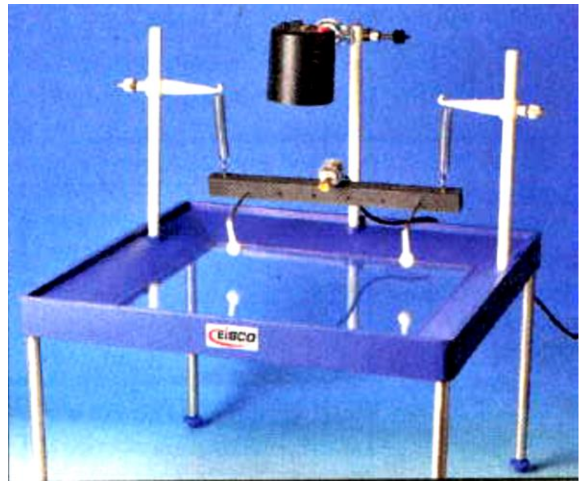
Experiment 3: Interference and Diffraction

Part I: Diffraction and Interference of Water Waves.

A) Part A's objective is to see how the amount of diffraction depends on the wavelength as waves pass through an opening. The apparatus is a ripple tank: A glass-bottomed tank of water is between a light above and a screen below. A horizontal bar in the tank, hung from springs, bounces as a motor on it shakes, creating waves. Each wave acts as a lens, focusing light into a bright area on the screen, where it is observed. In part A, waves pass through an opening between two metal barriers.



Before adding water, place the tank on an 18" by 24" sheet of paper with the extra few inches extending beyond the side opposite the vibrating bar. The light on the tank uses a 12 volt bulb. Use it only with the 12 V power source which should have been provided.

Start up the ripple tank and use the metal barriers to build a wall across it with an opening about 2 cm wide. The two balls on the ripple bar should be turned up out of the way or removed. If the image isn't clear, try rubbing dirt and bubbles off the tank's glass bottom with your fingers, dissolving the dirt in the water.

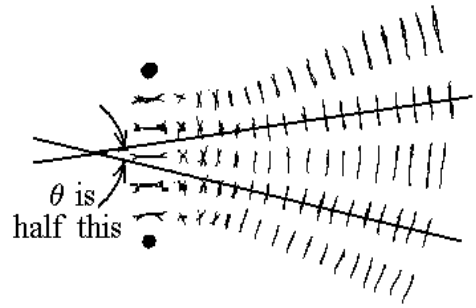
Vary the wavelength to compare the behavior of waves whose wavelength is larger than the opening to waves which are a good deal smaller than the opening. If you don't see enough of a difference, you can vary the size of the opening too. Sketch what you see.

As your conclusion for this part, state under what conditions waves more or less reach all places behind the wall, and under what conditions they don't.

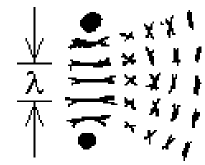
B) You will verify that $m\lambda = d \sin\theta$ correctly describes the maxima of a "double slit" interference pattern. You use the ripple tank again, this time with waves from two balls hung from the bar. These two coherent sources are equivalent to double slit interference. The interference pattern on the screen is traced. λ is measured from the standing wave between the two sources, d and θ are measured from the tracing with a ruler and a protractor. $m\lambda$ and $d \sin\theta$ are each calculated, and compared to see if they match.

Take out the barriers. Raise the bar and turn down the two plastic balls so they are all that touch the water, about half submerged. Having the centers of the balls 4.5 to 6 cm apart, so that their images on the screen are 10 to 15 cm apart, works best. Rotate the bar supports to get the balls as close as possible to the back edge of the tank.

Start it up. Notice that the maxima curve near the sources; $m\lambda = d \sin\theta$ is invalid there. Using a ruler, draw lines through the centers of the first order maxima out where they are straight. Extend the lines behind the sources to where they meet. Measure the angle formed and divide by 2 to get θ measured from the center. Repeat for second order; these lines may not cross at the same point as first order.



Notice the standing wave along the line between the two sources formed by the identical waves traveling in opposite directions. This is the easiest place to measure the wavelength. Each flickering bright spot is an antinode; mark as many of them as you can clearly see. Measure across them and divide to get λ. Also measure d, the distance between the two sources. Measure d on the screen, not at the balls themselves, to be consistent with your other measurements.



Calculate mλ and d sinθ for the first two orders. For your conclusion, say whether the equation $m\lambda = d \sin\theta$ seems to be correct. (Assume 10% uncertainty in both mλ and d sinθ.)

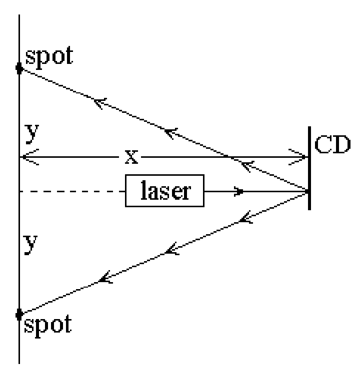
After the instructor approves your results, please drain the tank. If the water level is low enough to carry it there without sloshing some out, pour from a corner into the sink. Otherwise, use a large sponge to remove some first.

