Section: Monday / Tuesday   Name: _____

(circle one)   Partners: _____

_____

PHYSICS 107 LAB #5: SOUND PROPAGATION: DIFFRACTION, INTENSITY, AND SOUND INTENSITY LEVEL

Equipment: Red laser, slits and slides, slide stand, rulers and meter sticks, white paper, Sound Level Meter, Speaker, 2 banana cables, , Function Generator

OBJECTIVES

1. To observe the diffraction from single opening and a single obstruction.

2. To study the variation of intensity with distance from a point source.

3. To get familiar with Sound Intensity Level measurements.

Notes:

Do not look into a laser beam because eye damage is likely to result! Also, avoid looking at reflections from shiny surfaces.

Both sound and light propagate as waves (as a sound's frequency is sensed as a 'pitch', a light's frequency is sensed as a 'color.') For much of this lab we'll use light rather than sound waves simply because it's easier to make light waves 'behave' – having such long wavelengths, sound waves easily reflect off tables and people and diffract around obstacles which makes it difficult to measure the strength of *just* the sound coming *directly* from *your* source (instead of also that reflected and coming from other lab groups' sources.)

Throughout this handout, shaded areas in the diagrams will indicate where the light is bright. In your sketches, the shaded regions should also show where the light is.

Readings:

**Reading:**   Sections 4.2, 5.1 - 5.3

PART ONE: Single-Slit Diffraction

Theory

When laser light passes through a small slit, it forms a diffraction pattern of bright and dark fringes (as shown below). The central bright fringe is wider than the others. The angle (θ) between the center of the middle *bright* fringe and the center of the first *dark* fringe is related to the width (D) of the slit and the wavelength (λ) of the light by

$$\sin \theta = \lambda / D.$$

See picture on next page.

Pattern on wall
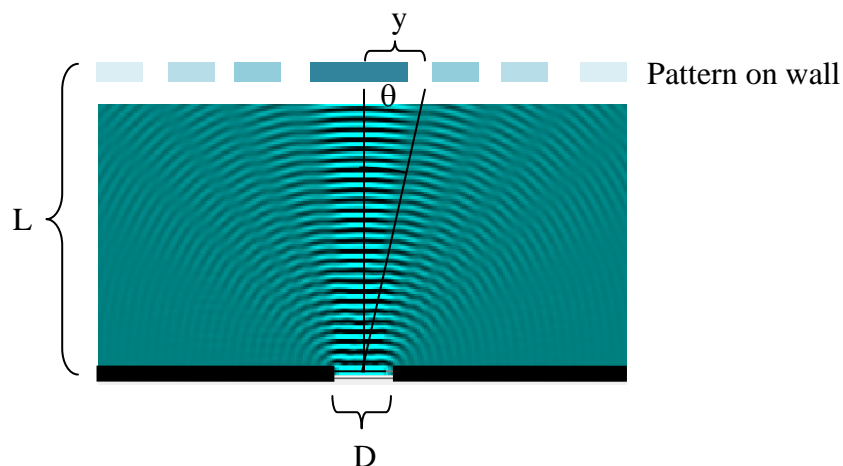
Simulation

You'll use a simulation to see how wavelength, gap width, and the angle of diffraction relate.

1. On the computer, open http://www.falstad.com/ripple/.
2. In the applet's "set up" menu (top right), select "single slit" (near the top of the list.)
3. You'll see something like the image above (though upside down and live). In particular, you should observe that there's a central region for which the waves ripple most strongly. It's even more pronounced if you click the "3-D View" box.
4. When you decrease the "source frequency" you're also causing the *wavelength* to *increase.* As you do that, the angular width of the strong central region

1 pt
                        Increases / Stays the Same / Decreases   (circle one)

5. When you increase the "source frequency" you're also causing the *wavelength to decrease.* As you do that, the angular width of the strong central region

1 pt
                        Increases / Stays the Same / Decreases   (circle one)

Question: qualitatively, does the angular width (or 'diffraction angle') vary with changes in the wavelength as the equation on the previous page suggests? Explain.

