Resonance Tube

Equipment

1	Open Speaker	WA-9900
1	Patch Cords (set of 5)	SE-9750
1	Economy Resonance Tube	WA-9495
1	Quad Temperature Sensor (only need one temperature probe)	PS-2143

Introduction

A sine wave generator drives an open speaker to create a standing sound wave in a resonance tube. The driving frequency and the length of the tube are varied to study their relationship to wavelength and the speed of the sound wave. The concepts of nodes, anti-nodes, and harmonics are investigated for both closed and open tubes.

Setup

1. In PASCO Capstone, open the Hardware Setup and click on Signal Generator #1 on the 850 Interface and select the Output Voltage Current Sensor.

2. Click on the Signal Generator at the left of the screen and open the controls for 850 Output 1. Set the sine wave amplitude to 0 volts.

Figure 1: Equipment Setup

3. Connect Output 1 on the interface to the speaker using two banana patch cords. Polarity does not matter.

4. Place the Resonance Tube horizontally, as shown, with the speaker near the open end. Place the speaker at a 45° angle to the end of the tube, not pointed directly into it.

5. The inner (white) tube slides inside the blue tube to adjust the effective length of the closed tube.

6. Connect the Temperature Sensor to any of the *PASPORT* inputs on the interface and connect the temperature probe into port 1 of the sensor.

7. Create a Digits Display and select the Temperature.

Theory-Closed Tube of Variable Length:

A resonating tube with one end open and the other end closed will always have a node at the closed end and an anti-node at the open end. A node represents an area where the velocity of the air is a minimum (zero), and an anti-node represents an area where the velocity of the air is a maximum. If the tube is resonating at a particular fixed frequency, the tube will resonate as shown below, where the curved lines represent the velocity profile of the air in the tube.

As the length of the active part of the tube is increased, the sound becomes loud at each successive node and quiet at the antinodes. Note that the distance between the nodes is ½ λ. For all types of waves, the frequency (f) and the wavelength (λ) are related to the speed (v) of the wave as given by Equation 1.

$$v = \lambda f \qquad (1)$$

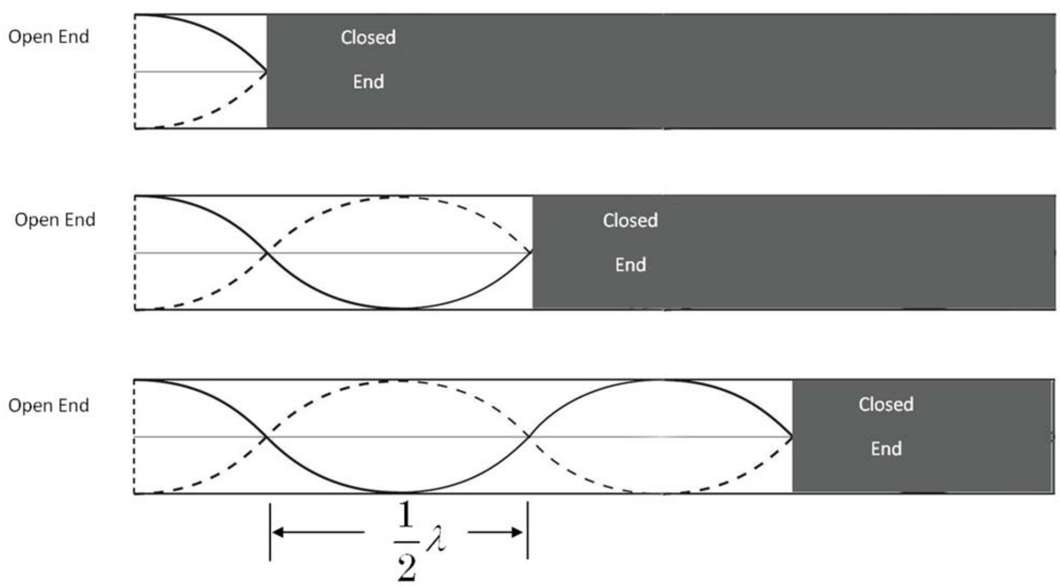

Figure 2: Modes of Vibration in a closed Tube of Variable Length

Procedure

1. Slide the two tubes together, so that the tube length is zero. Open the Signal Generator at the left. Set the frequency for 300 Hz and the amplitude on a reasonable level.

