Numerical Problems

Physics

CHAPTER NO. 9(PHYSICAL OPTICS)

Question 9.1:- Light of wavelength 546 nm is allowed to illuminate the slits of Young's experiment. The separation between the slits is 0.10 mm and distance of screen from the slits where interference effects are observed is 20 cm. At what angle first minimum will fall? What will be the linear distance on the screen between adjacent maxima?

Solution:- Wavelength of light = λ = 546 nm = 546 x 10⁻⁹ m = 5.46 x 10⁻⁷ m

Slit spacing = d = $0.10 \text{ mm} = 0.10 \text{ x} 10^{-3} \text{ m} = 1.0 \text{ x} 10^{-4} \text{ m}$

Distance between slits and screen = L = 20 cm = 0.20 m

Condition for mth order minima is d sin $\theta = (m + \frac{1}{2}) \lambda$

For first minima, m = 0

d sin $\theta = \frac{\lambda}{2}$ sin $\theta = \frac{\lambda}{2d} = \frac{5.46 \times 10^{-7}}{2 \times 1.0 \times 10^{-4}} = 2.73 \times 10^{-3}$ $\theta = \sin^{-1} (2.73 \times 10^{-3})$

$$\theta = 0.16^{\circ}$$

Distance between two adjacent maxima on screen $\Delta Y = \frac{\lambda L}{d} = \frac{0.20 \times 5.46 \times 10^{-7}}{1.0 \times 10^{-4}}$

 $\Delta Y = 1.1 \text{ x } 10^{-3} \text{ m}$

$\Delta Y = 1.1 \text{ mm}$

Question 9.2:- Calculate the wavelength of the light, illuminating two slits 0.5 mm apart and produces an interference pattern on the screen placed 200 cm away from the slits. The first bright fringe is observed at a distance of 2.40 mm from the central bright image.

Solution:- Slit spacing = $d = 0.5 \text{ mm} = 5 \text{ x } 10^{-4} \text{ m}$

Distance between slits and screen = L = 200 cm = 2 m

Distance of first bright fringe from central bright fringe = $Y_1 = 2.40 \text{ mm} = 2.40 \text{ x} 10^{-3} \text{ m}$

The position of mth order bright fringe from central bright fringe is measured as $Y_m = \frac{m \lambda L}{d}$

In this case, m = 1

$$Y_1 = \frac{\lambda L}{d}$$

$$\lambda = \frac{Y_1 d}{L} = \frac{2.40 \times 10^{-3} \times 5 \times 10^{-4}}{2}$$

$$\lambda = 6.0 \times 10^{-7} \text{ m} = 600 \times 10^{-9} \text{ m}$$

$\lambda = 600 \text{ nm}$

Question 9.3:- In double slit experiment second order maximum occurs at an angle of θ = 0.25°. The wavelength is 650 nm. Determine the slit separation.

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Solution:- Order of maximum = m = 2Angle = $\theta = 0.25^{\circ}$

Wavelength of light = λ = 650 nm = 6.50 x 10⁻⁷ m

Slit separation = d

Condition for m^{th} order maximum is $d\,\sin\theta=m\,\lambda$

 $d = m\lambda/\sin\theta = (2)(5.46 \text{ x } 10^{-7})/\sin(0.25^{\circ})$

 $d = 0.30 \ge 10^{-3} m$

<u>d = 0.30 mm</u>

Question 9.4:- A monochromatic light of wavelength 588 nm is allowed to fall on the halfsilvered glass plate G_1 in the Michelson interferometer. If mirror M_1 is moved through 0.233 mm, how many fringes will be observed to shift?

Solution:- Wavelength of light = λ = 588 nm = 5.88 x 10⁻⁷ m

Distance moved = $L = 0.233 \text{ mm} = 0.233 \text{ x} 10^{-3} \text{ m}$

Number of fringes shifted = m

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

m = $\frac{2L}{\lambda} = (2)(0.233 \times 10^{-3})/(5.88 \times 10^{-7})$

<u>m = 792</u>

Question 9.5:- A second order spectrum is formed at an angle of 38.0° when light falls normally on the diffraction grating having 5400 lines per centimeter. Determine wavelength of light used.

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Solution:- Order of spectrum = m = 2

Angle = θ = 38.0°

Number of lines on the grating = N = 5400

Length of the grating = L = 1 cm = 0.01 m

Grating element = $d = L/N = 0.01/5400 = 1.85 \text{ x} 10^{-6} \text{ m}$

Wavelength = λ

Condition for m^{th} order maximum with a grating $d\,\sin\theta=m\,\lambda$

 $\lambda = d \sin \theta / m = (1.85 \text{ x } 10^{-6})(\sin 38.0^{\circ})/2$

 $\lambda = (1.85 \text{ x} 10^{-6})(0.62)/2$

 $\lambda = 0.57 \text{ x } 10^{-6} \text{ m} = 570 \text{ x } 10^{-9} \text{ m}$

$\lambda = 570 \text{ nm}$

Question 9.6:- A light is incident normally on the grating which has 2500 lines per centimeter. Compute wavelength of spectral line for which the deviation in second order is 15.0°. Solution:- Number of lines on grating = N = 2500

