DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J - Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module-IV (Waves and Optics) Lecture-4

Problem Solving

1. A single slit of width 1 mm is illuminated by light of wavelength 589 nm. Find the angular spread of the central maxima of diffraction pattern observed.

SOLUTION Given $\lambda = 5.89 \times 10^{-7}$ m and slit-width (b) 1.0×10^{-3} m.

Formula used is $b \sin\theta = m\lambda$

For first minima, $m = 1$

$\therefore \quad \sin\theta = \lambda/b$

$$\theta = \sin^{-1}[\lambda/b] = \sin^{-1}\left[\frac{5.89 \times 10^{-7}}{1.0 \times 10^{-3}}\right]$$

$$\boldsymbol{\theta = 0.03374^\circ}$$

The angular spread of central maximum is 2θ

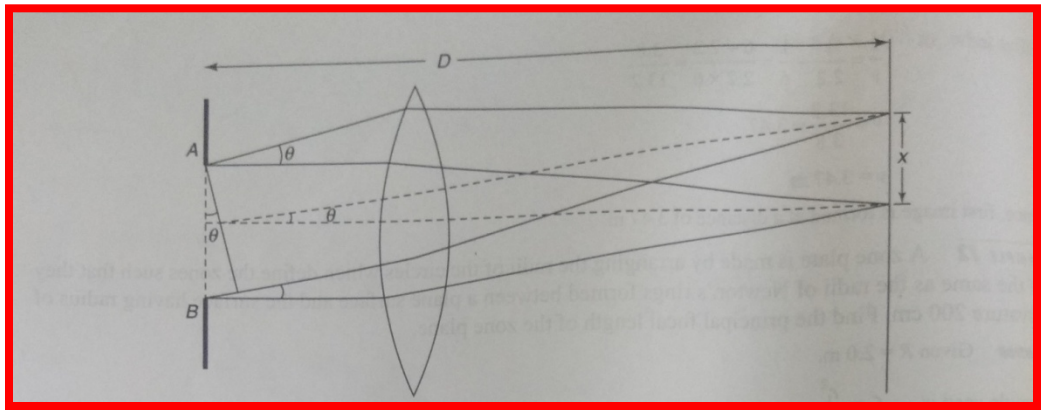
$\therefore \quad 2\theta = 2 \times 0.03374$

$$\boldsymbol{2\theta = 0.0675^\circ}$$

Therefore, angular spread of central maximum is 0.0675°.

2. In Fraunhofer type diffraction at narrow slit of width 0.2 mm, a screen is placed 1.2 m away from the slit. In the fringe pattern, first minimum lie at 3.7 mm on either side of the central maximum. Find out the wavelength of light.

Solution: given- b = .2mm, D = 1.2 m and x = 3.7 mm



From the given figure, if θ is very small, then

$$\sin\theta = \frac{x}{D}$$

condition of minima $b \sin\theta = m\lambda$

For $m = 1$, then $\sin\theta = \lambda/b$

By using Eqs. (i) and (ii), we get

$$\frac{\lambda}{b} = \frac{x}{D} \text{ or } \lambda = \frac{xb}{D} = \frac{3.7\times10^{-3}\times2\times10^{-4}}{1.2}$$

$\lambda = 6167$ Å

3. In Fraunhofer diffraction at a slit of width 1.2×10^{-6} m, find the half-angular width of the central bright maximum if the slit is illuminated by light of wavelength 5.89×10^{-7} m

Given: $b = 1.2 \times 10^{-6}$ m and $\lambda = 5.89 \times 10^{-7}$ m

Formula: $b \sin\theta = m\lambda$

For first minimum $m = 1$

$$\sin\theta = \lambda/b = 5.89 \times 10^{-7} / 1.2 \times 10^{-6}$$

$$= 0.491$$

$$\theta = \sin^{-1}(0.491)$$

$$\theta = 29.41^\circ$$

4. Parallel beam of light (5.0×10^{-7} m) is normally incident on a slit. The central maximum fans out at 30° on both sides of the direction of the incident light. Calculate the slit width. For what width of the slit the central maximum would spread out to 90° from the direction of the incident light?

Given: $\theta = 30°$ and $\lambda = 5.0 \times 10^{-7}$ m

Formula: $b \sin\theta = m\lambda$

For first minimum $m = 1$

$b = \lambda / \sin\theta = 5.0 \times 10^{-7}$ m / Sin 30°

$= 1.0$ µm

$\theta = 90°$, $b = ?$

$b = 5.0 \times 10^{-7}$ m / Sin 90° = 0.5 µm

5. A Parallel beam of light (5890 x 10^{-10} m) is incident perpendicularly on a slit of width 0.1 mm. Calculate angular width and linear width of central maximum formed on the screen 100 cm away.

