Physics 213 Laboratory

Longitudinal Standing Waves in an Air Column

**Purpose:** We shall determine the velocity of sound in air by studying longitudinal standing waves in an air column.

**Theory:** In the text it is shown that if two travelling waves of identical wavelength move in opposite directions, (see figure to the right) they add to form a standing wave. Each node-to-node distance in the standing wave is half as long as the wavelength of the travelling wave.

In the experiment, a resonance (standing wave) is set up in an air column in a vertical glass tube. The top of the tube is open. A water surface of adjustable height forms the bottom of the air column; this causes the air column to be closed at the bottom and open at the top. Standing waves can only exist in the air column when there is a node at the closed end and an antinode at the open end. Possible standing waves are shown in the diagram to the left.

Since each node-to-node distance is half the wavelength of the travelling waves, standing waves can only be set up if the length of the air column is 1/4, or 3/4, or 5/4, or 7/4, etc. of a wavelength. In the experiment a tuning fork of known frequency is held above the air column, and the water level is moved up or down, thus changing the length of the air column. Whenever the length becomes equal to one of these values, a standing wave is set up and causes the sound to become much louder.

The listener observes the water levels which produce standing waves. These levels are exactly 1/2 wavelength apart so the wavelength can be determined. Then from

\[
\text{Velocity} = (\text{wavelength})(\text{frequency})
\]
the velocity of sound in air can be calculated.

Theoretically the velocity of sound in a gas is proportional to the square root of the absolute temperature, so it can be calculated from

\[
V_{\text{Sound at } T(K)} = V_{\text{Sound at } 273^0 K} \sqrt{\frac{T}{273}}
\]

where \( V_{\text{Sound at } 273^0 K} \) is 331.4 meters/second (in air)

Note: Detailed analysis shows that the antinode at the open end of the tube is actually located slightly outside the tube by a distance of (.3)(diameter of tube.)

Procedure: The apparatus used includes a resonance tube and holder, 500 and 1000 hertz tuning forks, rubber mallet, meter stick, large aluminum beaker, thermometer, and water.

1. Put enough water in the resonance apparatus to enable the water level to be varied over the length of the tube.

2. Using the 500 hertz tuning fork, strike the fork with the mallet and hold the fork over the open end of the tube. Vary the water level to locate the positions that produce a resonance. The sound gets much louder at the resonance position. You can expect the first resonance position between 15 and 20 centimeters from the top of the tube. Others should be at about 3, 5, and 7 times this distance. Locate each resonance as accurately as possible and record these positions.

3. Repeat step 2 using the 1000 hertz tuning fork.

4. Record the room temperature and measure the diameter of the tube.

Calculations:

1. For the 500 hertz data, calculate the distance from each resonance to the next. These distances should be similar and equal to half the wavelength. Average these distances and double the result to find the experimental wavelength.

2. Calculate the velocity of sound in air by using

\[
\text{Velocity} = (\text{frequency})(\text{wavelength})
\]

3. Repeat calculation steps 1 and 2 for the 1000 hertz data.
4. Convert the room temperature to absolute temperature and calculate the velocity of sound in air at that temperature. Compare this with the experimental results from calculations 2 and 3.

5. Calculate the position of the antinode near the open end of the tube (exactly 1/4 of a wavelength from the highest resonance position.) Is it outside the tube by about .3 times the tube diameter?