Lab 10

Interference and Diffraction

What You Need To Know:

The Physics In the past two labs we've been thinking of light as a particle that reflects off of a surface or refracts into a medium. Now we are going to talk about light as a wave.

If you take two waves and add them together, or *superimpose* them, they will combine together to form a new wave. Below, in **Figure 1**, you see two different cases in which two waves can add together.

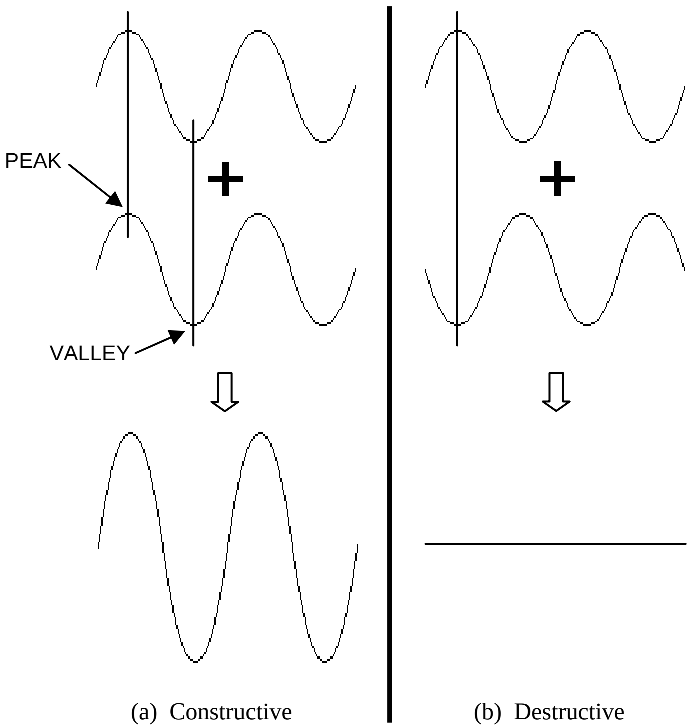

FIGURE 1 – Interference of two waves

In case **1a**, the two waves are *in phase*, which means that they both reach a peak (or valley) at the same time. When these waves are combined the result will give you *constructive interference*.

In case **1b**, the two waves are *out of phase* in such a way that peaks match with valleys. When these waves are combined the result will give you *destructive interference*.

If these are waves of light, then we could say that constructive interference would give us a *brighter* light. For light waves that give us destructive interference, we would get *darkness*.

Let's say that we have a situation in which laser light is incident on two very small slits. The slits are a distance, **d**, apart and a screen is placed a distance, **L**, from the slits. See **Figure 2**. Light from a laser is mono-chromatic – meaning it is made up of light with one wavelength. We use a single wavelength of light so that we can simplify the analysis of the interference effects. If we shine a laser on the slits, the light waves will

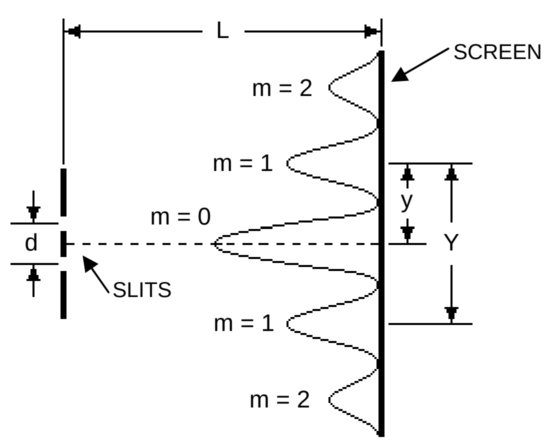

FIGURE 2 – Double slit interference

travel through each slit and then proceed to the screen. For points on the screen that are off of the central axis, one wave of light will travel a farther distance than the other. If the two waves of light are *in phase* when they meet at the screen then you will see a bright spot (constructive interference). If the two beams of light are *out of phase* when they meet then you will see a dark spot (destructive interference). As a result, you should see a pattern of bright and dark spots (or fringes) on the screen. This pattern is shown as peaks of brightness and valleys of darkness in **Figure 2**.

The location of the **bright fringes** can be found using the following equation. The derivation of this equation will be shown to you in your class or by your lab TA …

$$y = \frac{m\lambda L}{d}$$

y is the distance from the central axis to a **bright** fringe (in m)
m is the order/fringe number (m = 1, 2, 3, …)
$\boldsymbol{\lambda}$ is the wavelength of the light (in m)
L is the distance from the slits to the screen (in m)
d is the distance between the slits (in m)

In the lab you will be measuring the distance, **Y**, from one bright fringe to its counterpart fringe on the other side of the central axis. See **Figure 2**. You will then divide this distance by two, **y = Y/2**, and use this value in the above equation. This process will give you more accurate data.

