Diffraction and Interference

Object: To observe the interference of light in various situations, and to use this phenomenon of interference to measure the wavelength of light.

Apparatus: Two lasers, optics bench, single slit, double slit, and diffraction grating, movable screen and Light Sensor, PASCO Interface, computer, and Data Studio Software

PROCEDURE

In this experiment we will first use a diffraction grating to measure the wavelength of laser light passing through it. We will then use a special Light Sensor to measure and record the diffraction pattern created by the laser light passing through a narrow single-slit, and then a double slit. You will make a number of theoretical predictions and then compare your results with measurements taken from a printout of the diffraction patterns.

Part I. Measuring the wavelength of the laser light with a diffraction grating

1. Position the red laser such that it is approximately 90 cm from the viewing screen. The viewing screen should have a square nut and a thumbscrew to allow installation. *The viewing screen can be slid up and down the optics bench without totally removing the thumb screw. If the thumbscrew is loosened slightly, the viewing screen can be slid along the optics bench. The viewing screen can be removed from the optics bench by sliding it off the end. Again, the thumbscrew does not need to be totally removed to remove the viewing screen from the optics bench. Please take care not to lose the square nut located in the slot of the optics bench when loosening the thumbscrew. If the viewing screen Is removed from the optics bench, make sure the square nut is still securely threaded to the thumbscrew.*
2. Tape a piece of paper to the viewing screen so you can mark the diffraction patterns. Do not mark directly on the viewing screen.
3. Mount the bracket that has the Diffraction Grating taped to it on the optics bench somewhere between the laser and the viewing screen.
4. Plug in the laser and slide the switch on the back of the laser to the on position. At the very least, you should see a bright spot (Central Maximum) approximately centered on your viewing screen. Adjust the position of the diffraction grating by sliding it on the optics bench such that the 1st order dots are also visible. You should position the diffraction grating such that the distance between the 1st order dots is maximized.
5. Record the positions of the diffraction grating and the viewing screen on the data sheet. Determine the distance (L_G) between the diffraction grating and the viewing screen. Note that the brackets that snap on to the optics bench all have pointers near their bases. If you consider the edge of the pointer that is nearest the diffraction grating, the distance between that nearest edge and diffraction grating is 1.5cm.

6. Mark the positions of the Central Maximum and the 1st order dots on the paper taped to the screen. Using a ruler or vernier caliper, measure the distance ($2y_1$) between the First Order dots. Record this information on the data sheet. You may find it easier to remove the viewing screen from the optics bench to make accurate measurements.
7. Determine the distance between the slits of your diffraction grating. Using this information and your measurements, determine the wavelength of the red laser light. Note that you probably cannot use the small-angle approximation discussed in class in this part. Record the wavelength you calculated for your red laser, and use it for the rest of the lab. While the actual wavelength of the laser is not known, the **expected** range of possible wavelengths is written on the back of the laser – whether this is accurate or not, I don't know. But it doesn't matter, since you have just **calibrated** your laser.
8. If you removed it to make your measurements, remount the viewing screen on the optics bench at its previous location as recorded on the data sheet.
9. Now you will have the opportunity to make some predictions when a green laser (532 nm) is diffracted by your diffraction grating. For your predictions you should assume that your diffraction grating will start in the same position as it was in step 7 above and the wavelength of the green laser is 532 nm. Calculate the angle of the **2nd order** diffraction pattern of the green light, and where the screen must be placed in order to have the **2nd order** spots span the width of your screen (you'll have to measure the width). After you have made your predictions that are requested on the data sheet, your TA will visit your station with a green laser.
10. After your TA visits your station, carefully remove your viewing screen without losing the square nut and remove the diffraction grating from the optics bench.

Part II. Computer and Interface Setup

1. Connect the PASCO Interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Light Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Rotary Motion Sensor stereo phone plugs to Digital Channels 1 and 2 (yellow plug in channel 1).

Part III. Equipment Setup

1. Mount the red laser such that it will be pointed towards the light sensor mounted to the rotary motion apparatus. The red laser should be located approximately 90 cm from the light sensor
2. Place the bracket with the single-slit in between the laser and the light sensor. The slit should be located approximately 5 cm from the laser. If you consider the edge of the pointer that is nearest the disk containing the slits, the distance between that nearest edge and the slit is 2.5cm.

3. Turn on the **power switch** on the back of the laser. Rotate the position of the single-slit diffraction slide so that the laser beam passes through the slit marked a = 0.08 mm and forms a clear diffraction pattern. **Note:** the slit should be vertical and centered in the mounting bracket. A piece of white paper may serve as a temporary viewing screen to see the diffraction pattern.

