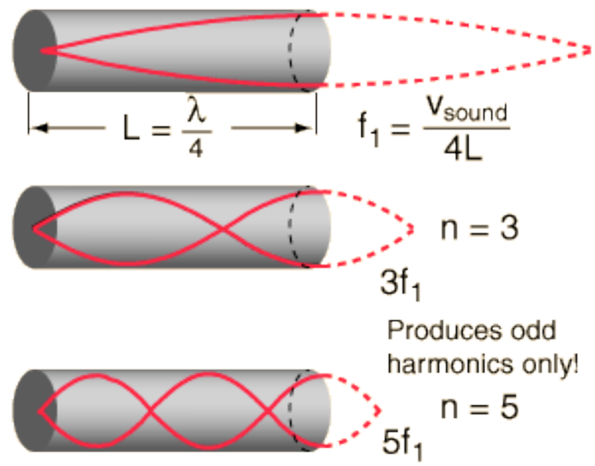
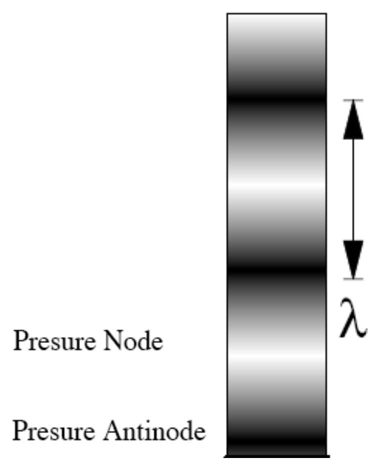
PreLab 6 – Standing Waves in an Air Column

Standing waves are set up in wind instruments when air is blown through them. The pressure vibrations are a result of sound waves moving back and forth in opposite directions along the tubes. These waves interfere with each other in such a way to form **standing waves**.
In our lab the air column is "fixed" at one end by a cover. At the other end of the tube is open and attached to a speaker and a frequency generator

Standing waves in a closed-end tube



Any medium (i.e., water or a stretched wire) that can support traveling waves can be made to resonate. When a medium is made to resonate, energy is efficiently exchanged between whatever is vibrating the medium and the medium itself. The standing-wave concept can be used to determine the resonant frequency of air columns.
Imagine a column of air that is open at the top but closed at the bottom. Suppose a tuning fork or other suitable single-frequency sound source excites this column of air. The column will resonate (you will hear a loud sound) when the tuning fork source excites the air column at one of its natural (resonant) frequencies. The resonant frequency of the column occurs when its length L is such that an antinode occurs at the open end where air molecules are free to vibrate, and a node occurs at the closed end where the air molecules are not allowed to vibrate. In general, the condition for an antinode at the open end and node at the closed end is $L = n\lambda/4$, where n = 1, 3, 5, 7, ... In this case, the wavelength λ of the standing wave is defined by $\lambda = 4L/n$.



The diagram above illustrates this:
The **pressure nodes** in the diagram correspond to those places where the pressure does not change at all, while the pressure **antinodes** are the places where the variation in the pressure is a maximum.
We can ''tune'' the frequency of the speaker sound to resonate with length of the tube. From the above condition for resonance, you can determine the wavelength of the resonant standing waves and if the frequency of the speaker is given, you can the use the following relationship to calculate the velocity of sound: $v_s = f\,\lambda$, where v is the speed of either one of the traveling waves that make up the standing wave, f is the frequency of the standing wave, and λ is the wavelength of the standing wave. Note that the standing wave and both of the traveling waves that compose it have *identical* frequencies and wavelengths. Note: The speed of sound in air in normal conditions of temperature and pressure is
$v_s = 343$ m/s .

LAB 6 & Lab Report

Name: ___________________________ **Section**: _______________

Frequencies in an Air Column

Equipment: function (or frequency) generator, speaker, cables, closed-end tube, thermometer

This lab will familiarize you with the phenomenon of resonance and allow you to measure the speed of sound in air.
You will then compare your experimental value to the expected value.
The speed of sound in air depends on the temperature. The speed of sound in air in normal conditions of temperature and pressure is given by $v_s = 343$ m/s.
The boundary condition at the speaker end of the tube is "mostly" closed but because of the details of the construction of the speaker and its mounting, this end of the tube demands a boundary condition which is in between a displacement antinode and a node.

Register the length of the tube: L = _______________

(a) Start at low frequencies. Vary the frequency of the frequency generator slowly until you reach point where you have added a half wavelength to the standing wave pattern. The sound coming from the tube is maximized. Repeat the previous step by adding additional half-wavelengths to the tube and record the frequencies read.

(b) Record the room temperature with a thermometer. Calculate the expected sound velocity from the relation $v_s = 332$ m/s ± 0.6 m/s/°C. That is, the speed increases by 0.6 m/s for each degrees Celsius increased, starting from 0^o C.
CAUTION: You can damage the speaker by overdriving it. Raise the amplitude cautiously. The sound from the speaker should be clearly audible, but not loud. Note also that many function generators become more efficient at higher frequencies, so you may need to reduce the amplitude as you raise the frequency. A distorted sound from the speaker indicates that the speaker is producing overtones and this will confuse your results.

1) Describe your results for this experiment. Show a table of frequencies measured.

2) What is the temperature of the room? What is the expected speed of sound?

3) Using the formulas presented in the PreLab, calculate the lowest frequency which should be audible in the tube (**fundamental frequency**). Show the derivation of your numbers.

4) Calculate what you would expect for the frequencies of standing waves within one open and one closed-end tube. This should follow from equations $\lambda = 4L/n$ (n=1,3,5,…) and $f = v/\lambda$.

5) Calculate what you would expect for the standing wave frequencies within a tube with two closed ends. This should follow from equations $\lambda = 2L/n$ (n=1,2,3,4,…) and $f = v/\lambda$. Note that in this case the fundamental frequency is twice that of the previous case (question 4).

6) Your measurements should allow you to conclude what is the best model for the tube. Closed ends, or one open and one close end? Why?

7) Explain the reasons for a discrepancy of your experiment and the expected theoretical description.

4 Do you think that the diameter of the tube has an effect on the resonance? (Think about the speakers on your stereo.) Explain.