

## THE SPEED OF SOUND

**Objectives:**

- To measure the speed of sound in air in three different ways.
- To compare and reflect on your results, taking into account the uncertainties in your measurements.

**To Do Before Lab:**

- Read this lab

**Apparatus:** Microphones, oscilloscope, Al rods, ultrasonic transmitter and receiver, optical bench, signal generator, speaker.

### Introduction:

In this lab we measure the speed of sound  $c_s$  three ways. The first method is a direct measurement of the propagation of a sharp pulse of sound over a known distance. This is a crude but direct method. In the second method we find the speed of sound by observations of travelling waves. The third method uses properties and observations of standing waves. Finally in the last part we compare and reflect on the results of the three methods.

Enjoy!

### Part I: Measuring $c_s$ with Time Delay

In this method we measure the speed of sound by directly measuring the time required for sound to travel over a known distance. Two microphones are connected to the inputs of the oscilloscope. Set them about 1.5 meters apart facing in the same direction. You can monitor the voltage output from the two microphones with the scope.

(1) Try out the apparatus making a sharp sound in front of the first microphone by hitting the two Al rods together. Do you see evidence for a time delay between the signals from the two microphones? If so, move the two cursors to the beginning of the two signals (if you can't find the right knob ask your instructor). The box labeled "Delta" on the right hand side of the screen gives the time difference between the two cursor lines. Repeat this measurement a few times (you will have to hit the Run/Stop button to reactivate the scope). Estimate the uncertainty in the measured time delay.

(2) What else do you need to measure to find the speed of sound? Measure it and estimate the uncertainty. Determine the speed of sound and use a propagation of error analysis to find the uncertainty in the speed. After writing your result in standard form, celebrate your first measurement of the speed of sound by drawing a box around this result.

### Part II: Measuring $c_s$ via Wavelength, Period, and Frequency

In this second method we find the speed of sound with measurements of wavelength and frequency.

(1) Set up the optical bench with the ultrasound transmitter- receiver pair about 10 cm apart. Connect the transmitter to the signal generator and the receiver to Channel 2 of the scope.

Connect the signal generator to Channel 1. Use the trigger menu to change the scope from Single to Normal, so that it can continuously monitor the signals.

(2) Set the signal generator to about 25kHz with an amplitude of no more than  $\frac{1}{4}$ . Adjust the sweep rate of the scope (sec/div) so that you see a few periods of the signal coming from the signal generator. Adjust the volts/div to get an appropriately sized signal. The receiver has a high Q/narrow frequency response, so the transmitter frequency must be set carefully to match the resonant frequency. Adjust the frequency of the signal generator until you get a maximum signal from the receiver. Move the receiver forward or backward slightly until the trace from the receiver is in phase with the trace from the signal generator. Record the position of the receiver with uncertainty.

(3) Now move the receiver away from the transmitter noting at what position the two signals are in phase again. How far did you move the receiver? How far did you move it in terms of the wavelength of the sound waves? (This is a KEY point!)

(4) Carefully move the receiver away from the transmitter, counting the number of wavelengths. Think about and explain why it makes sense to move the receiver many wavelengths. From your data determine the wavelength and estimate the uncertainty. Use the Measure feature on the scope to determine the frequency of the sound waves and estimate the uncertainty. Calculate the speed of sound with uncertainty. This is it! Finish this part by flourishing a pen to box this result.

### **Part III: Measuring with the Wavelength, Period and Frequency of Standing Waves**

The last method uses not just a single sound, nor a traveling wave but a standing wave in a glass tube. It is similar to the standing wave on a string lab.

(1) Place the loudspeaker near one end of the long glass tube, so sound waves can enter the tube. Place the microphone near the other end of the tube to measure the intensity of the sound coming from the tube. Set the signal generator to around 1000 Hz, with an amplitude of about  $\frac{1}{4}$ . Adjust the scope as necessary. Adjust the frequency of the signal generator until a standing wave resonance is detected. Listen (or watch the scope) and you will know when you've got one. Find at least 5 other resonant frequencies.

(2) Determine the speed of sound with uncertainty. Celebrate your last speed of sound measurement with a box.

### **Part IV: Summary and final results**

(1) State your three results with uncertainties.

(2) Discuss the variation in values for the speed of sound from each method. Can the discrepancies be explained in terms of random errors, or is there evidence for systematic errors in one or more of the methods?