Chapter 36 End-of-Chapter Problems

Halliday & Resnick, 10th Edition

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Hit me where it Matters

1 Problem 1

The distance between the first and fifth minima of a single-slit diffraction pattern is 0.35 mm with the screen 40 cm away from the slit, when light of wavelength 550 nm is used. (a) Find the slit width. (b) Calculate the angle θ of the first diffraction minimum.

1.1 Solution (a)

Estimate $\sin\theta \approx \theta \approx \tan\theta = \frac{y}{D}$. $D = 40\,\mathrm{cm}$ and never changes in this case. y does change, so we can create a Δy.

$$a\sin\theta = a\frac{y}{D} = m\lambda \tag{1}$$

We can create a Δy on one side and Δm on the other, for a separation between the first and fifth fringes.

$$a\frac{y}{D} = m\lambda \tag{2}$$

$$a\frac{\Delta y}{D} = \Delta m\lambda \tag{3}$$

$$a = \frac{\Delta m}{\Delta y}\lambda D = \frac{4}{0.35\,\mathrm{mm}} * 550\,\mathrm{nm} * 0.4\,\mathrm{m} = \boxed{2.51\,\mathrm{mm}} \tag{4}$$

1.2 Solution (b)

Divide the distance between fringes by four.

$$\Delta y = \frac{0.35\,\mathrm{mm}}{4} = 87.5\times10^{-6}\,\mathrm{m} \tag{5}$$

Divide this by the distance to the screen to find the approximate angle.

$$\theta = \frac{87.5\times10^{-6}\,\mathrm{m}}{0.4\,\mathrm{m}} = \boxed{2.2\times10^{-4}} \tag{6}$$

2 Problem 5

A single slit is illuminated by light of wavelengths λ_a and λ_b, chosen so that the first diffraction minimum of the λ_a component coincides with the second minimum of the λ_b component. (a) If $\lambda_b = 350\,\text{nm}$, what is λ_a? For what order number m_b (if any) does a minimum of the λ_b component coincide with the minimum of the λ_a component in the order number (b) $m_a = 2$ and (c) $m_a = 3$?

2.1 Solution (a)

We can define a relationship between y_a and y_b.

$$y_a = y_b \tag{7}$$

Approximating $\sin\theta \approx \theta \approx \tan\theta$, we have a relationship equation between y and λ for both a and b.

$$a \sin\theta = a\frac{y_a}{D} = m_a \lambda_a \tag{8}$$

$$a\frac{y_b}{D} = m_b \lambda_b \rightarrow y_a = y_b = \frac{m_b \lambda_b D}{a} \tag{9}$$

$$a\frac{\frac{m_b \lambda_b D}{a}}{D} = m_a \lambda_a = 2 m_b \lambda_b \tag{10}$$

In this case, m_a would be equal to 1, while m_b would be equal to 2.

$$\lambda_a = 2\lambda_b = 2 * 350\,\text{nm} = \boxed{700\,\text{nm}} \tag{11}$$

2.2 Solution (b)

4

2.3 Solution (c)

6

3 Problem 9

A slit 1.00 mm wide is illuminated by light of wavelength 589 nm. We see a diffraction pattern on a screen 3.00 m away. What is the distance between the first two diffraction minima on the same side of the central diffraction maximum?

3.1 Solution

Use the single slit diffraction equation. Use Δy and Δm, the latter of which will be equal to 1. Also use the small angle approximation.

$$a \sin\theta \approx a\frac{y}{D} = m\lambda \tag{12}$$

$$y = \frac{m\lambda D}{a} \tag{13}$$

$$\Delta y = \frac{\Delta m \lambda D}{a} = \frac{1 * 589\,\mathrm{nm} * 3.00\,\mathrm{m}}{1.00\,\mathrm{mm}} = \boxed{1.767\,\mathrm{mm}} \tag{14}$$

4 Problem 13

4.1 Solution

5 Problem 15

5.1 Solution

6 Problem 19

6.1 Solution

7 Problem 21

7.1 Solution

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