Wave Optics

Question1

For an aperture of 5×10^{-3} m and a monochromatic light of wavelength λ, the distance for which ray optics becomes a good approximation is 50 m , then $\lambda =$

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Options:

A.

$5000 \stackrel{o}{A}$

B.

$6000 \stackrel{o}{A}$

C.

$5400 \stackrel{o}{A}$

D.

$6500 \stackrel{o}{A}$

Answer: A

Solution:

According to Fresnel distance

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

$$\begin{aligned}\lambda &= \frac{a^2}{Z_F} = \frac{\left(5 \times 10^{-3}\right)^2}{50} \\ &= 0.5 \times 10^{-6} \text{ m} \\ &= 5000 \times 10^{-10} \text{ m} \\ &= 5000 \text{Å}\end{aligned}$$

Question2

In Young's double slit experiment with light of wavelength λ, the intensity of light at a point on the screen where the path difference becomes $\frac{\lambda}{3}$ is (I is intensity of the central bright fringe)

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Options:

A.

I

B.

$\frac{1}{2}$

C.

$\frac{1}{3}$

D.

$\frac{I}{4}$

Answer: D

Solution:

Given, $\Delta x = \frac{\lambda}{3}$

$\theta = \pi \cdot \frac{\Delta x}{\lambda}$

$\theta = \frac{\pi \cdot \lambda}{3 \cdot \lambda} = \frac{\pi}{3}$

So, $I' = I_{\max} \quad \cos^2 \theta$

$I' = I_{\max} \cdot \cos^2\left(\frac{\pi}{3}\right)$

$I' = \frac{I_{\max}}{4} \quad \therefore I_{\max} = I$

$I' = \frac{I}{4}$

Question3

In Young's double slit experiment, intensity of light at a point on the screen, where the path difference becomes λ is I. The intensity at a point on the screen, where the path difference becomes $\frac{\lambda}{3}$ is

TG EAPCET 2024 (Online) 10th May Morning Shift

Options:

A. $\frac{1}{4}$

B. $\frac{1}{3}$

C. $\frac{21}{3}$

D. 31

Answer: A

Solution:

We know that the resultant intensity in Young's double slit experiment is given as

$I_{\text{res}} = I_1 + I_2 - 2\sqrt{I_1 I_2} \cos \phi$

where $\phi =$ phase difference,

$I_1 = I_2 = I_0$

$\phi = \frac{2\pi}{\lambda} \Delta x$

For path difference is, $\Delta x = \lambda$

$$\phi_1 = \frac{2\pi}{\lambda} \times \lambda = 2\pi$$

$$I_{\text{res}} = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos(2\pi)$$

$$I_{\text{res}} = I = 4I_0$$

$$I_0 = \frac{I}{4}$$

For path difference, $\Delta x = \frac{\lambda}{3}$

$$\phi_2 = \frac{2\pi}{3}$$

$$\cos\frac{2\pi}{3} = \frac{-1}{2}$$

$$I' = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos\left(\frac{2\pi}{3}\right)$$

$$I' = 2I_0 - I_0$$

where ρ is resistivity

(iii) $\vdots$ Subsitute the value of I_0)

$I' = \frac{I}{4}$

Question4

The diameter of the objective of a telescope is 3.6 m . The limit of resolution of the telescope for a light of wavelength 540 nm is

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Options:

A. 1.22×10^{-7}rad

B. 1.83×10^{-7}rad

C. 0.61×10^{-7}rad

D. 3.76×10^{-7}rad

Answer: B

Solution:

Given, $d = 36$ m

$\lambda = 540$ nm

From Rayleigh criterion, $\theta = 1.22 \frac{\lambda}{D}$

$$= \frac{1.22 \times 540 \times 10^{-9}}{3.6}$$

$= 183 \times 10^{-9} \text{rad}$

$= 1.83 \times 10^{-7} \text{rad}$

Question5

Young's double slit experiment is performed with monochromatic light of wavelength $6000 \AA$. If the intensity of light at a point on the screen, where path difference of $2000 \AA$ is I_1 and the intensity of light at a I point on the screen, where the path difference is $1000 \AA$ is I_2, then $I_1 : I_2 =$

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Options:

A. 1 : 3

B. 2 : 1

C. 1 : 1

D. 4 : 5

Answer: A

Solution:

