

# 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  $\theta$  of the first diffraction minimum.

## 1.1 Solution (a)

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

$$a \sin \theta = a \frac{y}{D} = m\lambda \quad (1)$$

We can create a  $\Delta y$  on one side and  $\Delta m$  on the other, for a separation between the first and fifth fringes.

$$a \frac{y}{D} = m\lambda \quad (2)$$

$$a \frac{\Delta y}{D} = \Delta m \lambda \quad (3)$$

$$a = \frac{\Delta m}{\Delta y} \lambda D = \frac{4}{0.35\text{ mm}} * 550\text{ nm} * 0.4\text{ m} = \boxed{2.51\text{ mm}} \quad (4)$$

## 1.2 Solution (b)

Divide the distance between fringes by four.

$$\Delta y = \frac{0.35\text{ mm}}{4} = 87.5 \times 10^{-6}\text{ m} \quad (5)$$

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

$$\theta = \frac{87.5 \times 10^{-6}\text{ m}}{0.4\text{ m}} = \boxed{2.2 \times 10^{-4}} \quad (6)$$

## 2 Problem 5

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

$$y_a = y_b \quad (7)$$

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

$$a \sin \theta = a \frac{y_a}{D} = m_a \lambda_a \quad (8)$$

$$a \frac{y_b}{D} = m_b \lambda_b \rightarrow y_a = y_b = \frac{m_b \lambda_b D}{a} \quad (9)$$

$$a \frac{\frac{m_b \lambda_b D}{a}}{D} = m_a \lambda_a = 2m_b \lambda_b \quad (10)$$

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

$$\lambda_a = 2\lambda_b = 2 * 350 \text{ nm} = \boxed{700 \text{ nm}} \quad (11)$$

### 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  $\Delta y$  and  $\Delta m$ , the latter of which will be equal to 1. Also use the small angle approximation.

$$a \sin \theta \approx a \frac{y}{D} = m\lambda \quad (12)$$

$$y = \frac{m\lambda D}{a} \quad (13)$$

$$\Delta y = \frac{\Delta m \lambda D}{a} = \frac{1 * 589 \text{ nm} * 3.00 \text{ m}}{1.00 \text{ mm}} = [1.767 \text{ mm}] \quad (14)$$

## 4 Problem 13

Monochromatic light with wavelength 538 nm is incident on a slit with width 0.025 mm. The distance from the slit to a screen is 3.5 m. Consider a point on the screen 1.1 cm from the central maximum. Calculate (a)  $\theta$  for that point, (b)  $\alpha$ , and (c) the ratio of the intensity at that point to the intensity at the central maximum.

### 4.1 Solution (a)

Use the definition of the tangent, then use the arctangent.

$$\tan(\theta) = \frac{y}{D} \quad (15)$$

$$\theta = \arctan\left(\frac{y}{D}\right) = \arctan\left(\frac{0.011}{3.5}\right) = \boxed{0.003143 \text{ rad}} \quad (16)$$

### 4.2 Solution (b)

Calculate  $\alpha$  using its definition.

$$\alpha = \frac{\pi a}{\lambda} \sin \theta = \frac{\pi(25 \times 10^{-6} \text{ m})}{538 \times 10^{-9} \text{ m}} \sin(0.003143 \text{ rad}) = \boxed{0.4588} \quad (17)$$

### 4.3 Solution

This is just calculating the intensity at that angle but foregoing the initial intensity.

$$I_{\text{ratio}} = \left(\frac{\sin \alpha}{\alpha}\right)^2 = \left(\frac{\sin(0.4588)}{0.4588}\right)^2 = \boxed{0.931} \quad (18)$$

## 5 Problem 15

### 5.1 Solution

## 6 Problem 19

### 6.1 Solution

## **7 Problem 21**

### **7.1 Solution**

## **8 Problem 37**

### **8.1 Solution**

## **9 Problem 39**

### **9.1 Solution**

## **10 Problem 45**

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## **11 Problem 47**

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## **12 Problem 49**

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