Part II: Track spacing on a CD

<u>CAUTION</u>: Looking directly into the laser beam is dangerous like looking at the sun. Keep the beam and its reflections down at table-top level and keep your eyes above this level.

You will measure the distance between the tracks on a compact disk. You shine a laser on a CD. The way the light scatters from the equally spaced "lines" of pits is equivalent to having many parallel slits, so it acts like a diffraction grating. By measuring the angle for first order reflection, you can calculate the spacing from the grating equation.

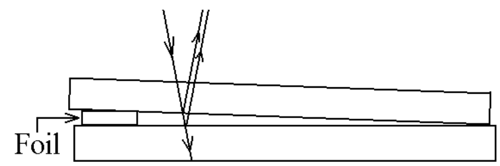
Mount the CD in the holder at least 8 cm from the laser, with a small piece of folded paper between the CD and the screw. The laser should hit at about the same height as the CD's hole, where the tracks are fairly vertical. The incoming beam should be normal to the CD, so arrange for the 0^{th} order reflection to land on the laser's aperture. Behind the laser and parallel to the CD should be a wall or a screen from under a ripple tank.



Locate the first order maxima. If you have trouble finding them, place a sheet of paper a few inches from the CD, where you can find them easily, then follow them out. Measure the distance from one first order spot to the other, then divide by 2 to get y, the distance from the central maximum. The central maximum won't show on the screen because the laser blocks it. Measure x, the distance from the CD to center of the screen. (You won't use them for anything, but also notice the second order maxima, more than twice as far to the side.)

Find θ using trigonometry. The wavelength of a helium-neon laser is 632.8 nm. Calculate the distance between the tracks.

Part III. Thin film interference.



You will use thin film interference to measure the thickness of a piece of aluminum foil. The thin film in this case is made of air, sandwiched between a pair of glass plates. Rubber bands clamp the plates in contact at one end, while the foil holds their other ends slightly apart, making a wedge-shaped air space. This is viewed with monochromatic light from a mercury lamp, which is reflected from both the top and bottom of the air gap. Where the plates touch, the path difference between these rays is zero, and they interfere destructively there. (One of them undergoes a phase reversal on reflection.) That would be $m = 0$ in the equation for thin film interference. As you go toward the foil, the next dark band is $m = 1$, where the gap is $\lambda/2$ thick giving a path difference of $(1)\lambda$. If you count dark bands from the contact point to the edge of the foil, this tells you m at the edge of the foil. Putting this into the equation tells you how thick the gap is there, which is the thickness of the foil.

Please do not take the apparatus apart, as the glass will then probably have to be cleaned before the experiment will work again.

Observe interference fringes by looking at the reflection of the mercury lamp. With its green filter, this lamp radiates light with a single wavelength, 546 nm. Count (as accurately as you can) the dark interference fringes along the length of the air wedge. Moving some sharp pointer, such as a pencil, along the glass will help you keep track of where you are as you count. You will have to move the lamp to see them. Use this number to compute the thickness of the foil. Don't be concerned if you are not getting quite the same thing as the group next to you; a little dust or a wrinkle in the foil could hold the glass farther apart than for another group.

Use a micrometer to measure its thickness directly. Do not take the apparatus apart; get another piece of foil from the same roll. First, check how the micrometer is zeroed. You will probably find that it's off by at least a fraction of a division. Then, when you read the thickness of the foil, correct your reading accordingly. Estimate an uncertainty for both values of the thickness.

In your conclusion,

1. State whether they agree with each other, and also
2. Comment on which method is the most accurate and why.

Altogether, this lab asks for five conclusions: One each for parts IA, IB, II, and the two questions just above for III.

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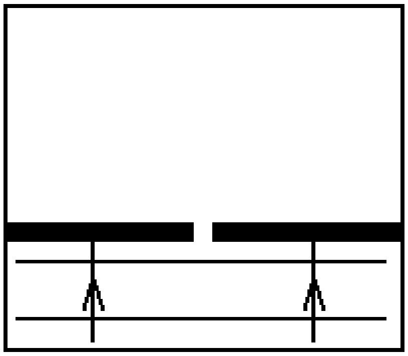
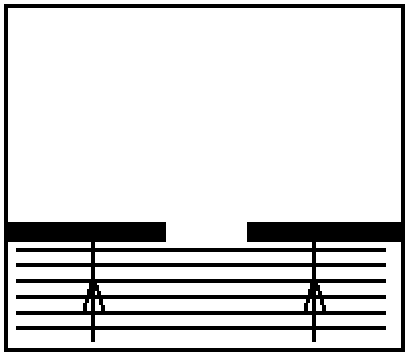
Part I. A) Finish Pictures:





B) λ = ____________________ d = ____________________

First Order: θ =______________ d sinθ = ______________ m λ = ______________

Second Order: θ =______________ d sinθ = ______________ m λ = ______________

Part II:

distance between spots = ______________ y = ______________ x = ______________

Calculate θ:

Calculate d:

Part III:

Number of fringes =______________

Compute thickness:

Measured thickness =______________