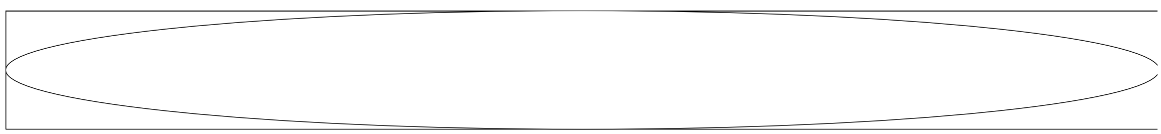
LAB 3: Resonant Flame Tube

REQUIRED READINGS: **Vibrating Air Columns p. 63-65**

Theory:

This experiment is both a visual and auditory exploration of the speed of sound in a tube filled with a gas that is not air. The tube will be filled with gas that will be lit so that the standing waves are visible. A speaker is attached to drive the waves and the resonances can be heard. Once resonant frequencies have been found the wavelength and the speed of sound in the tube can be calculated.

Since the pipe is closed on both ends, resonance occurs when there are nodes at both ends. For example the first displacement resonance looks like this:



This is half a wavelength. So the equation for the wavelength of each resonance can be written as: $\lambda = \frac{2L}{n}$; where n = 1, 2, 3 The frequency can be read directly from the apparatus. Because of the geometry of our system the flames will go out at frequencies below about 400Hz. So, for this lab, we will not concern ourselves with $n < 4$. With the wavelength and the frequency, the velocity for each resonance can be found directly from the equation: $v = f\lambda$.

However, this experiment entails some error. So, instead of finding the velocity directly, you will graph at least 8 points on a graph, draw a best fit line and then find the slope of the line. Make the graph large. (Do not be afraid of using an entire sheet of paper just for the graph.) Remember that the slope of a line can be found by picking two arbitrary points on the line (not data points!) that are far apart ((x1, y1) & (x2, y2)), and following the equation: $slope = \frac{y_2 - y_1}{x_2 - x_1}$. Since we are looking for velocity and $v = f\lambda$, we want to graph f vs. ($\frac{1}{\lambda}$), where f is on the y-axis and ($\frac{1}{\lambda}$) is on the x-axis. The slope of the line would then be exactly the experimental velocity of the sound in the gas in m/s.

Now, that we have the velocity of sound in the gas we need a way to figure out what gas is in the tube. This can be done by comparing the experimental value to a list of known speeds for specific gases. In the procedure you are walked through this comparison step by step. You will need to know how to compute the mass of gases in AMU. AMU means atomic mass units. Quite simply it is the atomic number of the atom times the number of atoms. For example, Hydrogen gas has a formula of H_2, meaning it has two hydrogen atoms. Each hydrogen atom has an atomic number of 1, so H_2 has an AMU = 2*1 = 2. Another example is air. Air is mostly nitrogen gas or N_2. Nitrogen has an atomic number of 14. Air, therefore, has an AMU = 2*14 = 28. The AMU for a compound can be found by simply adding all the components together.

Equipment:

At least one person in your group should bring their book.

You will need a large closed pipe (2.428m). The small, evenly spaced holes need to be facing up. Securely fasten the gas hoses to the gas outlets at the workbench. Plug the generator into the speaker. WARNING: once the gas is turned on be sure to light the flames! We do NOT want unburned gas escaping into the room. As another precaution, open the door to the lab room to vent gas and fumes.

Procedure:

Turn on the gas and place a lighter to each of the small holes to light them. Turn the gas down until only the blue part of the flame is showing. Turn on the generator. Find at least eight resonances for the flame tube. (Resonances can clearly be seen in the shape of the flames. They can also be heard through the speaker output by a trained ear.)

Write down the frequency for each resonance and note the resonance number. Sketch the waveform of the flames.

Once you have found the resonances turn the gas off.

Analysis:

1) For each resonance sketch both the pressure and displacement waves in the tube.

2) Find the wavelength, λ, for each resonance. Then make a table of frequencies with their corresponding $\frac{1}{\lambda}$.

3) Plot f vs. ($\frac{1}{\lambda}$). Draw a best-fit line through your data points. (The slope of this line should be equal to the velocity of the waves in the tube.)

4) What is the velocity of sound in the tube?

5) Is this the same as the velocity of sound in air?

6) Open your book to page 44. Divide Table 1 into separate lists of gases, liquids, and solids. Each list should be organized by increasing speed.

7) Compute the mass of each gas in AMU. (See the theory section for examples.)

8) Plot speed vs. mass.

9) Based on the velocity of sound in the tube and the graph, what mass do you expect the gas in the tube to have? What gas does this most closely match?