There is also an interference effect when there is only one slit. This is called *diffraction*. In this situation the light interferes with itself to produce bright and dark fringes on the screen. The main difference in the pattern is that the central bright spot for one slit is twice as wide as the central bright spot for two slits. See **Figure 3**. There are other differences but they will be left for you to discover during the lab. Also, the width of the slit is **a.** **NOTE:** This is not the distance between the slits, like for two slits. For diffraction you will be using the *dark fringes* as reference points when you are taking data.

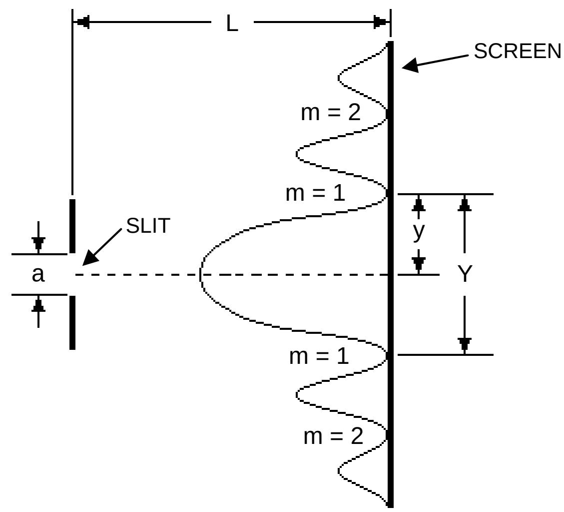

FIGURE 3 – Single slit diffraction

The equation for the locations of the **dark fringes** is given below. Again, the derivation will be left to the lecture class or your lab TA …

$$y = \frac{m\lambda L}{a}$$

y is the distance from the central axis to a **dark** fringe (in m)
m is the order/fringe number (m = 1, 2, 3, …)
$\boldsymbol{\lambda}$ is the wavelength of the light (in m)
L is the distance from the slit to the screen (in m)
a is the width of the slit (in m)

Notice that the two equations are pretty much the same except for the **d** in one denominator and the **a** in the other. Also, one equation is for locating *bright* fringes due to *interference* with *two slits*. The other is for *dark* fringes due to *diffraction* with a *single slit*. You will be using these two equations to calculate the wavelength of the light from the laser. You will then compare this value to the known value of the wavelength.

The Equipment You will be using the same optical bench set-up that you used last week. See **Figure 4**. In this lab however you will be using a laser as the light source. **Do not shine the laser into your lab partner's eyes!** There should be paper on your table for you to attach to the screen with a black clip. **Do not write on the screen!**

Sharing Duty You are sharing duty for this lab. You will each take a turn marking fringes on the screen for a particular pattern. You will do calculations on the markings that **you** made. You do **not** have to show the data or the calculations for your lab partner's pattern. However, you *will* take your lab partner's final average wavelength for the pattern he/she used.

What You Need To Do:

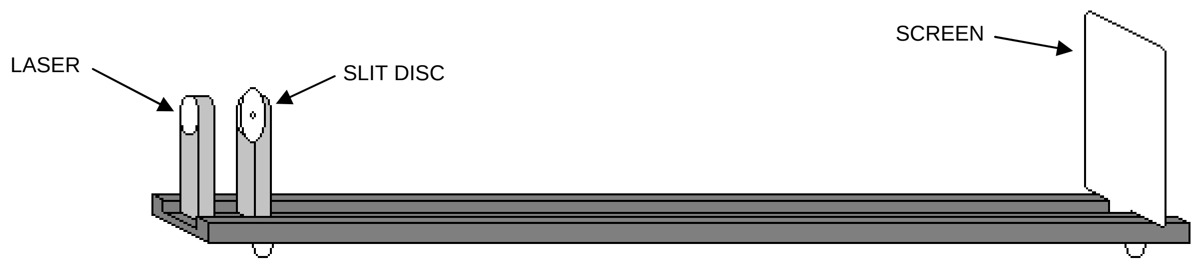

FIGURE 4 - Optical bench and accessories.

Part 1 – Single Slit Place the Single Slit Disc on the optical bench. It should be about 3 or 4 cm from the laser. Rotate the disc so that the **0.08 mm** (use 0.088 mm for calculations) slit is in the path of the laser beam. The screen should be at **110 cm**. Using the black clip on the screen, attach the piece of paper to the screen. Adjust the laser to the left or the right so you get a bright and sharp pattern on the screen. Make a copy of the chart at the right on a separate piece of paper. "**m**" should range from **1 to 6**. Now do the following …

- Write on the piece of paper, "Single Slit, a = 0.088 mm". Also place the value in your chart.
- Measure the distance, **L**, from the slit to the screen. NOTE: The disc is not even with the marker at the base of the mount.

