Online Lab: Resonance of Sound

Name: Date:

Instructor: Section:

Objective:

Determine the resonant frequencies of a closed and open ended pipe exposed to sound waves. Verify the relationship between the frequency of the sound (f), the speed of sound in air (v) and the length of the Tube (L) changed by clicking on the Tube itself.

Aparatus:

A frequency generator, with digital readout and which was also used to produce standing waves on a string, will be used to drive a small speaker and generate sound waves of a given frequency. The sound waves enter a tube filled with air, which can be either open (cap removed) or closed (cap on). The length of the pipe (L) can be varied by moving an insert back and forth.

Resonance in an open tube – i.e., a tube that is open at both ends

Sound from the sound source (speaker) travels down the tube and reflects back from the opposite end which is *open*. At resonance, both ends must be points of maximum disturbance called *antinodes* (A). There must be at least one point of minimum disturbance between antinodes, called a *node* (N), and hence the distance between the ends of the tube bust be at least $\lambda/2$. But there might be two, three, or more nodes between the ends of the tube. The first four resonant conditions for an open tube of length L are shown in Figure 1. The resonance conditions are also summarized.
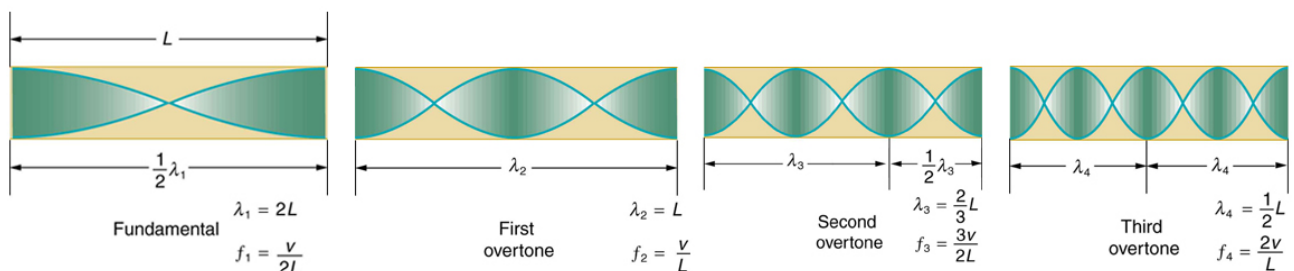

Figure 1: Lowest four resonant frequencies for an open pipe.

The pattern is clear. The possible resonant frequencies of an open tube of length L are:

$$f_n = n\frac{v_s}{2L}, \; where \; f_1 \; = \; \frac{v_s}{2L} \tag{1}$$

where n = 1, 2, 3, 4 . . . (all integers).

Resonance in a closed tube – i.e., a tube open at one end and closed at the other

Sound from the source travels down the tube and reflects back from the opposite end, but in this case the opposite end is *closed*. At resonance, the closed end of the tube must be a point of minimum disturbance (i.e., a node (N) whereas the other end, near the sound source, must be an antinode (A). The minimum part of a wavelength between an antinode A and a node N is a quarter wavelength, and hence the length of the tube must correspond to $\lambda/4$ for the lowest resonant frequency. The four lowest resonant frequencies for a tube of length L are shown in Figure 2, along with the conditions for resonance.
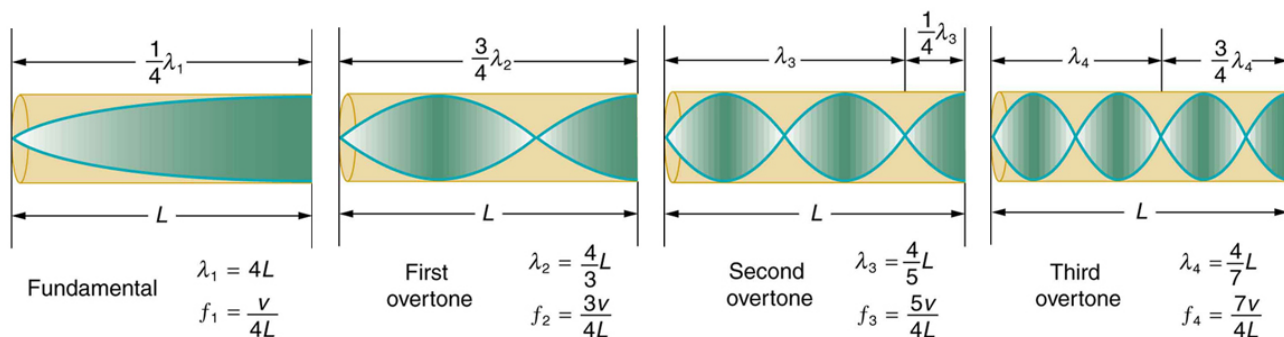

