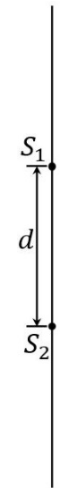
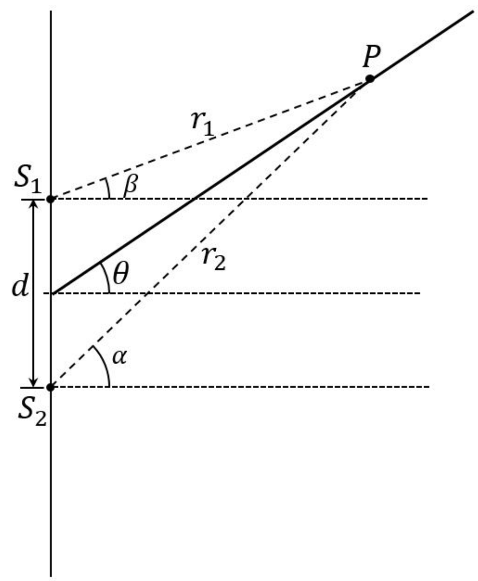
Wave Optics Module Student Guide

Activity 1: Double Slit Theory (10 minutes)



The top view diagram at right shows two point sources of sinusoidal waves. The waves travel outward in the horizontal plane away from both sources. Consider a point in the horizontal plane of the two sources. If the distance of this point from S_1 is r_1, and the distance of this point from S_2 is r_2, then we define $\Delta r=|r_2-r_1|$.

A. Sketch the sources on a piece of paper. On your diagram, indicate the regions for which the value of Δr is (i) largest and (ii) smallest. What are the largest and smallest values of Δr for this situation, in terms of source separation d? Take a photo of your diagram and include it in your presentation.



The diagram at the right shows an arbitrary point, point P, that lies near two point sources of sinusoidal waves. The two sources are in phase with each other. In this activity, we consider how the phase difference of the waves arriving at point P changes as point P is moved outward along the dark line, away from the sources.

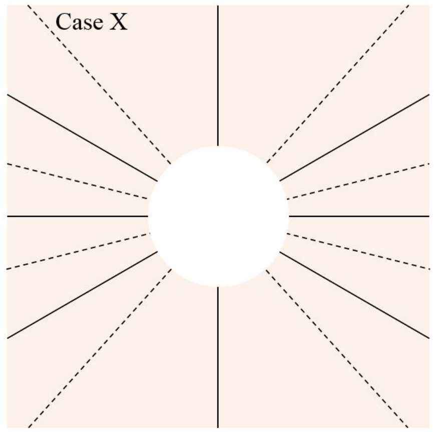
B. How do the angles α, β, and θ compare?
C. Suppose that point P is moved away from the sources along the dark line, so that θ is fixed. In the limit that point P is very far from the sources, what values do the angles α and β approach?
D. On a piece of paper which you can photograph and include in your presentation, draw an enlarged diagram of the region around S_1 and S_2 in case in which point P is very far away. In your diagram, r_1 and r_2 should be parallel. On your diagram, indicate the line segment that represents how much farther point P is from S_2 than it is from S_1. Label this distance Δr. Determine a relationship between θ, Δr, and d.

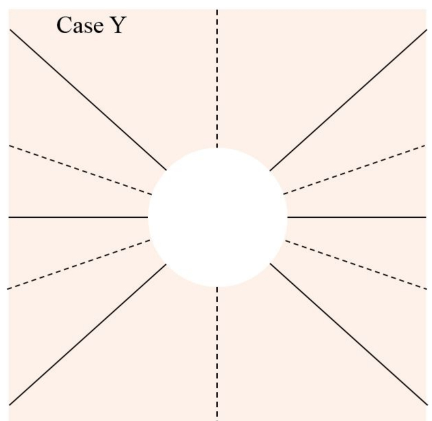
Activity 2: Two Source Interference Pattern (15 minutes)

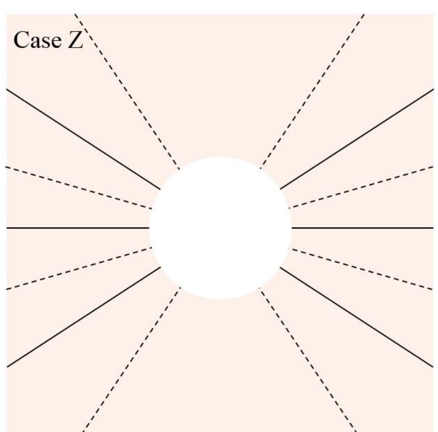
Each of the diagrams below shows all the **antinodal lines** of constructive interference (**solid**) and all of the **nodal lines** of destructive interference (**dashed**) due to two point sources. Both sources emit sinusoidal waves with the same frequency, wavelength and phase in all directions. The sources, which are not shown, lie along a vertical line near the centre of the white circle.