1 pt

6. In the applet, the third menu from the top allows you to choose for "Mouse = edit walls." With that selected, you can now draw or erase the barrier in order to make the gap wider or narrower. Keeping the frequency (and so wavelength) constant, make the gap wider. As you do that, As you do that, the angular width of the strong central region

                    Increases / Stays the Same / Decreases   (circle one)

Question: qualitatively, does the angular width (or 'diffraction angle') vary with changes in the gap width as the equation on the previous page suggests? Explain.

1 pt

Experiment

First, you will use the diffraction pattern produced by a laser shining through a slit to determine the laser's wavelength.

1. Set up the red laser to pass through a single narrow slit of width 0.02 mm to a sheet of paper on the wall (the slide has 4 individual slits of different widths, in the order labeled at the top.) The sheet should be about 1 meter from the slit. Record the width of the slit used below (it works best to use one of the narrower ones).

1 pt

$D =$ _____ mm

2. Measure the distance between the slit and the sheet.

1 pt

$L =$ _____

3. Determine the distance (y) between the middle of the *central bright* spot and the middle of the first *dark* spot beside it on one side of the pattern (as shown in the diagram on the previous page). It is easiest to measure the width of the central bright spot (from one the dark spot on its left to the one its right) and divide that distance by two.

1 pt

$y =$ _____

4. You now have values for two legs of a triangle, a trig function relates those to the angle we want: $\tan\theta = \dfrac{y}{L}$ and so $\theta = \arctan\left(\dfrac{y}{L}\right)$.

Calculate the angle θ to the middle of the first dark fringe.

3 pts

$\theta_2 =$ _____ °

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5. Using the width of the slit (D), calculate the wavelength of the laser. Show all of your work.

3 pts

$$\lambda = \underline{\hspace{2in}}$$

Question: How does your measurement compare to the known wavelength of the red laser (650 nm, 1 nm = 10^{-9} m)? Calculate the percent difference. If they differ by much more than 20%, find and fix your mistake.

2 pts

Next, you will see how the slit width affects the diffraction angle.

Question: Using the same laser, what diffraction angle, $\theta_{16\text{-th}}$, would the theoretical relation predict if you used a slit of width D = 0.16mm?

2 pts

$$\theta_{16\text{-th}} = \underline{\hspace{2in}}°$$

6. Shift the slide over so that the laser now shines through the 0.16 mm wide slit and determine the diffraction angle as you did before (steps 3 and 4 above.)
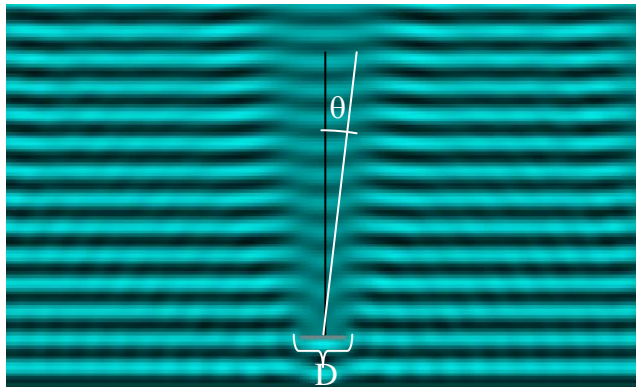
1 pt

$$\theta_{16\text{-exp}} = \underline{\hspace{2in}}°$$

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Question: How do the theoretically predicted and experimentally determined diffraction angles compare – what's the % difference?

2 pts

PART TWO: Single-Barrier Diffraction

A narrow barrier will produce a similar pattern to that produced by a narrow opening of the same width.

Simulation

1. In the simulation, change the set up to "plane wave" (about half way down the list), then change the mouse to "edit walls" and so draw a small obstacle as shown in the picture above (except up near the top, where the waves are coming from.)
2. In the shadow of the obstacle, you should see a relatively still region where the ripples are weak.
3. When you decrease the "source frequency" you're also causing the *wavelength* to *increase*. As you do that, the angular width of the strong central region

1 pt

Increases / Stays the Same / Decreases   (circle one)

Question: qualitatively, does the angular width of the shaded region vary with the changing wavelength as the equation on the first page suggests? Explain.

1 pt

Experiment

Now, you will use a diffraction pattern to determine the width of a hair.

7. Take a hair from someone in your group. Stretch the hair on a microscope slide so that it is straight and tape it down. Carefully, clip the slide to the holder.

