Experiment: The Speed of Sound

Objectives:

a. to measure the frequency of pure tones and investigate the frequencies of natural sounds
b. to measure the speed of sound in air
c. to determine the value of γ for diatomic gases

Materials:

- tuning fork
- LoggerPro software and LabPro interface
- microphone/sound sensor
- electronic synthesizer
- a long hollow tube
- a tape measure
- a thermometer or temperature probe

Preliminary Questions:

1. A sound travels a distance d= 300 m in 0.88s. What is the speed of sound?

2. If a sound of frequency f=1000 Hz is produced, how would the pressure of the air change in time? Sketch your prediction below on the pressure vs. time graph. Mark the value of the period on the graph.

3. If a sound with a frequency f=500 Hz is generated, how would the graph pressure vs. time be different from the graph sketched at the question 2 above?

4. Do you think that the sound of your voice, while holding a note, will be a pure tone?

Part I: Investigating Sound Frequency

Sounds consisting of only one frequency are called pure tones. Pure tones are generated by tuning forks or electronic devices, such as the tones of a telephone. Most of the sounds produced naturally consist of more than one frequency. The frequency with the higher amplitude is the main frequency. In this lab you will analyze the frequency of the sounds generated by a tuning fork, an electronic synthesizers and your own voice.

Procedure:

1. Connect the Microphone to the LabPro interface then start LoggerPro.

2. Open the LoggerPro experiment file: "34 Tones Vowels Telephone" from the *Physics with Vernier* directory

3. Hit the tuning fork with a rubber hammer (please don't use a hard object to hit the tuning fork) and bring the tuning fork next to the microphone. Press "Collect". Using the Analyze/Examine tool, measure the time to complete 5 cycles. Enter your results in the table below.

4. Repeat step 3 using a different tuning fork. Cut and paste one of the graphs into Word.

5. Calculate the % Error by using the value for the frequency engraved on the tuning fork.

Number of cycles	time	Period	frequency	Actual frequency	% Error

6. Locate the electronic synthesizer. You can select different instruments (piano, organ, guitar etc). Generate the same note using 2 different instruments and describe the similarities and the differences below. Collect the sounds using sound level sensor.

7. Repeat the step 6 mimicking the same note using your own voice.

8. What similarities and differences do you notice between the graphs generated in steps 6 and 7 above?

Part II: The Speed of Sound & Measurement of γ

Compared to most objects, 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 stop watch 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. You will time the echo and measure the distance traveled to calculate the speed of sound:

v = distance/time

The speed of sound in gases depends on the temperature and nature of the gas. In air, the speed of sound is given by the relation:

$$v_{sound} = \sqrt{\frac{\gamma k T}{m_{air}}}$$

where m_{air} is the average mass of an air molecule ($m_{air} = 4.74 \times 10^{-26}$ kg) and k is Boltzmann's constant.

Objectives:

a. Determine the speed of sound and compare this value to the accepted value.
b. Use the speed of sound to estimate γ for air

Procedure:

1. Connect the Vernier Microphone to CH 1 on the LabPro Interface then start the LoggerPro software.

2. Open the LoggerPro experiment file: "33 Speed of Sound" from the *Physics with Vernier* directory.

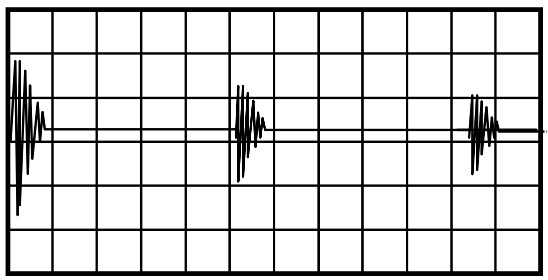
3. Close the end of the tube. This can be done by inserting a plug or standing a book against the end so it is sealed. Measure and record the length of the tube.

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

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

6. Begin data collection then produce a sharp "clack" or "snap" sound near the opening of the tube. *Striking two pieces of wood together makes a good sound. 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 (± uncertainty).

DATA TABLE:

Closed Tube	
Length of tube	m
Temperature of room	°C

Trial	**Travel time**	
1		
2		
3		
4		
5		**Uncertainty**
Average Time		
Average Speed	**m/s**	

ANALYSIS

1. Calculate the average speed of sound in air, including uncertainty. Record the value in the table above.

2. The accepted speed of sound at atmospheric pressure and 0 °C is 331.5 m/s. The speed of sound increases 0.607 m/s for every °C. Calculate the speed of sound at the temperature of your room and compare your measured value to the accepted value.

   $v_{accepted}$ = ____________

   $v_{measured}$ = ____________ **% Error =** ________

3. The speed of sound in a gas is given by the relation:

$$v_{sound} = \sqrt{\frac{\gamma kT}{m_{air}}}$$

   where:

   k is Boltzmann's constant = 1.38×10^{-23} J/K
   T is the room temperature, in K
   m_{air} is the average mass of an air molecule ≈ 4.74×10^{-26} kg

   Using the above expression, calculate γ for your experimental values of v_{sound}.

4. Compare your experimental value for γ with the theoretical value (for diatomic gas: $\gamma = \frac{c_P}{c_V} = \frac{\frac{7}{2}}{\frac{5}{2}} = \frac{7}{5}$). Calculate the % Error.