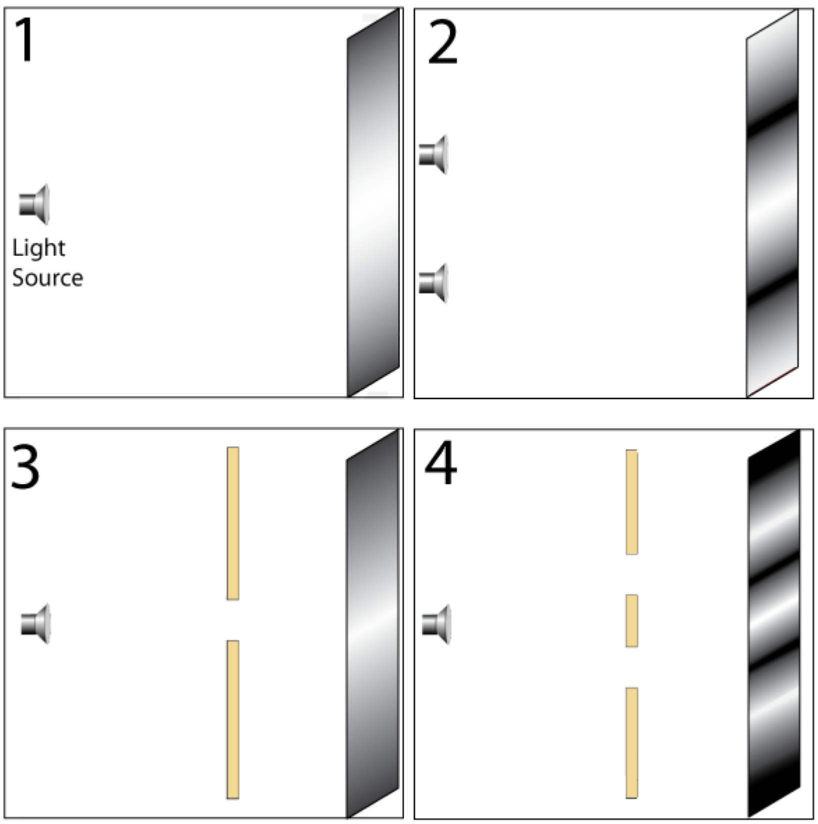
Physics 2020
Lab 13
Wave Interference

Name					
Section		Tues	Wed	Thu	
	8am	10am	12pm	2pm	4pm

Introduction

Consider the four pictures shown below, showing pure yellow lights shining toward a screen. In pictures 3 and 4 below, there is a solid wall between the light and screen, with one or two slits cut in to let the light through. Compare the four scenarios.

- What do you think might be happening to the light to create these different patterns? Discuss with your group and write your ideas in the space below.



Part 1: Wave Interference Simulation

A. Open the PhET simulation “Wave Interference.” Explore the simulation to get a feel for the controls.

- Try to recreate the pictures shown on page 1 with the simulation. Describe what you had to do with the simulation to reproduce the pictures.

- Compare what you learned from the simulation to your ideas from page 1. Which ideas would you keep? What ideas would you change? *(Did you notice the third bright spot right behind the wall in case 4?)*

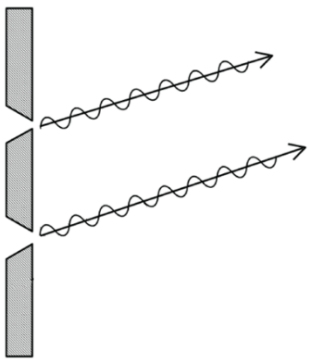
- What happens to the pattern on the screen when the *lights* are brought closer to each other?

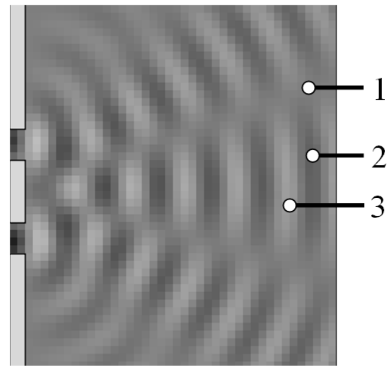
- What happens to the pattern on the screen when the *lights* are farther apart?

- What happens to the pattern when the *slits* are brought closer and farther apart?

B. Interference from Two Slits

The pictures below show two ways of representing light waves from two slits. On the right picture, three points are marked 1, 2, and 3.



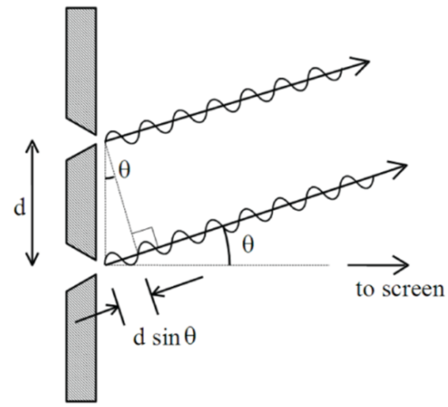


- Estimate the brightness of the light you would see on a screen placed at points 1, 2, and 3.

