

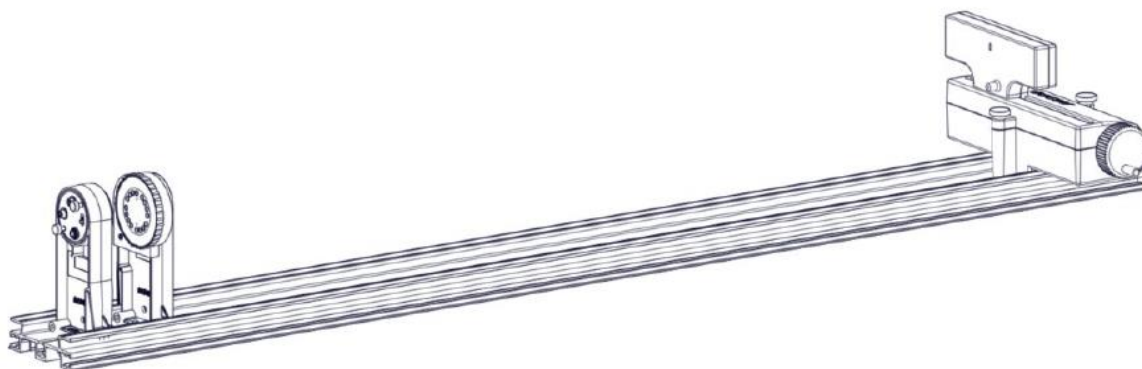
Interference and Diffraction Lab

We are going to examine the phenomena of interference and diffraction of light waves. Interference is the result of two or more waves adding their intensities in space depending on the relationship of their phase. Two waves completely in phase, add constructively to the sum of the individual waves. Two wave completely out of phase, add destructively subtracting their individual waves. In between these two cases, we get a more complicated addition. When two waves are in phase and completely add, you get a bright spot. When two waves are completely out of phase and completely subtract, you get a dark spot.

Diffraction is the bending of waves when they encounter openings or barriers. This bending then causes parts of the waves to interfere with itself also producing bright and dark spots, but the patterns are slightly different.

This lab will examine two slit interference and diffraction from a single slit. We will vary the distance between the two slits and the wavelength of light used for the two slit cases. For the single slit, we will again vary the wavelength, but then also the width of the slit used.

The physical set up looks similar to



The object on the far left is the coherent light source either a red or a green laser. The object just to the right of the laser is an assembly, which provides the different slits we will illuminate by the laser. At the far right is a light sensor, which translates left and right by turning the crank. The light sensor measures the intensity of the light received while there is a position sensor inside that records a local distance the unit is translating in mm.

General Lab Apparatus Set-Up:

The distance between the slits and the sensor should be 1.00 m. To determine this, look closely on the slit holder and you will see a reference point to get a measurement of track position. Also look at the light sensor holder.



To the left is the space in the holder for the slits, this is located at 10. cm on the track. Similarly, on the right is the holder for the light sensor you can see the light sensor is located at 110. cm. The separation between slits and screen is the required 1.00 m

On the back of the light sensor there is an aperture width, it should be set to 0.5 mm as shown below. If the sensor is not seen in your Capstone file, note the power button also in this photo and press that if needed to turn on the sensor.



Finally, the slits illuminated by the laser are at the 9 O'clock position.



The orientation on the left would have the single slit 0.02 mm wide slit illuminated, while the one on the right would be a double slit 0.04 mm wide and separated by 0.25 mm.

Be sure the laser shining on the slits makes a reasonably sharp and focused pattern on the light sensor. Rotate the crank to slide the sensor left and right and view the pattern. Run the Capstone file for this lab found on the Professor's website. Lastly be sure the light sensor's usb cable is hooked up to one of your computers and the sensor is powered on. To collect data, you will select the red record button.

