

Velocity of Sound

Purpose: To measure the velocity of sound by examining the phase difference between points on a sound wave propagating through air and thus gain experience at using an oscilloscope and working with Lissajous patterns.

Equipment: Oscilloscope, audio signal generator, microphone, 2 meter stick, speaker, 256 Hz tuning fork resonator box.

Introduction:

The velocity, v , of the sound in a liquid or gas can be shown to be

$$v = \sqrt{B/\rho}$$

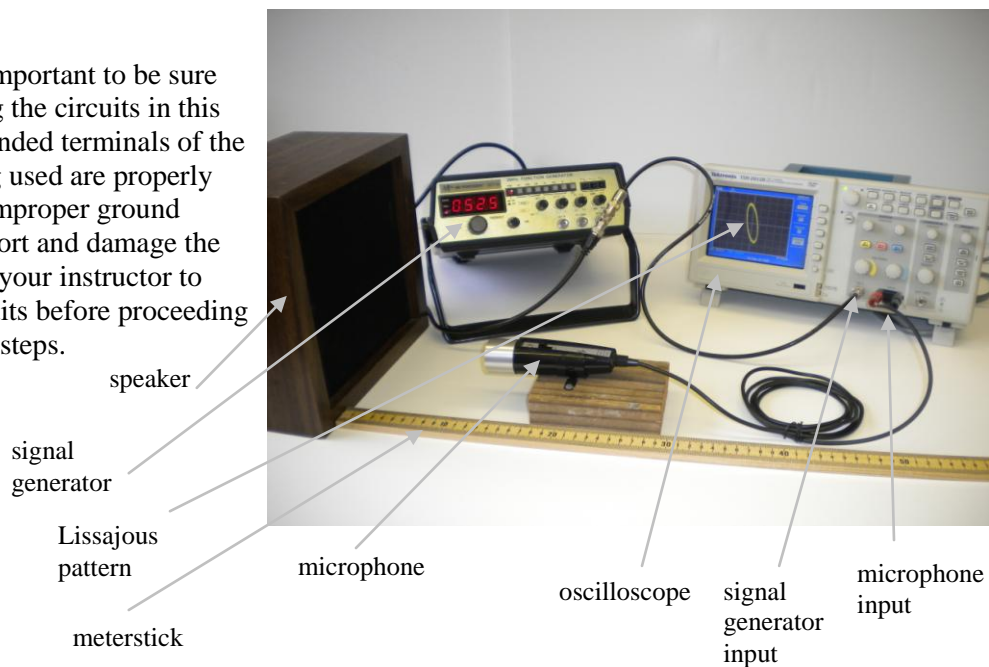
Where ρ is the density and B is the bulk modulus of the medium. In general B depends on temperature. For sound waves in a gas where the volume changes can be considered adiabatic, one can show that the velocity of the sound depends on temperature in the following way:

$$(1) \quad v = \sqrt{\gamma RT/W}$$

Where γ is the ratio of specific heat at constant pressure to that at constant volume ($\gamma = 1.402$ for air), R is the universal gas constant ($R = 8.314 \text{ J/mole-k}$), and W is the molecular weight of air ($W = 0.0288 \text{ kg/mole}$).

In this lab, we will use a signal generator to produce a voltage that varies sinusoidally in time. If we think of the waveform generated by the signal generator as a reference signal, we can easily view differences in frequency and amplitude between the reference signal and another waveform using an oscilloscope. Your instructor will explain how this voltage can be compared with another sinusoidal signal to form a Lissajous pattern on the oscilloscope.

Note: It is especially important to be sure that when wiring the circuits in this lab that the grounded terminals of the equipment being used are properly connected. An improper ground could cause a short and damage the equipment. Ask your instructor to check your circuits before proceeding in the following steps.



Procedure:

1. Connect CH1 of the oscilloscope to the signal generator and obtain a trace of the signal generator output for a frequency of about 250 Hz. Become familiar with the various controls on the oscilloscope, such as vertical gain (VOLTS/DIV), horizontal gain (SEC/DIV), MEASURE, DISPLAY, AUTOSET, etc.
2. Connect the horizontal input of the oscilloscope to a microphone and with the help of your instructor, obtain a Lissajous pattern on the oscilloscope by using a 256 Hz (or other) tuning fork and resonator box as a second input to the microphone. Adjust the frequency of the signal generator until a one to one Lissajous pattern is obtained. Explain the pattern displayed. In a similar manner adjust the signal generator to obtain one to one, two to one, one to three, and three to one Lissajous patterns. Explain how each of these patterns is formed.
3. Adjust the frequency of the signal generator to 4000 Hz by using a frequency counter to precisely measure the frequency. With the signal generator and microphone still attached (as above) to the oscilloscope, also attach a speaker to the signal generator. Obtain a Lissajous pattern on the oscilloscope and note how the Lissajous pattern changes shape as the microphone is moved toward or away from the speaker. This change results from the varying phase difference between the two sources.
4. Position the microphone directly in front of the speaker and adjust the horizontal and vertical gain of the oscilloscope until they are approximately equal. Move the microphone in a straight line directly away from the speaker until the ellipse becomes a straight line inclined at about 45° . Mark this position.
5. Slowly move the microphone directly in front of the speaker and observe the change in the pattern as the phase between the two signals changes. When the ellipse again returns to its original straight line inclined at 45° , the microphone has been moved a distance of one wavelength. Continue moving the microphone away from the speaker until the signal is too weak to be useful. Measure the total distance moved to the last whole wavelength and record this along with the total number of wavelengths through which the microphone was moved.
6. Repeat steps 3, 4, and 5 for frequencies of 5000 and 6000 Hz.
7. Compute the velocity of sound for the average wavelength obtained for each frequency. Obtain an average velocity of sound (equation 1) at the temperature observed during the experiment.
8. Starting with equation 1 show that the velocity of sound in m/sec can be written approximately (for small T_c) as:

$$v = 332.5 + 0.61 T_c$$

Where T_c is the temperature of the air in C. (hint: Write the temperature in equation 1 as $T = 273 + T_c$ and put the expression in a form suitable for using a binomial expansion for small T_c .)