Lab Report: Interference and Diffraction of Light

Name: Date:

Instructor: Section:

Single Slit Theory:

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by

$$a \; sin\ \theta = m\lambda \quad (m = 1, 2, 3, ...) \tag{1}$$

where a is the slit width, θ is the angle from the center of the pattern to the m^{th} minimum, λ is the wavelength of the light, and m is the order (1 for the first minimum, 2 for the second minimum, . . . counting from the center out). See Figure 1a.

Since the angles are usually small, it can be assumed that

$$sin\ \theta \;\approx\; tan\ \theta.$$

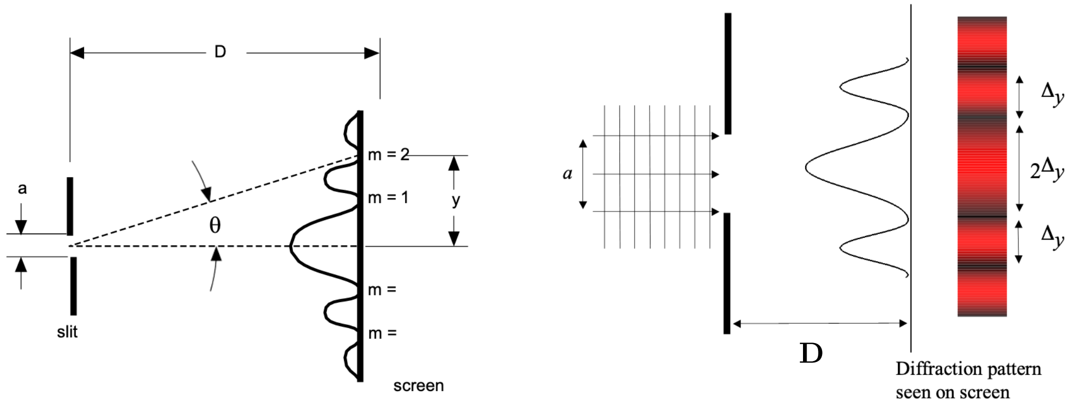
From trigonometry,

$$tan\ \theta \;=\; \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the m^{th} minimum and D is the distance from the slit to the screen as shown in Figure 1a. The diffraction equation can thus be solved for the slit width:

$$a \;=\frac{m\lambda D}{y} \quad (m = 1, 2, 3, ...). \tag{2}$$

It can be shown that the spacing between adjacent maxima or adjacent minima on the screen is $\Delta y = \lambda\ \frac{D}{a}$ except for the the dark fringes on either side of the the central maximum in a single-slit diffraction pattern which has a width of $2\Delta y$ as seen in Figure 1b.



(a) Single Slit Diffraction Pattern (b) Single Slit Diffraction on Screen

Figure 1: Single Slit Diffraction

Double Slit Theory:

When light passes through two slits, the two light rays emerging from the slits interfere with each other and produce interference fringes. The angle to the maxima (bright fringes) in the interference pattern is given by

$$d\ sin\ \theta = m\lambda \quad (m = 0, 1, 2, 3, ...) \tag{3}$$

where d is the slit separation, θ is the angle from the center of the pattern to the m^{th} maximum, λ is the wavelength of the light, and m is the order (0 for the central maximum, 1 for the first side maximum, 2 for the second side maximum, . . . counting from the center out). See Figure 2.

Since the angles are usually small, it can be assumed that

$$sin\ \theta \ \approx \ tan\ \theta.$$

From trigonometry,

$$tan\ \theta \ = \ \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the m^{th} maximum and D is the distance from the slits to the screen as shown in Figure 2. The interference equation can thus be solved for the slit separation:

