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Single-Slit Diffraction

Experimental Objectives

To observe the interference pattern formed by monochromatic light passing through a single slit. Compare the diffraction patterns of a single-slit and a double slit.

Use the light sensor to measure the intensity of the maxima in a single-slit diffraction pattern created by monochromatic laser light passing through a single-slit. Use the rotary motion sensor to measure the relative positions of the minima and maxima in the diffraction pattern. Use DataStudio to record and display the light intensity and the relative position of the minima and maxima in the pattern and to plot intensity versus position.

Theory

When you observe light from a single source through a single small slit the light bends or "diffracts" around the slit edges, softening the shadows and often producing maxima and minima of intensity within the geometrical shadow, where light would not go if it traveled in straight lines past the slit. The pattern of light intensity called the diffraction pattern widens as the slit is narrowed. The brightest intensity maximum is in the center of the diffraction pattern and is flanked symmetrically on either side by alternating minima and maxima.

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by $\frac{a}{2}\sin\theta = m\frac{\lambda}{2}$, (Eq. 1)

where a is the slit width, θ is the angle from the center of the pattern to the mth minimum, λ is the wavelength of the light, and m is the order.

Since θ is small, this equation may be rewritten as $\lambda = \frac{ay}{mL}$, (Eq. 2)

where L is the distance to the screen and y is the distance from the center of the diffraction pattern to the mth minimum.

Equipment Needed

Optics Bench	Light Sensor
Rotary Motion Sensor	Aperture Bracket
Linear Translator	Diode Laser
Single Slit Accessory	Double Slit Accessory

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PART A: Computer and Equipment Setup

1. The experimental apparatus has 3 plugs. Insert the yellow jack into digital input 1 of the 850 interface. Insert the black jack into digital input 2. Insert the 8 pin din plug into analog input A. Make sure the box's power button is lit.

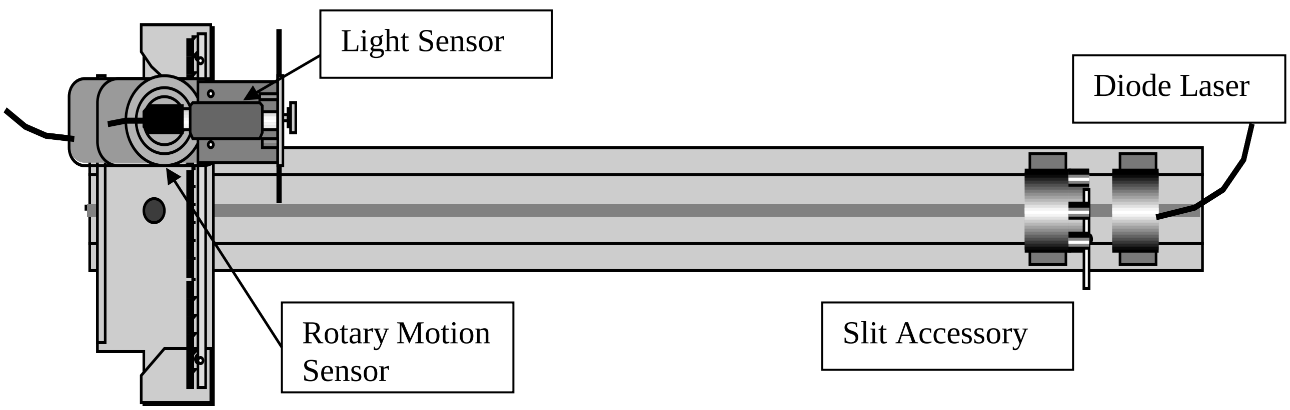
2. Double click on the Capstone icon 

3. When the software is running, click on the "Hardware Setup" icon 

4. An image of the 850 box should appear. If it doesn't, ask for assistance. On the 850 image, click on digital input 1 and choose "Rotary Motion Sensor." Click on analog input A and choose "Light Sensor." Then click again on the "Hardware Setup" icon to dismiss it.

5. Double click the graph icon  on the righthand side of the window. A graph should appear.

6. Click on <Select Measure> on the horizontal axis and choose "Position" under



"Rotary Motion Sensor." Click on <Select Measurement> on the vertical axis and choose "Light Intensity."

