Question 1:

Monochromatic light having a wavelength of 589nm from the air is incident on a water surface. Find the frequency, wavelength and speed of (i) reflected and (ii) refracted light? [1.33 is the Refractive index of water]

Answer:

Monochromatic light incident having wavelength, λ = 589 nm = 589 x 10^{-9} m

Speed of light in air, **c = 3 x 10^{8} m s^{-1}**

Refractive index of water, μ = **1.33**

(i) In the same medium through which incident ray passed the ray will be reflected back.

Therefore the wavelength, speed, and frequency of the reflected ray will be the same as that of the incident ray.

Frequency of light can be found from the relation:

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

Hence, **c = 3 x 10^{8} m s^{-1}, 5.09 × 10^{14} Hz, and 589 nm** are the speed, frequency, and wavelength of the reflected light.

(b) The frequency of light which is travelling never depends upon the property of the medium. Therefore, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

Refracted frequency, **v = 5.09 x 10^{14} Hz**

Following is the relation between the speed of light in water and the refractive index of the water:

$$v = \frac{c}{\lambda} = v = \frac{3\times10^{8}}{1.33} = 2.26 \times 10^{8} \text{ m s}^{-1}$$

Below is the relation for finding the wavelength of light in water:

$$\lambda = \frac{v}{V} = \frac{2.26\times10^{8}}{5.09\times10^{14}} = 444.007 \times 10^{-9} \text{ m} = 444.01 \text{nm}$$

Therefore, 444.007 × 10^{-9} m, 444.01nm, and 5.09 × 10^{14} Hz are the speed, frequency, and the wavelength of the refracted light.

Question 2:

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

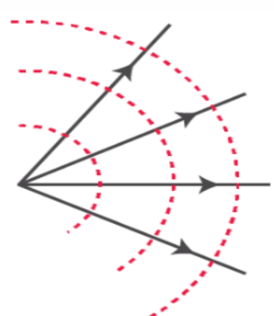
(i) Light diverging from a point source.

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

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

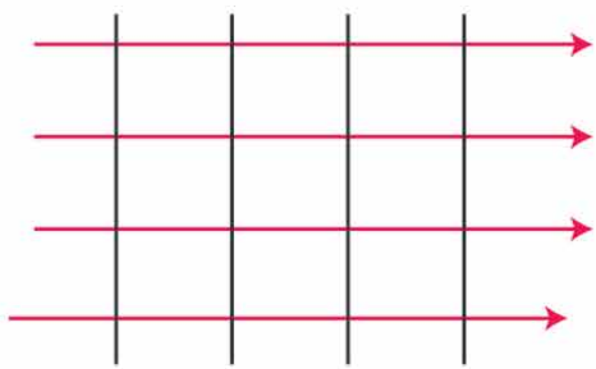
Answer:

(i) When the light diverges from a point source, the shape of the wavefront is spherical. Following is the figure of the wavefront:



Point source

(ii) When the light is emerging from the convex lens, the shape of the wavefront is parallel odd. In this case, the point source is placed at its focus.



Wavefront

(iii) When the light is coming from a distant star that is intercepted by the earth, the shape of the wavefront is plane.

Question 3:

(i) The refractive index of glass is 1.5. What is the speed of light in glass? Speed of light in a vacuum is (3.0×10^8 m s^{-1})

(ii) 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?

Answer:

(i) Refractive Index of glass, μ = **1.5**

Speed of light, c = 3×10^8 ms^{-1}

The relation for the speed of light in a glass is: $v = \frac{c}{\mu}$

= $\frac{3\times10^8}{1.5}$ = $2 \times 10^8 m/s$

Hence, the speed of light in glass is 2×10^8 m s^{-1}

(ii) The speed of light is dependent on the colour of the light. For a white light, the refractive index of the violet component is greater than the refractive index of red component. So, the speed of violet light is less than the speed of the red light in the glass. This will reduce the speed of violet light in glass prism when compared with red light.

Question 4:

In Young's double-slit experiment, 0.28mm separation between the slits and the screen is placed 1.4m away. 1.2cm is the distance between the central bright fringe and the fourth bright fringe. Determine the wavelength of light used in the experiment.

Answer:

Distance between the slits and the screen, **D = 1.4 m**

and the distance between the slits, d = 0.28 mm = 0.28×10^{-3} m

Distance between the central fringe and the fourth (n = 4) fringe,

u = 1.2cm **= 1.2×10^{-2} m**

For a constructive interference, following is the relation for distance between the two fringes:

$u = n \lambda \frac{D}{d}$

Where, **n = order of fringes**

= 4 λ = **Wavelength of light used**

$u = n \lambda \frac{D}{d}$

$\frac{1.2 \times 10^{-2} \times 0.28 \times 10^{-3}}{4 \times 1.4}$

= 60 × 10^{-7} = 600nm

600nm is the wavelength of the light.

Question 5:

In Young's double-slit experiment using the 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 $\frac{\lambda}{3}$?