- Describe how you might use a picture like the one on the left to support your prediction and explain what is happening at points 1, 2, and 3 on the right. *We are interested in **your** ideas. Write down all the ideas you can think of. You can use the simulation to help you.*

PART 2: Double Slit Interference

A. In the pictures on the last page, the rays were emitted in all directions from the slits. But now, let's concentrate on the rays that are emitted in a direction θ toward a distant screen (θ is measured from the normal to the barrier). One of these rays has a further distance to travel to reach the screen; this *path difference* is equal to *d·sin(θ)*.



- Predict the brightness on the distant screen if the path difference is **exactly** one wavelength λ (or any integer number of wavelengths)? Explain your reasoning.

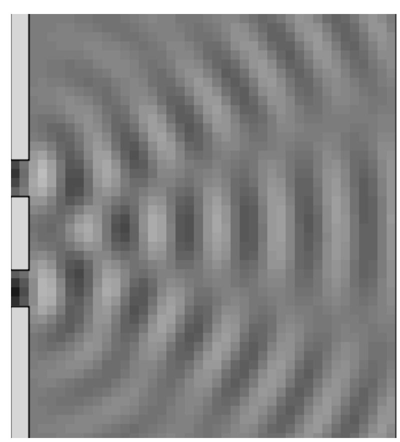
- Predict the brightness if the path difference is λ/2, 3λ/2, or 5λ/2, etc.?

- For each equation below, identify which one would tell you the angles (θ) at which you would see bright spots and which one will tell you the angles (θ) for dark spots.

		Bright or Dark?
m = 0, ±1, ±2, …	$d\sin\theta = m\lambda$	
	$d\sin\theta = (m + \frac{1}{2})\lambda$	

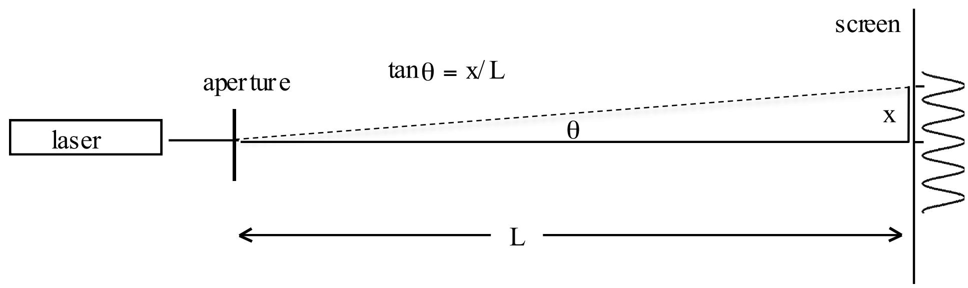
- What ideas from part 1B would you keep and which would you revise?

- How do the equations above support your predictions of brightness and the pattern shown on the right?



Small angle simplification:

If θ is small (<< 1 radian), then $\sin(\theta) \cong \theta$ (in radians) and bright spots occur on the screen at $\theta = m\frac{\lambda}{d}$; dark spots would occur at $\theta = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}$. As shown below, the angle θ (measured from the center of the screen) is related to the distance *x* measured on the screen by $\tan(\theta) =$ *x*/*L*, where *L* is the distance from the screen to the source of light (the aperture).



If the angle θ is small (less than a few degrees), then $\sin(\theta) \approx \tan(\theta) \approx \theta$ (in radians) is an excellent approximation. Thus, the locations of the interference bright spots are given by $\theta = \frac{x}{L} = m\frac{\lambda}{d}$.

- What happens to the interference pattern if d is increased? Explain your reasoning.

- What happens to the interference pattern if d is decreased? Explain your reasoning.

- Are your answers to above consistent with your answers to part 1A (page 2)?

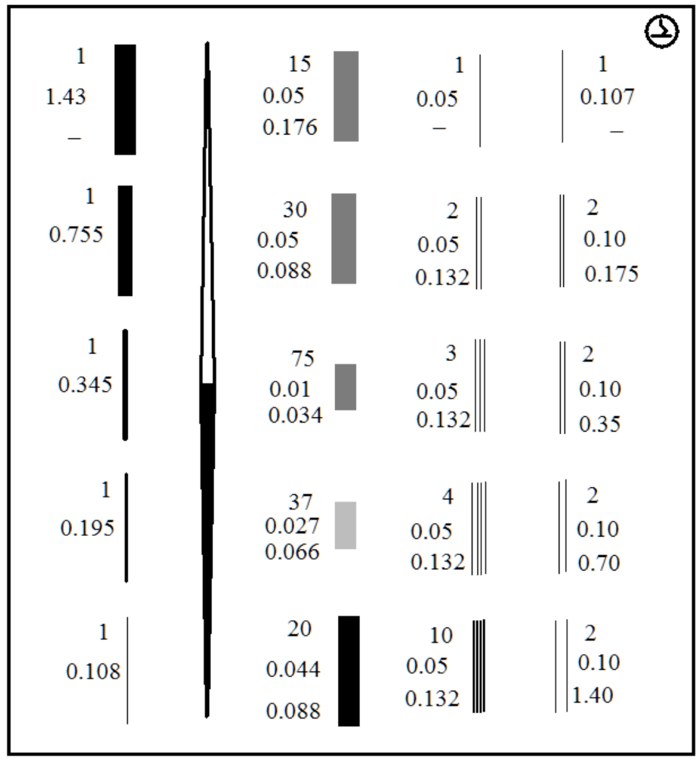
Part 3: Diffraction Pattern from Double Slits