8. Position the laser so that it shines on the hair and creates a pattern similar to what you saw for a narrow slit.

9. Measure the distance between the hair and the screen.

1 pt

$$L = \underline{\hspace{3cm}}$$

10. Determine the distance (y) between the middle of the *central bright* fringe and the middle of the first *dark* fringe on one side of the pattern (as shown in the diagram above). It is easier to measure the distance between the centers for the *dark* fringes on either side of the central *bright* fringe and divide that distance by two.

1 pt

$$y = \underline{\hspace{3cm}}$$

11. Calculate the width of the hair. Show all of your work.

3 pts

PART THREE: Sound Intensity Level

Theory

As a wave radiates from a source, its intensity (rate of energy transmission per area) decreases as the wave front's area grows. For a wave radiating uniformly in 3-D from a point source, the shape of the wave front is spherical; then as the sphere's area goes like $4\pi r^2$, the intensity decreases with distance as $1/r^2$. This fact is known as the Inverse Square Law. So, the ratio of intensity measurements made at two different distances, r_1 and r_2, from a source is $\dfrac{I_1}{I_2} = \dfrac{\frac{1}{r_1^2}}{\frac{1}{r_2^2}} = \dfrac{r_2^2}{r_1^2} = \left(\dfrac{r_2}{r_1}\right)^2$.

As the book discusses, it's convenient for us to compare Sound Intensity Levels, rather than intensities, where $SIL_1 - SIL_2 = 10dB\log\left(I_1\big/I_2\right)$. Replacing the ratio of intensities with that of distances, and rearranging a little, we have

$$SIL_1 = SIL_2 - 20dB \log\left(\frac{R_1}{R_2}\right).$$
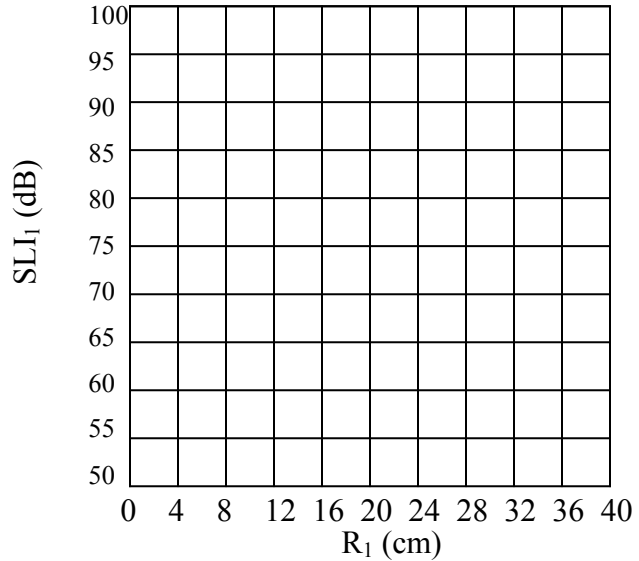
Which is found near the bottom of page 78.

1. To get a feel for what this equation predicts, use it to fill in the table below and then plot SIL_1 vs. R_1.
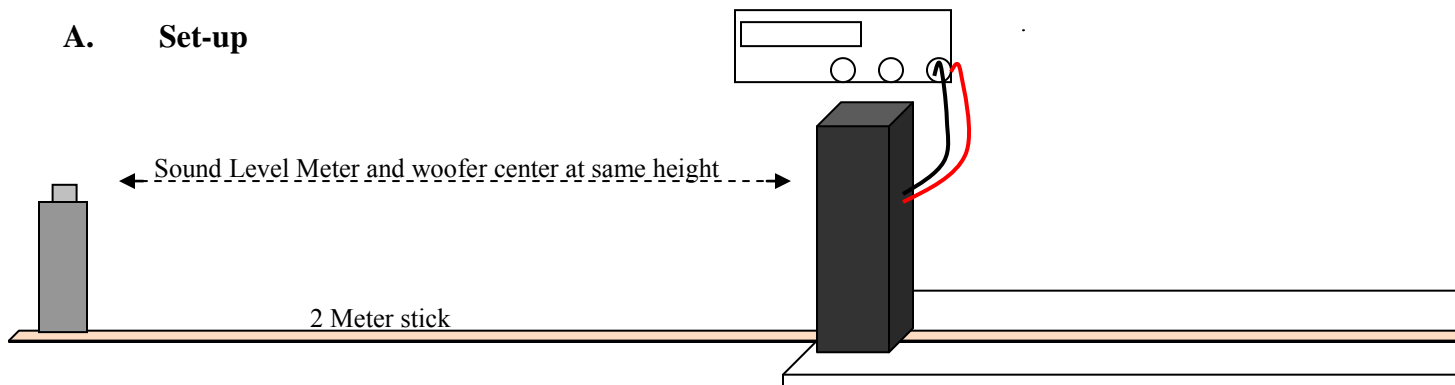
$SIL_2 = 90$ dB