First Year Numerical Problems Physics Length of the grating = L = 1 cm = 0.01 mOrder of spectrum = m = 2Angle = $\theta = 15.0^{\circ}$ Grating element = $d = L/N = 0.01/2500 = 4 \times 10^{-6} m$ Wavelength = λ Condition for mth order maximum with a grating d sin $\theta = m \lambda$ $\lambda = d \sin \theta / m = (4 \times 10^{-6})(\sin 15.0^{\circ})/2$ $\lambda = (4 \times 10^{-6})(0.259)/2$ $\lambda = 0.518 \text{ x } 10^{-6} \text{ m} = 518 \text{ x } 10^{-9} \text{ m}$ $\lambda = 518 \text{ nm}$ Question 9.7:- Sodium line ($\lambda = 589$ nm) is incident normally on the grating having 3000 lines per centimeter. What is the highest order of the spectrum obtained with this grating? **Solution:-** Wavelength of light = λ = 589 nm = 5.89 x 10⁻⁷ m Number of lines on grating = N = 3000Length of the grating = L = 1 cm = 0.01 mGrating element = $d = L/N = 0.01/3000 = 3.33 \times 10^{-6} m$ Condition for mth order maximum with a grating d sin $\theta = m \lambda$ In order to obtain value of highest order, $\theta = 90^{\circ}$ and $\sin \theta = \sin 90^{\circ} = 1$ d sin 90° = $m_{max} \lambda$ $m_{max} = d/\lambda = (3.33 \times 10^{-6})/(5.89 \times 10^{-7}) = 5.66$ It means fifth order of spectrum are complete and sixth order is incomplete. $m_{max} = 5$ Question 9.8:- Blue light of wavelength 480 nm illuminates a diffraction grating. The second order image is formed at an angle of 30° from the central image. How many lines in a centimeter of the grating have been ruled? **Solution:-** Wavelength of light = λ = 480 nm = 4.80 x 10⁻⁷ m Order of spectrum = m = 2Angle = $\theta = 30^{\circ}$ Length of grating = L = 1 cm = 0.01 mNumber of lines = N Condition for mth order maximum with a grating d sin $\theta = m \lambda$ We know that $d = \frac{L}{N}$

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 $\frac{L}{N}\sin\theta = m\lambda$

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$N = \frac{L \sin \theta}{m \lambda} = \frac{(0.01) \sin 30^{o}}{(2)(4.80 x \, 10^{-7})}$

 $N = 0.000520 \ge 10^7$

<u>N = 5200</u>

Grating must have 5200 lines per centimeter.

Question 9.9:- X-rays of wavelength 0.150 nm are observed to undergo a first order reflection at a Bragg angle of 13.3° from a quartz (SiO₂) crystal. What is interplanar spacing of the reflecting planes in the crystal?

Solution:- Wavelength of x-rays = $\lambda = 0.150$ nm = 0.150 x 10⁻⁹ m

Order of diffraction = m = 1

Angle = $\theta = 13.3^{\circ}$

Bragg's law for crystal diffraction of x-rays is **2** d sin θ = m λ

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

 $d = (1)(0.150 \times 10^{-9})/(2)(\sin 13.3^{\circ})$

 $d = 0.326 \times 10^{-9} m$

d = 0.326 nm

Question 9.10:- An X-ray of wavelength λ undergoes a first order reflection from a crystal when its angle of incidence to a crystal face is 26.5°, and an X-ray beam of wavelength 0.097 nm undergoes a third order reflection when its angle of incidence to that face is 60.0°. Assume that the two beams reflect from the same family of planes, calculate (a) the interplanar spacing of the planes and (b) the wavelength λ .

Solution:- Wavelength of first x-ray beam = $\lambda_1 = \lambda$ Angle of incidence = $\theta_1 = 26.5^{\circ}$ Order of diffraction = m₁ = 1 Bragg's law for crystal diffraction of x-rays is 2 d sin $\theta_1 = m_1 \lambda_1$ 2 d sin 26.5° = (1) λ $\lambda = 0.89$ d ------ Eq. (1) Wavelength of second x-ray beam = $\lambda_2 = 0.097$ nm = 0.097 x 10⁻⁹ m Angle of incidence = $\theta_2 = 60^{\circ}$ Order of diffraction = m₂ = 3 Bragg's law for crystal diffraction of x-rays is 2 d sin $\theta_2 = m_2 \lambda_2$ 2 d sin 60° = (3) (0.097 x 10⁻⁹) d = 0.168 x 10⁻⁹ m <u>d = 0.168 nm</u> Put value of d in Eq. (1)

 $\lambda = (0.89)(0.168 \text{ nm})$

 $\lambda = 0.150 \text{ nm}$

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