Figure 2: Lowest four resonant frequencies for a closed pipe of fixed length.

Once again, the pattern is clear. The possible resonant frequencies of a closed tube of length L are: given by:

$$f_n = n\frac{v_s}{4L}, \; where \; f_1 \; = \; \frac{v_s}{4L} \tag{2}$$

where n = 1, 3, 5, 7 . . . (all <u>odd</u> integers).

A sound wave is a longitudinal wave, where the oscillation is along (or opposite to) the direction of propagation i.e speed. This does not change any of the equations used before. If the sound generated by the speaker corresponds to a frequency f, then this results in a traveling wave with wavelength: $\lambda = v_s/f$. For a given frequency the wavelength depends on the speed of propagation v_s. This speed depends on the medium through which the wave travels. For example the speed of sound in air is v_s=343 m/s at room temperature. But in helium the speed of sound is much larger and is v_s=965 m/s. So a sound wave of a given frequency will have different wavelengths in air and in helium.

Resonance Tube Lab

In this lab you will be looking at standing waves that are created in wind instruments. When you load the program you will have 5 random length tubes generated for you. You can use the tube with both ends open or with one end closed. You should be able to find fundamental frequency and at least one higher harmonic for each tube.

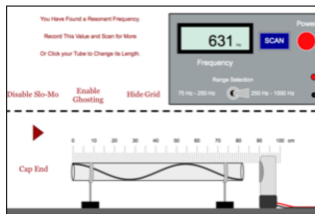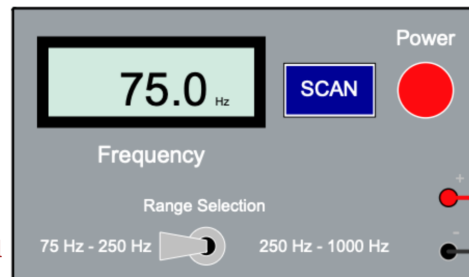When you are ready to start the experiment, click on the begin button.

Figure 3: Initial screen after clicking *HTML* link to open Resonance Tube Simulator Website
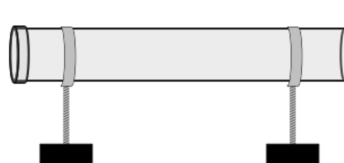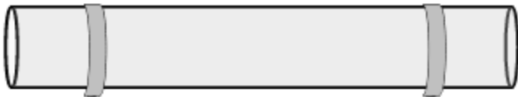
Resonance Tube Lab

Figure 4: Initial Configuration after opening the Resonance Tube Lab Simulator

Online Resonance of Sound Experiment Instructions:

1. Go to the following website:
   http://www.thephysicsaviary.com/Physics/Programs/Labs/ResonanceTubeLab/

2. Figure 3 shows an example of what you should see on your screen.

3. <u>Press the **Begin** Button</u> on the "Resonance Tube Lab" simulation to open the simulator.

4. Figure 4 shows an example of what you should see on your screen.

5. Description of the Buttons used during the Experiment is given below:

   (a) When the program is loaded, there a **5 RANDOM LENGTH Tubes generated**.

   (b) Click **Activate Grid** to turn the ruler on to measure the length of the Tube.

   (c) **Remove Cap** <u>Button</u> on the Left side of the Tube when selected, the cap will be taken off and the Tube is Open on both ends.

