Experiment 13
Speed of Sound in Air

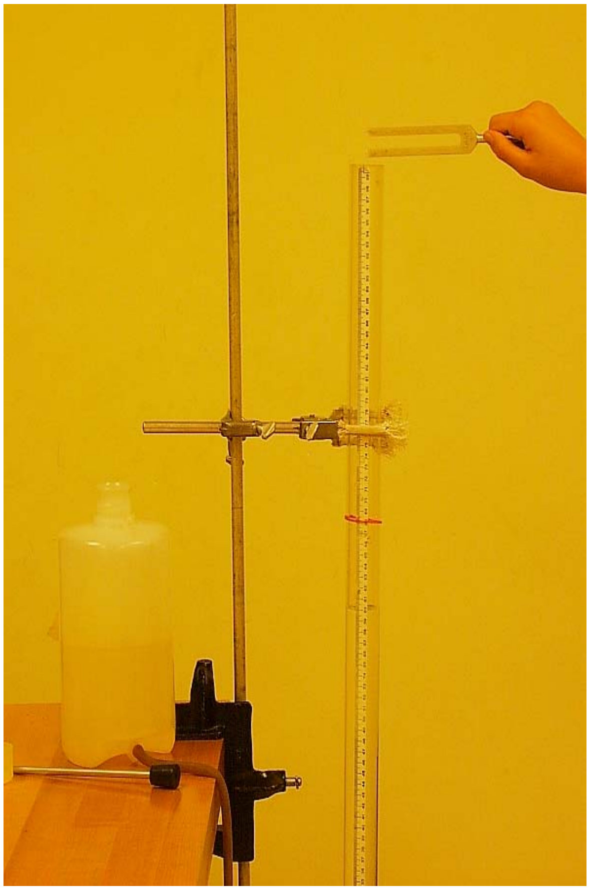

Fig. 13-1 Sound Tube

EQUIPMENT
Sound Tube
2 Tuning Forks
Mallet
Water Jug
Rubber Hose
Rubber Bands
Clamps and Rod

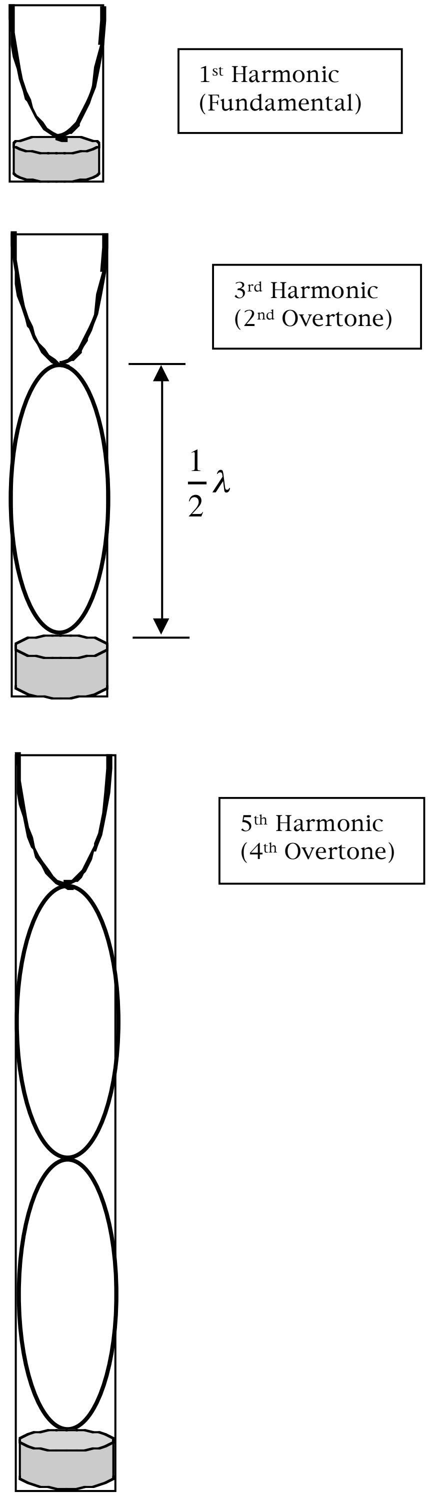

Fig. 13-2 Displacement of Air

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Advance Reading
(Halliday,Resnick and Walker) Chapter 16, Sections 16-12, 16-13. Chapter 17, Sections 17-3, 17-4 and 17-17.

