



Standing Waves in Air

Objective

Students will explore standing wave phenomena through sound waves in an air tube.

Equipment List

PASCO resonance tube with speaker and microphone, PASCO PI-9587B Digital Frequency Generator, Digital Oscilloscope.

Theoretical Background

As a sound wave propagates in a tube, it is reflected from each end and interferes with itself. If the wavelength length and frequency of the wave are just right for the tube, the forward going waves interfere with the reflected ones and form standing waves in the tube. We say this tube is at “resonance” with the sound waves and the frequency “resonant frequency”.

The condition for the existence of such standing waves is mostly determined by the physical constraint of the tube. For open-end tubes (both ends are open), air molecules are free to move at both ends, allowing maximal displacements at the ends. Therefore, anti-nodes for the displacement are expected at both ends of the tube. For close-end tubes (one end closed, the other open), the motions of air molecules are constraint at the close-end, allowing minimal displacements.

Therefore, a node for displacements is expected at the close-end and anti-node at the open-end. The first three standing wave modes of each case are shown in Fig. 1, which are called the first, second, and third harmonics, respectively.

In this experiment, an open-end tube is used to study the standing waves in a tube produced by sound waves. The length of the tube determines the wavelengths of the sound waves that could form standing waves in the tube. As shown in Fig. 1,

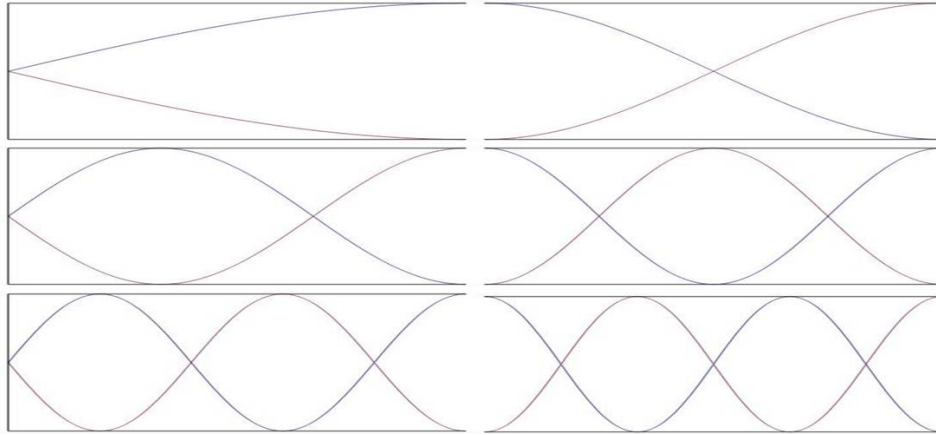


Fig. 1 The first three standing wave patterns in a closed (left) and an open (right) tube.

the distance between adjacent nodes or adjacent anti-nodes corresponds to half of the wavelength. Therefore, the wavelength of the n -th harmonic, λ_n , is related to the length of the tube, L , through the following equation.

$$\lambda_n = \frac{2L}{n} \quad (1)$$

Provided that the sound speed is a constant in the tube, the frequency of the n -th harmonic, f_n , is then

$$f_n = \frac{v}{\lambda_n} = \left(\frac{v}{2L}\right) \times n = f_1 \times n \quad (2)$$

Procedure

1. Measure the length of the resonance tube. Record the length on the datasheet.
2. Set the resonance tube horizontally on the table, with the speaker placed a few centimeters from one end of the tube, as shown in Fig. 2a. Connect the speaker to the “Low Ω ” outputs of the frequency generator, as shown in Fig. 3, and connect the “High Ω ” outputs to “CH1” of the digital oscilloscope. **DO NOT** turn on the generator at this moment.
3. Place the microphone close to the other end of the tube, connect the microphone output to “CH2” of the oscilloscope with the BNC-to-clips connectors, and turn on the microphone, as shown in Fig. 2b-d.
4. Set up the oscilloscope as following:
 - a. Turn on the oscilloscope.

