SOLVED NCERT QUESTIONS

1. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light? Refractive index of water is 1.33.

Sol. (a) For reflected light, wavelength, frequency and speed remain same as incident light.

$\lambda = 589$ nm, $c = 3 \times 10^8$ ms^{-1}.

$$\nu = \frac{c}{\lambda} = \frac{3\times10^8}{589\times10^{-9}} = 5.09 \times 10^{14}\text{ Hz.}$$

(b) **For refracted light:** The frequency of the refracted light is the same as the incident frequency. The speed changes due to change in wavelength.

$\because \quad n = 1.33$

$$\therefore \nu = \frac{c}{\lambda} = \frac{3\times10^8}{1.33} = 2.26 \times 10^8\text{ ms}^{-1}.$$

$$\text{Wavelength, } \lambda = \frac{v}{\nu} = \frac{2.26\times10^8}{5.09\times1014} = 0.444 \times 10^{-6} = 444 \times 10^{-9}\text{ m}$$

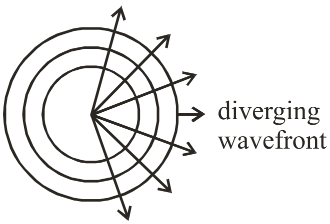
2. What is the shape of the wavefront in each of the following cases:

(a) Light diverging from a point source.

(b) Light emerging out of a convex lens when a point source is placed at its focus.

(c) The portion of the wavefront of light from a distant star intercepted by the Earth.

Sol. (a) Spherical.



(b) Plane.

When a point source is placed at the focus of a convex lens, the emergent rays are parallel, hence the wavefront is plane.

(c) Plane.

As the star is very far away, therefore the wavefront reaching us is a very large sphere and a small area on the surface of a large sphere is nearly plane.

3. (a) The refractive index of glass is 1.5. What is the speed of light in glass?

(Speed of light in vacuum is 3.0×10^8 ms^{-1})

(b) Is the speed of light in glass independent of the colour of light? If not, which of the two colours red and violet travels slower in a glass prism?

Sol. (a) $n = 1.5$, $c = 3 \times 10^8$ ms^{-1}.

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ ms}^{-1}$$

(b) Speed of light in glass is not independent of the colour of light, because each colour of light has a chacteristic wavelength and speed of light as well as refractive index depends on wavelength.

The refractive index of violet colour is greater than the red colour; hence, the violet colour travels slower in a glass prism.

4. In a Young's double-slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

Sol. $d = 0.28$ mm $= 0.28 \times 10^{-3}$ m

$D = 1.4$ m, $x = 1.2$ cm $= 1.2 \times 10^{-2}$ m,

$n = 4$,

As, $$x = \frac{n\lambda D}{d}$$

$$\therefore \quad \lambda = \frac{1.2 \times 10^{-2} \times 0.28 \times 10^{-3}}{4 \times 1.4} = 6 \times 10^{-7} \text{ m} = 600 \times 10^{-9} \text{ m} = 600 \text{ nm}$$

5. In Young's double-slit experiment, monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. What is the intensity of light at a point where path difference is $\frac{\lambda}{3}$

Sol. As the resultant intensity at a point,

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

When the path difference $= \lambda$, phase difference $= 0°$

$\therefore \quad I_R = I + I + 2\sqrt{I \times I}\cos 0° = 2I + 2\sqrt{I^2} \times 1 = 2I + 2I = 4I = K.$

When the path difference $= \frac{\lambda}{3}$, phase difference $\phi = \frac{2\pi}{3}$

$\therefore \quad I'_R = I + I + 2\sqrt{I.I}.\cos\left(\frac{2\pi}{3}\right) = 2I + 2\sqrt{I^2} \times \left(-\frac{1}{2}\right) = 2I - \frac{2I}{2} = I$

$\therefore \quad I' = \frac{K}{4}$

6. In a double-slit experiment the angular width of a fringe is found to be 0.2° on a screen placed 1 m away. The wavelength of light used is 600 nm. What will be the angular width of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water to be 4/3.

Sol. Angular width, $\beta_1 = 0.2°$, $\lambda_1 = 600 \times 10^{-9}$ m, $n = \frac{4}{3}$, $\lambda_2 = ?$

As, $\beta_1 = \frac{\lambda_1}{d}$; $\beta_2 = \frac{\lambda_2}{d}$

$\because \quad n = \frac{c}{v} \Rightarrow n = \frac{v\lambda_1}{v\lambda_2} \Rightarrow n = \frac{\lambda_1}{\lambda_2}$

$\therefore \quad \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1} = \frac{1}{n} = \frac{3}{4}$

$\therefore \quad \beta_2 = \frac{3}{4} \times \beta_1 = \frac{3 \times 0.2°}{4} = 0.15°$

7. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5)

Sol. $\mu = 1.5$,

As $\tan i_p = \mu \Rightarrow \tan i_p = 1.5$

$\therefore \quad i_p = 56.3°$

8. Light of wavelength 5000 Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

Ans. Wavelength of incident light = 5000 Å.

There is no change in the wave length and the frequency of reflected light.

$\therefore \quad \lambda = 5000$ Å, frequency, $\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{5000 \times 10^{-10}} = 6 \times 10^{14}$ Hz.

When the reflected ray is normal to the incident ray,

$\angle i + \angle r = 90°$

$\because \angle i = \angle r$

$\therefore \angle i + \angle i = 90°$

$\Rightarrow 2i = 90°$

$\therefore i = 45°$

9. Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm.

Sol. $\alpha = 4 \text{ mm} = 4 \times 10^{-3} \text{ m}$, $\lambda = 400 \text{ nm} = 4 \times 10^{-9} \text{ m}$

As the Fresnel distance,

$$Z_F = \frac{a^2}{\lambda} = \frac{(4\times10^{-3})^2}{400\times10^{-9}}$$

$$= \frac{(4\times4\times10^{-6}\times10^{7})}{4} = 40 \text{ m}$$