Name____________________________________ Section_____________ Date__________

CONCEPTUAL PHYSICS: Hewitt/Baird **Tech Lab**

Light Waves Interference Pattern Geometry

The Fringe of Optics

Purpose

To construct the mathematical relation describing interference patterns

Apparatus

computer PhET simulation: "Wave Interference" (available at http://phet.colorado.edu)

Note: it's helpful if there is a means to magnify/zoom the image on the screen. If there is, write the key combination here:

Discussion

The modern study of light began in the late 1600s and early 1700s with Isaac Newton in England and Christiaan Huygens in the Netherlands. Newton theorized that light consisted of particles. Huygens theorized that light consisted of waves. In 1801, Thomas Young offered convincing evidence for the wave model of light when he demonstrated that light could produce an interference pattern.

Because light wave interference produces bands of light and dark, the results are often referred to as *fringe* patterns. The pattern produced depends on the characteristics of the light and the arrangement used to produce it. The "Wave Interference" simulation allows us to manipulate the light and interference arrangement. By observing the consequences of these manipulations, we can put together the mathematical expression that relates the various variables to one another.

Procedure

INITIAL SETUP

Step 1: When the simulation opens, maximize the window so that it occupies as much screen area as possible. Then click the tab labeled "Light". Use the button at the bottom of the simulation window to pause the animation.

Step 2: In the main (animation) section of the simulation window, activate the screen. Then activate the intensity graph. Then maximize the wave animation by clicking the green box with the "+" symbol.

Step 3: In the control panel section of the simulation window, activate the two-slit barrier. Set the slit width to 525 nm (the second tick mark past zero on the slider). Set the barrier distance to 2590 nm (fourth tick—midpoint on the slider). Set the slit separation to 1750 nm (the midpoint on the slider).

Step 4: Play the animation (un-pause the simulation).

Step 5: In the light source controls (lower left side of the window), change the color to yellow-green (set the selector to the boundary between yellow and green). Watch for several seconds as the light passes through the slits to form a fringe pattern on the screen.

Step 6: In Part A, we want to observe changes in the fringe pattern. The pattern may narrow or widen. That is, the peaks (maxima) and valleys (minima) may get closer together or farther apart. As a means for comparison, place a marker on the graph as follows (and as shown in Figure 1):

a. In the control panel section, click "Measuring Tape." Drag the tail end up so the tape is vertical.

b. Move the tape base so that its red crosshairs mark the minimum immediately below the central maximum on the vertical scale of the intensity graph. (If zoom/magnification is possible, do so now.)

c. Move the end of the tape so that it marks the minimum directly above the central maximum.

More curriculum can be found in Pearson Addison Wesley's **Conceptual Physics Laboratory Manual: Activities · Experiments · Demonstrations · Tech Labs** by Paul G. Hewitt and Dean Baird. ISBN: 0321732480

The space indicated by the tape measure is actually a minimum-to-minimum distance, but it serves as a good "proxy" for the distance *y* in Figure 1. A pattern with a larger *y* would also have a greater minimum-to-minimum distance.

Step 8: (Zoom back out.) The initial setup should resemble the configuration in Figure 1 below.

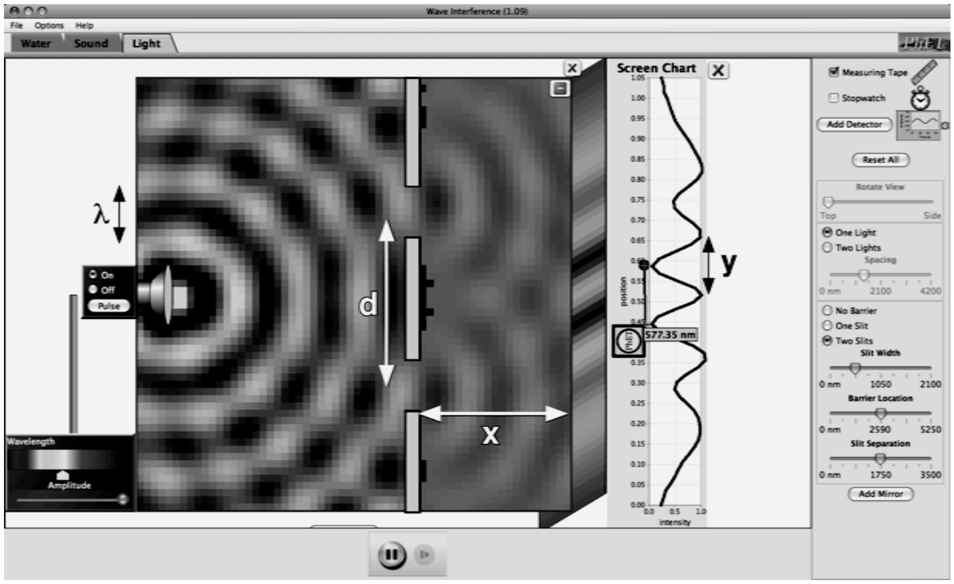

Figure 1. Two-slit interference pattern.

