

## Lab 08 - Wave Nature of Light

NAME: \_\_\_\_\_

**Time spent on Lab 08**= approximately 2 hours, does not need to be done at one sitting

**Materials needed**= Access to computer and high speed internet, Java installed on the computer

### Learning Objectives:

- Use geometry to manipulate sources of light
- Analyze the results of the this manipulation to interpret physical properties

First proceed to the following website and download the Java file:

<https://phet.colorado.edu/en/simulation/wave-interference>

Once the Java file is open, you should see something like the screenshot below:

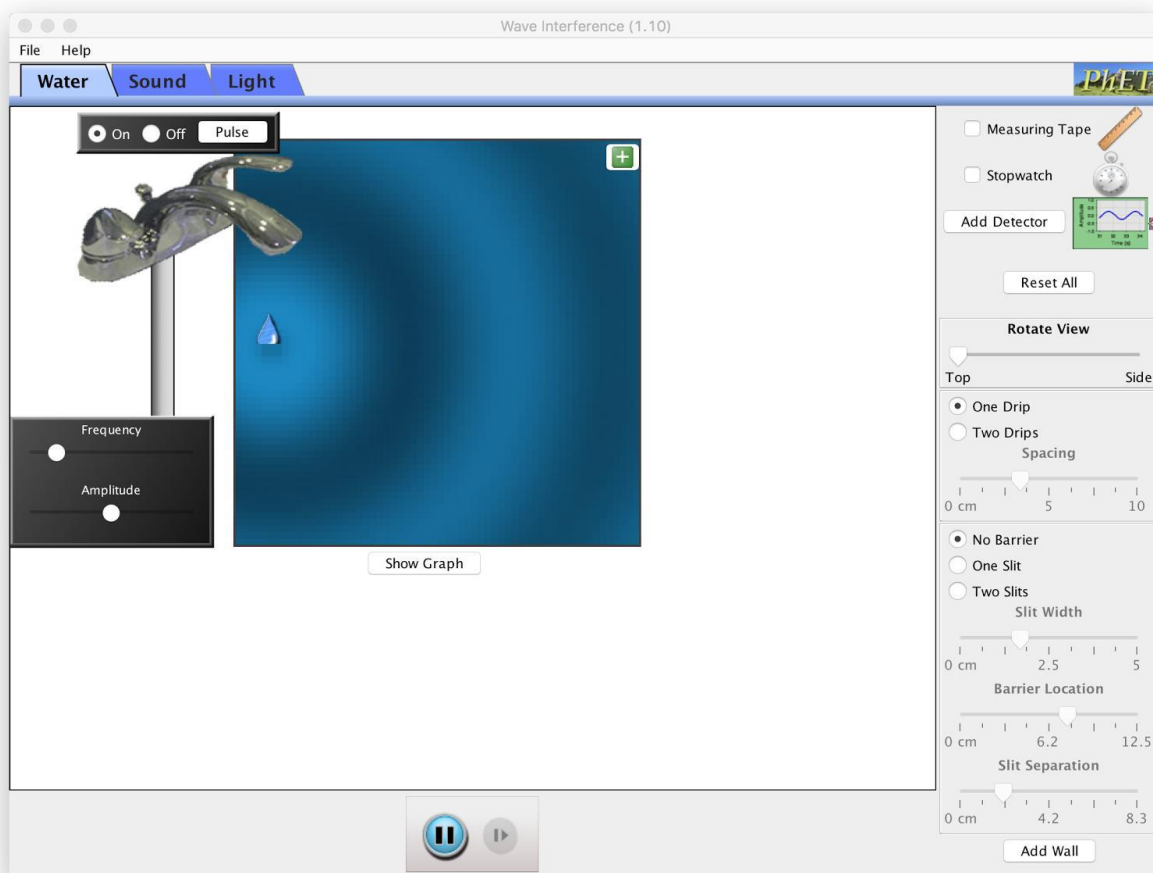


Figure #1

Before we begin experimenting with light, take a few minutes to watch this video:

[https://www.youtube.com/watch?v=J\\_xd9hUZ2AY](https://www.youtube.com/watch?v=J_xd9hUZ2AY)

And keep the simulator on the first tab to experiment with creating water waves!

The photograph below shows the interference of two water waves produced by two coherent sources operating at the same frequency and in phase. The waves travel outward at a constant speed from the two sources at the center bottom of the picture.