   (d) **Cap End** <u>Button</u> on the Left side of the Tube when selected, the cap will be placed at the end of the Tube and the Tube is Closed at one end.

   (e) Button on the frequency generator is used to search for Resonant Frequencies in the tube.

   (f) Range Selection switch points to the 75 Hz - 250 Hz Range when facing <u>Left</u> or points to the 250 Hz - 1000 Hz when facing <u>Right</u>.

   (g) The Length of the Tube can be changed at any time by simply clicking on the tube itself.

   NOTE: **RECORD <u>NA</u>** (for Not Available in the given Range) in the blank for any frequency that is not found within the range of 75 Hz - 1000 Hz.

Resonant Frequencies of a Closed Tube: L = ~55 cm

1. **SET** the length of the tube as close to 55 cm as possible.
   Record the actual Length of the Tube here. $L_1 =$

2. Press the **Cap End** Button on the Left side of the Tube. (Close Tube Configuration)

3. Calculate the first 4 Resonant Frequencies, f_n for a Closed Tube using Equation 2. Record your calculated values in the Table on the Left Side below (**Calculated Closed Tube**).

4. Click **SCAN**. It will stop scanning when the first frequency of a is reached f_1.
   If a frequency is NOT found in the given range, Record **NA**
   Record the first frequency of a Closed Tube. $f_1 =$

5. Click **SCAN**. Record the third frequency of a closed Tube. $f_3 =$

6. Click **SCAN**. Record the fifth frequency of a closed Tube. $f_5 =$

7. Click **SCAN**. Record the seventh frequency of a closed Tube. $f_7 =$

Resonant Frequencies of an Open Tube: L = ~55 cm

1. Press the **Remove Cap** Button on the Left side of the Tube to remove the cap.

2. **Calculate** the first 4 Resonant Frequencies, f_n for an Open Tube using Equation 1. Record your calculated values in the Table on the Right Side below (**Calculated Open Tube**).

3. Click **SCAN**. It will stop scanning when the first frequency of an is reached f_1.
   Record the first frequency of a Open Tube. $f_1 =$

4. Click **SCAN**. Record the frequency of an Open Tube. $f_2 =$

5. Click **SCAN**. Record the third frequency of an Open Tube. $f_3 =$

Table 1: Resonant Frequency of an Open and Closed Tube at L = ~55 cm

Calculated Closed Tube		Calculated Open Tube	
Harmonic (Number)	**frequency, f_n (Hz)**	**Harmonic (Number)**	**frequency, f_n (Hz)**
n = 1		n = 1	
n = 3		n = 2	
n = 5		n = 3	
n = 7		n = 4	

Resonant Frequencies of a Closed Tube: L = ∼80 cm

1. **SET** the length of the tube as close to 80 cm as possible.
   Record the actual Length of the Tube here. $L_2 =$

2. <u>Press the **Cap End** Button</u> on the Left side of the Tube. (Close Tube Configuration)

3. Calculate the first 4 Resonant Frequencies, f_n for a Closed Tube using Equation 2. Record your calculated values in the Table on the Left Side below (**Calculated Closed Tube**).

4. Click **SCAN**. It will stop scanning when the first frequency of a is reached f_1.
   <u>Record the first frequency of a Closed Tube.</u> $f_1 =$

5. Click **SCAN**. <u>Record the third frequency of a closed Tube.</u> $f_3 =$

6. Click **SCAN**. <u>Record the fifth frequency of a closed Tube.</u> $f_5 =$

7. Click **SCAN**. <u>Record the seventh frequency of a closed Tube.</u> $f_7 =$

Resonant Frequencies of an Open Tube: L = ∼80 cm

1. <u>Press the **Remove Cap** Button</u> on the Left side of the Tube to remove the cap.

2. **Calculate** the first 4 Resonant Frequencies, f_n for an Open Tube using Equation 1. Record your calculated values in the Table on the Right Side below (**Calculated Open Tube**).

