 v_d - v_d = 0.25 \times 10^8$$

$$\Rightarrow 0.125 v_d = 0.25 \times 10^8$$

$$\Rightarrow v_d = \frac{0.25 \times 10^8}{0.125} = 2 \times 10^8 \text{ m/s}$$

$$\begin{aligned} \therefore \text{Velocity in rarer medium } v_r &= 1.125 \times v_d \\ &= 1.125 \times 2 \times 10^8 \\ v_r &= 2.25 \times 10^8 \text{ m/s} \end{aligned}$$

2.25×10^8

or μ

$$\frac{\mu_r}{\mu_a} = \frac{V_{ar}}{V_r} = \frac{3 \times 10^8}{2.25 \times 10^8} = \frac{3}{2.25} = 1.333$$

or (iii)