Solution Given $\lambda = 5.89 \times 10^{-7}$ m, b = 1.0×10^{-4} m and $D = 1.0$ m.

Formula used is $b \sin\theta = m\lambda$

For angular width of central maximum

$$\sin\theta = \frac{\lambda}{b} \quad (m = 1 \text{ for first minimum})$$

$$= \frac{5.89 \times 10^{-7}}{1.0 \times 10^{-4}} = 5.89 \times 10^{-3}$$

$$\theta = \sin^{-1}(0.00589)$$

$$= 0.3375°$$

Therefore, the total angular spread of central maximum is 2θ, then

$$2\theta = 2 \times 0.3375°$$

$$2\theta = 0.675°$$

For linear width formula used is

$$\sin\theta = \frac{x}{D}$$

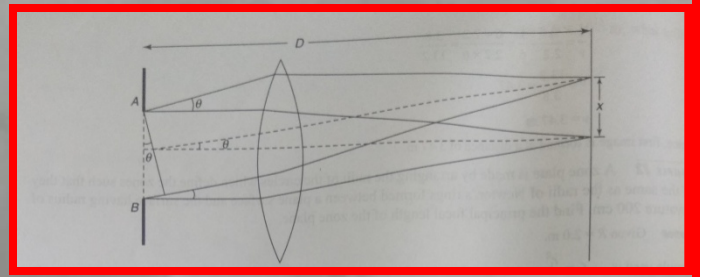
$$x = D \sin\theta = 1.0 \times 5.89 \times 10^{-3}$$

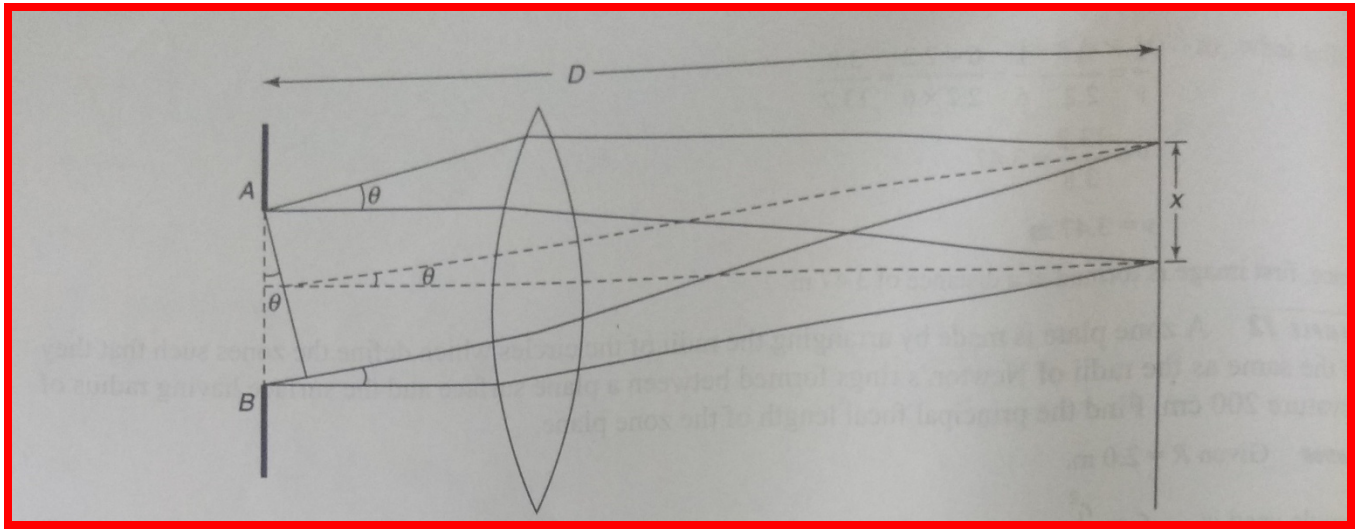
$$= 5.89 \times 10^{-3} \text{ m}$$

Total linear separation = $2x = 2 \times 5.89 \times 10^{-3}$ m

$$= 0.01178 \text{ m}$$

$$= \mathbf{1.178 \text{ cm}}$$




D
A
θ
θ
θ
B
X