Match each letter shown in the figure to the correct distance description.

d ·	· *the space from one wave crest to the next*
λ ·	· *the distance from central maximum to first-order maximum*
x ·	· *slit-to-screen distance*
y ·	· *the slit separation*

PART A: VARYING THE VARIABLES

Step 1: Amplitude: *A*.

a. Increase the amplitude to its maximum value using the light source amplitude control. Allow several seconds for the high-intensity light to travel to the screen. Record your observations.

b. What difference—if any—does increasing the amplitude *A* have on the fringe pattern spacing *y*?

y ~ A   y ~ 1/A   y does not depend on A

c. Based on your conclusion, ***reducing*** the amplitude will cause the pattern to

contract (decrease y).   expand (increase y).   remain the same.

d. Reduce the amplitude to one-fourth the maximum value. Doing so makes the amplitude less than it was in the initial setup. Describe the result and state whether or not it is consistent with your conclusion.

e. Set the amplitude to full and leave it there for the remainder of the experiments.

Step 2: Slit-to-Screen Distance: x. Examine Figure 1 to review the location of x in the configuration.

a. ***Increase*** the slit-to-screen distance by moving the barrier ***away*** from the screen. Notice that the sim's "Barrier Location" values indicate distance from the front wall of the light chamber, while slit-to-screen distance is the distance from the barrier to the screen. To increase x, we decrease the "Barrier location" value. Set the barrier near 1300 nm (second tick mark past zero). Record your observations.

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b. What difference—if any—does increasing the screen distance x have on the fringe pattern spacing y?

$y \sim x$ $y \sim 1/x$ y does not depend on x

c. Based on your conclusion, ***reducing*** the screen distance will cause the pattern to

contract (decrease y).   expand (increase y).   remain the same.

d. Move the barrier to the fifth tick mark past zero (approximately 3240 nm). Doing so makes the screen distance smaller than it was in the initial setup. Describe the result and state whether or not it is consistent with your conclusion.

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e. Return the barrier to a distance 2590 nm from the source so that the initial setup is restored.

Step 3: Slit Separation: d. Examine Figure 1 to review the location of d in the configuration.

a. Increase the slit separation to 3500 nm (maximum setting). Record your observations.

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b. What difference—if any—does increasing the slit separation d have on the fringe pattern spacing y?

$y \sim d$ $y \sim 1/d$ y does not depend on d

c. Based on your conclusion, ***reducing*** the slit separation will cause the pattern to

contract (decrease y).   expand (increase y).   remain the same.

d. Reduce the slit separation to approximately 875 nm (second tick mark past zero). Doing so makes the slit separation smaller than it was in the initial setup. Describe the result and state whether or not it is consistent with your conclusion.

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e. Return the slits to a separation of 1750 nm so that the initial setup is restored.

Step 4: Wavelength: λ. Examine Figure 1 to review the distance λ in the configuration.

a. Increase the wavelength by changing the source color to a deep red. Set the point of the color selector approximately one centimeter from the far right end of the spectrum. Record your observations.

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b. What difference—if any—does increasing the wavelength λ have on the fringe pattern spacing y? If zoom/magnification is possible, engage it to inspect the minimum-to-minimum distance relative to the tape measure. The tape measure shows the minimum-to-minimum distance for yellow-green light.

$y \sim \lambda$ $y \sim 1/\lambda$ y does not depend on λ

c. Based on your conclusion, ***reducing*** the wavelength will cause the pattern to

contract (decrease y). expand (increase y). remain the same.

d. Reduce the wavelength by selecting a bright blue/violet color. Doing so makes the wavelength shorter than it was in the initial setup. (If the central maximum is not well defined, try reducing the slit width a little bit.) Describe the result and state whether or not it is consistent with your conclusion.

e. Return the color to yellow-green (and the slit width to 525 nm) so that the initial setup is restored.

PART B: MANIPULATING THE MATH

Step 1: Write a ***single*** proportionality that summarizes all the findings from Part A.

Step 2: Move the barrier to approximately 1300 nm (second tick past zero) from the source and observe the expected change in the fringe pattern. Now restore the spacing of the initial setup by changing ***only*** the slit separation. Do not move the barrier and do not change the source color. Zoom may be helpful here.

a. How did you succeed?

b. How does the proportionality support this solution?

Step 3: Restore the slit separation to the initial set up value (1750 nm). The pattern is once again as observed in Step 2. Now restore the spacing of the initial setup by changing ***only*** the wavelength of the source. Do not move the barrier and do not change the slit separation. Zoom may be helpful here.

a. How did you succeed?

b. How does the proportionality support this solution?

Step 4. Quit/Exit the simulation.

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Summing Up

Answer the following questions without the use of the simulation.

Original Arrangement: See Figure 1

Suppose that light with a certain wavelength λ were shining on a pair of slits some distance *d* apart. On a screen some distance *x* from the slits, an interference pattern is produced. The space from the central maximum to the first-order maximum is *y*.

1. Describe ***three different*** changes you could make to the Original Arrangement that would make the pattern wider (increase *y*).

a. ______________________________

b. ______________________________

c. ______________________________

2. Suppose the wavelength in the Original Arrangement were decreased.

   a. What would happen to the spacing of the pattern?

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   b. With the wavelength decreased, how could the screen be moved so as to restore the original spacing of the pattern?

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3. Suppose the slit spacing in the Original Arrangement were increased.

   a. What would happen to the spacing of the pattern?

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   b. With the slit spacing increased, how could the wavelength of the light be changed so as to restore the original spacing of the pattern?

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