10. WAVE THEORY OF LIGHT

1. The refractive indices of water for red and violet colours are 1.325 and 1.334 respectively. Find the difference between velocities of the two colours in water. ($c = 3 \times 10^8$ m/s)

Given :

$\mu_r = 1.325$

$\mu_v = 1.334$

To Find :

$v_r - v_v$

Formula :

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

Solution :

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

$$v_r = \frac{c}{\mu_r}$$

$$= \frac{3\times10^8}{1.325}$$

$\therefore \quad v_r = 2.264 \times 10^8$ m/s

Similarly

$$v_v = \frac{c}{\mu_v}$$

$$= \frac{3\times10^8}{1.334}$$

$\therefore \quad v_v = 2.249 \times 10^8$ m/s

Now,

$v_r - v_v = 2.264 \times 10^8 - 2.249 \times 10^8$

$= 0.015 \times 10^8$ m/s

$\therefore \quad v_r - v_v = 1.5 \times 10^6$ m/s

2. Red light of wavelength 6400 $\overset{o}{A}$ in air has wavelength 4000 $\overset{o}{A}$ in glass. If the wavelength of violet light in air is 4400 $\overset{o}{A}$, find its wavelength in glass.

Given :

$(\lambda_r)_{air} = 6400\ \overset{o}{A}$

$(\lambda_r)_{glass} = 4000\ \overset{o}{A}$

$(\lambda_v)_{air} = 4400\ \overset{o}{A}$

To Find :

$(\lambda_v)_{glass} = ?$

Formula :

$$\frac{(\lambda_r)_{air}}{(\lambda_r)_{glass}} = \frac{(\lambda_v)_{air}}{(\lambda_v)_{glass}}$$

Solution :

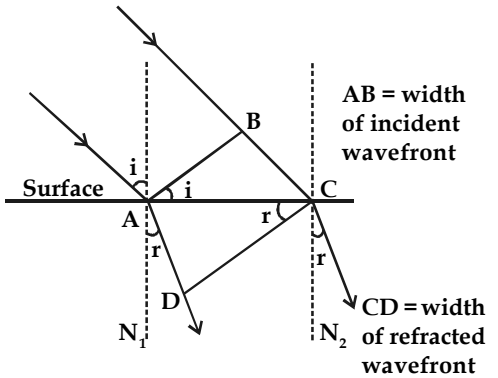
$$\frac{(\lambda_r)_{air}}{(\lambda_r)_{glass}} = \frac{(\lambda_v)_{air}}{(\lambda_v)_{glass}}$$

$$(\lambda_v)_{glass} = (\lambda_v)_{air} \times \frac{(\lambda_r)_{glass}}{(\lambda_r)_{air}}$$

$$= \frac{4400\times4000}{6400}$$

$\therefore \quad (\lambda_v)_{glass} = 2750\ \overset{o}{A}$

3. The width of a plane incident wavefront is found to be doubled in a denser medium. If it makes an angle of 70^0 with surface, calculate the refractive index for the denser medium.



Given :

$i = 70^0$

$CD = 2AB$

To Find :

$\mu = ?$

Formula :

i) $\frac{\cos i}{\cos r} = \frac{AB}{CD}$

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

Solution :

$$\frac{\cos i}{\cos r} = \frac{AB}{CD}$$

$$\frac{\cos 70^0}{\cos r} = \frac{AB}{2AB} \quad [\because CD = 2AB]$$

$$\frac{0.3420}{\cos r} = \frac{1}{2}$$

$$\cos r = 0.684$$

$$\therefore r = 46^0 48'$$

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

$$\mu = \frac{\sin 70^0}{\sin\left(46^0 48'\right)}$$

$$= \frac{0.9397}{0.7290}$$

$$\therefore \mu = 1.279$$

4. If the difference in velocities of light in glass and water is 0.25×10^8 m/s, find the velocity of light in air [Given : $\mu_g = 1.5$, $\mu_w = 4/3$]

Given :

$\mu_g = 1.5$ and

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

$v_w - v_g = 0.25 \times 10^8$ m/s

To Find :

$c = ?$

Formula :

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

Solution :

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

$\mu_g = \frac{c}{v_g}$ and $\mu_w = \frac{c}{v_w}$

$\therefore v_g = \frac{c}{\mu_g}$ and $v_w = \frac{c}{\mu_w}$

$\therefore v_w - v_g = \frac{c}{\mu_w} - \frac{c}{\mu_g}$

$= c\left[\frac{1}{\mu_w} - \frac{1}{\mu_g}\right]$

$\therefore 0.25 \times 10^8 = c\left[\frac{1}{\frac{4}{3}} - \frac{1}{1.5}\right]$

$= c\left[\frac{3}{4} - \frac{10}{15}\right]$

$= c\left[\frac{3}{4} - \frac{2}{3}\right]$

$= c\left[\frac{9-8}{12}\right]$

$\therefore 0.25 \times 10^8 = c\left[\frac{1}{12}\right]$

$\therefore c = 12 \times 0.25 \times 10^8$

$= 3.00 \times 10^8$ m/s

$\therefore c = 3 \times 10^8$ m/s

5. A ray of light travelling through air, falls on the surface of glass slab at an angle i. It is found that the angle betweeen the reflected and refracted ray is 90^0. If the speed of light in glass is 2×10^8 m/s, find the angle of incidence.
[c = 3×10^8 m/s]

Given :

$c_a = 3 \times 10^8$ m/s

$c_g = 2 \times 10^8$ m/s

The angle between reflected and refracted ray i.e. $\angle BOD = 90^0$

To Find :

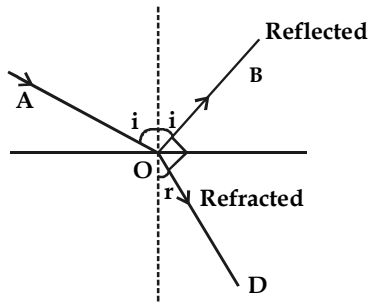
i = ?

Formula :

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

Solution :

From formula



From the figure, $i + r + 90^0 = 180^0$

$\therefore \quad i + r = 90^0$

$\therefore \quad r = 90^0 - i$

Now $\mu = \frac{c_a}{c_g}$

$= \frac{3 \times 10^8}{2 \times 10^8}$

$\therefore \quad \mu = 1.5$

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

$= \frac{\sin i}{\sin\left(90^0 - i\right)}$

$\therefore \quad \mu = \frac{\sin i}{\cos i} = \tan i$

$\therefore \quad \tan i = 1.5$

$\therefore \quad i = \tan^{-1}(1.5)$

$\therefore \quad i = 56^0 19'$

6. If the critical angle of a medium is $\sin^{-1}\left(\frac{3}{5}\right)$, find the polarising angle.

Given :

$i_c = \sin^{-1}\left(\frac{3}{5}\right)$

To Find :

i_p = ?

Formula :

$\mu = \tan i_p$

Solution :

$\sin i_c = \frac{3}{5}$ (from given data)

But,

$$\mu = \frac{1}{\sin i_c}$$

$$= \frac{1}{\frac{3}{5}} = \frac{5}{3}$$

Now,

$\therefore \quad \mu = 1.667$

$\mu = \tan i_p$

$\therefore \quad i_p = \tan^{-1}(\mu)$

$\therefore \quad i_p = \tan^{-1}(1.667)$

$\therefore \quad i_p = 59^0 2'$