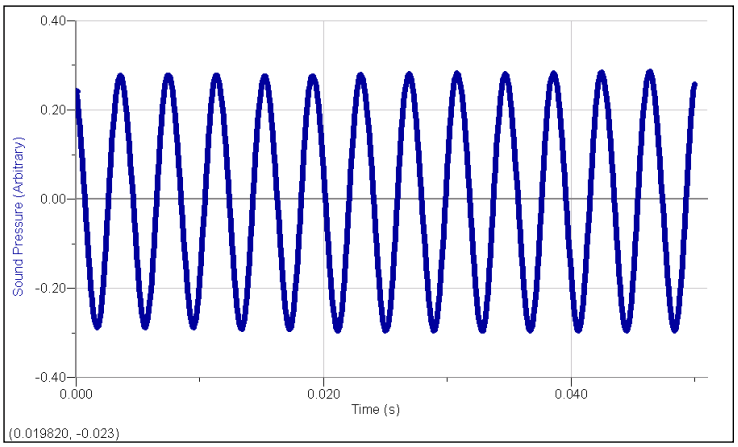
Lab 1: Sound Fundamentals

Part 1. Sound Waves

Sound waves consist of a series of air pressure variations. A Microphone diaphragm records these variations by moving in response to the pressure changes. The diaphragm motion is then converted to an electrical signal. Using a Microphone and a computer interface, you can explore the properties of common sounds.

The first property you will measure is the *period*, or the time for one complete cycle of repetition. Since period is a time measurement, it is usually written as *T*. The reciprocal of the period (1/*T*) is called the *frequency*, *f*, the number of complete cycles per second. Frequency is measured in hertz (Hz). 1 Hz = 1 s^{-1}.

A second property of sound is the *amplitude*. As the pressure varies, it goes above and below the average pressure in the room. The maximum variation above or below the pressure mid-point is called the amplitude. The amplitude of a sound is closely related to its loudness.



OBJECTIVES

- Measure the frequency and period of sound waves from tuning forks.
- Measure the amplitude of sound waves from tuning forks.
- Observe beats between the sounds of two tuning forks.

MATERIALS

computer	Logger *Pro*
Vernier computer interface	Tuning forks
Vernier Microphone	Thermometer

PROCEDURE

1. Connect the Microphone to Channel 1 of the computer interface.

2. Open the "32 Sound Waves" file in the *Physics with Vernier* folder. The computer will take data for just 0.05 s to display the rapid pressure variations of sound waves. The vertical axis corresponds to the variation in air pressure and the units are arbitrary. Click Zero to center waveforms on the time axis.

3. Strike a tuning fork against a soft object such as a rubber mallet or the rubber sole of a shoe. *Striking it against a hard object can damage it.* Produce a sound with a tuning fork, hold it close to the Microphone

and click ▸ Collect. The data should be sinusoidal in form, similar to the sample on the front page of this lab. If you strike the fork too hard or too softly, the waveform may be too rough; try again.

4. Note the appearance of the graph. Count and record the number of complete cycles shown after the first peak in your data.

5. Click the Examine button, . Drag the mouse between the first and last peaks of the waveform. Read the time interval Δt, and divide it by the number of cycles to determine the period of the tuning fork waveform.

6. Calculate the frequency of the tuning fork in Hz and record it in your data table.

7. In a similar manner, determine amplitude of the waveform. Drag the mouse across the graph from top to bottom for an adjacent peak and trough. Read the difference in y values, shown on the graph as Δy.

8. Calculate the amplitude of the wave by taking half of the difference dy. Record the value in your data table.

9. Print the graph and glue it into your lab notebook.

10. Save your data by choosing Store Latest Run from the Experiment menu. Hide the run by choosing Hide Data Set from the Data menu and selecting Run 1 to hide.

11. Repeat Steps 3–9 for a second tuning fork at a different frequency. Store the latest run. It will be stored as Run 2. Then hide Run 2.

Tuning fork or note	Number of cycles	Δt (s)	Period (s)	Calculated frequency (Hz)

Tuning fork or note	Amplitude (V)

ANALYSIS

1. In the following analysis, you will see how well a sine function model fits the data. The displacement of the particles in the medium carrying a periodic wave can be modeled with a sinusoidal function. The general form of *any* wave is:

$$y = A\sin(2\pi f t)$$

In the case of sound, a longitudinal wave, the *y* refers to the change in air pressure that makes up the wave. *A* is the amplitude of the wave (a measure of loudness), and *f* is the frequency. Time is represented with *t.*

Logger *Pro* will fit the function *y* = A * sin(B**t* + C) + D to experimental data. A, B, C, and D are parameters (numbers) that Logger *Pro* reports after a fit. Specifically for the sound waves, what do the fit parameters

(A, B, C, and D) in Logger Pro's fit correspond to? Which are important to characterizing the sound wave and which are not?

Choose Show Data Set from the Data menu and select Run 1 to show the waveform from the first tone. Keep the other runs hidden. Click the Curve Fit button, and select Run 1 from the list of columns. Select "A*sin(B**t* +C) + D (Sine)" from the list of models. Click Try Fit to perform the curve fit.