Objective
The objective of this experiment is to measure the speed of sound in air.

Theory
Sound is a longitudinal wave requiring a medium in which to propagate. The speed of sound depends on properties of the medium such as bulk modulus, density, and temperature.

To calculate the speed of sound in air, v, we will determine the wavelength, λ, of the sound produced by a tuning fork of known frequency, f:

$$v = \lambda f \qquad \text{(Eq. 13-1).}$$

A vibrating tuning fork generates a sound wave that travels outward. When held above a sound tube, the wave will travel down the tube, reflect off the water surface, then return to the top. When the column of air in the tube has an appropriate length (height) for a given tuning fork, a standing wave is produced, and the air will resonate.

When considering the displacement of air for resonance (constructive interference), there is an anti-node near the open end of the tube, and a node at the water surface where the sound is reflected (refer to Fig. 7-2). To locate multiple resonances for a particular tuning fork, one must be able to change the height of the air column in the tube. This will be accomplished by changing the water level in the tube: raise or lower the water reservoir (jug) and the water level will change accordingly.

The distance between one resonance and the next is λ/2:

$$\frac{\lambda}{2} = |x_1 - x_2| \qquad \text{(Eq. 13-2).}$$

When one knows the frequency of the tuning fork, the speed of sound can be calculated using Eq. 8-1.

Equipment Note
- Hold the tuning fork by the handle only.
- Hold the tuning fork away from the sound tube when you strike it.
- Strike the tuning fork *only* with the rubber of the mallet.
- Position the *end of the tuning fork above the center of the sound tube*, parallel with the floor; align the tines of the tuning fork vertically (one tine above the other). Refer to Fig. 13-3.
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- When it is necessary to strike the tuning fork again, first stop the oscillations by holding the tuning fork against your shoulder.

Fig.13-3

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PROCEDURE

1. Lift the water container to a height such that the sound tube *almost* fills with water; do not crimp the hose or allow the water to overflow.
2. Adjust the water level to 15 cm below the top of the tube; hold the water at this position for 5 seconds. Adjust the water level to 25 cm below the top; hold at this position for 5 seconds. Adjust the water level to 20 cm below the top and hold for 5 seconds.
3. Your partner will repeat.
4. Refer to Fig. 7-3 and the *Equipment Note*. Strike the tuning fork and hold it above the sound tube. Allow the water level to drop as you listen for resonance.

5. *To determine the precise water level when resonance occurs, adjust the water level until the sound is most intense. This will likely require you to raise and lower the water level through the relevant point several times in order to locate the precise location of peak resonance. Hold the water at this level while your partner records the position of the water surface.*

6. To determine λ, you must find at least one other resonance location in order to calculate $\lambda/2$. Find two more.
7. Calculate λ_{avg}.
8. Calculate the speed of sound using λ_{avg} for this tuning fork.
9. Repeat the above procedure for the other tuning fork.
10. Calculate an average value for the speed of sound.
11. Calculate a theoretical value for the speed of sound using:

    $$v = (331.50+0.61T)\text{m/s} \quad \text{(Eq. 13-3)}$$

    where T is the temperature in degrees Celsius. Use the nearest thermometer, located at the front and back of the room, to measure the temperature.

12. Compare your average value for the speed of sound with the theoretical value.
13. There is a chart on the board. Record both your experimental and theoretical values for the speed of sound.
14. Determine the class average for the experimental speed of sound, $v_{E\text{-}avg}$, and theoretical speed of sound, $v_{T\text{-}avg}$.
15. Compare the class average values of $v_{E\text{-}avg}$ and v_T