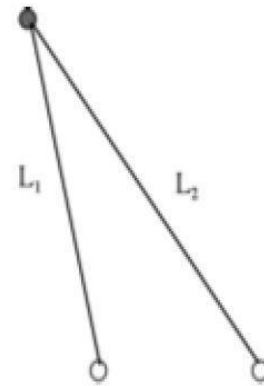
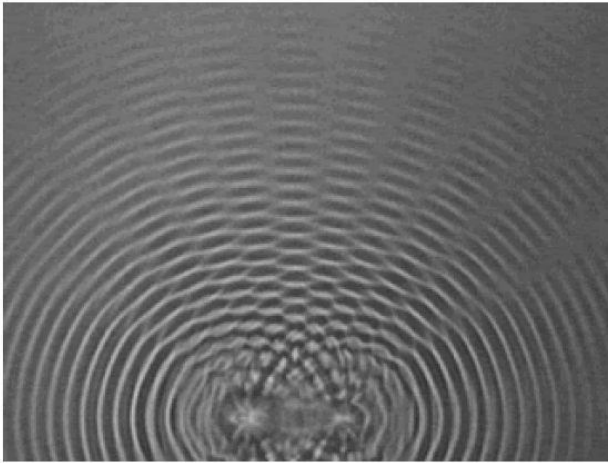


Figure #2

1. Describe the pattern produced by the interfering waves.

The pattern produced by the interference wave from the two sources in phase is that of crests and troughs in step with one another resulting in an interference pattern along the lines. When the waves from the two sources are out of phase, the resulting crests and troughs are out of step with one another producing interference fringes of minimum and maximum wave motion.

Now in the simulator, select "Light" as the wave source. There should now be one light source producing a red wave as shown below:

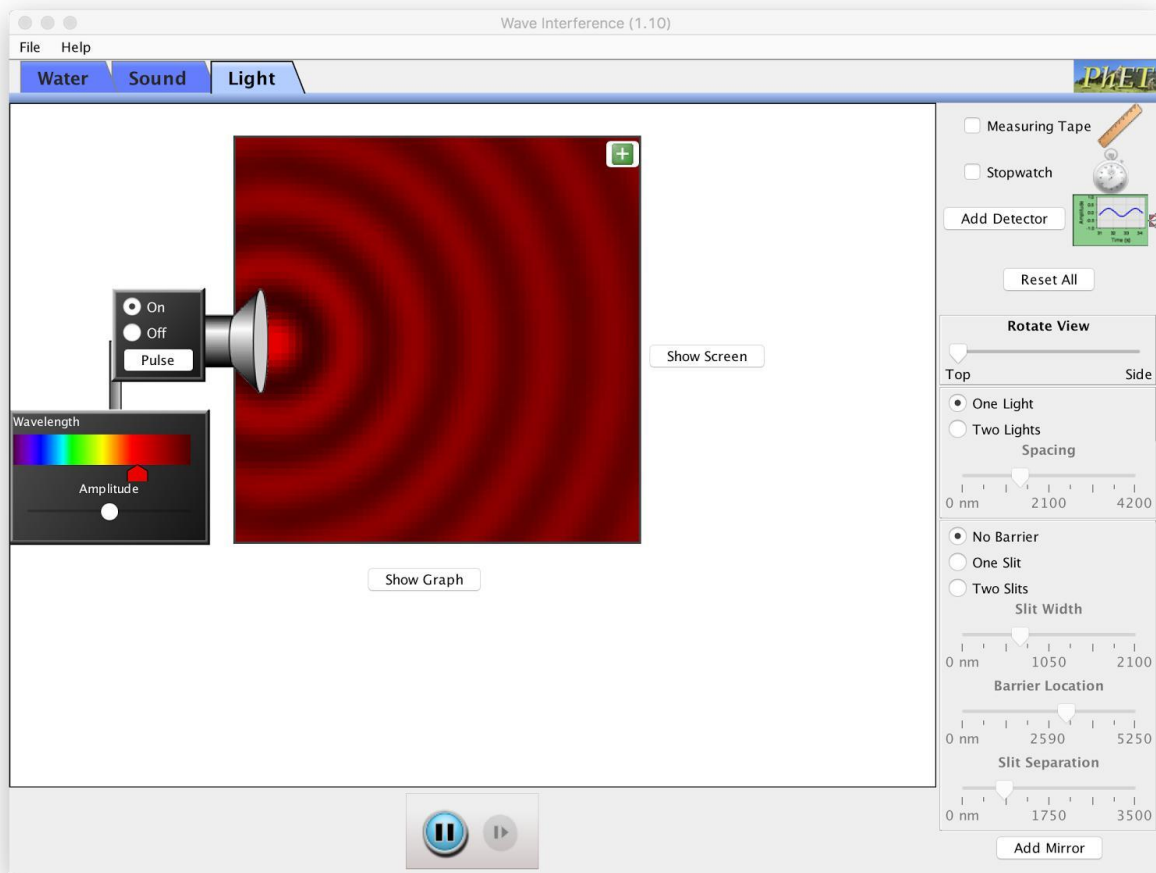


Figure #3

This is a top down view depicting the peaks of circular light waves as red rings and the troughs of these circular waves as the black rings.