2. Extend the white tube, increasing the tube length. The loudness of the sound will noticeably increase as you approach resonance. Move the tube in and out to pinpoint the position that gives the loudest tone. Record this position.

3. Continue extending the white tube to find all the positions that cause a resonance. Each of these positions represents a node in the standing wave pattern.

4. Calculate the distance between the nodes, and take the average if you have more than one value. Use this distance to calculate the wavelength of the sound wave.

5. Use the frequency of the sine wave generator to calculate the speed of the wave.

6. Set the Signal Generator frequency for 400 Hz and repeat the above procedure. How does the speed of the wave compare to the previous wave at 300 Hz?

7. The actual speed of the wave is the speed of sound in air, which is temperature dependent. This theoretical value can be calculated using

   $$v = 331 \text{ m/s} + 0.6\ T$$

   where T is the temperature of the air in degrees Celsius. Measure the air temperature and calculate the actual speed of sound.

8. Compare your measured values for the speed of sound to the actual value. Calculate the percent deviation.

   $$\%\ Error = \frac{|Actual - Experimental|}{Actual} \times 100\%$$

Theory-Open Tube of Fixed Length:

A resonating tube with both ends open will always have an anti-node at both ends, and at least one node in between. The number of nodes is related the wavelength and the harmonic. The first harmonic (or fundamental) has one node, the second harmonic has two, etc., as shown here. For a tube of fixed length, at higher harmonics, the frequency is higher and the wavelength is shorter.

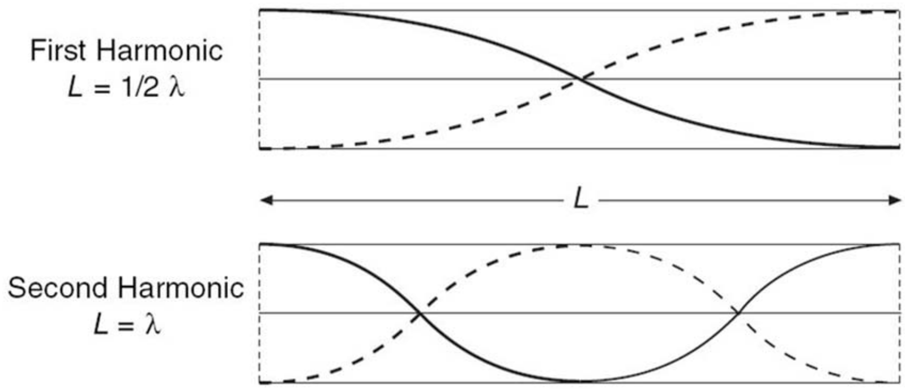

Figure 3: Modes of Vibration in an Open Tube of Fixed Length

Procedure

1. Slide the inner tube all the way out, and separate it from the outer tube. Use only the outer blue tube with two open ends.
2. Set up the Signal Generator and the speaker as before. Start with the frequency at 50 Hz and slowly increase it. Find the frequency of the fundamental (to the nearest 1 Hz).
3. Calculate the wavelength using the frequency and the actual speed of sound you calculated in Part I. How does this compare to the length of the tube?
4. Increase the frequency of the Signal Generator and determine the frequency of the second and third harmonic. How do these compare to the fundamental?

Analysis

1. In a pipe organ which pipes make the low notes, the long ones or the short ones?
2. Which pipes in a pipe organ sound the lower frequency, the long ones or the short ones? Which pipes sound the longer wavelengths?
3. Suppose that in this experiment the temperature of the room had been lower; what effect would this have had on the distance between nodes for each reading? Explain.
4. How would an atmosphere of helium affect the pitch of an organ pipe?

Conclusions

Summarize the differences between an open and closed tube. Also discuss:

- How the velocity, wavelength, and frequency changed as the tube length was varied.
- How the velocity, wavelength, and frequency changed for the part of the experiment in which the tube length was constant.