Experiment #1 Two Slit Interference

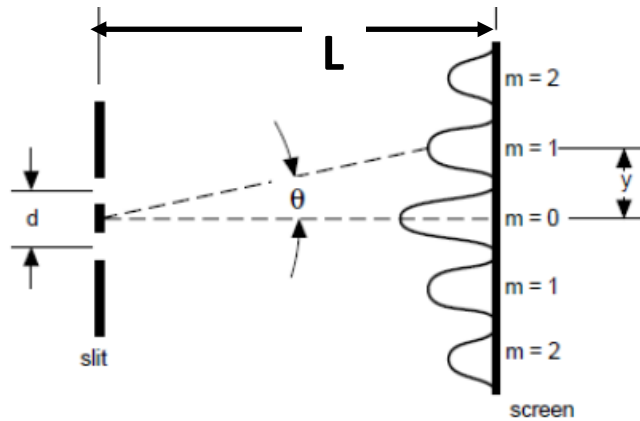
When light impinges on two slits the path from the slits to the screen is slightly different. The path difference is found to be

$$\text{path difference} = d \sin(\theta)$$

To create bright spots, we need constructive interference so the path difference must satisfy the condition that the waves arrive an integer number of wavelengths different. So we get the relationship

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

The sketch below shows the fringes and identifies the variables.



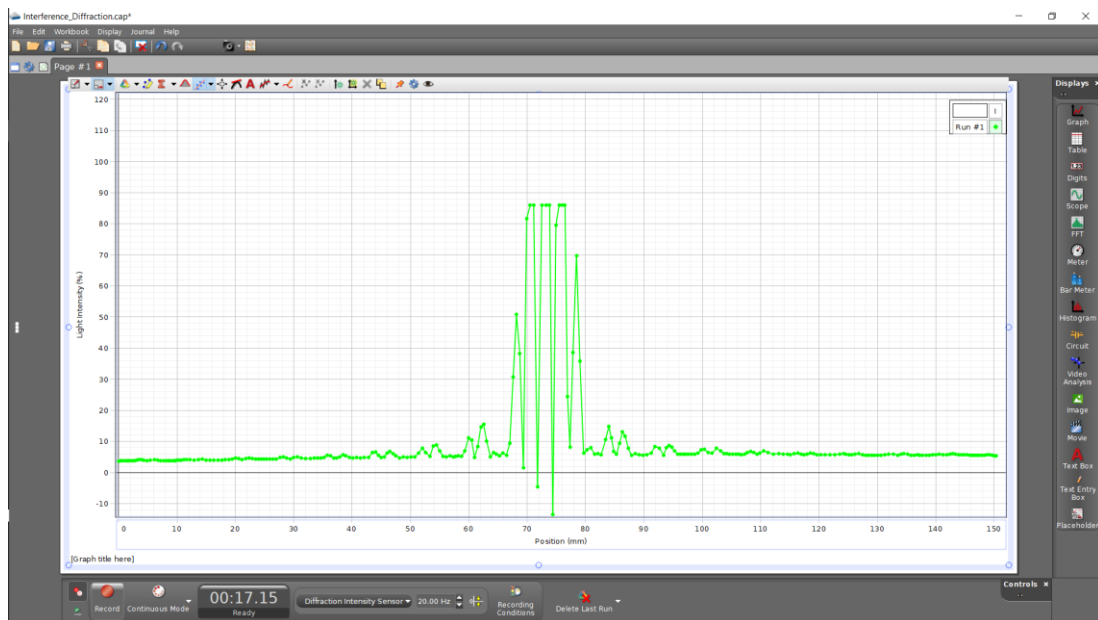
In the lab you would see the following:



