General Physics II Lab (PHYS-2021)
Experiment OPTC-4:
Interference and Diffraction of Light

Name: ______________________ Lab Section: __________

Objective:

The purpose of this experiment is to examine the diffraction pattern formed by laser light passing through single and double slits then verify that the positions of the minima/maxima in the diffraction pattern match the positions predicted by theory.

Single Slit Theory:

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by

$$a \sin\theta = m\lambda \quad (m = 1, 2, 3, ...) \tag{1}$$

where a is the slit width, θ is the angle from the center of the pattern to the m^{th} minimum, λ is the wavelength of the light, and m is the order (1 for the first minimum, 2 for the second minimum, . . . counting from the center out). See Figure 1a.

Since the angles are usually small, it can be assumed that

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

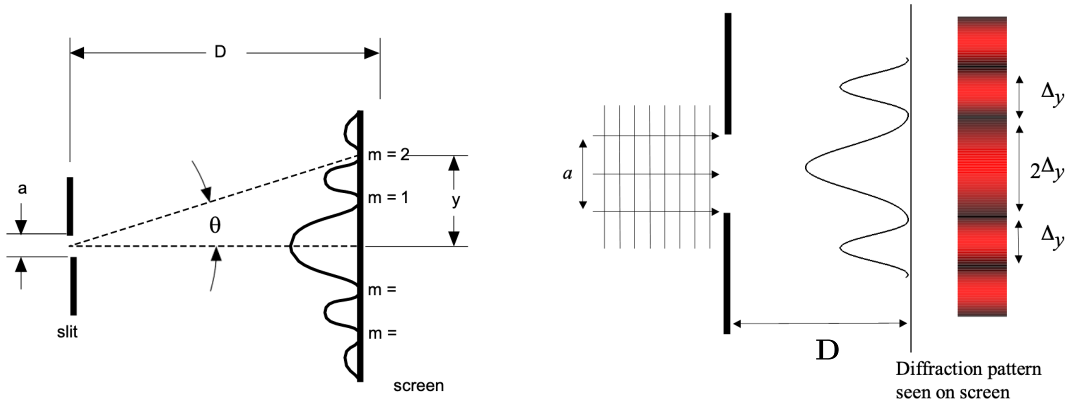
From trigonometry,

$$\tan\theta = \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the m^{th} minimum and D is the distance from the slit to the screen as shown in Figure 1a. The diffraction equation can thus be solved for the slit width:

$$a = \frac{m\lambda D}{y} \quad (m = 1, 2, 3, ...). \tag{2}$$

It can be shown that the spacing between adjacent maxima or adjacent minima on the screen is $\Delta y = \lambda \frac{D}{a}$ except for the the dark fringes on either side of the the central maximum in a single-slit diffraction pattern which has a width of $2\Delta y$ as seen in Figure 1b.



(a) Single Slit Diffraction Pattern (b) Single Slit Diffraction on Screen

Figure 1: Single Slit Diffraction

Double Slit Theory:

When light passes through two slits, the two light rays emerging from the slits interfere with each other and produce interference fringes. The angle to the maxima (bright fringes) in the interference pattern is given by

$$d \ sin \ \theta = m\lambda \quad (m = 0, 1, 2, 3, ...) \tag{3}$$

where d is the slit separation, θ is the angle from the center of the pattern to the m^{th} maximum, λ is the wavelength of the light, and m is the order (0 for the central maximum, 1 for the first side maximum, 2 for the second side maximum, . . . counting from the center out). See Figure 2.

Since the angles are usually small, it can be assumed that

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

From trigonometry,

$$tan \ \theta \ = \ \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the m^{th} maximum and D is the distance from the slits to the screen as shown in Figure 2. The interference equation can thus be solved for the slit separation:

$$d \ = \frac{m\lambda D}{y} \quad (m = 0, 1, 2, 3, ...) \tag{4}$$

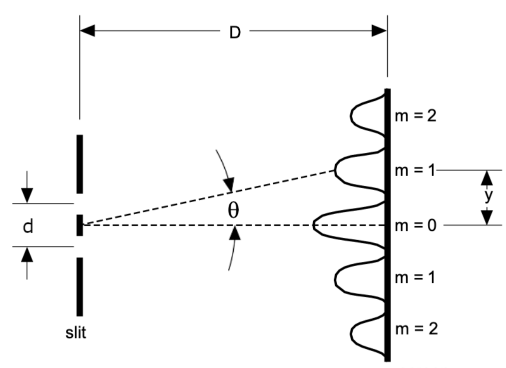


Figure 2: Interference Fringes for Double Slit

Part A - Diffraction from a Single Slit:

1. Place the screen at 110 cm, the Single Slit Disk flag at 12 cm and the Green Laser at 1.5 cm on the optics bench so that the Slit-to-Screen Distance (D) = 1.00 m. The Single Slit Disk in its holder should be about 3 cm in front of the laser. See Figure 3 below.

