## Experiment 9

# Standing Waves and the Speed of Sound

### Preparation

Prepare for this week's experiment by reviewing last week's experiment and by reading the parts of your book that cover sound, wavelength, speed of sound, standing waves, and resonance.

### Principles

Sound is a longitudinal wave, which means that the oscillations of the air molecules are in the same direction as the motion of the wave. That is, the air molecules vibrate back and forth in the same direction that the sound wave is moving. The air is alternately compressed and rarefied as the wave travels from the source. You can represent this with a wave that shows the air pressure as a function of distance. The areas of maximum or minimum pressure are called pressure antinodes; the area between two adjacent antinodes where the change in air pressure is zero is called a pressure node.

Consider what happens when a sound wave travels down a long thin tube that is closed at one end. The diameter of the tube is small compared to its length. When the wave reaches the end of the tube it is reflected back. The reflected wave will undergo a 180° phase shift.

The incident and reflected waves can constructively or destructively interfere with each other. If the air column is the right length the incident and reflected waves will constructively interfere, creating a standing wave which will have the same frequency, but a larger amplitude than the incident wave.

In this experiment tuning forks of different frequencies are the sound sources. The length, $L$, of the air column is changed by raising or lowering the water level in the tube. The opening at the top will be a pressure node. When the surface of the water is at a pressure antinode the reflected wave will reinforce the incident wave and the amplitude of the reflected sound will increase. The distance between the node at the top of the column and the first antinode will be about $1/4\ \lambda$, where $\lambda$ is the **wavelength**. The distance between any two adjacent nodes or antinodes is $1/2\ \lambda$, so resonance will occur at $3/4\ \lambda$, $5/4\ \lambda$, $7/4\ \lambda$, etc. In other words:

$$L = \frac{n\lambda}{4} \quad = 1, 3, 5, 7...$$

The wavelength will then be twice the distance between two adjacent antinodes.

In actuality the pressure node is not located at the top of the tube, but rather about .6 $r$ above it, where $r$ is the inner radius of the tube and the distance is measured from the top of the tube to the center of the tuning fork.

The formula for the velocity of sound, $v$, is:

$$v = f\lambda$$

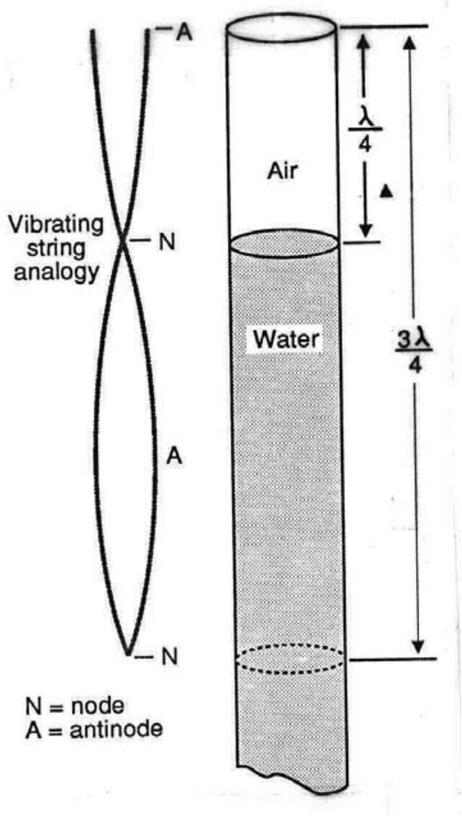
The wavelength multiplied by the frequency will give a value for the speed of sound in air which can then be compared to the accepted value of:

$$v = (331 + .61T)\ m/sec$$

where *T* is the temperature of the air in Centigrade.

**Equipment**

*1 water column*
*1 battery filler*
*1 beaker*
*2 different tuning forks*
*1 mallet*
*paper towels as needed*




**Procedure**

Do not let the vibrating tuning fork strike the edge of the tube. Do not strike the tuning fork with anything other than the rubber mallet; this could ruin the fork.

1. Raise the reservoir to the top of the tube enough water to reach the bottom of the reservoir.

2. Hold a tuning fork so that its center is about .6r from the top of the tube. Record the frequency of the tuning fork.

3. Strike the tuning fork with the mallet and lower the water until you hear the first resonance. Adjust the water level to get the maximum sound volume. Record the position of the node to the nearest .2 cm.

4. Continue to strike the tuning fork and lower the water level until you have found all the resonances. The nodes should be regularly spaced. Disregard any resonances that have a higher pitch than the tuning fork.

5. Repeat the procedure for another tuning fork with a different frequency.

6. Drain all the water from the water column.

7. Record the air temperature in the room.

## Analysis

1. Calculate the accepted value for the speed of sound..

2. For each tuning fork find the difference between the positions of adjacent antinodes. Average this value. Multiply by 2 to find the wavelength for each frequency.

3. For each tuning fork multiply the frequency by the wavelength to find the experimental speed of sound in air.

4. Find the percent error for each experimental value for the speed of sound. Find the average experimental speed and its percent error.