Resonance Tube Demonstration Kit

A. Purpose

When the sound wave propagates into the tube, the tube will vibrate and resonate despite the tube end is closed or opened. The Styrofoam balls inside the tube will be deposited as heaps. Observe heaps to identify antinodes and nodes.

B. Theory

The sound of the wave generator compresses the air and causes oscillation. If the oscillation is great enough, it causes resonance. The resonance only occurs when the frequency of the wave generator and the tube are the same, and the end of the tube is the antinode of a standing wave. In addition, if the end of the tube is closed, the end is the node of the standing wave. The oscillation frequency times the wavelength equals to the speed of sound in the tube. The speed of sound in the air can be expressed as:

$$V = f\lambda$$

(f is frequency of sound / λ is wavelength of sound)

The speed of sound in the air is related to the temperature so

$$V = V_T = 331.4 + 0.6T$$

(V_T (m/s), T is the temperature ℃)

By the compression of the air, Styrofoam balls inside the tube shows the feature of standing waves. Hence, we can measure the wavelength of the standing wave, as shown in **Figure 1**. (λ is the wavelength, N is the antinode of the standing wave and A is the node of the standing wave.)

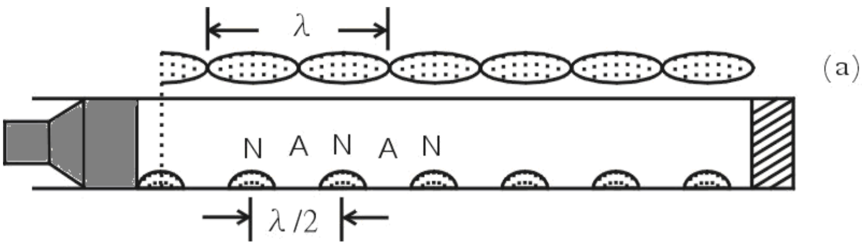


Figure 1

When sound propagates in the air, the change of displacement and the pressure of air is similar to a piston moving back and forth regularly in the tube. The moving piston forms condensation and rarefaction waves and the compression and expansion of pressure. The motion and the sound wave propagate along the tube. Based on kymatology, if the time is t (assume t = 0), the displacement of air can be expressed as:

$$S_{(x)} = S_m Cos(kx)$$

(S_m is displacement amplitude / k is angular wave number)

The change of the air pressure can be expressed as:

$$\Delta P_{(x)} = \Delta P_m Sin(kx)$$

(ΔP_m is the amplitude of air pressure.)

From the above formulas, the phase of $S_{(x)}$ and $\Delta P_{(x)}$ is $\frac{\pi}{2}$. When the phase reaches its maximum, the pressure is zero. On the contrary, when the phase is zero, the pressure reaches its maximum. The above formulas can be expressed as **Figure 2**. Note: the pressure amplitude is not equal to the displacement amplitude.