4. Record the slit width "a" of the single-slit pattern you use on the Data Sheet.

5. Move the **Rotary Motion Sensor** until you position the Light Sensor and Aperture at the midline of the track.

6. Rotate the **Aperture** disk mounted to the Light Sensor to the slit marked number 3.

7. Using the vertical and horizontal knobs on the back of the laser, adjust the laser so the diffraction pattern is centered on the Aperture slit number 3.

8. Turn the wheel of the **Rotary Motion Sensor** until the Light Sensor and Aperture Assembly stops at the left side of the mounting bracket.

9. **You do not need to calibrate the Light Sensor.** However, set the gain switch to 10. After your first data run, if the curve is not fairly smooth, you may need to adjust the gain to 100; if the peak is blocked off at the top, you may need to set the gain from 10 to 1. When in doubt, **ask your instructor** to look at your graph before printing.

Part IV. Software Set-up

1. Start Data Studio, and select *Create Experiment.*
2. Inform the software which analog port you plugged the **Light Sensor** into by selecting the **Light Sensor** icon and dragging it to the appropriate analog port.

3. Inform the software which digital port you plugged the yellow wire of the **Rotary Motion Sensor** into by selecting the **Rotary Motion Sensor** icon and dragging it to the appropriate digital port. Note that the software will automatically indicate that the black wire is plugged into the adjacent digital port.

4. Double click on the **Rotary Motion Sensor** icon that is connected to the interface to open the *Sensor Properties* window.

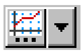
5. Under the *General* tab, Change the **Sample Rate** to 100Hz. The radio button should already be selected as **Fast (>1Hz)**.

6. Under the **Measurement** tab, uncheck the *Angular Position Ch1&2 (deg)* box, and check the *Position Ch1&2 (m)* box.

7. Click **OK**.

8. Create a graph of Light Intensity.

9. Change the x-axis from time to position by dragging the **Position Ch1&2** icon from the data section to the x axis of the graph. When the x axis is enclosed in a dotted box, drop the icon.

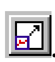
10. Double click somewhere within the body of the actual graph, or click on the **Graph Settings** button  located on the graph toolbar to open the Graph Settings window. Select the Tools tab. Under the Smart Tools, set the *Data Point Gravity* to 0. Select **OK.**

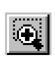
Part V. Collecting Data for the Single Slit Pattern

1. With the **Rotary Motion Sensor** positioned at the left end of the mounting bracket, click the **Start** button.

2. Slowly slide the **Rotary Motion Sensor** to move the **Light Sensor** and aperture across the Diffraction pattern.

3. When the assembly stops at the right end, click the **Stop** button.

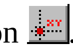
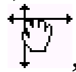
4. Click on the Graph window to make sure it is active, and maximize the window to fill the entire screen.
5. Press the autoscale button .

6. Use the Zoom Select option  to magnify the central max, and the first and secondary maximums. (When repeating this process for the Double Slit Pattern, you should include the 3rd, 4th, and 5th secondary maximums in the magnification.)

7. If the graph is very jagged, you may need to change the gain of the **Light Sensor** to 100 and re-run the Diffraction pattern again. If the central max gets “blocked”off, you may need to adjust the gain of the **Light Sensor** down and re-run the diffraction pattern again.

8. Print a copy of the graph for each member of your group.

Part VI. Analyzing the Single Slit Data

1. With the graph window active, click on the **Smart Tool** button . When the smart tool curser has the following appearance , it can be moved to any location on the graph.

2. Use the Smart Tool to determine the center of the Central Maximum, and manually record the position on your printed graph.

3. In addition, find the centers of each of the following, and manually record the values on your graph:
   a. Centers of both First Order Minimums (p = 1)
   b. Centers of both Second Order Minimums (p = 2)

4. Complete the Single Slit portion of the Data and Calculation Sheet.

5. Before beginning the next slit pattern, the data from the previous slit pattern will need to be deleted from the graph, or a new graph can be created for the new slit pattern data.

Part VII. Recording the Double Slit Pattern

1. You will now generate a diffraction pattern using a double slit. Use a double slit with a width of a = 0.08 mm and separation of d = 0.25 mm.

2. Replace the Single Slit Disk and Bracket with a Double Slit Disk and Bracket. Make sure the correct slit is positioned vertically in the center of the bracket. If you consider the edge of the pointer that is nearest the disk containing the slits, the distance between that nearest edge and the slit is 2.5cm.

3. Use the Smart Tool to determine the center of the Central Maximum, and manually record the position on your printed graph.

