Lab 14: Resonance and the Speed of Sound in Air (AP):

Abstract:

(3) This lab took us through the process of examining the different frequencies of resonance in open and closed tubes, dealing with different harmonics in the open tubes (Part 1, Tube Length = 0.739 m) and fundamental harmonics in the closed tubes (Part 2). For Part 1, we calculated a speed of 359.553 m/s, and for part 2 we calculated a speed of 316.66 m/s.

Theory:

(4) The speed of wave particles is measured by the equation $v = f\lambda$, where f is the frequency of the waves, and λ is the wavelength of the waves. In an open tube system (Part 1), where each end contains a node, the equation $L = (n\lambda)/2$ gives the length of the tube, where n = harmonic number. In a closed tube system (Part 2), where one end contains an antinode, the equation is modified to $L = ((2n-1)\lambda)/4$. Each of these equations were related to determine equations for frequency as shown on the attached sheet. The resulting equations were $f = (v/2L)n$ for Part 1, and $f = (v/4)(1/L)$ for Part 2. very nicely done

Experimental:

Part 1:

We began by powering up the wave generator and attaching it to a speaker. We experimented with different frequencies, attempting to discover which was the fundamental resonance frequency by listening for a low resonance while the speaker was placed nest to the tube as shown on the attached sheet. We found the fundamental resonance, at 210 Hz (see attached sheet for wavelength calculation). We repeated the processes with the following harmonics, creating this data table:

Harmonic	Frequency (Hz)
1	210
2	430
3	700
4	990
5	1250

Part 2:

For the second part of our experiment we used a graduated cylinder and the same wave generator and speaker system as shown on the attached sheet. For each trial, we changed the water level in the cylinder, thus changing the "length" of the tube, and found the fundamental resonance for each length, measuring the frequency. As shown in this data table:

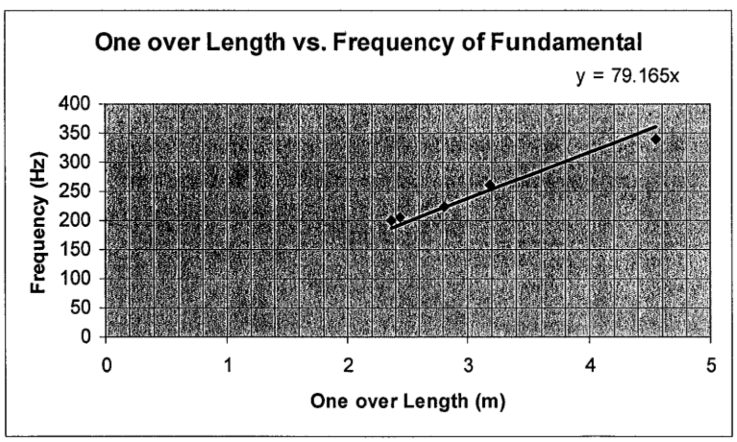
Length (m)	Frequency of Fundamental (Hz)
0.22	340
0.314	260
0.355	225
0.41	205
0.423	200

A simple graph of this data was insufficient for the information wanted, as the equation we have is $f = (v/4)(1/L)$, a linear equation was needed to determine a proper slope, so another column was added that listed the values for 1/L:

9

Length (m)	One over L	Frequency of Fundamental (Hz)
0.22	4.545454545	340
0.314	3.184713376	260
0.355	2.816901408	225
0.41	2.43902439	205
0.423	2.364066194	200

A graph of 1/L vs. frequency appeared like this:



As the above graph shows, the slope of f = (v/4)(1/l) was 79.165, meaning that (v/4) = 79.165. Now it is possible to solve for the velocity of the waves:

$$(v/4) = 79.165$$
$$v = 79.165(4)$$

$$v = 316.66 \text{ m/s}$$

9

The percent order calculated when taking the actual speed of sound, 343 m/s, looks like this:

$$\%err = (((316.66)-(343)/343) \times 100$$

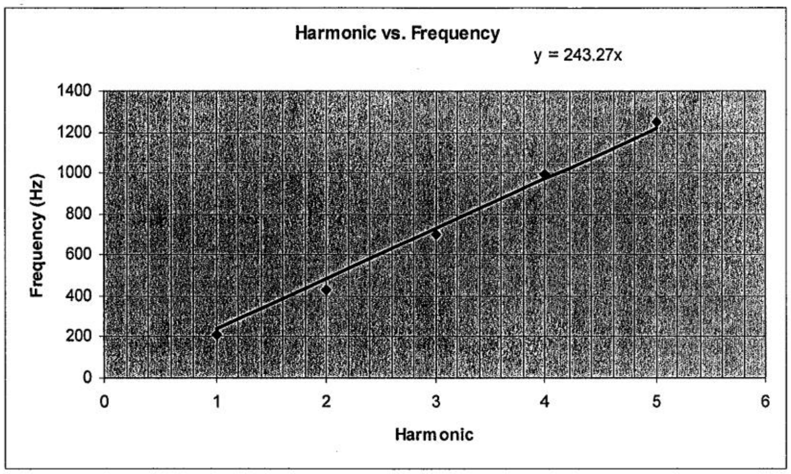
$$= -7.679 \text{ \% error}$$

Discussion:

4

a) A bugle can play different notes because the air within the tube will resonate at several different frequencies, creating the different harmonics of that tube. The bugle player must just cause the air to vibrate at those resonance frequencies to play different notes.
b) If someone makes the instrument longer, the instruments frequency will lower, because the same amount of waves must now pass through a longer distance, thus there will be a lower number of waves per second.
c) Due to my lower percent error, I'm inclined to say that Part 1 gave the most accurate data. Also, the experiment for Part 1 felt more accurate, the tubes length was constant and easily measurable, so even if the frequency was a little off that aspect would remain accurate. In contrast, the water level in Part 2 and the frequencies both needed to be measured each trial, creating more room for error.

Our graph for this data followed the equation f = (v/2L)n, as derived on the attached sheet. The graph looks like this:



The slope of this graph, as shown by the equation, is (v/2L), and calculated by Microsoft Excel to be 243.27, meaning that (v/2L) = 243.27. With this information, and knowing that the length of our tube was 0.739 m, we can solve for the velocity:

$$(v/2L) = 243.27$$
$$v = 243.27(2L)$$
$$v = 243.27(1.478)$$

$$v = 359.553 \text{ m/s}$$

The actual speed of sound is 343 m/s, so the percent error would be calculated like this:

$$\%\text{err} = (((359.553)-(343))/343) \times 100$$

$$= 4.826 \text{ \% error}$$