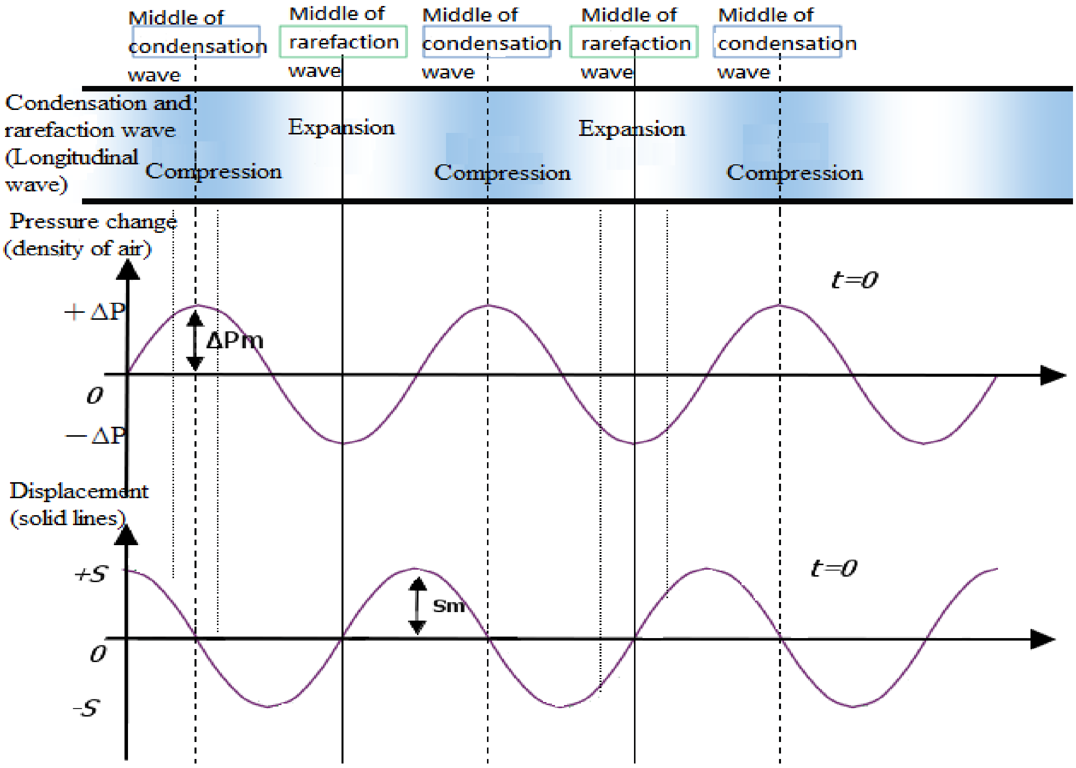


Figure 2

In **Figure 1**, the peak of Styrofoam balls is the antinode of the standing wave where the change of pressure is the minimal. At the node of the standing wave where the change reaches its maximum, Styrofoam ball is at the lowest location. Standing waves and the change of pressure are shown in **Figure 1 (a)**.

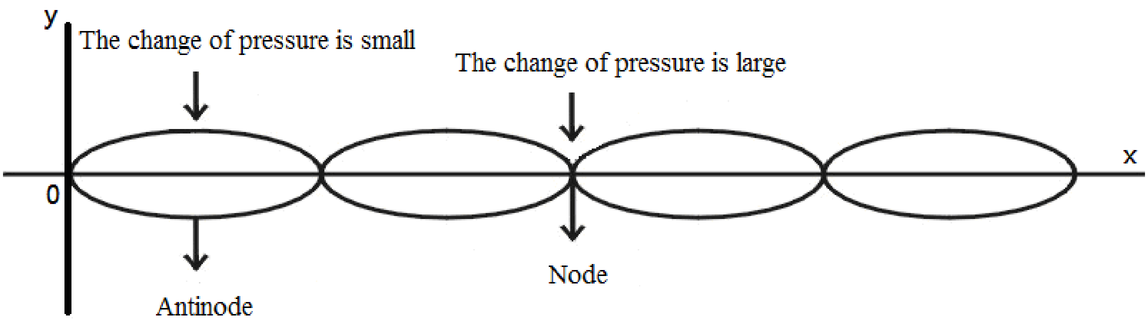
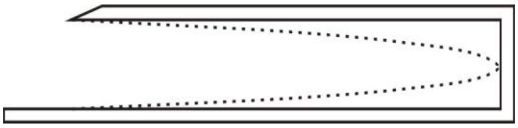


Figure 1 (a)

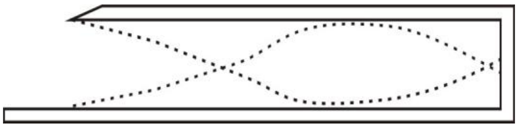
In an air column, the relationship between the wavelength and the length of tube can be discussed from open-end tube and closed-end tube. Their relationships are shown in **Figure (b)**

Closed-end tube：

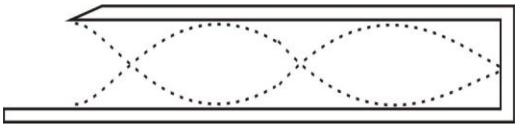
Length of the tube: $\ell = \frac{N}{2}\lambda$ Wavelength: $\lambda = \frac{2}{N}\ell$ N= Number of antinodes (N=1、2、3…)



