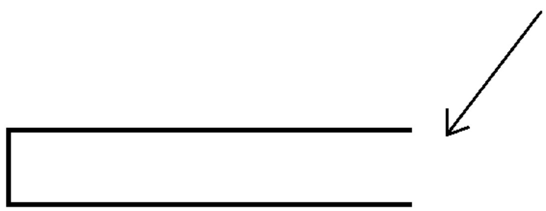
Resonance in an Air Column

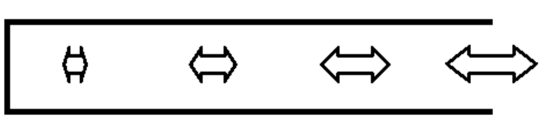
Equipment	Qty.
tubes for resonance	5
Vernier caliper	1
Sounds of Music Pitch Software	1
ruler	1

The production of standing waves in a tube forms the basis for many musical instruments. Perhaps the simplest way to make a tone in this way is by blowing across the open end of a tube whose other end is closed.



The air moves into the end of the tube, raising the pressure inside, which then rebounds outward to deflect the flow across the open end. The lowered inside pressure then allows the flow to move back inside, and this unstable flow maintains a cycle that repeats many times per second.

The air in the tube compresses and rarifies like a spring, motionless at the closed end and moving the most at the open end.



This motion is identical to a section of the air in a long tube when two identical sound waves are traveling in opposite directions, waves whose wavelength is 4 times the length of our short tube. Identical waves traveling in opposite directions form a standing wave, and so the motion of the air in the tube comprises a standing wave whose wavelength is 4 times the length of the tube. A sound wave's frequency, wavelength, and speed are related by:

$$f\lambda = v$$

We'll measure the frequency of the tone produced by blowing into a tube and assume that this is the frequency of the standing wave in the tube. Then taking the wavelength as 4 times the length of the tube, we'll compute the speed of sound, and compare it to a theoretical value.

Procedure

1. Choose 5 tubes from the tray of tubes. Try to get an assortment of lengths.
2. You can use a frequency identifying app on your phone. One is called Pitched Tuner (icon at right).

3. Alternatively, you can open a browser on your computer and go to this address: http://www.pascioly.org/sounds
4. When you play a tone, the frequency should read out in the middle of the screen. If it doesn't, you might have to click on the link above the readout where it says "Make sure you are using the address…"
5. If there is still no response, the computer's internal microphone might not be enabled.

6. Hold a finger over one end of the tube that you want to play and blow across the other end. Record the frequency here.
$$f = \_\_\_\_\_\_\_\_\_\_\_\_ Hz$$
7. Measure and record the length of the tube. $L = \_\_\_\_\_\_\_\_\_\_\_\_ m$
8. Measure the inner diameter of the tube. $d = \_\_\_\_\_\_\_\_\_\_\_\_ m$
9. It turns out that the wave node is actually about $0.7d$ outside the end of the tube, where d is the inner diameter of the tube, so add $0.7d$ to the length of the tube to find one quarter of the wavelength of the standing wave.
10. Multiply this by 4 to obtain the wavelength of the wave.
$$\lambda = 4(L + 0.70d)$$
11. Knowing the tone's frequency and its wavelength, determine the speed of sound.
$$v = f\lambda$$
12. Repeat this procedure for all 5 tubes.

width	**length**	**freq**	$\boldsymbol{\lambda}$	$\boldsymbol{v}$
Average sound speed				

Theoretical Speed of Sound

The speed of sound in a gas is related to several of the parameters of the gas:

$$v = \sqrt{\gamma kT/m}$$

γ is the adiabatic index of the gas, which for a diatomic gas like air is $7/5$. k is Boltzmann's constant, and its value is $1.3865 \times 10^{-23} J/K$. T is the temperature in kelvin and room temperature is about $295\ K$. m is the mean mass of a molecule of the gas.

1. Assuming that the molar mass of air is 28.97 g/mol, find the average mass of an air molecule in SI units.
$$m = \_\_\_\_\_\_\_\_\_ kg$$
2. Look at the thermometer in the back of the room to find the temperature and convert to kelvin.
$$T = \_\_\_\_\_\_\_\_ K$$
3. Calculate the sound speed with this information. $v = \_\_\_\_\_\_\_\_ m/s$
4. Taking this value as the correct sound speed, find the percent error of the sound speed that you determined in the experiment. $\%\ err = \_\_\_\_\_\_\_$