- b. Set up the trigger source by pressing “Trigger Menu” (located at the right side of the oscilloscope) and then selecting “CH1” as the “Source” with the bottom around the LCD screen.

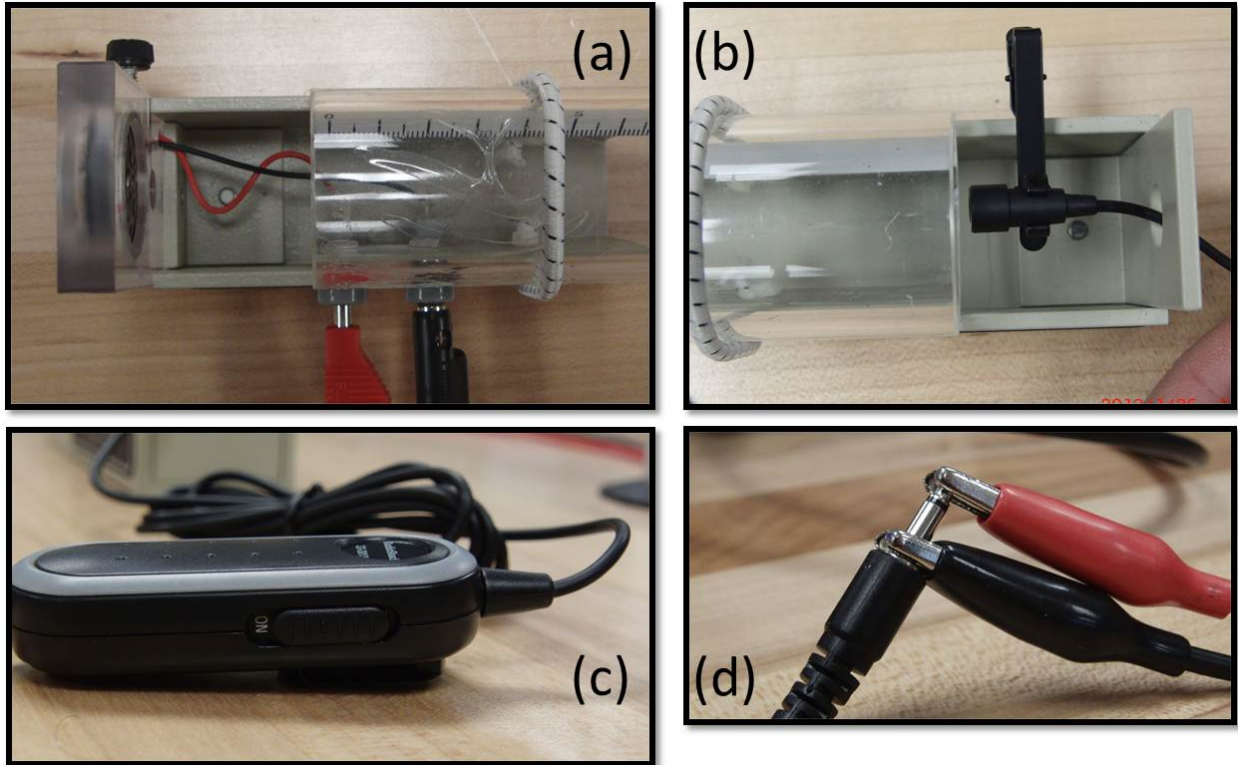


Fig. 2 The setup for the speaker (a) and the microphone (b-d).

5. Set up the frequency generator as following:
(NOTE: it is not too hard to destroy a speaker with inappropriate voltage, so ask for help if you are not certain what you are doing.)
 - a. Make sure that the “amplitude” of the frequency generator is set to its minimum (clock-wise to the end).
 - b. Turn on the frequency generator.
 - c. With the default frequency 1000.0Hz, slowly increase the amplitude until you can clearly hear a “weak” tone from the speaker. (You should also see a sinusoidal wave form on the oscilloscope.)
 - d. Adjust the frequency to 100.0Hz.

