Name: ____________________

Partner(s): ____________________

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Date: ____________________

Diffraction and Interference

Purpose

An interesting optical effect occurs when light encounters a small barrier, such as a line, a slit or a dot. This effect is known as diffraction, or interference (depending on the barrier), and is a consequence of the fact that light behaves like a wave. This effect is of practical importance, as it places a limit on how well an optical device, such as a microscope, or eyeglasses, or a telescope works. It is also used to probe the nature of very small things, such as the arrangement of atoms, or molecules, in a crystal and complex molecules, such as DNA. In this lab, we examine this effect using multiple slits and use the observed diffraction patterns to measure the wavelength of a laser. Finally, we will examine the diffraction pattern of a two-dimensional structure.

Theory

As light encounters a barrier, it is diffracted. If the barrier is a single slit, it will diffract and produce a pattern with multiple maxima separated by nodes, as seen in Figure 1. The largest maximum is known as the central fringe.

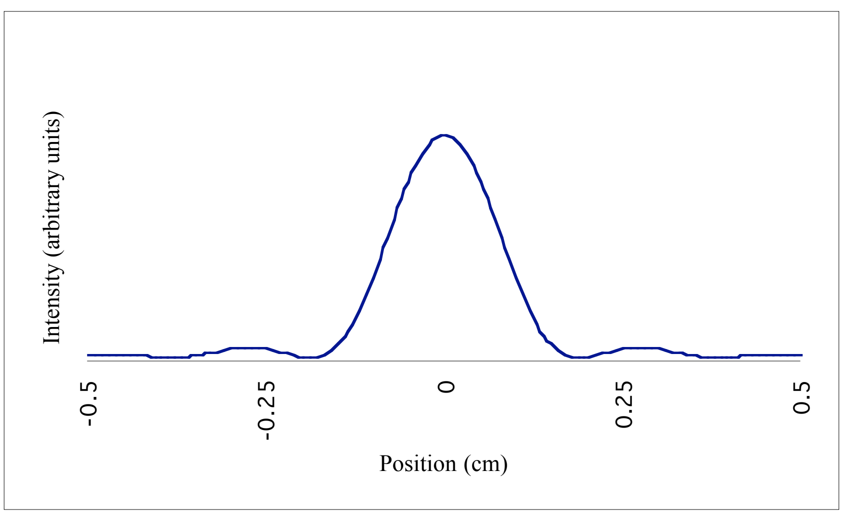


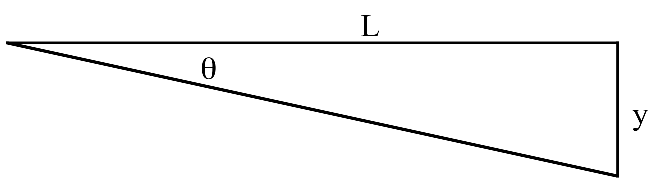
Figure 1: Single Slit Diffraction

The locations of the ***minima*** are analytically given by the Equation 1 and the intensity is described by Equation 2.

$$m\lambda = a\sin\theta \qquad (1)$$

$$I = I_o\left[\frac{\sin\left(\frac{\pi a\sin\theta}{\lambda}\right)}{\frac{\pi a\sin\theta}{\lambda}}\right]^2 \qquad (2)$$

where m is the index of the minima (the two minima closest to the central fringe have an index of 1, the second closest have an index of 2, and so on), λ is the wavelength of the light diffracted, ***a* is the width of the slit**, θ is the angle from the slit to the measurement with respect to the location of the central fringe, as seen in Figure 2, and I_o is the intensity of the central fringe. When the angle of diffraction is small, we can make a very useful approximation, known as the small angle approximation, seen below.



$$\sin\theta \approx \theta \approx \tan\theta = \frac{y}{L}$$

Figure 2

In the limit of small angles, Equations (1) and (2) become:

$$m\lambda = a\frac{y}{L} \qquad (3)$$

$$I = I_o\left[\frac{\sin\left(\frac{\pi a y}{\lambda L}\right)}{\frac{\pi a y}{\lambda L}}\right]^2 \qquad (4)$$

If there are multiple slits, the spacing for the **maxima** are given by Equation 5.

$$m\lambda = d\sin\theta \qquad (5)$$

where m is the number of the maxima (the peak nearest the central fringe is 1, the second nearest peak is 2, and so on), λ is the wavelength of the light diffracted, **d is the distance between the slits**, θ is the angle from the slit to the measurement with respect to the location of the central fringe.

