Physics 197 Lab 3:   Speed of Sound and Pipe Resonances

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Laptop Computer		1	8	8			
Installed Vernier Software Folder	Logger Pro 3.9	1	8	8			
LabQuest Mini Interface Box	Vernier	1	8	8			
Microphone with interface cord	Vernier MCA-BTA	1	8	8			
Large paperclip stand for microphone		1	8	8			
Cardboard Tube (from pipe resonance)		1	8	8			
USB to micro USB cable for Lab Quest		1	8	8			
Tuning forks 512 Hz, 1024 Hz,2048 Hz*		1 set	8	8 sets			
Water filled Pipe Resonance Apparatus		1	8	8			
Stand and clamps to hold water tube		1	8	8			
Plastic beaker and deionized water		1	8	8			
Rubber stopper for striking tuning fork		1	8	8			

* Only 2x 1024Hz, 2048 Hz, Share these

Layouts:

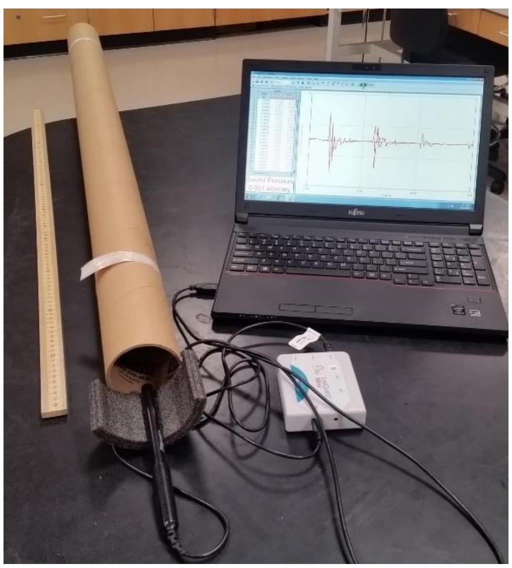


Figure 1: Equipment for Speed of Sound

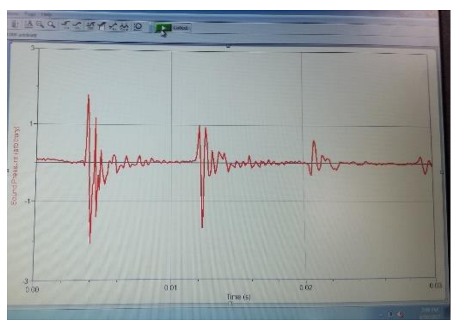


Figure 2: Speed of Sound Echo Data

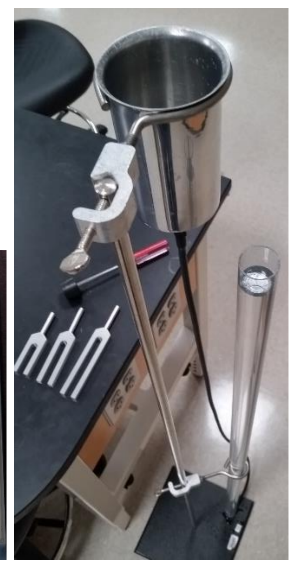
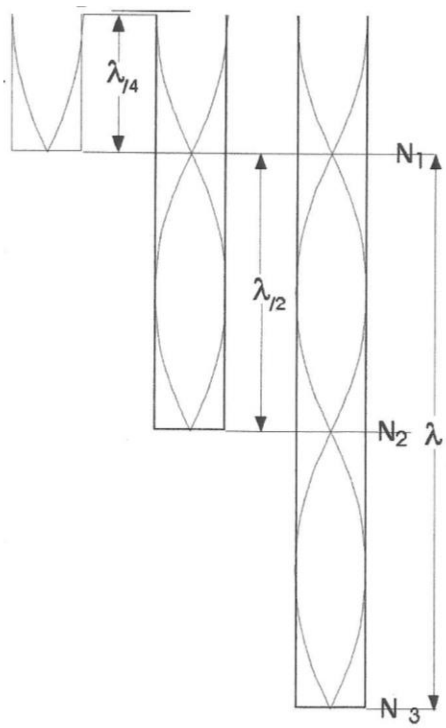


Figure 3: Equipment for Pipe Resonances

Summary:

In this lab, students will investigate sound waves first by measuring the speed of sound directly by timing an echo in a tube, and then by investigating pipe resonances by listening to a tuning fork above an open pipe. Figure 1 shows the apparatus for measuring the speed of sound. Students will snap their fingers and measure the resulting sound pressure with a microphone. Figure 2 shows sample waveforms with the direct sound, a first echo, second echo, and third echo. For each echo the sound travels twice the length of the tube which is closed at the far end. By measuring the time between echoes the speed of sound is determined. Figure 3 shows the apparatus for investigating pipe resonances. Students will strike a microphone, hold it above a hollow tube partially filled with water, and listen for the sound to get louder at certain times as the water height in the tube is varied. The length of the air in the tube at resonance is related to the wavelength of the sound, which is in turn a function of the tuning fork frequency and the speed of sound in air. Resonance conditions at a number of harmonics can be obtained.

PreLab:



The figure to the left shows the magnitude of the sound displacement versus height for certain resonance conditions in a vertical pipe which is closed at one end (the bottom) and open at the other end (the top). Remember that the figure is diagrammatic, so that even though the air molecule displacement direction is vertical, the graphs show magnitudes in the horizontal direction. Nodes are labelled. Copy the figure into your notebook and label the nodes and antinodes. For frequencies of 512Hz, 1024 Hz and 2048 Hz, calculate the wavelength of sound assuming the speed of sound is 344 m/s. Given that for the second experiment (Lab B) the height of the water (corresponding to the location of the bottom node) can be adjusted, what length of air above the water would you calculate for the three frequencies and the three resonance conditions shown?