7. Place the linear rack with the rotary motion sensor on the end of the optics bench at the 100 cm mark. Mount the Single Slit holder at the 8.5 cm position on the optics bench.

8. Mount the light sensor onto the aperture bracket by screwing the aperture bracket post into the threaded hole on the bottom of the light sensor.

9. Put the post into the rod clamp on the end of the rotary motion sensor. Tighten the rod clamp thumbscrew to hold the aperture bracket and light sensor in place.

10. Rotate the aperture disk on the front of the aperture bracket until the number "2" slit is in front of the light sensor opening.

11. Set the switch on top of the light sensor to 100.

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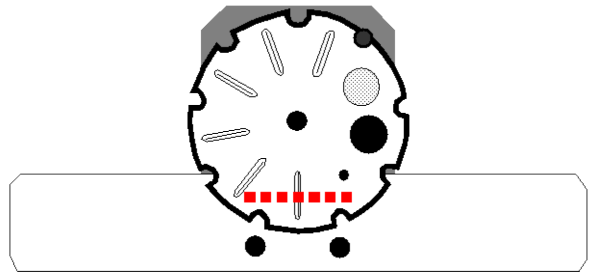
12. Turn on the power switch on the back of the diode laser. Adjust the position of the single slit set on the slit accessory so that the laser beam passes through the single-slit with a = 0.04 mm. If needed adjust the vertical and horizontal knobs on the back of the laser until you see a clear, horizontal diffraction pattern on the white screen of the aperture bracket.



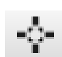
13. Move the rotary motion sensor/light sensor along the rack until the maximum at one edge of the diffraction pattern is next to the slit in front of the light sensor.

14. Place the end stop so it sits up against the rotary motion sensor, this will help you start each run from the same position.

PART B: Data Recording

1. Move the rotary motion sensor/light sensor along the rack until the maximum at one edge of the diffraction pattern is next to the slit in front of the light sensor.
2. Begin recording data.
3. Slowly and smoothly, move the rotary motion sensor/light sensor so that the maxima of the diffraction pattern move across the slit on the aperture disk.
4. When the entire diffraction pattern has been measured, stop recording data.

PART C: Data Analysis

1. Click on the  icon and choose "Add Coordinates/Delta Tool." When the tool appears, right click on it and choose "Show Delta Tool."
2. Move the main tool to the center of the central maxima.
3. Move the other part of the tool to the first minimum.
4. The delta *x* is the linear distance between positions. Record your value of the order *m* and *x* in the Data Table for each minima position.
5. Measure the distance from the single-slit accessory to the aperture bracket. Be careful to measure the positions of the slit and the aperture, rather than the brackets they are mounted on. Record in the Lab Report section as *L* in meters.
6. Repeat procedure for the single slits with a = 0.08 mm and a = 0.16 mm.

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PART D: Effect of Single Slit on width of Double Slit Diffraction

1. Using the same setup, record the single-slit diffraction pattern for a = 0.08 mm.
2. Remove the single slit set and replace with the double slit set. Record the double-slit pattern for a = 0.08 mm, d = 0.25 mm.
3. Observe the single-slit diffraction pattern superimposed on the double-slit diffraction pattern. Print your graph.

Calculations

1. Plot a graph of the linear distance y versus order m. Calculate the slope of your graph. Determine whether the relationship between y and m is linear.
2. Using the value of the slope calculate the wavelength, λ, for the laser.
3. Calculate the percent difference of your measured wavelength and the theoretical wavelength of the laser (650 nm).

Questions

1. How does the diffraction of light depend on the width of the slit?
2. Is your graph of y versus m for the single slit diffraction pattern qualitatively consistent with the small angle approximation given by Equation 2? Explain.
3. How does the intensity of the double-slit pattern vary along with the single-slit intensity?

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Lab Report

a = _______ mm   *L* = ____________ m

Order (m)	Linear Distance (y)

Wavelength, λ = ______________

% Difference = _______________

a = _______ mm   *L* = ____________ m

Order (m)	Linear Distance (y)

Wavelength, λ = ______________

% Difference = _______________

a = _______ mm   *L* = ____________ m

Order (m)	Linear Distance (y)

Wavelength, λ = ______________

% Difference = _______________