

## 4C Lab – Interference and Diffraction

**Goal:** To observe a single slit diffraction pattern and the double slit diffraction-interference pattern

### Equipment:

Optics bench and laser  
Box with slits and screen, component holders  
Tensor lamps (keep them low please)  
Vernier calipers, rulers  
Two-meter sticks, Meter sticks

**Background:** For a single slit, the diffraction of light about the aperture can be expressed in terms of the minimum and maximum intensities a distance  $L$  away from the slit. The first zeroes occur at angles given by:

$$a \sin \theta = \lambda \quad (1)$$

where  $a$  is the slit width. More generally, the points of zero intensity can be expressed:

$$a \sin \theta = m_d \lambda \quad m_d = 1, 2, 3, \dots \quad (2)$$

Interference occurs when there are two or more coherent sources such as light from a laser passing through two slits of minimum (zero) width. The interference maxima are given by:

$$d \sin \theta = m_i \lambda \quad m_i = 0, 1, 2, 3, \dots \quad (3)$$

where  $d$  is the separation distance between the slits. The interference minima are given by:

$$d \sin \theta = (m_i + \frac{1}{2}) \lambda \quad (4)$$

Slits of zero width are ideal, and those used in lab do have width. Thus, one observed the interference pattern modulated by the diffraction pattern. The angle for the first diffraction minimum can be set to equal the  $m_i^{\text{th}}$  interference maximum. Or:

$$\sin \theta = \lambda/a = m_i \lambda/d \quad (5 \text{ found by combining 2 and 3})$$

$$m_i = d/a \quad (6)$$

### Procedure – Part 1, Single Slit Diffraction

1. Set up the optics bench with the laser at one end and the component holder a small distance in front of the laser. You will be drawing the patterns directly into your lab notebook, so you might want to point toward the chalkboard or computers. If you are sitting in the middle row... good luck!
2. Select the single slit component and put it on the holder. Observe all four patterns. What happens to the width of the central diffraction maximum as the slit gets wider?
3. Choose one of the slits with a 0.04mm or 0.08 mm width and observe the pattern. Position your lab book so that you can copy at least through the fifth minima on each side of the central maxima. Do not forget to measure and record the distance from the slit to your lab notebook  $L$ .

### Analysis – Part 1

Compute the slit width  $a$  from your measurements using equation (2).

The wavelength of the laser is 632.8nm and your  $m_d$  values range from 1 to 5. The angle can be found by taking the distance from the central diffraction maximum to the middle of the zero point, call that  $y$ . You have five  $y$  values left, 5  $y$

values right, average each pair for 5  $y$  values corresponding to the five values of  $m_d$ . Alternatively, you can measure the distance from the left diffraction minimum to the same order diffraction minimum on the right side and divide by 2.

Either way:

$$\tan \theta = y/L$$

$$\theta \ll 1$$

$$\tan \theta \approx \sin \theta$$

Your 5 values for  $y$  correspond to 5 values of  $a$ . Calculate the average slit width, the standard deviation and the standard error. Do your results fall within uncertainty of the printed value?

### Procedure – Part 2: Double Slit

1. Select the double slit component and place it on the holder in front of the laser. There are four different combinations of slit width and spacing. Observe the diffraction-interference pattern for all four. Confirm that the central diffraction maximum for the slit widths 0.04mm and 0.08mm are the same size on your screen as in part 1.
2. Choose a double slit pattern and copy the pattern directly into your own lab book. You need to be able to distinguish all the interference fringes in the central and secondary diffraction maxima. For this, you may need to change the screen placement. If so, be sure to measure and record the distance from the slit to the screen,  $L$ . Be sure you copy the fringes into your lab book!
3. Count the number of bright fringes in the central diffraction maximum. Is the last fringe seen only a fraction of the whole fringe? Try to “guess-timate” the fraction of fringe present.
4. After you have analyzed your first double slit, you will do a second double slit. Please do not put away the equipment until you are finished with all the analysis.

### Analysis – Part 2

1. Calculate the slit width  $a$  using  $m_d = 1$  and the size of the central diffraction maximum:  $a = \frac{\lambda}{\sin \theta}$
2. Calculate  $d$  by measuring the distance from dark fringe to dark fringe on each side of the central interference maxima for the fringes you have in the central diffraction maxima. That is:  $2y_1, 2y_2, 2y_3, \dots$  for as many as you have. Using the condition for destructive interference:

$$d = (m_i + \frac{1}{2}) \frac{\lambda}{\sin \theta}$$

Average your values for  $d$ .

3. Calculate  $d/a$  using your values from the two steps above.
4. The number of bright fringes  $N$  should equal:

$$N = 2 m_i - 1$$

where  $m_i$  is the interference maximum which does not appear because it falls at the same place as the first diffraction minimum. Compare with equation (6) to find:

$$d/a = \frac{1}{2} (N + 1)$$

5. Compare your values with each other. Compare your values to the printed values. Note that the  $d/a$  ratio may not be an integer.
6. Repeat for another double slit width and spacing, choose one with the ratio  $d/a$  close to an integer. For this second slit, you do not need to calculate  $a$  and  $d$  directly, only  $d/a$  from the number of bright fringes.