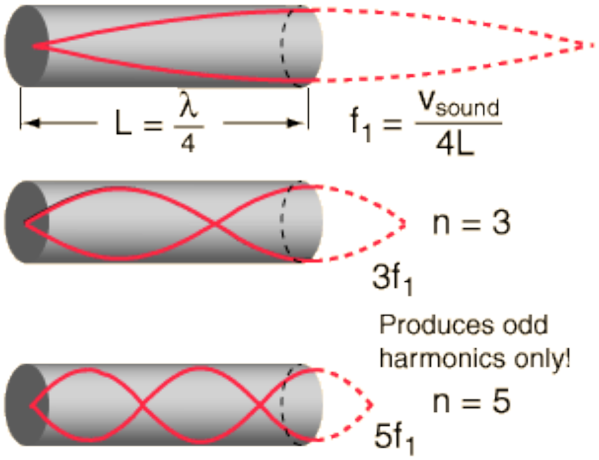
PreLab 7 – Standing Waves in an Air Column - II

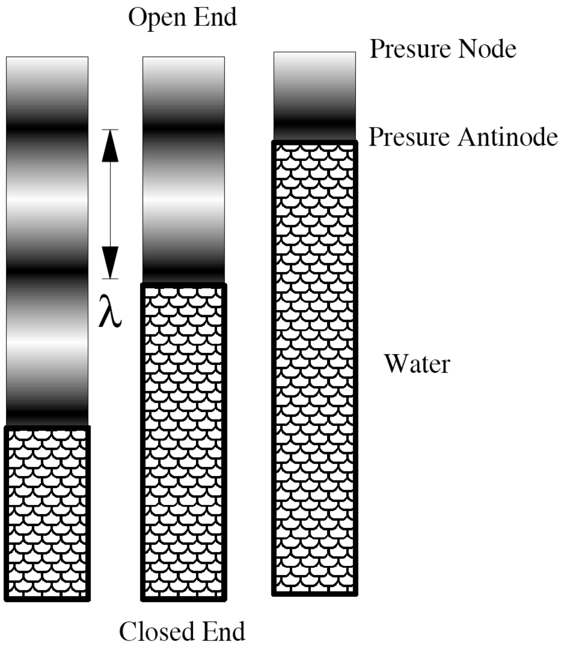
It is possible to increase the amplitude of an oscillating medium to very large levels, and with a seemingly small amount of energy, by shaking the system at a particular frequency. Loosely speaking, this phenomenon is called ''resonance.'' One example of resonance is the famous case of the crystal champagne glass and the opera singer. If you tap a champagne glass lightly with a spoon, it produces a musical note. This oscillation frequency of the glass when it is allowed to vibrate freely is its ''natural'' frequency. When the singer sings at this frequency, the glass absorbs the sound energy, oscillates with ever increasing amplitude and then breaks when the glass vibrates too much. In this lab you will again observe the phenomenon of resonance in a vibrating column of air, this time using tuning forks.

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 $n = 1, 3, 5, 7, \ldots$. In this case, the wavelength λ of the standing wave is defined by $\lambda = 4L/n$.



The diagram on the right 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 pressure variation with respect to ambient pressure is a maximum.

We can use different tuning forks to generate frequencies and find the length of the tube that the sound resonates in one of the vibration modes. From the above condition for resonance, you can determine the wavelength of the resonant standing waves and if the frequency of the tuning fork 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 both of the traveling waves, which compose the standing wave, 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. But you will measure the temperature and calculate this speed.

LAB 7 & Lab Report

Name: ______________________________ **Section**: ________________

Frequencies in an Air Column

Equipment: tuning forks, fixed tube filled with water, transparent open tube, ruler , thermometer

Note: Use tuning forks with frequency greater than 256 HZ.

1. Fill the PVC reservoir with water at a relatively low position.
2. Hold a vibrating tuning fork over the open end of the tube while changing the water level. Locate a fundamental resonance (loudest sound) by manipulating the water level and reactivating the fork. You will manipulate the water level by raising/lowering the tube in the reservoir.
3. Read the water levels X_1 and X_2 at two successive resonance points (loudest sound) and record them on the data sheet.
4. Calculate the wavelength from the formula:

$$\lambda = 2\,|X_1 - X_2|.$$

5. Record the frequency of the tuning fork used. Calculate the velocity of sound and record it.
6. Repeat the above steps for three different frequencies of tuning forks.
7. Record the room temperature with a thermometer. Calculate the accepted speed of sound.

Report:

1. Describe your results for this experiment.

2. Name the different factors necessary for resonance and a standing wave in this apparatus. You may want to draw a sketch.

3. If both the ends of the tube were closed (i.e., fixed and rigid), sketch the standing wave and identify the nodes and antinodes.

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

5. How well do you think you could measure the water level positions that correspond to resonant conditions? Explain your error estimate.

6. Calculate the percentage error for your value of the speed of sound. Explain what you think caused a difference from the accepted value.