The light source in this part of the experiment is a He-Ne laser which produces a monochromatic beam with a wavelength of **λ = 632.8 nm**. The power output of our lasers is small, but still enough to damage your retina if you look directly into the beam.

NEVER LOOK INTO A LASER BEAM.

The plate you have contains several single, double, and multiple slits. (See figure to the right.)
The numbers are those given by the manufacturer and are *not* always accurate.

Place the plate in its holder and mount it on the optical bench a few centimeters in front of the laser. Place a piece of white paper in the clipboard and place it at the far end of the bench.



N = number of lines (top), D = width in mm (middle), d= spacing in mm(bottom)

- Spend a few minutes exploring. What do you notice? Is it what you expect?

- Just for the **double-slits** in the plate, list all the things that affect the pattern on the screen.

PART 4: Testing Plate Specifications

In this part we will test the manufacturer's specifications for the double-slits in the plate.

- Measure the distance L from the slit to the screen and record it here:

- How far apart would you expect the peaks in the intensity to be for a slit-spacing of 0.35 mm and wavelength of 632.8 nm? Give the answer both in angle (radians) and in mm, using your screen distance L.

Observe the interference pattern on your paper screen for the double-slit labeled with a separation of 0.35 mm (the one in the middle of the right-most column on the plate). With a pencil, mark the positions of as many of the dark spots that you can see and measure the spacing x between adjacent dark spots on the screen.

- What is happening to the light to make the dark spots appear on the screen?

- What measurements do you need to make to allow you to compute the actual slit separation? Record those measurements here.

- Compute *d*, the actual slit separation. How close is it to the manufacturer's number? (e.g. within 10%? within 1%?)

- Compute *d*, the actual slit separation, for two of the other double-slits in the plate (pick any two). How close are they to the manufacturer's numbers?

- Based on your measurements, would you buy any more plates from this manufacturer? Why or why not?

- In the Wave Interference PhET simulation, would you say that the flashlight is drawn to scale? If it *was* drawn to scale, how big would the flashlight be?

PART 5: Resolving Power of the Human Eye (if time allows)

Let's measure the resolving power of your eyes to see how close your vision is to "perfect," that is, let's examine diffraction-limited performance. Diffraction effects limit the resolution of any optical instrument to an angle $\theta \cong \frac{\lambda}{D}$, where λ is the wavelength of the light used, and D is the diameter of the light-gathering optical element (e.g. the pupil of your eye). This limit is the angular size of the smallest thing you can see. Any details that are smaller than this will blur together, even if you have excellent ("perfect") vision.

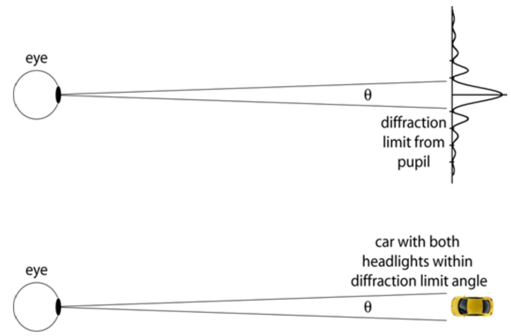


Figure 1: Diffraction limit: Two headlights would be irresolvable, and would look like a single blurred light.

1. Measure the diameter D of the pupil of your eye (in normal room-light). With one eye open, look closely at the image of your pupil in a mirror and measure your pupil's diameter with a clear plastic ruler placed on the mirror or over your eye.
   - Record your pupil diameter here:

2. To measure the angular resolution of your eye, your partner will first stand on a "zero position" mark on the floor. Begin by standing so far that the chart cannot possibly be resolved (Beyond a certain distance, the human eye cannot resolve the bars due to diffraction effects, and the arrays appear as unresolved gray blotches rather than stripes. You should not know which orientation is used!!)

3. Come up with a simple procedure with your partners to determine the maximum distance L away from the paper at which you can consistently distinguish between horizontal or vertical bars. Describe your procedure and results for L (for each lab partner) below.

4. If the center-to-center separation of the lines is called "x", the angle θ you can resolve is θ = x/L.
   - Measure x, and then calculate and record θ in radians and in degrees here:

   Compare this angle with the theoretical diffraction-limited resolution of θ = λ/D. Use λ = 550 nm (middle of the visible spectrum).
   - How close are your vision and your partners' vision to "perfect"?