Speed of Sound

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 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. In this experiment, you will use this technique with a Microphone sensor 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 such as snapping your fingers next to the opening, the interface 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.

MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software
data-collection interface
Vernier Microphone
Thermometer or Temperature Probe
tube, 1–2 meters long
book or plug to cover end of tube
meter stick or tape measure
dog training clicker

PRELIMINARY QUESTION

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. Use the thermometer or temperature probe to measure the air temperature of the classroom. Record the room temperature in your data table.

2. 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 the length of the tube and record in the data table.

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

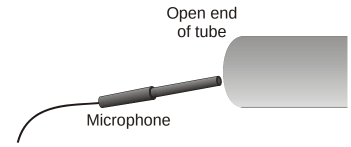

Figure 2

4. Connect the Microphone to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.

5. Choose New Experiment from the Experiment menu. Choose Collection Set up from the Experiment menu. Enter **5000** as the rate (samples per second). The number of points collected should be 151. Select OK

6. Choose Set Up Sensors ► Zero from the Experiment menu. This will center the data around the x-axis and is needed for using the trigger threshold indicated in Step 7d.

7. Set up the interface to trigger on the first loud sound the Microphone detects.
   a. Choose Advanced Set Up ► Triggering ► Set Up from the Experiment menu.
   b. Select the Microphone as the sensor to use as the trigger.
   c. Select **Increasing through Threshold** as the type of trigger to use.
   d. Enter **0.1** as the trigger threshold in the units of the sensor. This means that data collection will begin when voltage increases across this trigger level.
   e. Select OK.

8. Start data collection ( ). When you see the message *Waiting for Trigger*, click the dog training clicker near the opening of the tube. Data collection will begin when the trigger level is reached. After data collection is complete, a graph of Sound Pressure *vs*. Time will be displayed.

9. If you are successful, the graph will resemble the one in Figure 3. You may not see a third reflection. In this figure, each of three highest peaks corresponds to the same point on a waveform. The first peak is the initial sound, the second is the first reflection, and the third is a second reflection. Repeat data collection if necessary.

10. Tap any data point on a graph and use ► and ◄ to identify the time of the initial sound and first reflection. Record these values in the data table.

11. Repeat Steps 7–10 for a total of five trials. Be sure to click the Store Latest Data Set button ( ) prior to collecting each new run.

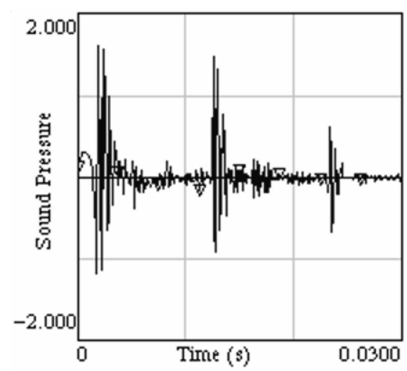

Figure 3

DATA

Temperature of room (°C)	
Length of tube (m)	

Trial	Time of direct sound start (s)	Time of echo start (s)	Time Interval (s)
1			
2			
3			
4			
5			
Average			

Speed (m/s)	

PROCESSING THE DATA

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 average time interval represents the time for sound to travel down the tube and back.

QUESTION

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

EXTENSIONS

1. Repeat this experiment, but collect data using a tube with an open end. How do the reflected waves for the closed-end tube compare to the reflections with an open-end tube? Explain any differences. Calculate the speed of sound and compare it to the results with a tube with a closed end.

2. Try performing this experiment without a tube. You need an area with a smooth surface. Multiple reflections may result (floor, ceiling, windows, etc.), adding to the complexity of the recorded data.

3. Fill a tube with another gas, such as carbon dioxide or helium. Be sure to flush the air out with the experimental gas. For heavier-than-air gases, such as carbon dioxide, orient the tube vertically and use a sealed lower end. Invert the tube for lighter-than-air gases.

4. Use this technique to measure the speed of sound in air at different temperatures.

5. Develop a method for measuring the speed of sound in a medium that is not a gas.