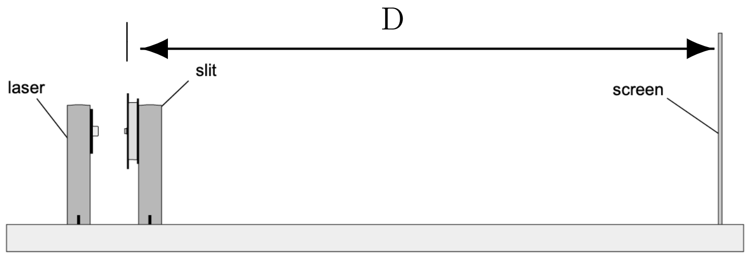


Figure 3: Optics Bench Setup.

2. Determine the distance from the slit to the screen. Note that the slit is actually offset from the center line of the slit holder. Record the the slit-to-screen distance under Table 1 below.

3. Cover the screen with a sheet of paper so that the paper faces the laser.

4. Select the 0.04 mm slit by rotating the slit disk until the 0.04 mm slit is centered in the slit holder. Adjust the position of the laser beam from left-to-right and up-and-down until the beam is centered on the slit using the screws on the back of the laser mount.

Table 1: Data and Results for the 0.04 mm Single Slit

	λ_{532} **(m=1)**	λ_{532} **(m=2)**	λ_{650} **(m=1)**	λ_{650} **(m=2)**
Distance between side orders, Δy_m				
Distance from center to side, y_m				
Slit Width, a_{calc}				
a % Difference				

Slit-to-screen distance (D): ____________________

5. With a sharp pencil, carefully mark the center positions of the minima in the diffraction pattern on the paper on the screen.

6. Measure the distance between the first order (m = 1) marks Δy_m and record this distance in column 1 of Table 1. Also measure the distance between the second order (m = 2) marks Δy_m and record this distance in column 2 of Table 1.

7. Make a sketch of the diffraction pattern on blank paper taped to the screen to be turned into instructor. Label wavelength, λ and slit width a.

8. Change the slit width to 0.02 mm and 0.08 mm and make sketches to scale of each of these diffraction patterns on the same paper as in 7.

9. Replace the Green Laser with the Red Laser at the 4.0 cm position on the optical bench. Repeat steps 4-7 with a sketch of the diffraction pattern with slit width of 0.04 mm.

10. Change the slit width to 0.02 mm and 0.08 mm and make sketches to scale of each of these diffraction patterns.

Analysis- Diffraction from a Single Slit:

1. Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order minima. Record these values of y in Table 1, row 2.

2. Using the average wavelength of the laser (650 nm for the Red Diode Laser or 532 nm for the Green Diode Laser), calculate the slit width twice, once using first order and once using second order. Record the results in Table 1, row 3.

3. Calculate the percent differences between the experimental slit widths and 0.04 mm using Equation 5 below. Record in Table 1.

$$\%_{Difference} = \left(\frac{a_{measured} - a_{actual}}{\frac{1}{2}\left(a_{measured} + a_{actual}\right)} \right) \times 100 \tag{5}$$

Conclusions - Diffraction from a Single Slit:

1. Does the distance between minima increase or decrease when the slit width is increased?

2. When the laser light λ increases (Green to Red) does distance between minimum increase or decrease?

Part B - Interference from a Double Slit:

1. Replace the Single Slit Disk with the Multiple Slit Disk so that D is again 1.00 meter.

2. Select the double slit with 0.04 mm slit width and 0.25 mm slit separation by rotating the slit disk until the desired double slit is centered in the slit holder. Adjust the position of the laser beam from left-to-right and up-and-down until the beam is centered on the double slit.

3. Verify the distance from the slits to the screen is 1.00 meter. **Note that the slits are actually offset from the center line of the slit holder.** Record the slit-to-screen distance under Table 2 below.

Table 2: Data and Results for the 0.04 mm / 0.25 mm Double Slit

	λ_{532} **(m=1)**	λ_{532} **(m=2)**
Distance between side orders, Δy_m		
Distance from center to side, y		
Slit Width, a		
Calculated slit separation, d		
% Difference		

Slit-to-screen distance (D): ______________________

4. Mark the positions of the maxima in the interference pattern on the screen.

5. Measure the distance between the first order ($m = 1$) marks, Δy_m and record this distance in column 1 in Table 2. Then measure the distance between the second order ($m = 2$) marks, Δy_m and record in column 2 in Table 2.

6. Make a trace on paper of the interference pattern to scale.

7. Change to a new double slit with the same slit width (0.04 mm) but different slit separation (0.50 mm) and make a sketch to scale of this new interference pattern.

8. Change to another double slit with a slit width of 0.08 mm and the original slit separation (0.25 mm) and make a sketch to scale of this new interference pattern.

Analysis - Interference from a Double Slit:

1. Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order maxima. Record these values of y in Table 2.
2. Using the average wavelength of the laser (532 nm for the Green Diode Laser), calculate the slit 1 separation twice, once using first order and once using second order. Record the results in Table 2.
3. Calculate the percent differences between the experimental slit separation and 0.25 mm using Equation 5. Record in Table 2.

Conclusions - Interference from a Double Slit:

1. Does the distance between maxima increase, decrease, or stay the same when the slit separation is increased?
2. Does the distance between maxima increase, decrease, or stay the same when the slit width is increased?
3. Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit separation is increased?
4. Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit width is increased?