3. Click **SCAN**. It will stop scanning when the first frequency of an is reached f_1.
   <u>Record the first frequency of a Open Tube.</u> $f_1 =$

4. Click **SCAN**. <u>Record the second frequency of an Open Tube.</u> $f_2 =$

5. Click **SCAN**. <u>Record the third frequency of an Open Tube.</u> $f_3 =$

6. Click **SCAN**. <u>Record the fourth frequency of an Open Tube.</u> $f_4 =$

Table 2: Resonant Frequency of an Open and Closed Tube at L = ∼80 cm

Calculated Closed Tube		Calculated Open Tube	
Harmonic (Number)	frequency, f_n (Hz)	Harmonic (Number)	frequency, f_n (Hz)
n = 1		n = 1	
n = 3		n = 2	
n = 5		n = 3	
n = 7		n = 4	

Analysis of a Closed Tube: $L_1 = \sim 55$ cm

1. **RECORD the <u>results of your analysis in (m) for the wavelength and (m/s) for the speed.</u>**

2. **Calculate** <u>λ_1, λ_3, and λ_5 of a Closed Tube and your measured L_1 value.</u>

$$\lambda_n = \frac{4L}{n}, \ for \ n \ = \ 1, 3, 5, 7, ... \ (Closed \ Pipe)$$

$\lambda_1 =$

$\lambda_3 =$

$\lambda_5 =$

3. **Find** <u>the speed of sound, v_s **for First 3 Resonant Frequencies ONLY** using your measured f_n values in Table 1 and the λ_n values above.</u>

$v_s = f_1 \times \lambda_1 =$

$v_s = f_3 \times \lambda_3 =$

$v_s = f_5 \times \lambda_5 =$

Analysis of a Closed Tube: $L_2 = \sim 80$ cm

1. **RECORD the <u>results of your analysis in (m) for the wavelength and (m/s) for the speed.</u>**

2. **Calculate** <u>λ_1, λ_3, and λ_5 of a Closed Tube and your measured L_2 value.</u>

$\lambda_1 =$

$\lambda_3 =$

$\lambda_5 =$

3. **Find** <u>the speed of sound, v_s **for First 3 Resonant Frequencies ONLY** using your measured f_n values and the λ_n values above.</u>

$v_s = f_1 \times \lambda_1 =$

$v_s = f_3 \times \lambda_3 =$

$v_s = f_5 \times \lambda_5 =$

Analysis of an Open Tube: $L_1 = \sim 55$ cm

1. **RECORD the** <u>**results of your analysis in (m) for the wavelength and (m/s) for the speed.**</u>

2. **Calculate** <u>λ_1, λ_2, and λ_3 of an Open Tube and your measured L_1 value.</u>

$$\lambda_n = \frac{2L}{n}, \; for \; n \; = \; 1, 2, 3, 4, ... \; (Open \; Pipe)$$

$\lambda_1 =$

$\lambda_2 =$

$\lambda_3 =$

3. **Find** <u>the speed of sound, v_s **for First 3 Resonant Frequencies ONLY** using your measured f_n values in Table 1 and the λ_n values above.</u>

$v_s = f_1 \times \lambda_1 =$

$v_s = f_2 \times \lambda_2 =$

$v_s = f_3 \times \lambda_3 =$

Analysis of an Open Tube: $L_2 = \sim 80$ cm

1. **RECORD the** <u>**results of your analysis in (m) for the wavelength and (m/s) for the speed.**</u>

2. **Calculate** <u>λ_1, λ_2, and λ_3 of an Open Tube and your measured L_2 value.</u>

$\lambda_1 =$

$\lambda_2 =$

$\lambda_3 =$

3. **Find** <u>the speed of sound, v_s **for First 3 Resonant Frequencies ONLY** using your measured f_n values and the λ_n values above.</u>

$v_s = f_1 \times \lambda_1 =$

$v_s = f_2 \times \lambda_2 =$

$v_s = f_3 \times \lambda_3 =$

Conclusions:

1. Discuss how well do your measured f_n values compare to your calculated f_n values?

2. Discuss how well do your measured v_n values compare to the accepted v_s values? Recall that the speed of sound in air is v_s=343 m/s at room temperature

3. How does the velocity, wavelength and frequency change as the length of the tube was varied?