EXPERIMENT 12: SPEED OF SOUND

Objective:

To determine the speed of sound in air.

Equipment:

The basic apparatus is a 1-meter long, 5-cm diameter resonance tube closed at one end by a movable piston. The position of the piston determines the length of the vibrating air column and thus the resonant wavelength and frequency of the tube. Mounted close to the open end of the tube is a small speaker driven by a variable-frequency audio oscillator. The audio oscillator has a digital display indicating the frequency of the signal. (If your oscillator does not have a digital display, your set-up will include an oscilloscope to monitor the oscillator signal.)

Theory:

Sound is a longitudinal wave. A wave consists of an oscillation in some medium. Ocean waves are transverse waves in water. (The water molecules oscillate perpendicular to the direction of propagation of the wave.) Sound waves are longitudinal waves in air. (The air molecules oscillate in the direction of propagation of the wave.) All waves are characterized by the following parameters:

- Amplitude (For sound waves the amplitude is related to how “loud” the sound is.)
- T-Period (The time between one maximum and the next)
- f-Frequency (The number of waves per unit time = 1/Period)
- \( \lambda \)-Wavelength (The distance between one maximum and the next)
- v-Velocity (The speed with which the wave propagates in a medium. Usually constant.)

Since speed times time gives distance traveled we can say the velocity of the wave times the period equals the wavelength

\[ \lambda = vT = v/f \]

When you set up a standing wave in an open tube, the oscillations will reinforce if the open end of the tube is an antinode and the closed end is a node. In other words, the distance from the open end to the closed end will be one quarter of a wavelength, as shown in the figure. If the piston is pulled out until the open length of the tube is \( 3\lambda \), we obtain another situation in which the sound waves reinforce.
**Procedure:**

**KEEP THE VOLUME ON YOUR SYSTEM LOW!**

1. Connect the output of the oscillator to the speaker. Change the oscillator settings and observe the relation between the frequency and the pitch of the sound from the speaker. Vary the oscillator to get desired values of the period.

2. With the frequency set to 600 Hz (period 1.7 msec), find the first piston position for which the tube resonates. At this air column length, the reflected wave from the piston is in phase with the incoming signal from the speaker. The two signals add constructively giving a loud response. Now increase the length of the air column to find other resonant points that also provide a loud response. Record these piston positions in your data table.

3. Repeat for five more frequencies spanning 600 - 1300 Hz.

**Data Table:**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Period (msec)</th>
<th>$x_1$ (m)</th>
<th>$x_2$ (m)</th>
<th>$x_3$ (m)</th>
<th>Wavelength (m) $\lambda = x_3 - x_1$</th>
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**Analysis:**

At a fixed frequency, the distance between piston positions measures one half the wavelength at that frequency.

1. Add to your data table values for the period and the wavelength at each frequency.

2. Plot wavelength vs. period for your data. Distance per cycle (wavelength $\lambda$) is the product of wave speed $v$ and the time per cycle (period $T$), so your data should show the linear relationship

$$\lambda = vT.$$
3. Determine the speed of sound in air from your data by evaluating the slope of your graph.

4. Compute the accepted value for a sound wave, \( v_{\text{accepted}} = 331 \text{ m/s} \sqrt{\frac{T_{\text{room}}(^\circ K)}{273^\circ}} \). Most thermometers report room temperature in degrees Fahrenheit. Convert room temperature to degrees Kelvin by using the following relationship:

\[
T_{\text{room}}(^\circ K) = \left( T_{\text{room}}(^\circ F) - 32^\circ \right) \times \frac{5}{9} + 273^\circ
\]

5. Find the percent difference between the accepted value for the speed of sound and the value you have determined experimentally.

**Report:**

In addition to the standard elements of a well written lab report described in the introduction to this manual, your report must include:

1) A sketch of the standing wave in the resonance tube. Label the positions \( x_1, x_2 \) and \( x_3 \) at which the piston was placed to produce resonance. Indicate the wavelength in your sketch.
2) Your data table.
3) Your graph of wavelength vs. period.
4) The computation of the accepted value for the speed of sound and its comparison with your experimental value.