Procedure

The experimental setup, as from above, is shown in Figure 3. A monochromatic laser, **λ = 632.8 nm**, is positioned on the short bench, a distance *L* from an observing screen. The laser should be positioned such that it points to the center of the screen. Slits will be positioned on a slide holder a few centimeters from the laser. To get the greatest resolution, the distance between the slit and the observing screen, *L*, should be as large as possible.

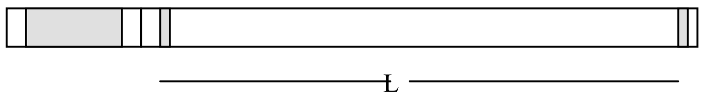


Figure 3

*Part 1: **Single** Slit*

Place the slide with a single slit aperture (Slide 9165-A) in the location labeled “Grating” in Figure 3. Record the observed diffraction pattern. It is important that you record the location of the brightest and least bright locations. Attach your measurements to the lab manual, making sure to include the slit width. You will make this measurement for two slits of different width on Slide 9165-A.

From your sketches, record the relevant data in the table below:

Slit	m	y	L	$\lambda_{experimental}$	λ_{actual}	% error
A	1					
	2					
	3					
B	1					
	2					
	3					

Part 2: ***Double*** *Slit*

Replace the slide with the single slit aperture with a slide containing the double slit aperture (Slide 9165-B). In this case, we will measure the spacing between the maxima. Attach your measurements to the lab manual, making sure to include the slit width and spacing. Repeat this measurement for a second double slit. From your sketches, record the relevant data in the table below:

Slit	m	y	L	$\lambda_{experimental}$	λ_{actual}	% error
A	1					
	2					
	3					
B	1					
	2					
	3					

Part 3: ***Quadruple*** *Slit*

Replace the slide with the double slit aperture with a slide containing a quadruple slit aperture (Slide 9165-C) and repeat the measurements made in the previous parts of this lab. From your sketches, record the relevant data in the table below:

Slit	m	y	L	$\lambda_{experimental}$	λ_{actual}	% error
A	1					
	2					
	3					
B	1					
	2					
	3					

Do the maximum and minimums become more defined as the number of slits increases? What you think would happen if there were many slits?

Part 4: Diffraction ***<u>Grating</u>***

Let's now observe what happens when there are many slits. To do this, we use a diffraction grating. Replace the slide with the quadruple slit aperture with a slide containing a diffraction grating (Slide 9127). Sketch what you observe below. Be sure to include any relevant measurements.

Is the small angle approximation still valid? If not, why?

Perform the appropriate calculation to determine the wavelength of the laser.

How do your previous results compare to this? Is there an improved accuracy with increasing slits? If so, why?

*Part 5: A **two-dimensional** diffraction pattern*

Place a two-dimensional slit pattern (*e.g.,* Slide 9165-D) in front of the laser and observe the diffraction pattern produced. The observed pattern can be recorded below.

Can you explain the observed pattern from what you have already done in this lab? The following hints may help.

- The two-dimensional slit pattern is the superposition of a number of one-dimensional slit patterns.
- Light obeys the principle of superposition.

Questions

1. In this experiment, we used a helium-neon laser, with λ = 632.8 nm. What spacing is needed between the slits, if you only want the first maxima to fit on the screen or sheet of paper you used for viewing the pattern? Assume that you are using the setup from Part 2 of this lab.

2. Would a violet laser, λ = 400 nm, improve the accuracy of the measurement that you made on the wavelength? Why or why not?

Initiative

<u>*Possible ideas:*</u>

1. Discuss how you could use the procedures in used in this lab to determine the structure of, say, a gamma globulin molecule? or DNA? or crystals of crystallite? Could you use a 632.8 nm laser?

Conclusions