2. Measure the wavelength of the light wave being produced. You will want to use the simulator's measuring tape.

780.73nm

3. Turn on the second light source. Explore the effect of changing the separation between the two sources on the interference pattern. Describe your observations.

When the two sources are moved further apart, there are more lines produced per a area and lines are closer together. When the two sources are moved closer to each other, lesser lines that are further apart are observed.

Now set the source separation to be  $3.5 \times$  the wavelength you measured in #2.

4. Locate two positions of maximum field movement above the central point. Using the simulation's tape measure, precisely measure the distance from each source to each maximum as shown in figure #2. Organize your data in the table below. You may want to expand the simulator size for ease of measuring, and "show the screen" to better view where maximums occur.

| Measurement # | $L_1$     | $L_2$     | $L_2 - L_1$ | $(L_2 - L_1)/\lambda$ |
|---------------|-----------|-----------|-------------|-----------------------|
| 1             | 557.83nm  | 628.76nm  | 70.93       | 0.0909                |
| 2             | 854.75nm  | 984.66nm  | 129.91      | 0.1665                |
| 3             | 1150.61nm | 1559.76nm | 409.15      | 0.5241                |

5. Calculate the difference in the distance of each source to each maximum, then divide by the wavelength, and record your answers in the last column of the table above.

6. What relationship between the differences and the wavelength best describes your data? Why?

a.  $L_2 - L_1 = n\lambda$ , where  $n = 0, 1, 2, 3, \dots$   
 b.  $L_2 - L_1 = (n + 0.5)\lambda$ , where  $n = 0, 1, 2, 3, \dots$

If the path difference is integrated with multiples of  $\lambda$ , maximum integration occurs on the screen. Path difference =  $0, \lambda, 2\lambda, 3\lambda$  and  $L_2 - L_1 = n\lambda$  where  $n = 0, 1, 2, 3, \dots$

7. Now locate two positions of minimum field movement above the center. Measure the distance from each source to each maximum. Organize your data in a table.

| Measurement # | $L_1$   | $L_2$   | $L_2 - L_1$ | $(L_2 - L_1)/\lambda$ |
|---------------|---------|---------|-------------|-----------------------|
| 1             | 3621.54 | 3672.91 | 51.37       | 0.0658                |
| 2             | 3428.85 | 3567.51 | 138.66      | 0.1776                |

8. Calculate the difference in the distance of each source to each minimum, then divide by the wavelength, and record your answers in the last column of the table above.

9. What relationship between the differences and the wavelength best describes your data? Why?

- a.  $L_2 - L_1 = n\lambda$ , where  $n = 0, 1, 2, 3, \dots$   
 b.  $L_2 - L_1 = (n + 0.5)\lambda$ , where  $n = 0, 1, 2, 3, \dots$

In order to get minimum intensity at a point on the screen, the path difference must be equal to half integral multiples of  $\lambda$ .  $L_2 - L_1 = \lambda/2, 3\lambda/2, 5\lambda/2$ . Therefore,  $L_2 - L_1 = (n + 1/2)\lambda$  where  $n = 0, 1, 2, 3, \dots$

The two-slit experiment is a method of producing two sources of coherent light waves, which can interfere with each other. A source of monochromatic light of wavelength  $\lambda$  is incident on two slits separated by a distance  $d$ . A screen is placed a distance  $L$  away. A diagram below illustrates this experimental setup.



Figure #4

10. Imagine plane waves (light waves from a distant source or from a laser) hitting the two slits on the left. Why might you consider the waves emerging from the slits to be from two coherent sources of light waves?

The two slits act as two separate sources of light which are coherent. It is because they are derived from the same original source. Even if there is any fluctuation in the phase of the original light source, it manifests itself in both slit sources hence they are said to be locked in phase and are always coherent. This was the same principle used by young in his double slit experiment.

11. We want to predict the positions  $P$  that will give us either a dark spot or a bright spot. Let's step through the argument for predicting a maximum. In the picture below, identify *only* the path length *difference* between the light reaching  $P$  from the two slits. Indicate it with the Greek letter  $\Delta$ .