Pitch $(\ell = \frac{1}{4}\lambda)$



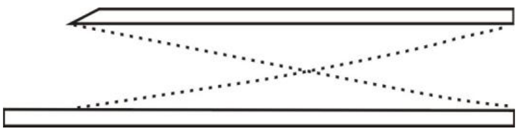
First overtone $(\ell = \frac{3}{4}\lambda)$



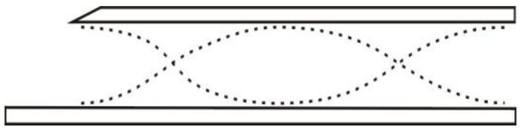
Second overtone $(\ell = \frac{5}{4}\lambda)$

Open-end tube：

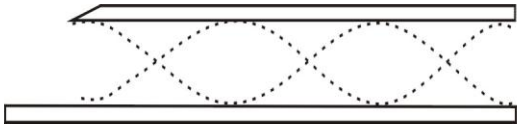
Length of the tube: $\ell = \frac{N}{2}\lambda$ Wavelength: $\lambda = \frac{2}{N}\ell$ N= Number of antinodes (N=1、2、3…)



Pitch $(\ell = \frac{1}{2}\lambda)$



First overtone $(\ell = \lambda)$



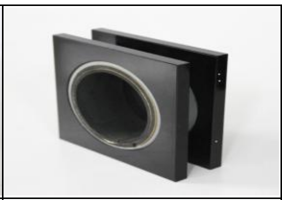
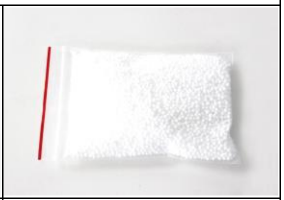
Second overtone $(\ell = \frac{3}{2}\lambda)$

Figure (b)

When a wave propagates in the tube, the wave reflects in open-end and closed-end tubes. When there is a standing wave in the closed-end tube, there must be nodes. On the other hand, if air vibrates in an open-end tube, there are antinodes.

C. Instrument

Instrument list					
No.	Accessory	Qty	No.	Accessory	Qty
1	Wave generator	1	2	Digital frequency generator amplifier	1
3	Resonance tube	1	4	Holder at the end of the tube	1
5	Styrofoam balls	1	6	Connecting wire	1