$$d \ = \frac{m\lambda D}{y} \quad (m = 0, 1, 2, 3, ...) \tag{4}$$

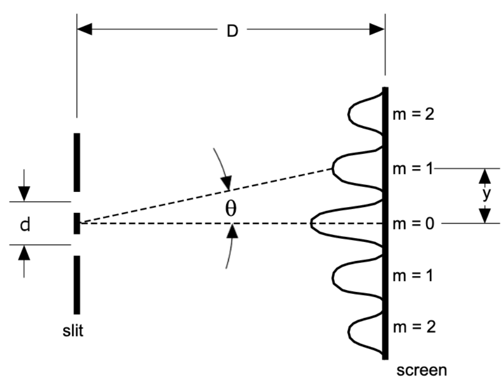
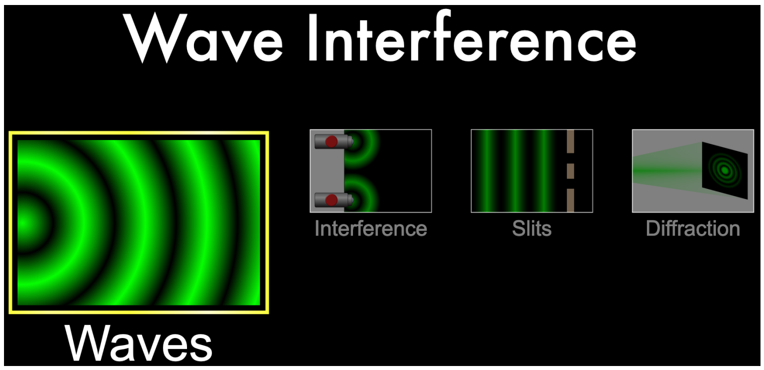


Figure 2: Interference Fringes for Double Slit

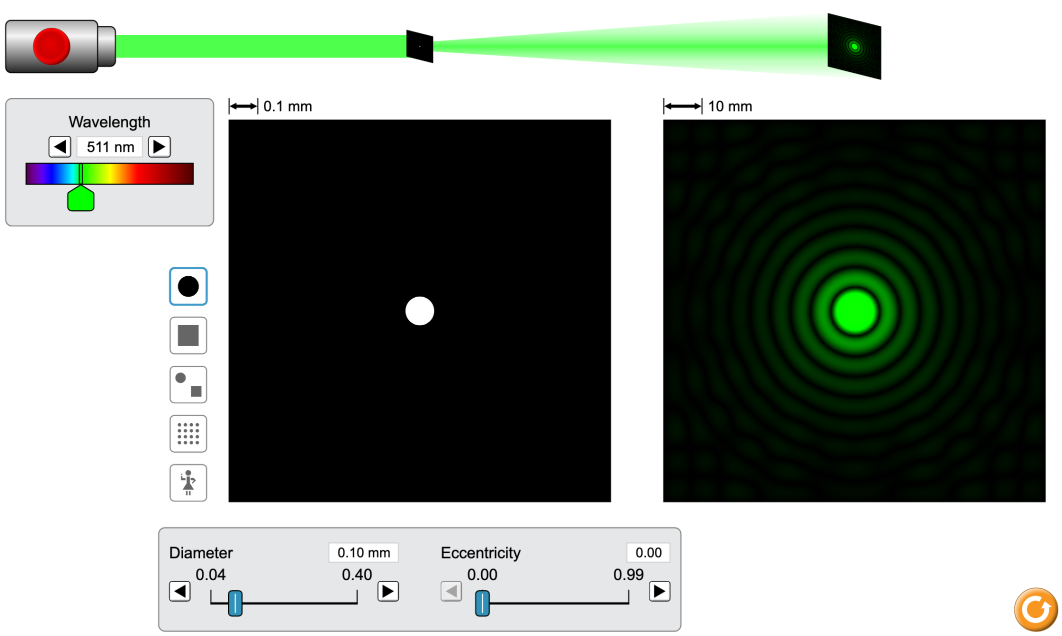
Online Experiment Setup Instructions: Interference and Diffraction of Light

1. Go to the following website:
   https://phet.colorado.edu/en/simulation/wave-interference

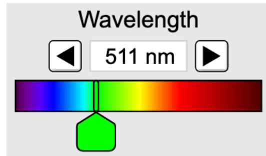
2. When the simulation page opens click "Play!". The Figure below shows an example of what you should see on your screen.



3. Click the "Diffraction" tab at the bottom of the window. Click the red button on the laser located at the upper left side of the window to Turn the laser ON.



Determine the Wavelengths of the Colors of Light



Use the slider at the upper right of the simulator to answer the following questions.