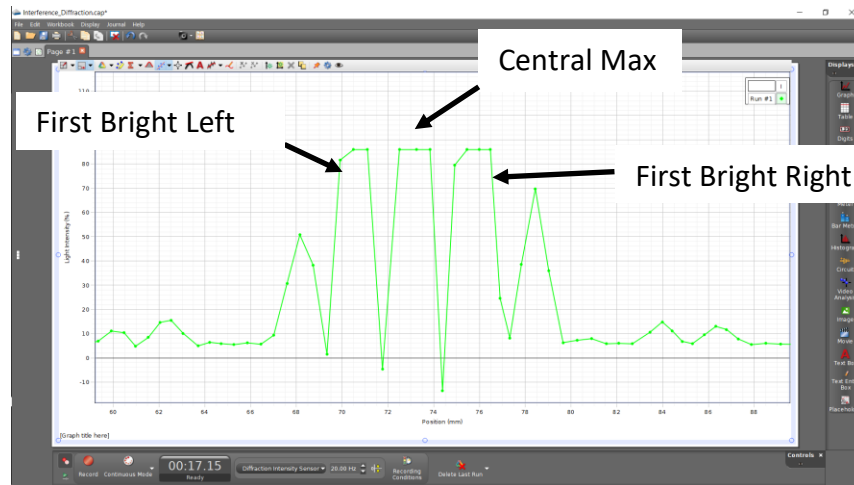
The slit shown is in front of a light sensor, which records the intensity of the light hitting the sensor. The unit moves along the track you see by a crank just off the right side of the picture. Using the Pasco Capstone Software, you can collect the light intensity data as a function of position. The unit has a rotary sensor that can be set to accurately provide a location of the sensor in mm. There are actually two lasers the red laser ($\lambda = 650 \text{ nm}$) and a green laser ($\lambda = 515 \text{ nm}$).



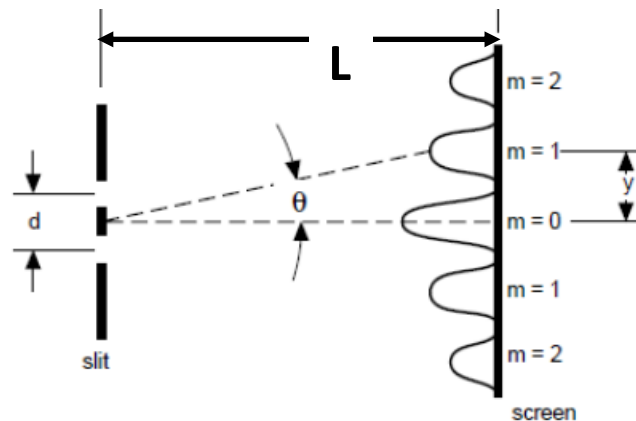
A plot of the data is shown below



To get the positions of the central max, the first bright left, and the first bright right, first expand the plot. Your lab instructor will guide you with this. You will then get something like



Now by double clicking on the plot, you should be able to bring up the cursor tool which will provide the coordinates. The x axis will be the position in mm. Try to get the center point of these peaks. Note the flat top is due to the intensity being bright enough to saturate the sensor. It would be better if the peak actually peaked, but it is time consuming to adjust the various parameters for each experimental set-up, so things are adjusted for the best for all set-ups you will do today. So, if you get flat peaks you can either eyeball the middle or find the two ends and average them to get the middle. Again, your lab instructor can guide you in this.



$$y = |P_{Central Max} - P_{First Bright}|$$

So using the positions found you can calculate the parameter y , which is the distance from the central max to the first bright either on the right or the left. Then dividing by L , the distance from the slits to the screen gives the tangent of the angle which you can use the inverse to find the angle as so:

$$\theta = \tan^{-1}\left(\frac{y}{L}\right)$$

However, Excel by default uses radians, so we must convert to degrees using the conversion factor

$$\theta_{degrees} = \theta_{radians} \left(\frac{180}{\pi} \right)$$

So in Excel use the formula

$$=ATAN(E11/SD5)*180/PI()$$

ATAN() is the inverse or arctangent function in Excel. In this case, E11 is the cell with the y distance in mm already calculated, and D5 is the cell with the slit to screen distance in mm (for 1.00 m use 1000 mm). PI() is the way Excel refers to π .

