Chapter 9 (Physical Optics) Numerical Problems

Q.1) In a young double slit experiment, the separation of the slits is 1 mm and red light of wavelength 620 nm is falling on it. Determine the distance between the central bright band and the fifth bright fringe on the screen which is 3 m away from the slit.

Answer:

Given Data:

Separation between slits = d = 1 mm = 1×10^{-3} m

Wavelength of red light = λ = 620 nm = 620×10^{-9} m

Distance between screen and slit = L = 3 m

To Find:

Distance between central bright band and fifth bright band = ΔY = $Y_5 - Y_0$ = ?

Solution:

We know that the position of mth bright fringe is given by,

$$Y_m = mL\frac{\lambda}{d} \qquad \text{.................................... (1)}$$

Where, m = 0, 1, 2, 3, ...

Therefore for central bright fringe, we have, m = 0.

So putting values, equation (1) becomes

$$Y_0 = 0 \times 3m \times \frac{620nm}{1mm} = 0 \qquad \text{.............................. (2)}$$

Similarly for fifth fringe we get,

$$Y_5 = 5 \times 3m \times \frac{620\times10^{-9}m}{1\times10^{-3}m} = 9300 \times 10^{-6}m \quad \text{..................................} (3)$$

So from equation (2) and (3), we get

$$\Delta Y = Y_5 - Y_0$$

Putting values, we get

$$\Delta Y = 9300 \times 10^{-6}\text{m} - 0 = 9300 \times 10^{-3}\,\text{mm}$$

Read more: [Class 11 Physics Notes for Sindh, kpk, Punjab and fbise.]

Q.2) Monochromatic light of wavelength 589.2 nm is used to illuminate the narrow slits 1 mm apart. Find the positions of the first dark and first bright fringes on the screen 100 cm away.

Answer :

Given Data:

Wavelength of monochromatic light = λ = 589.2 nm = 589.2×10^{-9} m

Distance between the slits = d = 1mm = 1×10^{-3} m

Distance between the screen and fringes = L = 100 cm = 1 m

To Find:

(a) Position of first bright fringe = Y_{bright} = ?

(b) Position of first dark fringe = Y_{dark} = ?

Solution:

For the position of bright fringe, we have

$$Y_m = mL\frac{\lambda}{d}$$

(a) For first fringe, m = 1, so putting values we get

$$Y_m = 1 \times 1m \times \frac{589.2 \times 10^{-9}m}{1 \times 10^{-3}m} = 589.2 \times 10^{-6}m$$

$$\boxed{Y_m = 5.98 \times 10^{-4}m}$$

(b) For position of dark fringe, we have

$$Y_m = \left(m + \frac{1}{2}\right)\frac{L\lambda}{d}$$

Putting values, we get

$$Y_m = \left(0 + \frac{1}{2}\right)\frac{1m \times 589.2 \times 10^{-9}m}{1 \times 10^{-3}m} = 294 \times 10^{-6}m$$

$$\boxed{Y_m = 2.94 \times 10^{-4}m}$$

Q.3) Two parallel slits are illuminated by the light of two wavelengths, one of which is 5.8 x 10^{-7} m. On the screen, the fourth dark line of the known wavelength coincides with the fifth bright line of the light of unknown wavelength. Find the unknown wavelength.

Answer :

Given Data:

Wavelength of first light = $\lambda_1 = 5.8 \times 10^{-7}$ m

To Find:

Unknown wavelength = $\lambda' = ?$

Solution:

Consider Y_m represents the position of fourth dark fringe where, m = 4 and $Y'_{m'}$ represents the position of fifth bright fringe and m' = 5. Moreover, as given condition is that the fourth dark line of known wavelength coincides with the fifth bright line of unknown wavelength. Therefore,

$$Y_m = Y'_{m'} \qquad \text{..................................} (1)$$

We know that for dark fringes,

$$Y_m = \frac{L}{d}(m + \frac{1}{2})\lambda$$

And for bright fingers,

$$Y'_{m'} = \frac{L}{d} m'\lambda'$$

Putting these values in equation (1), we get

$$\frac{L}{d}\left(m+\frac{1}{2}\right)\lambda = \frac{L}{d}m'\lambda'$$

$\Longrightarrow$ $$(m+\tfrac{1}{2})\lambda = m'\lambda'$$

$\Longrightarrow$ $$\lambda' = (m+\tfrac{1}{2})\frac{\lambda}{m'}$$

Putting values, we get

$$\lambda' = \left(4+\frac{1}{2}\right)\frac{5.8\times10^{-7}m}{5} = 5.2\times10^{-7}m$$

$$\boxed{\lambda' = 5.2\times10^{-7}\ \text{m}}$$

Q.4) When the movable mirror of a Michelson interferometer is moved 0.1 mm. How many dark fringes pass through the reference point, if light of wavelength 580 nm is used?

Answer:

Given Data:

Distance = d = 0.1mm = 0.1×10^{-3} m

Wavelength of light = λ = 580 nm = 580×10^{-9} m

To Find:

Number of dark fringes = m = ?

Solution:

For Michelson interferometer, we know that

$$\lambda = \frac{2d}{m}$$

$\Longrightarrow$ $$m = \frac{2d}{\lambda}$$

Putting values, we get

$$m = \frac{2 \times 0.1 \times 10^{-3} m}{580 \times 10^{-9} m} = 3.45 \times 10^{2}$$

i.e.

$$\boxed{m = 345 \text{ Fringes}}$$

Q.5) When the movable mirror on a Michelson interferometer is moved in one direction, 400 fringes appear to pass through the field of view when light of wavelength of 500 nm is used. What is the distance through which the mirror has been moved.