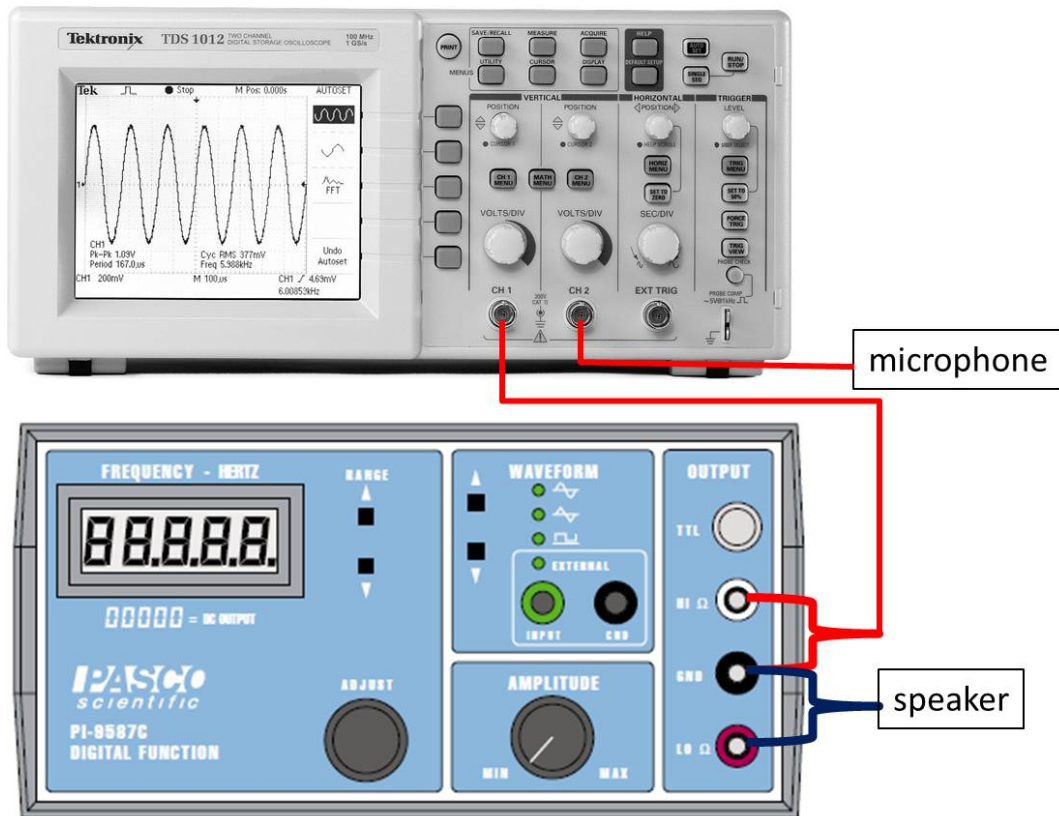


Fig. 3 Schematics for connections among instruments.

6. Slowly increase the “Frequency” from the generator, and monitor the “amplitude” of the waveform at “CH2” on the oscilloscope. This amplitude corresponds to the sound intensity measured by the microphone. Record the frequencies at which maximum intensities at the microphone are measured. The first frequency (should be below 200Hz) of such corresponds to the fundamental mode ($n=1$), and consequently the 2nd ($n=2$), 3rd ($n=3$), 4th ($n=4$), and so on.

(You might want to adjust the “VOLTS/DIV” and “SEC/DIV” settings on the oscilloscope to make the observation easier.)

Data Analysis

1. Calculate v_n for each mode with Eq.(2).
2. Plot the resonance frequency, f_n , as function of “ n ”.
3. Find the slope of this plot, and then use Eq.(2) to find the speed of sound, v_{exp} , in the tube.

Selected Questions

1. If one end of the tube is closed in this experiment, would you expect to measure higher or lower fundamental frequency ($n=1$)? Explain your answer.
2. This experiment can be used to determine speed of sound in different gas. Comparing tubes filled with helium gas and N_2 , respectively, from which tube will you measure higher fundamental frequency?