When you do the experiment, you should find that the water heights are slightly different from your calculation because the top antinode is not exactly at the location of the top of the tube. Look up a first order correction factor (related to the diameter of the tube) for the actual location of the top antinode, and determine how much that might affect the calculated height of the water needed to achieve resonance.

Lab A: Speed of Sound Measurement using tube echo and microphone:

Compared to most things you study in the physics lab, sound waves travel very fast. It is fast enough that measuring the speed of sound is a technical challenge. One method you could use would be to time an echo. For example, if you were in an open field with a large building a quarter of a kilometer away, you could start a stopwatch when a loud noise was made and stop it when you heard the echo. You could then calculate the speed of sound.

To use the same technique over short distances, you need a faster timing system, such as a computer. In this experiment you will use this technique with a Microphone connected to a computer to determine the speed of sound at room temperature. The Microphone will be placed next to the opening of a hollow tube. When you make a sound by snapping your fingers next to the opening (or using a dog clicker or hitting sticks together), the computer will begin collecting data. After the sound reflects off the opposite end of the tube, a graph will be displayed showing the initial sound and the echo. You will then be able to determine the round trip time and calculate the speed of sound.

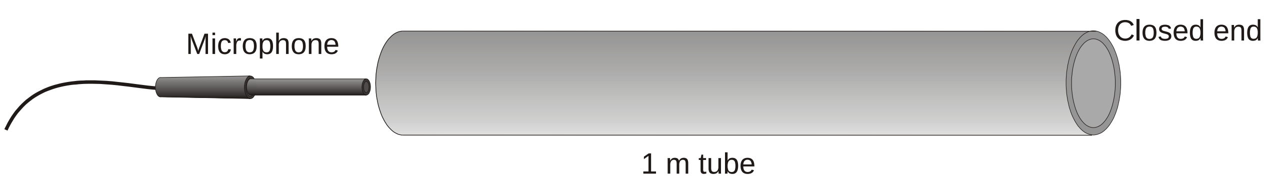


Figure 4

Set up the equipment as in Figure 1 and Figure 4. Connect the Vernier Microphone to Channel 1 of the LabQuest Mini interface, and connect the interface to the computer using a USB cable. Under the Start Menu find the Vernier Software folder, and open LoggerPro 3.9. You should see a display allowing you to measure sound pressure versus time. Zero the microphone, set the data collection time at 0.03s, and adjust data collection so it triggers automatically when the pressure exceeds some value like 0.1. When you snap your fingers near the microphone at the entrance to the tube, you should be able (after some practice) to get a waveform of sound pressure versus time like that in figure 2.

You should then measure the time interval between a repeating feature in the waveform. For instance, you might measure the time difference between the greatest magnitude peak in the first squiggle to the greatest magnitude peak in the second squiggle. The first squiggle is the direct sound of your fingers snapping, and the second signal is the same sound reflected off of the closed tube returning to the microphone. To get the speed of sound you would need to divide the travel distance by the time difference. The travel distance is approximately twice the length of the tube. If you try to measure this distance carefully (using the location of the stopper in the tube), what do you get for the speed of sound? This should be close to 344 m/s (assuming the room is about 20 degrees C). Include a sketch or print-out of your waveform in your notebook.

If you think about it, there is some uncertainty in the measurement due to the distance from your fingers to the microphone, to the tube entrance, and the distance from the tube entrance to the microphone. If you were to use the second two peaks, which involve one reflection (far closed end of tube) and three reflections (far closed end, near open end, and far closed end) the difference in travel distance should be twice the length of the tube (possibly corrected for actual reflection location at open end). Try calculating the speed of sound using the second two peaks. (The third peak should look like the second peak inverted, so the same feature will have the opposite sign).

Decide which is the best measurement method, then repeat that measurement three times, and average the results. Calculate the percentage error between your measurement and 344 m/s, and discuss possible reasons for any differences.

Lab B: Pipe resonances in an open tube with a variable height water column:

Set up the pipe resonance apparatus as in figure 3. Fill the apparatus using about 1 liter of deionized water. Adjusting the height of the metal container will cause the height of the water in the graduated cylinder to change. The rate of change will depend on the height differences.

The idea of this experiment is for one lab partner to strike a tuning fork, hold the tuning fork near the top of the tube, and to listen to variations in the sound intensity near the top of the tube as the water height is varied. At particular water heights, where the length of the air column above the water hits a resonance condition, the sound will be louder. The second lab partner should attempt to change the water height so it passes through a resonance condition, and to take note of the water height (or air column length) where this resonance occurs. It may be easier to find the resonance locations with the water falling or with it rising.

For each of the three tuning forks (512Hz, 1024 Hz and 2048 Hz), each lab partner should take turns finding and recording the heights where resonances occur. These should not be far from the distances calculated in the prelab. At 1024 Hz you should hear at least the 1^{st}, 3^{rd} and 5^{th} harmonics. At 2048 Hz you should be able to hear more (try to record the locations of the 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 9^{th}, 11^{th}, and 13^{th} harmonics).

Record your distances, and compare them to those calculated in the prelab. Discuss possible reasons for any discrepancies. If you were trying to measure the speed of sound using the known tuning fork frequencies and the measured resonance locations, would you get a better result taking the difference of two resonance locations? (Think about whether this might correct for an offset in the location of the displacement antinode position at the top of the tube, which is approximately 3/10 of a tube diameter above the top). Try this out by setting $\lambda/2$ equal to the difference of the $\lambda/4$ and $3\lambda/4$ measured resonance positions.

When you are done, make sure to include a one paragraph conclusion about the whole experiment (including Lab A and Lab B) in your notebook.