4. In addition, find the centers of each of the following, and manually record the values on your graph:
   a. Centers of both First Secondary Maximums (m = 1)
   b. Centers of both Second Secondary Maximums (m = 2)

5. Complete the Double Slit portion of the Data and Calculation Sheet, and do the accompanying problem. Then complete the lab cover page, addressing the questions you are asked to consider.

6. ***Before you leave your station, place all of the components on the optics bench. This should include the laser, the single slit set, the multiple slit set, the diffraction grating, and the viewing screen. The laser should be turned off and unplugged.***

NAME ____ **DATE** _______

DATA AND CALCULATION SUMMARY

Part I Diffraction Grating

Red Laser

Location of viewing screen on the optics bench…………………………… _______________

Location of Diffraction grating on the optics bench………………………… _______________

Distance from the diffraction grating to the viewing screen . . . . L_G = _______________

Distance between 1st Order Dots ……………………………………..$2y_1$ = _______________

Number of lines per unit width of the diffraction grating . . . . N = _______________

Measured wavelength of the red laser ………………………………..………λ = _______________

Range of the wavelength of the red laser as stated on the laser……………λ = ______ to _______

Green Laser

Will the spacing between the 1st order dots produced by the green laser be narrower or wider as compared to the 1st order dots produced by the red laser? Explain your prediction.

Where will the diffraction grating need to be positioned on the optics bench such that the 2nd order dots produced by the green laser will just fit on your viewing screen? Show your work.

Part II Single Slit

Distance from the single slit to the light sensor . . . . L_{SS} = _______________

Width of single slit ………………….. . . . . a = _______________

	Theoretical Value	Experimental Value	Percent Difference
Location of the 1st order minima wrt the Central Maximum			
Location of the 2nd order minima wrt the Central Maximum			

Part III Double Slit

Distance from the double slit to the light sensor . . . . L_{DS} = _______________

Width of the double slits . . . .……….. . . . . a = _______________

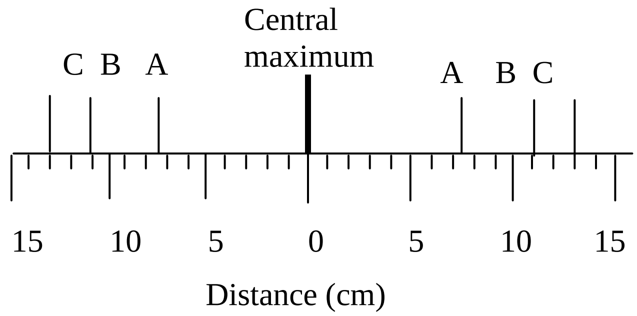
Separation between the two slits . . . . d = _______________

	Theoretical Value	Experimental Value	Percent Difference
Location of the first secondary maximum wrt the Central Maximum			
Location of the second secondary maximum wrt the Central Maximum			
Interference fringe spacing			

Before you leave your station, place all of the components on the optics bench. This should include the laser, the single slit set, the multiple slit set, the diffraction grating, and the viewing screen. The laser should be turned off and unplugged.

Follow-up Question

A diffraction grating is used to look at the spectrum of some element, as in your recent lab. The strongest spectral lines you can see are red, green, and violet. These lines for first order (m = 1) diffraction appear at the positions labeled A, B, and C on a scale on a screen, though not necessarily in that order of their colors. In this grating, the spacing between lines is 2000 nm, and the distance between the grating and the scale on the screen is 40 cm.



Note: the small angle approximation may not be very good approximation in this case, and should be avoided.

(a). Which of the three lines (A, B, or C) is:

Red? Green? Violet?

(b). What is the wavelength, in nm, of the spectral line labeled B?

(c). If the scale extended a long way to both left and right, what is the **highest** order (value of m) diffraction of the line labeled "C" you could expect to see? Give your reasoning.

PHYS 1510 Laboratory Report

Date ________________

Name ________________________ Banner ID _________________ Group ID ______________

Title of Experiment: ____

Instructions: After reading the description of the laboratory, perform the measurements for the three situations involving interference of light. Answer the questions related to the lab, and work out the problem in the back of the lab hand-out.

After answering these questions, write several sentences below that **summarize** what the laboratory was about. What did it attempt to show? In this lab, you measured the wavelength of red laser light. Do you think your measurement was close to being correct? Give two reasons why you think it was (or wasn't). What sources of error did you encounter in making your measurements or trying to analyze them? Describe the double-slit interference pattern you saw and discuss why you think it doesn't look as clear as the "perfect" ones in the book, e.g. Fig. 17.7