Answer:

Let I_1 and I_2 be the intensity of the two light waves. Their resultant intensities can be obtained as:

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

Where,

ϕ = Phase difference between the two waves

For monochromatic light waves:

I_1 = I_2

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

= $2I_1 + 2I_1\, cos\phi$

Phase difference = $\frac{2\pi}{\lambda} \times$ $Path\ difference$

Since path difference = λ, Phase difference, $\phi = 2\pi$ and I' = K [Given]

Therefore $I_1 = \frac{K}{4}$ . . . . (i)

When path difference= $\frac{\lambda}{3}$

Phase difference, $\phi = \frac{2\pi}{3}$

Hence, resultant intensity:

$I'_g = I_1 + I_1 + 2\sqrt{I_1 I_1} \cos\frac{2\pi}{3}$

=

$2I_1 + 2I_1(-\frac{1}{2})$

Using equation (i), we can write:

$I_g = I_1 = \frac{K}{4}$

Hence, the intensity of light at a point where the path difference is $\frac{\lambda}{3}$ is $\frac{K}{4}$ units.

Question 6: A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtain interference fringes in a Young's double-slit experiment.

(a) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.

(b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

Answer:

Wavelength of the light beam, λ_1 = **650 nm**

Wavelength of another light beam, λ_2 = **520 nm**

Distance of the slits from the screen = D

Distance between the two slits = d

(i) Distance of the n^{th} bright fringe on the screen from the central maximum is given by the relation,

x = $n\ \lambda_1\ (\frac{D}{d})$

For third bright fringe, **n=3**

Therefore x = $3 \times 650\frac{D}{d} = 1950\frac{D}{d} nm$

(b) Let, the n^{th} bright fringe due to wavelength λ_2 and $(n-1)^{th}$ bright fringe due to wavelength λ_2 coincide on the screen. The value of n can be obtained by equating the conditions for bright fringes:

$n\lambda_2 = (n - 1)\lambda_1$

520n = 650n − 650

650=130n

Therefore n = 5

Hence, the least distance from the central maximum can be obtained by the relation:

x = $n\ \lambda_2\ \frac{D}{d}$ = 5 $\times\ 520\frac{D}{d} = 2600\frac{D}{d}$ nm

Note: The value of d and D are not given in the question.

Question 7:

In a double-slit experiment, 0.2° is found to be the angular width of a fringe 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 $\frac{4}{3}$.

Answer:

Distance of the screen from the slits, **D=1m**

Wavelength of light used, λ_1 **= 600 nm**

Angular width of the fringe in air θ_1 **= 0.2°**

Angular width of the fringe in water= θ_2

Refractive index of water, $\mu = \frac{4}{3}$ $\mu = \frac{\theta_1}{\theta_2}$ is the relation between the refractive index and the angular width

$$\theta_2 = \frac{3}{4}\theta_1 \ \frac{3}{4} \times 0.2 = 0.15$$

Therefore, 0.15° is the reduction in the angular width of the fringe in water.

Question 8: What is the Brewster angle for air to glass transition? (Refractive index of glass=1.5.)

Answer:

Refractive index of glass, $\mu = 1.5$

Consider Brewster angle = θ

Following is the relation between the Brewster angle and the refractive index:

$tan\theta = \mu \ \theta = tan^{-1}(1.5)$ **= 56.31°**

Therefore, the Brewster angle for air to glass transition is 56.31°

Question 9: Light of wavelength 5000 Armstrong 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?

Answer:

Wavelength of incident light, $[\lambda]$ = 5000 Armstrong = **5000 x 10^{-10} m**

Speed of light, **c =3 x 10^8 m**

Following is the relation for the frequency of incident light:

v = $\frac{c}{\lambda}$ = $\frac{3 \times 10^8}{5000 \times 10^{-10}}$ = 6 × 10^{14}

The wavelength and frequency of incident light is equal to the reflected ray. Therefore, 5000 Armstrong and 6×10^{14} Hz is the wavelength and frequency of the reflected light. When reflected ray is normal to incident ray, the sum of the angle of incidence, $\angle i$ and angle of reflection, $\angle r$ is 90°.

From laws of reflection we know that the angle of incidence is always equal to the angle of reflection

$\angle i + \angle r$ = 90°

i.e. $\angle i + \angle i$ = 90°

Hence, $\angle i = \frac{90}{2}$ = 45°

Therefore, 45° is the angle of incidence.

Question 10:

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

Answer:

Fresnel's distance (Z_F) is the distance which is used in ray optics for a good approximation. Following is the relation,

$$Z_F = \frac{a^2}{\lambda}$$

Where,

Aperture width, a = 4 mm **= 4 × 10^{-3} m**

Wavelength of light, λ = 400 nm **= 400 × 10^{-9} m**

$$Z_F = \frac{(4 \times 10^{-3})^2}{400 \times 10^{-9}}$$ **= 40m**

Therefore, 40m is the distance for which the ray optics is a good approximation.