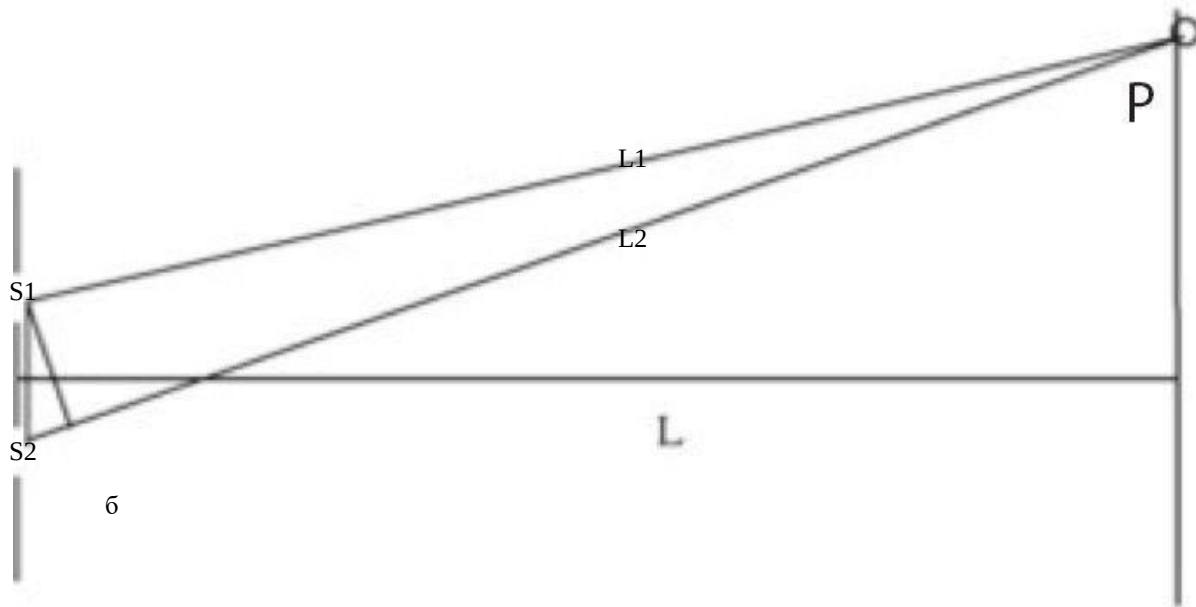


Figure #5

12. If the point P is a maximum then what must the path length difference,  $\delta$ , be in terms of the wavelength? (Recall your work in the data tables above)

If the path difference  $\delta$  is equal to integral multiple of  $\lambda$ , then the maximum intensity at P i.e.  $L_2 - L_1 = 0, \lambda, 2\lambda, 3\lambda \dots$

$L_1 = 0, \lambda, 2\lambda, 3\lambda \dots$

$\delta = n\lambda$ , where  $n = 0, 1, 2, 3 \dots$

Figure #6

13. Now express  $\delta$  in terms of  $d$  and  $\sin \theta$ .

Path difference  $\delta = BC$  from a  $\triangle ABC$ ,  $\sin \theta = BC/AB$  hence  $BC = AB \sin \theta = d \sin \theta$

14. Combine your expressions in 12 and 13, and write the resulting equation in the space below.

If the path difference is integral multiples of  $\lambda$ , then the maximum intensity formed  $\delta = n\lambda$ ,  $n = 0, 1, 2, 3 \dots$  therefore  $d \sin \theta = n\lambda$ ,  $n = 0, 1, 2, 3 \dots$

15. Now, using the small angle approximation,  $\theta \approx \sin \theta \approx \tan \theta$ , for angles less than about  $20^\circ$ , solve for  $y$  (the position on the screen) in terms of  $L$  and  $d$ .

$y = d/2 \sin \theta$ ,  $\tan \theta = Ld/2$  which is equal to  $\theta$  for small angles. This implies that  $y = d/2 \sin \theta$   
 $Ld$

16. What is the equation that gives the positions of the minimums along the screen?

$y = d/2 \sin \theta$

17. If you increase  $d$ , the distance between the slits, what should happen to the bright spots on the screen?

The number of bright spots increases because the wave have more time to interact and interfere creating a pattern which is much more spread

In summary, waves can interfere with one another and produce constructive and destructive interference fringes. And when light waves pass through slits that are small compared to the wavelength of the light, the waves can spread out and actually bend around corners! In this case it does not produce a nice shadow of the slit as you might expect but behaves more like

sound waves bending around a doorway (where the width of the doorway is comparable to the wavelength of the sound wave). Any time light waves encounter a very sharp edge or a very small opening a diffraction pattern can develop like the one seen above. If there is time, have your instructor show you the diffraction pattern from a CD or a diffraction grating.

- Portions of this lab were taken from ©Humanized Physics Project (HPP), Doane University.

**Once you have completed all lab questions, please download this document as a PDF only! Then upload this PDF to Blackboard under the assignment “Lab 08”, for grading.**