In YDSE, the intensity of light at a point on the screen is

$I = I_0 \cos^2 \left(\frac{\pi \Delta x}{\lambda}\right)$

Given, $\lambda = 6000 \times 10^{-10}$ m

Path difference,

$\Delta x_1 = 2000 \times 10^{-10}$ m

Path difference,

$\Delta x_2 = 1000 \times 10^{-10}$ m

For I_1,

$$I_1 = I_0 \cos^2\left(\frac{\pi \times 2000 \times 10^{-10}}{6000 \times 10^{-10}}\right)$$

$$I_1 = I_0 \cos^2\left(\frac{\pi}{3}\right)$$

$$I_1 = \frac{I_0}{4}$$

For I_2,

$$I_2 = I_0 \cos^2\left(\frac{\pi \times 1000 \times 10^{-10}}{6000 \times 10^{-10}}\right)$$

$$I_2 = I_0 \cos^2\left(\frac{\pi}{6}\right)$$

$$I_2 = \frac{3I_0}{4}$$

Therefore, the ratio $I_1 : I_2$ is

$$I_1 : I_2 = \frac{I_0}{4} : \frac{3I_0}{4}$$

$$I_1 : I_2 = 1 : 3$$

So, the ratio of the intensities is $1 : 3$.

Question6

If the slit width is 2 mm and wavelength of light used is $4000\overset{\circ}{\mathrm{A}}$, then Fresnel distance is nearly

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Options:

A. 2 mm

B. 10 m

C. 20 km

D. 2μ m

Answer: B

Solution:

Given:

Slit width $a=2 \mathrm{~mm}=2 \times 10^{-3} \mathrm{~m}$

Wavelength of light $\lambda=4000 \AA=4000 \times 10^{-10} \mathrm{~m}$

To find the Fresnel distance f_z, use the formula:

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

Substitute the values into the formula:

$f_z=\frac{\left(2 \times 10^{-3} \mathrm{~m}\right)^2}{4000 \times 10^{-10} \mathrm{~m}}$

Calculate:

$f_z=\frac{4 \times 10^{-6} \mathrm{~m}^2}{4 \times 10^{-7} \mathrm{~m}}=10 \mathrm{~m}$

Therefore, the Fresnel distance is approximately 10 meters.

Question7

When Young's double slit experiment is performed in air, the Y-coordinates of central maxima and 10 th maxima are 2 cm and 5 cm , respectively. If the apparatus is immersed in a liquid of refractive index 1.5 , the corresponding Y-coordinates will be

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Options:

A. 2 cm, 7.5 cm

B. 3 cm, 6 cm

C. $2 \text{ cm}, 4 \text{ cm}$

D. $\frac{4}{3}$ cm, $\frac{10}{3}$ cm

Answer: C

Solution:

Given:

Central maxima in air: $Y = 2$ cm

10th maxima in air: $Y = 5$ cm

Refractive index of liquid (μ): $1.5 = \frac{3}{2}$

When the apparatus is immersed in a liquid, the wavelength changes due to the refractive index. The relationship between wavelengths and refractive index is:

$$\mu = \frac{c}{v} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} = \frac{\lambda_{\text{vacuum}}}{\lambda'_{\text{medium}}}$$

From this, the new wavelength in the medium is:

$$\lambda'_{\text{medium}} = \frac{2}{3}\lambda_{\text{vacuum}}$$

Considering path difference along the X-axis:

The path difference for maxima is given by:

$$\Delta x = 0, \lambda, 2\lambda, \ldots, 10\lambda$$

For maxima along the Y-axis, the relationship is:

$$\Delta Y = \frac{\Delta x D}{d} = \frac{n\lambda D}{d} \Rightarrow \Delta Y \propto \lambda$$

Central maxima remains unchanged because it corresponds to $n = 0$:

$$Y' = 2 \text{ cm}$$

For the 10th maxima:

We know:

$$\frac{\Delta Y}{\Delta Y'} = \frac{\lambda}{\lambda'_{\text{medium}}}$$

By substituting the given values:

$$\frac{5-2}{Y'-2} = \frac{3}{2}$$

Solving for Y':

$$3 = \frac{3}{2}(Y' - 2)$$

$$Y' - 2 = 2$$

$$Y' = 4 \text{ cm}$$

Thus, the new coordinates when the apparatus is immersed in the liquid are 2 cm and 4 cm.
