Applet Exercise 1: Introduction to the Virtual Lab and Wave Fundamentals

Objectives:

1. Become familiar with the Virtual Lab display and controls.
2. Find out how sound loudness or intensity depends on distance from the source.
3. Determine the speed of the waves in the Virtual Lab.

Background:

Sound waves are invisible to the human eye, making them somewhat difficult to study without the proper equipment. In this series of labs, interactive physics applets will be used to make the invisible waves visible. Notice that this applet lets you see waves in two dimensions, similar to ripples on the surface of the water. Sound waves propagate in three dimensions, and as a result the waves in this lab will behave slightly differently from waves in 3D, although waves in any dimension share many common properties.

The first goal is to determine how the loudness or intensity of a sound wave depends on distance. Qualitatively, you know that the farther away you are from the source the softer it sounds, even if you are out in the open (i.e. no walls to absorb or reflect the sound). With the Virtual Lab, we can determine quantitatively how much softer the sound becomes as you move away. There are two possibilities for why the loudness decreases with distance: the sound might be absorbed by the medium (air), or the wave spreads out over a larger area. In the latter case, the total energy of the sound would stay the same, but the amount that reaches you would decrease.

The second goal is to determine the speed of the waves in this simulator. The speed at which a wave travels depends on the medium. For example, sound travels faster in water than in air. In class, you learned that the speed of sound in air was 343 meters per second. In this applet exercise, you will determine the velocity of the waves in the “medium” of the Virtual Lab. You will use the relationship speed = frequency x wavelength to determine the speed. You will set the frequency, measure the wavelength and, from these measurements, calculate the speed of the waves for several different frequencies. It is a special property of sound waves that the speed is independent of the frequency of the wave.

Instructions:

Part 1

1. Open the Virtual Lab applet by clicking on the Virtual Lab icon.
2. Let the applet run for a few seconds, then click the “Stopped” check box to stop the applet.
3. Set Simulation Speed = 8, Resolution = 140, and Damping = 2 (the minimum).
4. Notice the red and green bands radiating from one point near the top. The point where the waves start is called the *source*.

5. The color of the waves in the display indicates the air pressure at that point. Green indicates high pressure, or a *compression* of the air. Red indicates low pressure, or a *rarefaction* of the air. Answer questions A, B, C and D in the questions section below.

Part 2

6. Notice that when your mouse is over the display, the coordinates of your mouse are displayed in the bottom left corner of the applet. Place the mouse over the source and record the coordinates of the source on Table 1. The units are cm.
7. When you click anywhere on the display, a white square will appear. This is a *microphone* that records the intensity or loudness of the wave at that point. The sound intensity is displayed at the bottom of the right column. Place the microphone relatively close to the source and record its coordinates in Table 1. Restart the applet by unchecking the “Stopped” box and select a frequency between 150 and 200. Note that the units of frequency are Hz. Then record the microphone sound intensity. You might have to wait a few seconds for the intensity to settle down to a constant value. The intensity will fluctuate somewhat. Just try to estimate an average value.
8. Move the microphone slightly farther away from the source, record the coordinates and the sound intensity. Repeat this until you fill up Table 1 (you will need to place the microphone in at least six different spots – you will get better results if you avoid the edges of the display).
9. Fill in the remainder of Table 1 by following the formulas given at the top of each row.
10. Answer questions E, F, G and H.

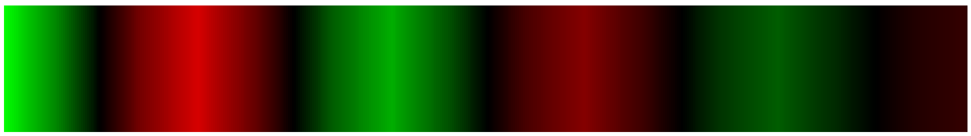
Part 3

11. Set the frequency slider bar to 25 Hz and let the applet run for a few seconds until the waves just fill the display.
12. Now you need to measure the wavelength associated with this frequency. Stop the applet. Using the coordinate display in the bottom left corner of the ripple tank, measure the length of one wave. Remember, a wavelength is the distance you need to move for the wave to go through one complete oscillation – in other words, it must go from green to red and back to green. If you increase the brightness, the length of one wave is the combined width of one green and one red band. You are simply looking for the coordinates of two similar points on two consecutive waves and finding the distance between them. For better accuracy, you can measure the distance necessary to go several wavelengths. Then divide the total distance by the number of wavelengths. Also, to better measure the wavelength, stop the applet and clear the waves. Restart the applet and stop it again just as the waves first reach the bottom of the screen. If you let the applet continue, you will notice some reflected waves from the edge of the display. These will interfere with your measurement.
13. Record the frequency and wavelength in Table 2.
14. Repeat steps 11 through 13 with the frequency slider bar at 50, 75, 100, 150, 200, 250, and 299 Hz.
15. Answer the questions below.

Questions:

Part 1

Below is a section of the Virtual Lab wave display. Remember that green indicates a compression (area of high pressure) and red indicates a *rarefaction* (area of low pressure). Black indicates the resting air pressure.



A. On the axis above, graph the air pressure as it appears on the section of the Ripple Tank, as seen above. The pressure you plot on the graph should follow the pressure shown by the red, green, and black coloration.

B. Label the graph with an O on each of the nodes and an X on each of the antinodes.

C. What kind of function does this graph resemble (i.e.what kind of mathematical equation would produce this graph)?

D. What happens to the amplitude as the distance from the source increases? Why do you think this happens? In other words, do the sound waves lose energy or is it because they spread out? If the waves spread out in two dimensions, the amount of energy passing a circle surrounding the source stays the same, but the circle gets bigger. How does the circumference of a circle depend on the distance from the center?

Part 2

Table 1:

Source Coordinates:	(x_{source}, y_{source}) = (cm, cm)				
Microphone Coordinates:	Intensity or loudness:	Distance from Source to mic:*	(Loudness) × (Distance):	(Loudness) × $(\text{Distance})^2$:	(Loudness)/ (Distance):
(,)					
(,)					
(,)					
(,)					
(,)					
(,)					

$$* \; Distance = \sqrt{(x_{source} - x_{microphone})^2 + (y_{source} - y_{microphone})^2}$$

E. Complete Table 1.

F. Which column (4, 5 or 6) is has more similar or somewhat constant values across the entire column?

G. From this, how does loudness depend on distance?

H. Which one of the following equations makes sense for relating loudness and distance from a source? Note that L = Loudness, D = Distance, C = constant value.

a) $L = C \cdot D$

b) $L = C / D$

c) $L = C \cdot D^2$

d) $L = C / D^2$

I. From the dependence you found in part H, can you determine if the loudness decreases because the waves are absorbed or because they spread out? Support your answer with the data. In Physical Lab #1, it turns out that $L = C/D^2$. Is this the same or different from what you found in this Virtual Lab? Why do you think they are the same or different?

Part 3

J. Complete Table 2.

K. Are the values for the velocity roughly constant for all the different frequencies and corresponding wavelengths? What is the average value for the velocity?

L. Does this applet exercise confirm the equation $v = f \cdot \lambda$? Why or why not?

M. Using your estimates in parts B and C, what would the wavelength be if the frequency is 130 Hz?

Table 2:

Frequency (Hz)	Wavelength (cm)	Velocity (cm/s): ‡
25		
50		
75		
100		
150		
200		
250		
299		