1. Drag the slider all the way to the left. This color is Violet.
   Record it's wavelength here ______ nm.
2. Drag the slider all the way to the right. This color is a Deep Red.
   Record it's wavelength here ______ nm.
3. Slowly drag the slider from the right to the left until the laser at the top turns Red.
   Record the wavelength here ______ nm.
4. Continue to drag the slider from the right to the left until the laser at the top turns Orange.
   Record the wavelength here ______ nm.
5. Continue to drag the slider from the right to the left until the laser at the top turns Yellow.
   Record the wavelength here ______ nm.
6. Continue to drag the slider from the right to the left until the laser at the top turns Green.
   Record the wavelength here ______ nm.
7. Continue to drag the slider from the right to the left until the laser at the top turns Blue.
   Record the wavelength here ______ nm.
8. As the wavelength decreases, the width of the central bright fringe (increases / decreases) ______ .
9. Use the Table below to verify your measured wavelength falls within the accepted range for each color.

Table 1: Color Wavelength Table

Color	**Red**	**Orange**	**Yellow**	**Green**	**Blue**	**Violet**
Wavelength	625 - 780	590 - 625	565 - 590	520 - 565	435 - 500	380 - 435

Single Slit

1. Click the Slits tab at the bottom of the window.
2. Click the Laser  button on the control panel to select it as the light source.
3. On the control panel located on the right, **Check** the box next to Screen and **Check** the box next to Intensity.
4. In the control panel section, click "Measuring Tape." Click on the blue circle and drag it to move it to the desired location. Click and Drag the red cross at the tail end to rotate or adjust the length of the tape.
5. Measure the distance between the slits and the screen by dragging the tape from top of the control panel and place it in front of the slit as shown in Figure 3. Place your mouse on the red cross and drag it across to the screen.

   Record the Slit-to-Screen Distance (D) ______ nm.

Figure 3: Measuring tape in front of slit.

Figure 4: Measure from the Slit to Screen.

6. Set the wavelength (color) to red. Set the slit width to 200 nm. Turn ON the laser . Slowly increase the slit width to its maximum value. What significant changes do you observe as you increase the slit width? **Hint:** One involves the Intensity Graph.
7. Does the distance between minima increase or decrease when the slit width is increased?
8. When the laser light λ increases (*e.g.* Green to Red) does distance between the minimum increase or decrease?

Double Slit

1. Change the number of Slits to Two on the control panel.

2. Verify the Laser is selected as the light source.

3. On the control panel located on the right, **Check** the box next to Screen and **Check** the box next to Intensity.

4. Turn On the Laser. Watch for several seconds as the light passes through the slits to form a fringe pattern on the screen. Observe that as light from the two slits arrives at a point on a screen, constructive or destructive interference will occur. As a result, bright and dark bands (fringes) will appear on the screen. These are known as an interference patterns.

5. Increase the slit-to-screen distance, L by moving the barrier away from the screen. Observe as the light passes through the slits and forms a fringe pattern on the screen. Decrease the slit-to-screen distance and observe. Describe the changes in the Fringe Display, the Screen and the Intensity Graph.

6. Use the measuring tape to set the Slit-to-Screen Distance (D) near 2760 nm.
   Record your actual distance here. ______ nm.

7. Set the slit separation $(d) = 400$ nm, the slit width $(a) = 600$ nm. Observe and Repeat for d to (600, 1200, 1800, 2400, 3200) nm after several seconds each.
   Describe the changes in the Fringe Display, the Screen and the Intensity Graph.

8. Reduce the wavelength by selecting a bright blue/violet color. Increase the wavelength by changing the source color to a deep red. Describe the changes in the Fringe Display, the Screen and the Intensity Graph.

9. Set the slit separation (d) to 800 nm. The average wavelength for green is $\sim \lambda = 532$ nm. Set the slit width (a) to 400 nm and very slowly increase it to 1200 nm. Describe the changes in the Fringe Display, the Screen and the Intensity Graph.

10. Light of wavelength 532 nm falls on a double slit with a slit separation of 400 nm. An interference pattern is produced on a screen at a distance, $L = 2765.0$ nm from the slits. Recall $y_m = \frac{mL\lambda}{d}$ and d Sin θ = mλ.

    (a) Calculate the separation on the screen, y_m of the two first-order (m=1) bright fringes, $2y_m$ on either side of the central image.

    Record $2y_1$ here: nm.

    (b) Calculate the separation on the screen, y_m of the two second-order (m=2) bright fringes, $2y_m$ on either side of the central image.

    Record $2y_2$ here: nm.

    (c) Calculate the angle from the center of the pattern to the first maximum (m=1).

    Record θ_1 here: nm.