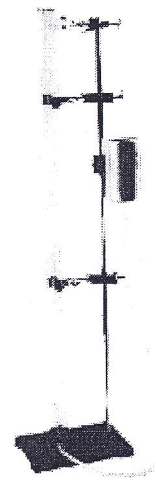
SPH3U: Resonance in Air Columns

You might have noticed that while singing in the shower, if you find the right pitch, the loudness of your voice increases significantly. Something about the sound wave you created matches the volume of air you are in and resonance is the result!

A: Finding a Resonant Length (Changing the air column length)

In this investigation, instead of changing the sound to match the volume of air, you will change the size of the volume of air to match the sound. You will use the air column resonance apparatus as shown to the right, along with a tuning fork (512 Hz or 480 Hz).



1. One group member will control the water level in the graduated cylinder by raising or lifting the water cup. Start with the water level close to the top of the graduated cylinder.

2. One group member will hold the tuning fork just above the tube, and keep striking it to keep it from becoming too soft. The group member controlling the cup should lower it so that the water level in the cylinder **slowly** decreases.

3. When the air column in the cylinder has reached the **first resonant length**, the tuning fork sound will suddenly become louder. Raise and lower the cup to find the height when the resonance is loudest, so that other group members can measure this air column height as accurately as possible. Record it in the table below.

4. Continue to lower the water level, until you have observed and recorded a **second resonant length**. Raise the water level to the top and repeat the entire procedure at least once or twice more to confirm your resonant length measurements. Complete the calculations below.

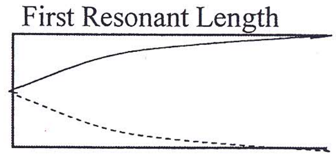
Tuning Fork Frequency f (Hz): 512	
1st Resonant Length (m): average: 0.165 m	
2nd Resonant Length (m): average: 0.50 m	

Tuning Fork λ (use $v = 344$ m/s, $v = f\lambda$): 0.672	m	
Length of half a wavelength ($\frac{\lambda}{2}$): 0.336	m	!!
2nd Resonant Length – 1st Resonant Length: 0.335	m	

This is an example of resonance in a ***closed column*** of air. A closed air column has one end closed and the other end open. When resonance occurs in the air column, a standing wave is created. Because this is a closed column of air, the standing wave always has **a node at the closed end** and **an antinode at the open end**. At the closed end, the air particles press against the surface and cannot move freely, which creates a node. This is similar to the reflection of a wave from a fixed end. At the open end they have the most freedom to move.

5. The shortest length of tube that produces a resonance is called the **first resonant length**. The standing wave for the first resonant length is shown in the diagram on the right. What fraction of a wavelength or cycle is represented by this standing wave? Using your measurement and the fraction of a cycle represented by this standing wave, calculate the wavelength of the sound wave.

First Resonant Length

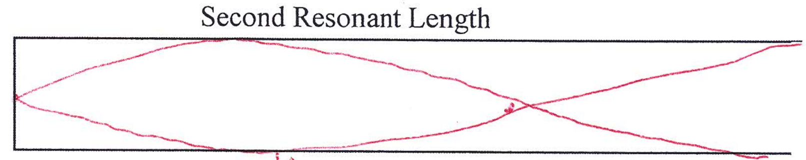


node anti-node

$\frac{\lambda}{4} = 0.165\text{m}$ $\lambda = 4(0.165\text{m}) = 0.66\text{m}$, close to 0.67 m

6. Sketch the standing wave for the second resonant length in the diagram (remember, there must be 1 more node and antinode). What fraction of a wavelength is in this air column? How much longer is the second resonant length than the first resonant length (in fractions of a wavelength)?

Second Resonant Length



node anti node anti-node

$\frac{3\lambda}{4} \longrightarrow \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{2\lambda}{4} = \frac{\lambda}{2}$ (half a wavelength!)