Single Slit

L = _______ **a** = _______

m	Y	y	λ
1			
2			
…			
6			

Your $\lambda_{AVE.}$:	
Your partner's $\lambda_{AVE.}$:	
Average $\lambda_{AVE.}$:	
% Error :	

- Using the 1st through the 6th order **dark** fringes, make marks at the estimated centers of the dark fringes.
- Label on the paper the order number for each pair of fringes.
- Remove the paper and put up a NEW piece of paper. (You EACH turn in one.)
- The other lab partner should repeat the above process for the slit on the disc of width **a = 0.16 mm** (use 0.175 mm for calculations).

EQUATIONS

$$y = \frac{Y}{2}$$

$$y = \frac{m\lambda L}{a}$$

Using your marked pattern, do the following for each fringe pair …

- Measure the distance, **Y**, from one dark fringe to the other for the same order number. See **Figure 3**. Place these values in the chart.
- Calculate the distance, **y**, which is the distance from the center of the central maximum to a dark fringe. Place these values in the chart.
- Using the Single Slit - Dark Fringe equation, calculate the wavelength for each order. (Make sure all of the values are in **meters** before you plug in the numbers.) Place these values in the chart.
- Find the average of your 6 wavelengths.
- Get your lab partner's average wavelength. Find the average of the two λ_{AVE}.
- Calculate a percent error based on the known wavelength for the laser light, 670 nm.

Question 1 Turn the disc to the Variable Slit section. Rotate the disc while the laser is centered on the variable slit. Describe what happens to the pattern as the slit width increases. Does this agree with the **y = mλL/a** equation? Explain.

Question 2 Turn the disc so that the laser is shining on one of the following three patterns: *squares*, *hexes*, or *holes*. For each pattern, describe or diagram what you are seeing. Based on what you have seen in the first part of the lab, explain why the patterns look the way they do for each type of "slit".

Part 2 – Double Slit Place the Multiple Slit Disc on the optical bench. It should be about 3 or 4 cm from the laser. Rotate the disc so that it is in the **Multiple Slit** section. Shine the laser on the **<u>2 Slit (not the 3 or 4 or 5)</u>** pattern, where **d = 0.125 mm**. (NOTE: Students use the wrong slit pattern for this most of the time. Reread the last two sentences and make sure you are using the correct slit pattern.) Using the clip on the screen, attach the same piece of paper you used for the single slit, but use the other side. Make another copy of the chart, but now it will be Double Slit and the "**a**" becomes a "**d**". Now do the following …

- Write on the piece of paper, "Double Slit, d = 0.125 mm". Also place the value in your chart.
- Measure the distance, **L**, from the slit to the screen.
- Using the 1st through the 6th order **bright** fringes, make marks at the estimated centers of the bright fringes.
- Label on the paper the order number for each pair of fringes.
- Remove the paper from the screen. The other lab partner should repeat the above process for **d = 0.25 mm**. This slit is in the Double Slit section where it says a = 0.04, d = 0.25.

Using your marked pattern, do the following for each fringe pair …

EQUATIONS

$$y = \frac{Y}{2}$$

$$y = \frac{m\lambda L}{d}$$

- Measure the distance, **Y**, from one bright fringe to the other for the same order number. See **Figure 2**. Place these values in the chart.
- Calculate the distance, **y**, which is the distance from the center of the central maximum to a bright fringe. Place these values in the chart.
- Using the Double Slit – Bright Fringe equation, calculate the wavelength for each order. (Make sure all the values are in **meters** before you plug in the numbers.) Place these values in the chart.
- Find the average of your 6 wavelengths.
- Get your lab partner's average wavelength. Find the average of the two λ_{AVE}.
- Calculate a percent error based on the known wavelength for the laser light, 670 nm.

Question 3 Turn the disc to the Variable Double Slit. Rotate the disc while the laser is centered on the variable slit. Describe what happens to the pattern as the slit separation increases. Does this agree with the **y = mλL/d** equation? Explain.

Question 4 Note that for the variable slit, the slit *width* stays the same but the slit *separation* changes. Does the pattern on the screen change according to this idea? Explain.

What You Need To Turn In:

Turn in your own sheet with a pattern for each type of slit. Make sure all of your data, calculations, and answers to questions are on paper other than the paper on the screen. You only need to do one sample calculation for each section.