For each case, determine the source separation, in terms of λ. For any case(s) for which it is not possible to determine the source separation exactly, at least try to determine the range into which the source separation must fall. You may find it helpful to first rank the cases by source separation.

Explain how you determined the source separations.





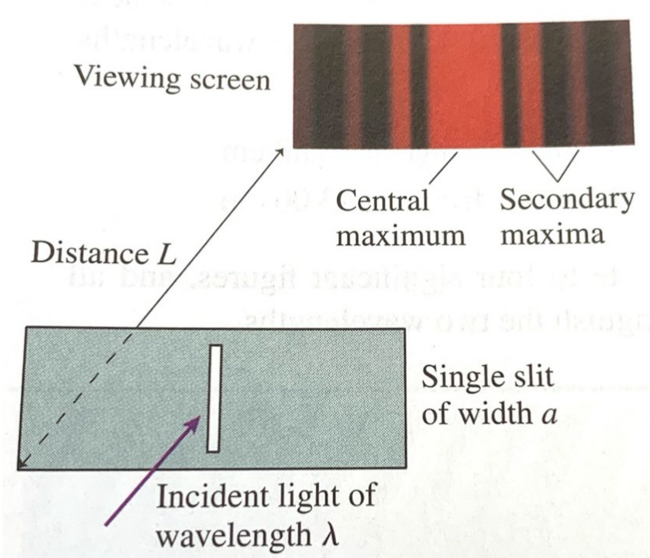


Activity 3: The Single Slit (15 minutes)

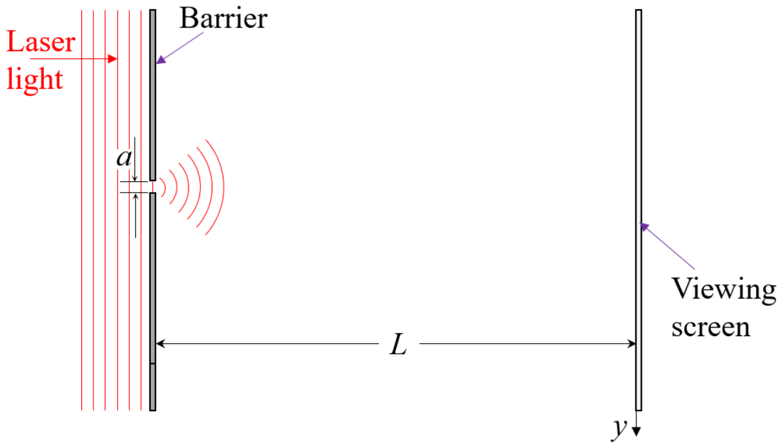
A laser is a monochromatic source of light. That means that, unlike most light, laser light contains only one colour, corresponding to a single wavelength. In this activity and the next you will use data from a PASCO OS-8525A Red Diode Laser, shown in the photo on the right.

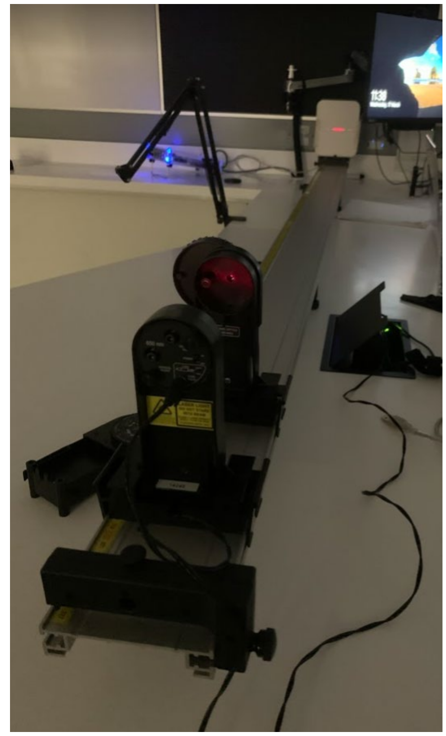
When you shine a laser onto a narrow slit in an opaque barrier, the barrier forms a shadow, and the slit acts as a window, allowing some laser-light through. When you observe the light that ends up on a white screen far from the slit, you notice something interesting. Instead of a shape that is like an image of the slit, there is a central bright region, and some dark and bright stripes on either side. (See Figure 33.11 from Knight pg.940.)

FIGURE 33.11 A single-slit diffraction experiment.