$R_2 = 5$ cm

3 pts

R_1 (cm)	SIL_1 (dB)
5	
10	
15	
20	
25	
30	
35	
40	

Experiment.

A.   Set-up

Sound Level Meter and woofer center at same height

2 Meter stick

1.   Place the Speaker at the edge of the table, facing out into the room, and stick a 2-m stick underneath it so the speaker's grill is at the 103 cm mark (the extra 3cm are because the speaker cone itself is about 3cm behind the grill.)

2.   Connect the Function Generator's output to the Speaker via two banana cables.

3.   Switch the Sound Level Meter (SLM) to its 'LO' setting (up to 90 dB), set the Response to Slow, and the Weighting to C.

B.   **Data Collection**

You will vary the Speaker – SLM separation from 5 to 40 cm. For each position, you will record the Sound Intensity Level. Note: Be careful that no one stands behind the SLM, in line with the speaker – sound from the speaker would reflect off the body and effect your measurements.

1.   To start, stand the SLM upright, centered on the 105 cm mark (so 5cm from the speaker cone, and with the meter itself just touching the mesh). Pick a tone on the function generator around 100 – 400 Hz and set its volume so the SLM reads about 90 dB. This will be your first data point for the table below.

2.   In the table on the next page, enter the Speaker – Meter separation and the SIL.

3.   Leaving the Function Generator's amplitude constant (thus a constant sound source), fill in the table for the Meter at 7 more positions. You'll need to switch down the Range to make the SLM more sensitive as you move the meter further away.

4.   Note: if the SIL actually goes up with an increase in Meter – Speaker separation, this is due to sound reflection in the room. Notify me so I can help you adjust the set-up to avoid this effect.
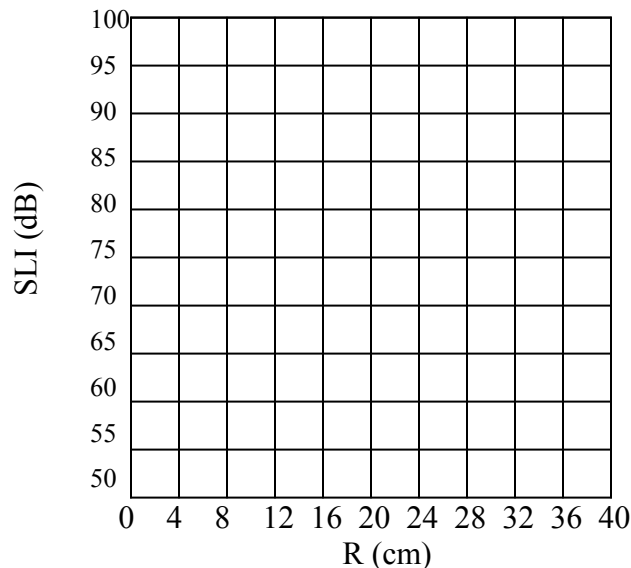
Meter-Speaker separation, R (cm)	***SIL*** *(dB)*
5 cm (R_2)	(SIL_2)
10	
15	
20	
25	
30	
35	
40	

2 pts

C.   **Analysis**

1.   Plot SIL vs. Meter – Speaker separation, R
2.   Trace the best fit curve (note, it won't be a straight line).

2 pts

D.   Conclusions

How does the curve plotted with real data compare with that predicted? Note: The exact appearance of your curve will depend on the amplitude of the Function Generator, so the two curves should not look *exactly* the same, but hopefully there are notable similarities.

2 pts