Answer :

Given Data:

Number of fringes = m = 400

Wavelength of light = λ = 500 nm = 500 × 10^{-9} m

To Find:

Distance = d = ?

Solution:

For Michelson interferometer, we know that

$$\lambda = \frac{2d}{m}$$

$$\Longrightarrow \qquad d = \frac{m\lambda}{2}$$

Putting values, we get

$$d = \frac{400 \times 500 \times 10^{-9} m}{2} = 10{,}0000 \times 10^{-9} m$$

Or,

$$d = 0.1\ mm$$

Q.6) A soap film has a refractive index of 1.40. How thick must the film be, if it appears black, when mercury light of wavelength 546.1 nm falls on it normally?

Answer :

Given Data:

Refractive index of soap film = n = 1.40

Wavelength of mercury light = λ = 546.1 nm = 546.1×10^{-9}m

To Find:

Thickness of film = x = ?

Solution:

If the soap film has some thickness then there will be a path difference of 2x. i.e.

$$P.D = 2x \qquad \text{..........................} (1)$$

However, for simple soap film, path difference is given by

$$P.D = \frac{1}{n} m\lambda \qquad \text{......................} (2)$$

Comparing equation (1) and (2), we get

$$2x = \frac{1}{n} m\lambda$$

$$\Longrightarrow \qquad x = \frac{m\lambda}{2n}$$

Putting values by taking, m = 1, we get

$$x = \frac{1 \times 546.1 \times 10^{-9} m}{2 \times 1.40} = 195.0 \times 10^{-9} m$$

Or,

$\boxed{x = 1.95 \times 10^{-7}\ m}$

Q.7) Find the polarizing angle for a glass of refractive index of 1.55.

Answer :

Given Data:

Refractive index of air = n_1 = 1

Refractive index for glass = n_2 = 1.55

To Find:

Polarizing angle = i_P = ?

Solution:

Brewster's law gives us that,

$$tan(i_p) = \frac{n_2}{n_1}$$

$$\Rightarrow \qquad i_p = tan^{-1}\left(\frac{n_2}{n_1}\right)$$

Putting values, we get

$$i_p = tan^{-1}\left(\frac{1.55}{1}\right) = tan^{-1}(1.55)$$

i.e.

$\boxed{i_p = 57^o}$

Q.8) A diffraction grating has 5000 lines per centimeter. At what angle does the second-order spectrum of the sodium yellow light of wavelength 589 nm occur?

Solution:

Given Data:

Number of lines = N = 5000 cm^{-1} = 500000 m^{-1}

Wavelength of light = λ = 589 nm = 589×10^{-9}m

Order of spectrum = m = 2

To Find:

Angle = θ = ?

Solution:

We know that,

$$d \sin\theta = m\lambda$$

Where, d = 1/N

$$\Rightarrow \quad \frac{1}{N} \sin\theta = m\lambda$$

$$\Rightarrow \quad \sin\theta = mN\lambda$$

$$\Rightarrow \quad \theta = \sin^{-1}(mN\lambda)$$

Putting values, we get

$$\Theta = \sin^{-1}(2 \times 500000 m^{-1} \times 589 \times 10^{-9} m) = \sin^{-1}$$

(0.589)

i.e.

$$\boxed{\Theta = 36^{\circ}}$$

Q.9) Light is incident normally on a grating which has 250 lines / mm. Find the wavelength of spectral line for which the deviation in second order is 12°?

Answer :

Given Data:

Number of lines = N = 250 $(mm)^{-1}$ = 250,000 m^{-1}

Order = m = 2

Deviation = ϴ = 12^o

To Find:

Wavelength of the line = λ = ?

Solution:

We know that,

d sinϴ = m λ

Where, d = 1/N

$$\Longrightarrow \quad \frac{1}{N} sin\theta = m\lambda$$

$$\Longrightarrow \quad \lambda = \frac{Sin\theta}{Nm}$$

Putting values, we get

$$\lambda = \frac{sin12^o}{250{,}000m^{-1} \times 2} = \frac{0.2079}{500000}$$

i.e.

$$\boxed{\lambda = 415.8 \text{ nm}}$$

Q.10) In a certain X-rays diffraction experiment the first order image is observed at an angle of 5° for a crystal plane spacing of 2.8 x 10^{-10} m. What is the wavelength of X-rays used?

Answer :

Given Data:

Order of image = m = 1

Angle = ɵ = 5°

Spacing of plane = d = 2.8 × 10^{-10}m

To Find:

Wavelength = λ = ?

Solution:

According to Bragg's law, we know that

$$2d\ \mathrm{Sin}\theta = m\lambda$$

$$\Rightarrow \qquad \lambda = \frac{2d\sin\theta}{m}$$

Putting values, we get

$$\lambda = \frac{2 \times 2.8 \times 10^{-10}m \times sin5^{o}}{1} = 0.488 \times 10^{-10}m$$

$$\boxed{\lambda = 0.49 \times 10^{-10}\mathrm{m}}$$

Q.11) An X-ray beam of wavelength 0.48 x 10^{-10} m is used to get Bragg reflection from a crystal at an angle of 20° for

the first order maximum. What are the possible layer plane spacing which give rise to this maximum?

Answer :

Given Data:

Wavelength of beam = λ = 0.48×10^{-10}m

Bragg's angle = ϴ = 20o

Order = m = 1

To Find:

Layer plane spacing = d = ?

Solution:

Bragg's law gives us,

$$2d \sin\theta = m\lambda$$

$$\Longrightarrow \quad d = \frac{m\lambda}{2sin\theta}$$

Putting values, we get

$$d = \frac{1 \times 0.48 \times 10^{-10} m}{2 \times sin20^o} = 0.702 \times 10^{-10} m$$

$$\boxed{d = 0.70 \times 10^{-10}\text{m}}$$