Now that you have the angle we can use the interference condition

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

Solving for slit separation d

$$d = \frac{m\lambda}{\sin(\theta)}$$

Since we are using the first bright spot we get

$$d = \frac{\lambda}{\sin(\theta)}$$

Again we need to remember trig functions in Excel use radians so to get the proper sin values we use the Excel equation to find d

$$=D7/SIN(H11*PI()/180)$$

Where D7 is the cell with the laser wavelength in mm, H11 is the angle found above in degrees and the PI()/180 is the conversion now from degrees to radians. This will provide the slit separation in mm.

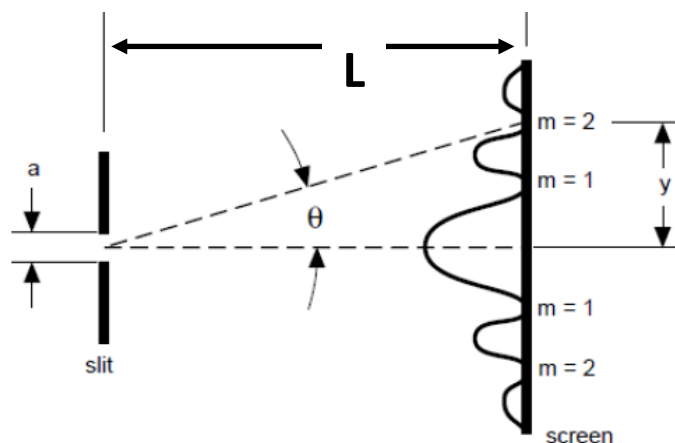
You can get the slit separation from both the Left and Right first bright. Average them and compare them with the theoretical value given and find a percent error using

$$\% Error = \frac{d_{Theory} - d_{Measured}}{d_{Theory}} \times 100$$

There are two slit separations 0.250 mm and 0.500 mm and there are two wavelengths red ($\lambda = 650 \text{ nm} = 6.50 \times 10^{-4} \text{ mm}$) and green ($\lambda = 515 \text{ nm} = 5.15 \times 10^{-4} \text{ mm}$). You will find four sets of values as indicated in the table you are completing in the Lab Worksheet.

Experiment #2 Single Slit Diffraction

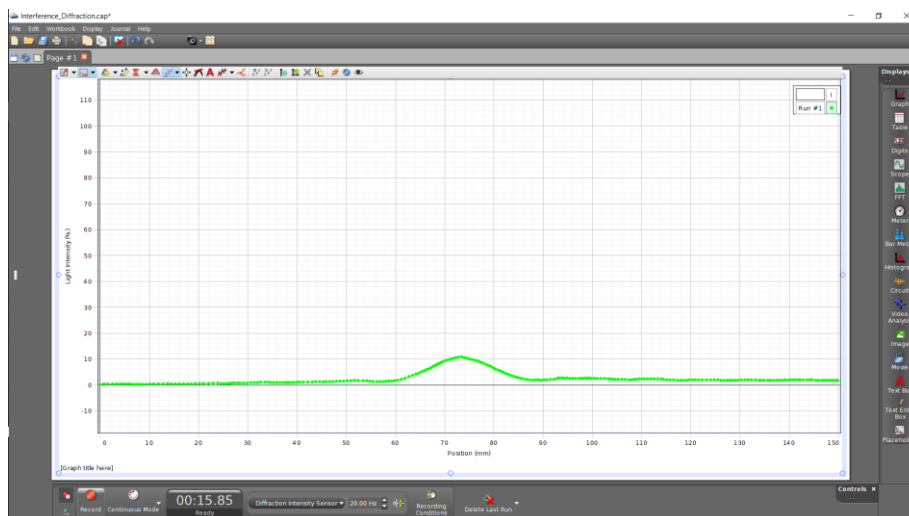
When light impinges on a single slit diffraction causes bending or a spreading of waves. The waves from one part of the slit interfere with waves from other parts and a set of light and dark spots or fringes also is created as illustrated below.