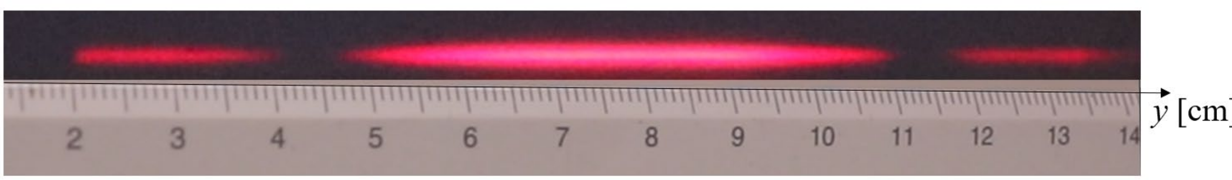


The laser light was shone on a tiny slit of width $a = (0.040 \pm 0.001)$ mm, and the pattern was observed on a viewing screen that was a distance of $L = (1.930 \pm 0.001)$ m away from the slit.





The schematic diagram shows the situation as viewed from above. The width of the slit is a, and on the viewing screen is the y-axis, which points down in this top-view. The photograph shows the actual experiment. The slit is vertical in this view, so it's width is measured horizontally. On the viewing screen, the y-axis goes to the right in the photograph. Below is a close-up image of the viewing screen, with a cm-ruler taped to it.



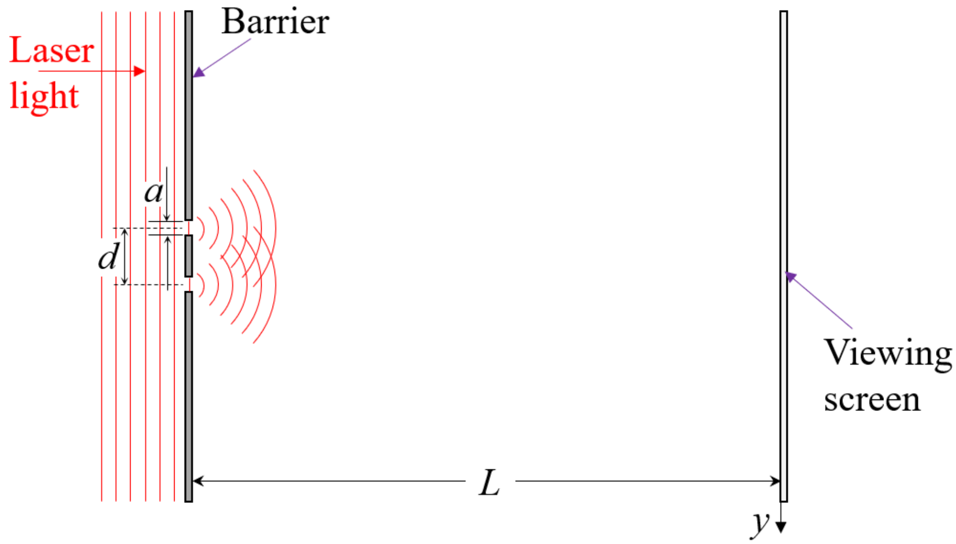
The analysis of the single-slit shows that the width, in the y-direction, of the central bright fringe is given by Eq.33.22:

$$w = \frac{2\lambda L}{a}$$

Here the width w is defined as being the distance between the first dark fringes on either side of the central maximum. From these data, estimate the wavelength of light. Compare your result to the wavelength listed on the yellow "LASER LIGHT DO NOT STARE INTO THE BEAM" sticker on the laser itself.

Activity 4: The Double Slit (15 minutes)

When laser light is shone on a barrier with two parallel narrow slits, each of width $a = (0.040 \pm 0.001)$ mm, separated by a distance $d = (0.50 \pm 0.01)$ mm, a different pattern is seen on the viewing screen the same distance $L = (1.930 \pm 0.001)$ m away from the slits. The single-slit pattern from Activity 3 is still seen, but it is split into a lot of interference fringes. The whole pattern is, on average, twice as bright, since there are now two slits open instead of one. However, the interference fringes cause the actual brightness to alternate between being 4-times as bright, and completely dark.



The spacing between interference fringes is approximately constant, and is given by Eq.33.6:

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

Count fringes in the image to try to determine Δy, and, from this, determine the wavelength of light from these data. Compare with your result from Activity 3. Which method is more precise, the single-slit or double-slit measurement?

This module was first written by Jason Harlow and Andrew Meyertholen in May 2016, adapted for online learning by Jason Harlow in March 2021. Activities 1 and 2 are adapted from "Tutorials in Introductory Physics" 1st edition by Lillian C. McDermott, Peter S. Shaffer and the Physics Education Group, Department of Physics, University of Washington (C)2002 by Prentice-Hall, Inc.