MEASURING THE SPEED OF SOUND USING AN ECHO

The speed of sound in air is so fast that we usually don't notice any delay. Sound can travel across a typical classroom in about 0.002 seconds. How can we measure the speed of something going so fast? What factors can affect the speed of sound?

Objectives

- Assemble an experimental setup capable of measuring the speed of sound.

- Learn how to use an oscilloscope to measure events spaced together closely in time.

- Accurately measure the speed of sound.

- Apply what is learned about the speed of sound to new situations.

Materials and Equipment

- Data collection system
- PASCO Wireless Sound Sensor
- PASCO Resonant Air Column
- Markers (2)

- Rod stand
- Clamp
- Cardstock and tape

Safety

Follow regular laboratory safety precautions.

Procedure

1. Lay the resonance tube on a flat surface and cover one end with a circle of cardstock about the same size using tape. It doesn't need to be a tight seal so don't use much tape.

2. Attach the clamp to the rod stand and then the clamp to the wireless sound sensor. See Figure 1.

3. Place the wireless sound sensor by the open end of the resonance tube and adjust its position and height so the microphone end is centered and even with the opening. See Figure 1.

4. Start the data collection software and connect it to the wireless sound sensor.

Figure 1

5. Create a scope display and select Sound Wave for the vertical axis. Time should be on the horizontal axis.

6. Change the recording mode from Continuous Mode to Fast Monitor Mode. Set the trigger to 4.

7. The speed of sound varies with temperature. At 0° C and standard atmospheric conditions the speed of sound is 331 m/s. It increases by 0.6 m/s for every degree above 0° C. Measure or estimate the temperature in your classroom and use it to find the speed of sound at that temperature. Show your work and result below.
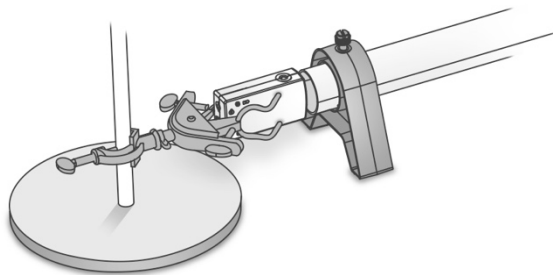
8. Estimate the time it takes a sound wave to travel the length of the resonance tube and return after reflecting off the end covered with cardstock. Using the measured length of the resonance tube and the speed of sound from step 7, find the total time for a sound wave to travel back and forth once through the resonance tube. Show your work and result below.

9. Adjust the time axis scale of the scope display so that it is at least 1.5 times longer than it needs to be to measure the time found in step 8. For example, it would take sound about 0.007 s to travel back and forth through a 1.2 m resonance tube. The time axis scale should go from zero to about 0.01 s in this case.

10. Using the data collection system, zero the wireless sound sensor and click the Monitor button. Data will only be recorded if the signal is above the trigger level of 4 set in step 6. If you notice that background noises are being collected, adjust the trigger up. It is desirable to have it set as low as possible but if it is too low, it will cause problems as background noise interferes.

11. While holding them firmly, gently tap the 2 markers together close to the wireless sound sensor being careful not to touch it, the resonant tube or the table. If data is not collected after trying several times, adjust the trigger level down. After data is collected, adjust the vertical axis scale so all the data is displayed. A good signal will appear starting at time zero, then die down to zero, then come back up when the echo hits the sound sensor. Keep tapping the markers until a signal like this is displayed. Be careful not to make any sounds and click Stop on the data collection system.

12. Use the data collection system to find the time when the echo hits the wireless sound sensor. Assuming that data collection started when the markers were tapped, this is the time it took the sound wave to travel down the resonant tube and return. This should be close to the time estimated in step 8. Record the time of the first part of the echo below. Use it and the length of the resonant column to find the speed of sound in the classroom. Show your work and results below.

    Sound wave travel time = _____ s

13. Repeat steps 11-12 four more times. Record the measured sound wave travel times in Table 1 below. Calculate and record the resulting speed of sound in the table.

Table 1: Speed of Sound in Air

Trial	Travel Time (s)	Speed of Sound (m/s)
1		
2		
3		
4		
5		

14. Average the 5 speed of sound calculations and determine the percent error assuming your estimate in step 7 is the theoretical value. Record your results and show your work below.

Questions and Analysis

1. List 2 specific sources of error in your procedure. Pick one and describe a way to reduce its effect on the resulting speed of sound.

2. A person stands at the top of a canyon wall 500 m directly above the bottom. They measure the temperature and use it to estimate the speed of sound to be 340 m/s. They look down and yell "hello". How much time will it take for them to hear the echo? Show all of your work below.

3. The person in question 2 learns that the temperature at the bottom of the canyon is different than at the top. If they heard the echo of their yell a little earlier than they expected, was it warmer at the bottom or colder? Explain your answer below.

4. The reason the speed of sound increases with temperature is because warmer air molecules have more energetic vibrational motion. The molecules can transfer the sound's pressure wave more quickly if they are vibrating faster. Based on this, how would the speed of sound change as a jet takes off from the runway and increases its altitude? Explain your answer below.

5. The speed of jet planes is sometimes given in terms of a Mach number where Mach 1 is the speed of sound, Mach 2 twice that and so on. The SR-71 set the record with a speed of Mach 6.7 at an altitude where Mach 1 = 300 m/s. How far did the pilot go during 1 blink of an eye (0.1 s)?