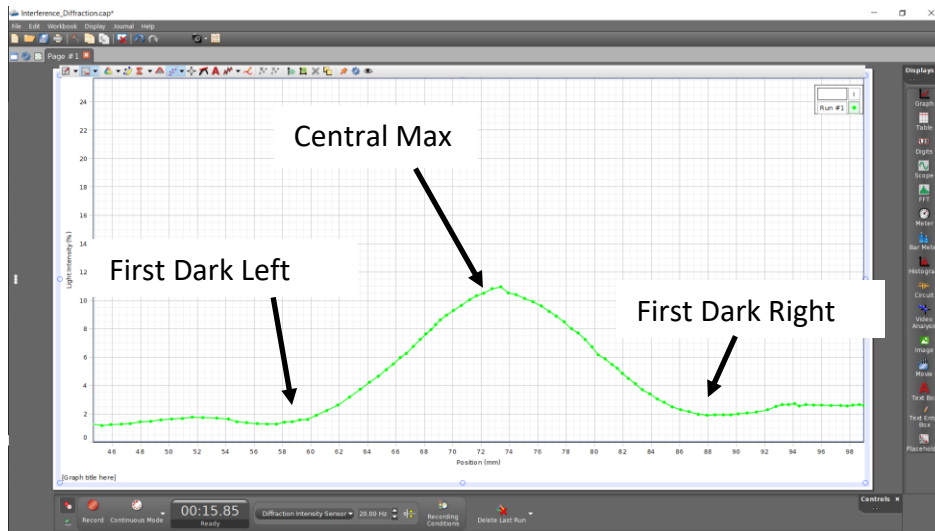
The condition this time for a dark spot and it is given by the equation

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

This experiment is very similar to the first experiment. Instead of getting bright fringe positions relative to the central max, you will get dark spots, which is where the curve is at the bottom. See the following plot



Again, as in the previous experiment expand the plot to get a better view such as seen on the next page.



Similar to what you did in Experiment #1 you put the cursor on the curve and find the position in mm of the central max and the two dark spots. Unlike the first experiment, you will have to use your best judgement of where the center of the central max is, and where the center or middle of the dark spots are. Again remember symmetry, the distances between the max and the dark spots is not likely to be exactly the same, but the two distances should not be too far off.

$$y = |P_{Central\ Max} - P_{First\ Dark}|$$

So using the positions found you can calculate the parameter y , which is the distance from the central max to the first dark either on the right or the left. Then dividing by L , the distance from the slits to the screen gives the tangent of the angle which you can use the inverse to find the angle as so:

$$\theta = \tan^{-1}\left(\frac{y}{L}\right)$$

As before we must convert to degrees using the conversion factor

$$\theta_{degrees} = \theta_{radians} \left(\frac{180}{\pi}\right)$$

So in Excel we use the formula

$$=ATAN(E11/D5)*180/PI()$$

Now that you have the angle we can use the diffraction condition

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

Solving for slit width a

$$a = \frac{m\lambda}{\sin(\theta)}$$

Since we are using the first dark spot we get

$$a = \frac{\lambda}{\sin(\theta)}$$

Again we need to remember trig functions in Excel use radians so to get the proper sin values we use the Excel equation to find a

$$=D7/SIN(H11*PI()/180)$$

Where D7 is the cell with the laser wavelength in mm, H11 is the angle found above in degrees and the PI()/180 is the conversion now from degrees to radians. This will provide the slit width in mm.

You can get the slit width from both the Left and Right first dark. Average them and compare them with the theoretical value given and find a percent error using

$$\% \text{ Error} = \frac{a_{\text{Theory}} - a_{\text{Measured}}}{a_{\text{Theory}}} \times 100$$

There are two slit widths 0.02 mm and 0.04 mm and there are two wavelengths red ($\lambda = 650 \text{ nm} = 6.50 \times 10^{-4} \text{ mm}$) and green ($\lambda = 515 \text{ nm} = 5.15 \times 10^{-4} \text{ mm}$). You will find four sets of values as indicated in the tables you are completing in the Lab Worksheet.