NAME ______________________________ CLASS ______________

# Experiment 33

# Speed of Sound

**Problem** How can the speed of sound in air be measured?

The speed of sound can be measured directly by timing the passage of a sound over a long, known distance. To do this with an ordinary watch requires a much longer distance than is available in the laboratory. It is convenient, therefore, to resort to an indirect way of measuring the speed of sound in air by making use of its wave properties. For all waves the following relationship holds,

$$v = f\lambda \tag{1}$$

where $v$ is the speed of the wave, $f$ is its frequency of vibration, and $\lambda$ is its wavelength. In this experiment, you are going to measure the wavelength of a sound of known frequency. You will then compute the speed of the sound.

**Apparatus** Variable length resonance tube or aluminum cylinder about 45 cm long; glass cylinder about 35 cm tall; half-meterstick; several tuning forks, from 256 to 512 vps; large rubber stopper about 5 cm in diameter; thermometer

**Needed Information and Skills** You will use the principle of resonance to determine the wavelength of the sound produced by a tuning fork of known frequency. When a tuning fork is sounded near the open end of a tube closed at the other end, a strong reinforcement of the tuning fork sound will be heard if the air column in the tube is the right length. This reinforcement is known as *resonance*. It is caused by the fact that the waves reflected from the closed end of the tube return to the top in phase with the new direct waves being made by the fork. The direct and reflected waves thus combine their effects.

To find the length of the air column that produces resonance for a given tuning fork, it is necessary to vary the length of the tube. Figure 33-1 shows two methods to accomplish this purpose.

In method (a) the reservoir is raised or lowered. In method (b) the metal tube is raised or lowered. In either case, the length of the air column in the tube is changed until the sound intensity is at a maximum. For a tube closed at one end, whose diameter is small compared to its length, strong resonance will

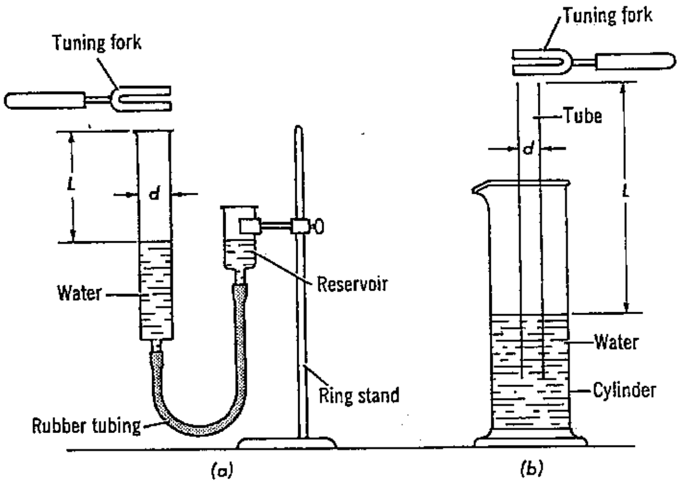

**Fig. 33-1.** Two methods useful in producing resonance by varying tube length.

occur when the length of the air column is one-quarter of a wavelength, $\lambda/4$, of the sound waves made by the tuning fork. A less intense resonance will also be heard when the tube length is $3/4\lambda$, $5/4\lambda$, and so on.

Since the shortest tube length for which resonance occurs is $L = \lambda/4$, it follows that $\lambda = 4L$. Practically, this relationship must be corrected for the diameter $d$ of the tube. This gives

$$\lambda = 4(L + 0.3d) \tag{2}$$

In this experiment $\lambda$, $L$, and $d$ will be measured in meters.

## Gathering the Data

Choose a tuning fork of known frequency. Strike the fork against the rubber stopper and bring the tuning fork over the open end of the resonance tube. Hold the tuning fork so that the tines vibrate toward and away from the surface of the water in the tube. The water level in the tube should be as high as possible, making the air column as short as possible. Slowly change the level of the water in the tube until you hear strong resonance. At this point measure the length of the air column in the tube $L$ in meters and record it in Table 33-1.

Record the frequency of the tuning fork. Measure the inner diameter of the tube with the meterstick and record this in Table 33-1. Note the room

**Table 33-1**

| Frequency $f$ (vps) | Length of Air Column $L$ (m) | Diameter of Tube $d$ (m) | Wavelength $\lambda$ (m) | Room Temperature $T$ (°C) | Speed $v$ (m/s) |
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temperature and record this in the table as well. Check your results by repeating these measurements with the same tuning fork.

Using several other tuning forks with different frequencies, make the same measurements and record them in the table.

## Solving the Problem

Using the values of $L$ and $d$ in Table 33-1, calculate the value of the wavelength $\lambda$ from Equation (2). Enter this value of the wavelength in the table.

Now, from Equation (1), $v = f\lambda$, calculate the value of the speed of sound in air and record this value in the table for each of the tuning forks used. Average the results, and record your average, together with your reading of the room temperature in degrees Celsius.

To check your results, you can calculate the value of the speed of sound in air from the following relation:

$$v = 331 \text{ m/s} + (0.6 \text{ m/s}\cdot{}^\circ\text{C})T \qquad (3)$$

where $T$ is the temperature in degrees Celsius and 331 m/s is the speed of sound in air at 0°C. Calculate and record your result.

Compare the result you obtained by resonance measurement with the calculated value obtained by using Equation (3). Assuming the calculated value is correct, determine the percent difference between the two values of the speed.

## Questions and Supplementary Activities

1. How could you use the method and the results of this experiment to determine whether the speed of sound in air depends upon its frequency? What do your results indicate about such a relationship?

2. How could the method of this experiment be used to determine whether the speed of a sound in air depends upon the atmospheric pressure?

3. When sound waves pass from air into water, their speed increases by a factor of 4. This means that either the wavelength or the frequency also increases by a factor of 4. Which is it? Explain.

4. An echo results when a sound is reflected from a distant surface such as the wall of a building. Suppose you are standing in an open field 500 meters from a reflecting wall. You have a starting pistol and a stopwatch. How would you use these to measure the speed of sound through the air between the wall and you?

## Challenge Experiment

Design an experiment for determining the frequency of an unmarked tuning fork.