PH263

# Resonance in Air Columns

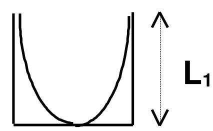
## I. EQUIPMENT LIST

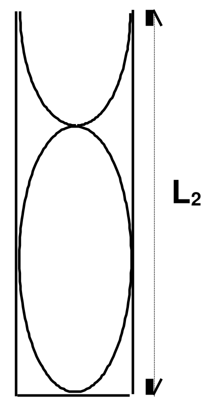
- Horizontal Resonance tube w/plunger
- Oscilloscope
- Function Generator
- BNC – Dbl Banana cable
- Microphone assembly
- 1 meter brass rod

## II. BACKGROUND INFORMATION

The air enclosed in a tube or pipe is elastic and can be set into vibration by placing a source of sound near one end of the tube. When the frequency of the sound source matches the natural or resonant frequency of the air column the amplitude of vibration will be much larger. This is due to an increase in the efficiency of energy transfer from the source to the column. The speed of sound of the medium in a tube can be calculated by finding the lengths that resonant for a known frequency.

A standing wave pattern is formed in the tube by the resonant frequency. The frequency of the standing wave pattern is determined by the length of the column and whether the ends are open or closed. The sound vibrations travel down the tube and reflect from the end (in the lab the end will be the surface of the plunger). If the length of the tube is an odd multiple of a quarter wavelength of the sound wave, $n(\lambda/4)$, where n= odd integer, then the reflected waves will reinforce the incoming waves and *the sound will increase in loudness.* This can be noted by listening or by using an oscilloscope. The plunger end of the air column will have a node and the open (air) end of the tube will have an antinode. (See figures to the right.)




For the open end of the tube the antinode is just outside the open end of the tube and this is called the end effect. The acoustical length of the tube is slightly longer than the physical length. This difference can be negated by taking the difference between two consecutive resonance points. The lengths would be for example $L_1 = \lambda/4$ and $L_2 = 3\lambda/4$ so $L_2 - L_1 = \lambda/2$. Solve for the speed of sound using the wave equation, $v = \lambda f$, where f is the frequency, $\lambda$ is the wavelength and v is the speed of sound in the medium.

The speed of sound in air is dependent on the temperature of the air and can be computed from $v = v_o + 0.6T$ where $v_o$ is the speed of sound in air at $0^oC$ (331.3 m/s) and T is the temperature in Celsius.

## III. EXPERIMENTAL PROCEDURE

A. The resonance tube apparatus consists of a clear tube, a plunger, a brass rod, a small microphone, and two end supports. All connections are made at the end where the speaker is located (left). DO NOT TOUCH THE SPEAKER SURFACE

B. Set the resonance tube assembly on the table.

C. Locate the small hole just below the speaker. Insert the microphone into the hole and tighten the thumb screw. DO NOT OVER TIGHTEN

D. Attach the BNC – Double Banana cable to the function generator and the two Banana plugs into the speaker ports.

E. Attach the BNC end of the microphone cable to CH 1 of the oscilloscope.

F. Measure the inner diameter of the tube using the Vernier Caliper and then set the tube between the end supports.

G. On the function generator, make sure the far right knob, the amplitude, is turned all the way **counter-clockwise**. This controls the volume of the speaker. If the amplitude is too high, the speaker could be damaged.

H. You will be using the following frequencies: 392.0 Hz, 440.0 Hz, 480.0 Hz

I. Set the function generator to the first frequency. The tone you hear does not have to be loud for the oscilloscope to register the sound. DO NOT SET THE VOLUME TOO HIGH OR YOU COULD DAMAGE THE SPEAKER.

J. Set the oscilloscope so you see a sine wave pattern for the particular frequency.

K. Adjust the plunger to find the first resonant point. Record the data and move the plunger from this point. Repeat by having different people adjust the plunger and look for resonance. Record your data. You may mark your locations on the tube using a wet-erase marker.

L. Do a theoretical calculation to check your setup.

M. Move the plunger to find the second resonant point in the air column. Repeat and record your data.

N. Repeat steps G thru K for a second frequency.

O. Get one of the "Unknown Frequency" generators and hook the BNC – Dbl. Banana cable to it. Record the Id number on the generator. Repeat steps G thru K for the "unknown frequency."
DO NOT REMOVE THE COVER OR MAKE ANY ADJUSTMENTS TO THE FUNCTION GENERATOR!

**Erase all marks made on the tube before putting away the equipment.**

## IV. DATA

Record the room temperature _________

Record the frequency, lengths for $L_1$ and $L_2$ in table format including units.

## V. CALCULATIONS

A. Compute the average length for the resonance lengths for each line of the data table. Add columns to your data table as necessary.

B. For a single frequency subtract the average $L_1$ from $L_2$ and solve for the wavelength. Multiply the wavelength by the frequency to compute the speed of the wave. Repeat for each frequency.

C. Compute the average speed of sound for the three frequencies.

D. Calculate the speed of sound from knowing the air temperature and the equation in the last paragraph of the Background information.

E. Calculate the percent difference for the speed of sound values calculated in parts C, D.

F. Determine the unknown frequency.

G. Build a graph of wavelength vs. frequency and second graph with a linear version of the first one. Write the equation of the line in terms of $\lambda$ and $f$, not the fit equation given by excel. Interpret the slope in terms of the appropriate physical quantity (of quantities) and use it to find the speed of sound.

H. Compare, i.e. calculate the percent difference between the speed of sound as calculated and as obtained from the graph with the theoretical value and comment.

## VI. CONCLUSIONS/QUESTIONS

A. How could you solve for the speed of sound if you could only find one resonance position for a given frequency?

B. The antinode at the top of the tube actually appears slightly above the end of the tube by an amount E (known as the end correction). Using the data for the wavelength solve for the end correction. Show your work.