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Question 1: Fraunhofer diffraction of vertical slit (width 0.3mm), the focal length of lens is 30 cm. Calculate the diffraction angle and position of first, second and third minima.

And also find the position of first, second and third maxima on either side of central spot. The slit is illumnated with yellow Sodium light of wavelength $\lambda = 6000\,\mathring{A}$.

Solution:- Condition for minima

$b \sin\theta = m\lambda$ where $m = \pm 1, \pm 2$

for small angle $\sin\theta \simeq \theta$ $\quad b = 0.3\,mm$

$b \sin\theta = m\lambda$

$b\theta = m\lambda$

$\theta = \frac{m\lambda}{b}$

for first, second, third minima

$\theta_1 = \frac{\lambda}{b}, \quad \theta_2 = \frac{2\lambda 2}{b}, \quad \theta_3 = \frac{3\lambda}{b}$

$\theta_1 = \frac{6000 \times 10^{-8}}{0.3 \times 10^{-1}} = 2 \times 10^{-3}$ rad

$\theta_2 = 4 \times 10^{-3}$ rad

$\theta_3 = 6 \times 10^{-3}$ rad

Distance d_1, d_2, d_3 of these minima from the central spot are

$d_1 = f\,\theta_1 = 30 \times 2 \times 10^{-3} = 0.06$ cm.

$d_2 = 2 \times 0.06 = 0.12$ cm

$d_3 = 0.18$ cm

for the condition of secondary maxima occur at $\beta = 1.43\pi, 2.46\pi$ and 3.47π

$(\theta_1)_{max} = \frac{1.43\lambda}{b} = 1.47 \times 2 \times 10^{-3}$

$(\theta_2)_{max} = \frac{2.46\lambda}{b} = 2.46 \times 2 \times 10^{-3}$

$(\theta_3)_{max} = \frac{3.47\lambda}{b} = 3.47 \times 2 \times 10^{-3}$

the $d_1 = f(\theta_1)_{max} = 30 \times 1.47 \times 2 \times 10^{-3} = 0.0$

$d_2 = f(\theta_2)_{max} = 30 \times 2.46 \times 2 \times 10^{-3} = 0.16$

$d_3 = 30 \times 3.47 \times 2 \times 10^{-3} = 0.21\,cm.$

Q.2. Consider a slit of width $b = 10\lambda, 5\lambda$ and λ and calculate the spread of central maxima

Ans.

We know that

$b \sin\theta = m\lambda$ $\quad m = 1$

$10\lambda \sin\theta = \lambda$

$\theta = 5.7^\circ$

for slit width of 5λ

$5\lambda \sin\theta = \lambda$

$\theta = 11.5^\circ$

for slit width

$\lambda \sin\theta = \lambda$

$\sin\theta = 1$

$\theta = 90^\circ$

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Q.3. Waves from He-Ne Laser with wavelength 6300°A are incident on a circular aperature of diameter 0.5mm What is the angular location of first minimum in the diffraction pattern. Also calculate the diameter of airy disc on screen 10 mm behind the aperature.

Ans. We know that $D = 0.5\times10^{-3}$

$$D \sin\theta = 1.22\lambda$$

$$0.5\times10^{-3} \sin\theta = 1.22\times630\times10^{-9}\,m$$

$$\sin\theta = 1.54\times10^{-3}$$

$$\theta = 0.087^\circ$$

On screen placed 10 m away the linear location of first minima is $x = D\tan\theta = D\theta$

$$x = (10)\times1.54\times10^{-3}$$

$$= 1.54\ cm$$

So diameter is about $1.54\times2 = 3\ cm$ approximately.

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Q.4. A plane metal sheet has a circular aperture of diameter 1mm. A beam of light $\lambda = 5000\,\text{Å}$ is incident upon normally. The shadow is cast on screen whose distance varies continuously. Calculate the distance at which the aperture will transmit 1, 2, 3, --- Fresnel zones.

Solution:- Let b_1, b_2, b_3 ---- distance at 1, 2, 3 - n zones are transmitted by an aperture of fixed radius r

$$n b_n \lambda = r_n^2$$

$$b_n = \frac{r_n^2}{n\lambda}.$$

$$b_1 = \frac{r_1^2}{\lambda} = \frac{(0.05)^2}{5\times10^{-5}} = 50\,cm$$

$$b_2 = \frac{r_2^2}{2\lambda} = \frac{50}{2} = 25$$

$$b_3 = \frac{50}{3} = 16.7$$

$$b_4 = \frac{50}{4} = 12.5$$

$$b_5 = 10$$

$$b_6 = 8.3$$

$$b_7 = 7.1$$

$$b_8 = 6.2 \ldots$$

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