Lab #4
Resonance of an air column

1. Objectives

To study longitudinal standing waves in an air column open at one end, and to measure the speed of sound in air.

2. Theory

Standing waves are produced by the superposition of two sinusoidal traveling waves of the same wavelength and speed traveling in opposite directions. Please refer to your notes and Serway chapters 16 and 18 for more information.

3. Apparatus

- variable length air column
- three tuning forks (1024 Hz, 512 Hz, and 384 Hz)
- and a thermometer
- sound sensor

4. Procedure

Measuring the frequencies of the tuning forks:

1) Turn the science workshop 500 interface on and start Science Workshop.
2) Connect the sound sensor to analog port A. Click on the analog plug and drag it to channel A in the program window. Select ***sound sensor*** for the device (an "ear" icon should appear next to the device).
3) Drag the FFT icon onto the sound sensor icon. An FFT (Fast Fourier Transform) is a frequency analyzer. Those of you who continue in engineering and sciences, will learn more about Fourier Transforms later in your studies. For now we will use the FFT to verify if the tuning forks are accurate.
4) Click on the "monitor"/"play" button. If you speak into the sound sensor you will see all the frequencies that are present in your voice. You will need to adjust the lower scale so that the frequency range goes past 1000 Hz.
5) Make the 1024 Hz fork vibrate by hitting the tip. Bring the tip very close to the sound sensor. Make sure the fork does not actually touch the sensor. You should see a nice sharp peak around the frequency value indicated on the tuning fork. The FFT will calculate the range of the fundamental frequency. Note-down the average of the range; this value is not very precise due to the quality of the sound sensor. Nevertheless compare this value to the nominal frequency of the tuning fork, (value stated by the manufacturer but not necessarily corresponding exactly to the real value).
6) Repeat for the two other forks.
7) Quit Science Workshop.

Setting-up the air column

1) Spread out throughout the entire lab (A214, A216, A212, A210). Make sure not to disturb other classes as the experiment is noisy.
2) Record the air temperature (in ˚C) ate the position you are working. Make sure that the mercury bulb is not touching anything except the air.
3) Slide the metal reservoir to the top of the stand. Add water to the air column until the water level is 3 to 4 cm from the top.

Measuring the resonance points and the speed of sound

1) Make the 1024 Hz fork vibrate loudly and hold it above the air column such that the ends of the fork are vibrating up and down. While the fork is vibrating, lower the water, by lowering the can, until the first resonance point is found. Repeat until you have found a total of 5 successive resonance points. Record the water level of each resonance to the nearest 1 mm. This is tedious and time consuming, and can only be achieved with team work.
2) Calculate the wavelength λ from your measurements. To do so, you will need to make four estimates of $\lambda/2$ from five resonance points. This is done by subtracting the positions of two adjacent resonance points. Find the average of these four estimates and calculate λ from this average.
3) Using the nominal value for the frequency of 1024 Hz fork, calculate the speed of sound, $v = \lambda f$.
4) Repeat steps 1-3 for the two other forks. Note that you will have fewer successive resonance points.
5) Calculate the average of the three speeds obtained above
6) Compare this average to the value obtained from the formula, where T_c is the temperature in celsius:

   $$v = 331.5\sqrt{1 + \frac{T_c}{273.15}} \text{ (m/s)}$$

5. in the discussion...

- Explain why for a one meter column, you get fewer successive resonance points as the frequency goes down.