Click OK to return to the graph. The model and its parameters appear in a floating box in the upper left corner of the graph. Record all fit parameters, carefully noting which ones are important for characterizing the sound wave and which are just arbitrary fit parameters.

Tuning fork or note	Parameter A (V)	Parameter B (s^{-1})	$f = B/2\pi$ (Hz)

2. Use the curve fit information to determine the frequency. Enter the value in your data table. Compare this frequency to the frequency calculated earlier. Which would you expect to be more accurate? Why?

3. Use the fit data to determine the amplitude of the waveform.

4. Hide Run 1 and show Run 2, the waveform of the second tone. Repeat Steps 1–3 for Run 2.

Part 2 - Speed of Sound

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, 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.

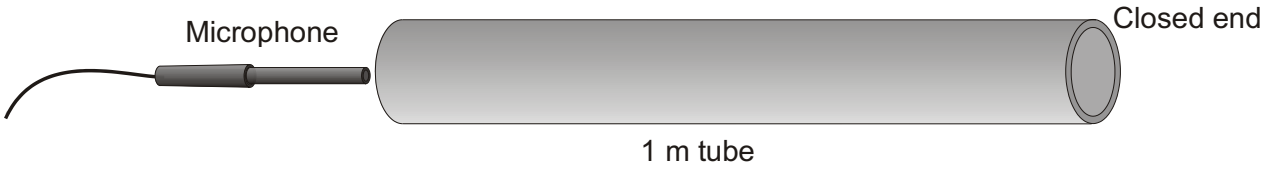


Figure 1

OBJECTIVES

- Measure how long it takes sound to travel down and back in a long tube.
- Determine the speed of sound.
- Compare the speed of sound in air to the accepted value.

PRELIMINARY QUESTION

1. A common way to measure the distance to lightning is to start counting, one count per second, as soon as you see the flash. Stop counting when you hear the thunder and divide by five to get the distance in miles. Use this information to estimate the speed of sound in m/s.

PROCEDURE

1. Connect the Vernier Microphone to Channel 1 of the interface.

2. Use a thermometer or temperature probe to measure the air temperature of the classroom and record the value in the data table.

3. Open the file "33 Speed of Sound" in the *Physics with Vernier* folder. A graph of sound level *vs.* time will be displayed.

4. Close the end of the tube. This can be done by inserting a plug or standing a book against the end so it is sealed. Measure and record the length of the tube in your data table.

5. Place the Microphone as close to the end of the long tube as possible, as shown in Figure 2. Position it so that it can detect the initial sound and the echo coming back down the tube.

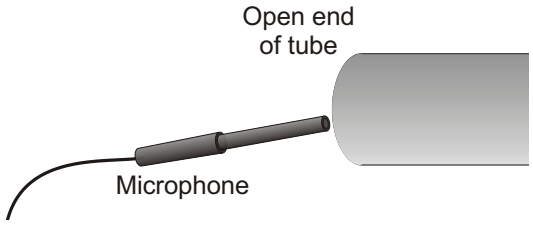
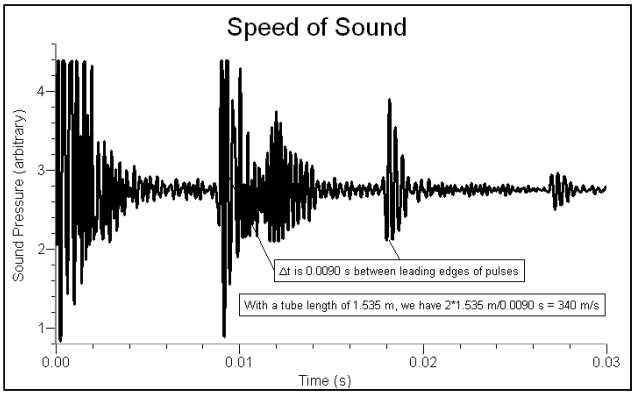


Figure 2

6. Click Collect to begin data collection. Click the dog training clicker or snap your fingers near the opening of the tube. This sharp sound will trigger the interface to begin collecting data.

7. If you are successful, the graph will resemble the one below. Repeat your run if necessary. The second set of vibrations with appreciable amplitude marks the echo. Click the Examine button, . Move the mouse and determine the time interval between the start of the first vibration and the start of the echo vibration. Record this time interval in the data table.



8. Repeat the measurement for a total of five trials and determine the average time interval.

Length of tube	m
Temperature of room	°C

Trial	Total travel time (s)
1	
2	
3	
4	
5	
Average	

Speed	m/s

ANALYSIS

1. From the time-pairs you recorded in the data table, calculate the differences to find the time interval, and then calculate the average time interval.

2. Calculate the speed of sound. Remember that your time interval represents the time for sound to travel down the tube and back.

3. The accepted speed of sound at atmospheric pressure and 0°C is 331.5 m/s. The speed of sound in air can then be given by the equation:

$$c_s = 331.5\ [m/s]\sqrt{\frac{T}{273\ [K]}}$$

   Calculate the speed of sound at the temperature of your room and compare your measured value to the accepted value.