Instrument picture				
				
1	2	3	4	5
				
6				

D. Experiment procedure

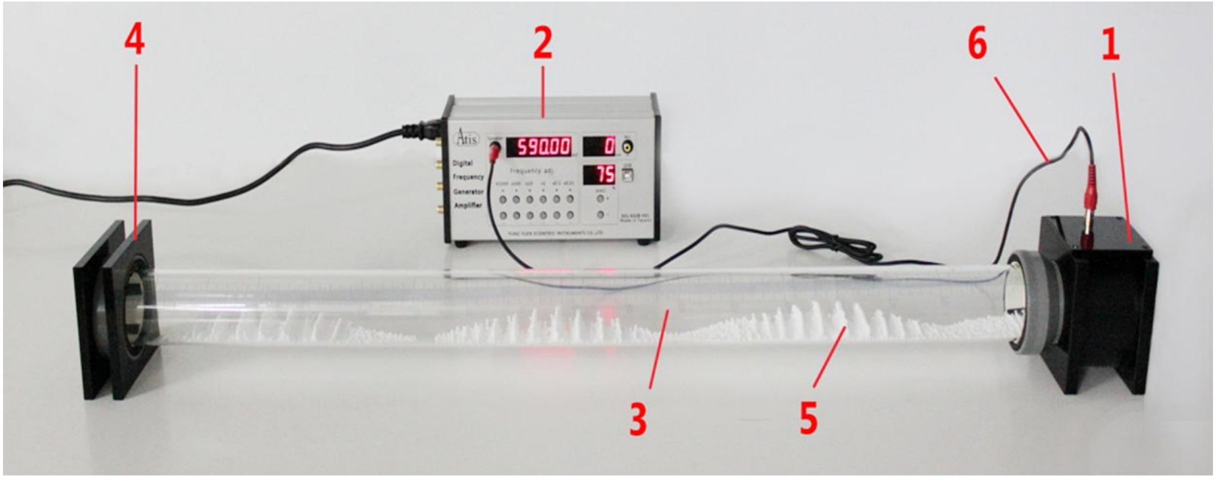


Figure 3 Experimental setup

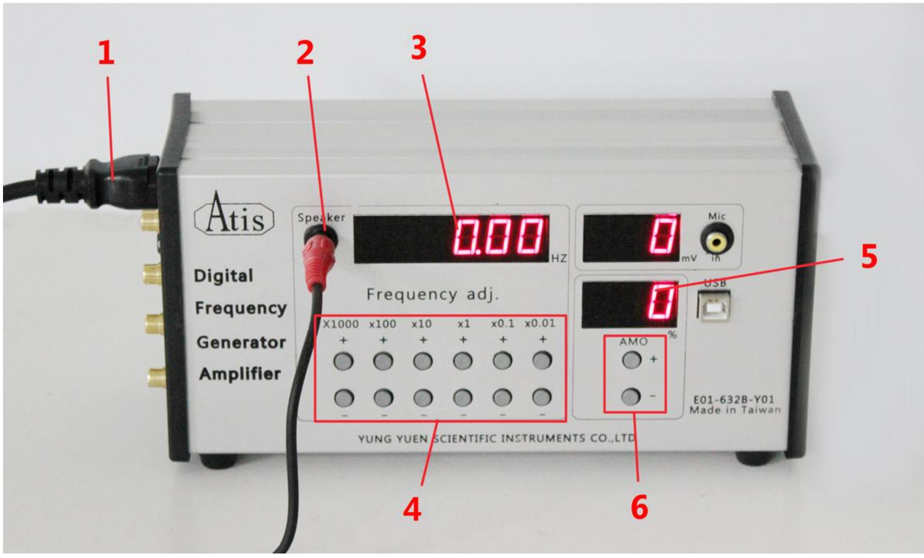


Figure 4 Digital frequency generator amplifier

Digital frequency generator amplifier			
No.	Accessory	No.	Accessory
1	Power	2	Speaker
3	Frequency display	4	Frequency adjustment button (decimal)
5	Amplitude display	6	Amplitude adjustment button

1. The experiment set up is shown in **Figure 3**. Connect the wave generator with resonance tube. Put Styrofoam balls into the tube. Before the experiment, shake the tube so balls can be uniformly distributed. Connect the holder with the end of the tube. Connect the wave generator to the AV wire.

   Note: Keep the scale on the tube upward.

2. When the wave generator is connected to the power, adjust the amplitude to 40-50% based on the instruction of **Figure 4** (adjust the amplitude according to the need of the observer). Increase the frequency gradually. Styrofoam balls will produce the standing wave like **Figure 3**.

3. Increase the frequency to identify the first overtone, second overtone and ect. Count the number of waves and measure frequency and the average half-wavelength. Write down the records on the recording sheet 1.

4. Use the scale on the tube to calculate the average peak of Styrofoam ball heaps.

   Calculation method: If there are 12 heaps, the difference between the seventh heap and the first heap is R_7-R_1. The difference between the eighth heap and the second heap is R_8-R_2 and so on till the difference between the twelfth heap and the sixth heap (R_{12}-R_6). The average of the sum of differences is the average distance of six heaps. The average divided by six is the distance between two heaps which is also the average half-wavelength ($\lambda/2$).

5. Change the end of the tube into a mesh cover and repeat the procedure.

E. Safety

1. During the experiment, be aware of the connection between the tube and the speaker. If they are not connected properly, the leakage will influence the experiment result.

2. Increase Styrofoam balls if needed. Find the best waveform.

3. Do not use the wave generator for a long time in case of damage on eardrums.

F. Experimental data

Recording sheet 1: Open-end tube					
Room temperature_________ (℃) **Wave speed under room temperature_________ (m/s)**					
____overtone / Trail	Experimental frequency	Numbers of wave	Average wavelength	Wave speed	Experimental error
1					
2					
3					
4					
5					
Average					
____overtone / Trail	Experimental frequency	Numbers of wave	Average wavelength	Wave speed	Experimental error
1					
2					
3					
4					
5					
Average					
____overtone / Trail	Experimental frequency	Numbers of wave	Average wavelength	Wave speed	Experimental error
1					
2					
3					
4					
5					
Average					