# **Standing Waves**

**Goal:** To measure the velocity of waves on a string and measure the velocity of sound.

#### Lab Preparation

To prepare for this lab you should read through the following material and you should also read through the equipment section.

The speed of a wave can be found two ways. If frequency and wavelength are known, then the speed of the wave can be found using

$$v = f\lambda$$

where v is the speed of the wave, f is the frequency of the wave, and  $\lambda$  is the wavelength of the wave. If tension in a string and mass per unit length of a string are know then the speed of the wave in a string can be found using

$$v = \sqrt{\frac{T}{\mu}}$$

where *v* is the speed of the wave, *T* is the tension in the string and  $\mu = m/L$  is the mass per unit length of the string.

In this lab you will produce standing waves in a string and also standing waves in air. A standing wave pattern is formed in a medium when two sets of identical waves pass through the medium in opposite directions (see Figure 1 below). Nodes are the part of the standing wave that remains stationary. The distance between nodes is  $\frac{1}{2} \lambda$ .

#### Equipment

For part I of the lab you will be using a setup like the one in Figure 1.



One end of the string is clamped to a device attached to a frequency generator similar to the tuning fork in Figure 1. The other end is attached to a force sensor that measures the tension in the string.

The frequency generator vibrates at a fixed rate of 120 Hz and it tries to make the string vibrate at the same rate. The string, however, will vibrate strongly only if the tension is adjusted to a suitable value. When the tension is suitable the string vibrates as a standing wave.

For part II of the lab you will have a device like the one shown in Figure 2.



Sound waves are generated by the tuning fork down into a column of air. By adjusting the level of the reservoir on the right you adjust the level of water on the left and thus change length of the resonance column. If you adjust the level to the correct spot you can set up a standing wave similar to the one shown in Figure 3 (here the standing waves are shown with transverse waves for easier viewing but they are really longitudinal waves in nature). Under these conditions, the air column resonates with the tuning fork and the intensity of sound from the system is considerably increased. This phenomenon of resonance enables us to determine when standing waves are being produced in the air column.

# Procedure

I. <u>The vibrating string</u>

See Figure 1 for the set up. To start with, open the "standingwave" file. Have the string be completely slack and zero the force sensor with "Zero" button.

Start the frequency generator and increase the tension until it is about 5 N. Slowly reduce the tension until a standing wave with 2 nodes along the string (not counting the ends) appears (see Figure 1). Adjust the tension slowly to achieve maximum standing wave amplitude. If the tension is adjusted below the correct value, the standing wave pattern disappears. Simply increase the tension again then slowly reduce tension again to achieve maximum standing wave amplitude. Record the tension *T* on your worksheet.

Measure and record the distance (*D*) between the two nodes. Use Figure 1 to help you calculate  $\lambda$ . Use this value of wavelength and the known frequency of the frequency generator to calculate the experimental value of speed,  $v_{\text{experimental}}$ .

The predicted value of speed (*v*) can be found using the tension and the known mass per unit length of the string ( $\mu = 3.9 \times 10^{-4} \text{ kg/m}$ ). Once *v* is found calculate the % difference between  $v_{\text{experimental}}$  and *v*.

Continue to reduce the tension on the string to find more sets of standing waves and repeat the process above. Always record the distance (D) to be between the outermost nodes (not counting the ends).

# Analysis of vibrating string

Open up the "manual graph" file and make a graph of  $v_{experimental}^2$  vs. *T* (since  $v_{experimental}$  is 0 when *T* is 0 include that point as well)\*\*. Find the slope of this line and use it to calculate a value for the mass per unit length of the string,  $\mu_{experimental}$ . Compare this value to the known value  $\mu$ . Print out a copy of the graph that includes the best-fit line.

\*\* $v_{experimental}^2$  vs. *T* means the  $v_{experimental}^2$  is on the y-axis and *T* is on the x-axis. This is because the  $v_{experimental}^2$  is the dependent variable and *T* is the independent variable.

### II. <u>The resonance tube</u>

## \*Please do not hit the tuning forks on the table to start it vibrating.

Start by recording the temperature in the room and the frequency of the tuning fork you are going to use.

<u>1<sup>st</sup> Resonance position.</u> You want to find the 1<sup>st</sup> resonance position as shown in Figure 3. To do this raise the water level in the resonance tube until it is near the top of the tube. Start the tuning fork vibrating by hitting it with the rubber hammer and place it right over the tube as shown in Figure 2. Lower the water level while listening for the first resonance (a louder sound) to occur. Once you have determined the approximate position of the first resonance point, make several trials by running the water surface up and down to find the exact point of maximum intensity and record its position.

<u>Additional resonance positions.</u> Using the same method as before, locate more resonance points by continually lowering the water surface until you find 5 resonance points or reach the bottom of the tube.

<u>Velocity of sound.</u> As shown in Figure 1 the distance between nodes is  $\frac{1}{2} \lambda$  (also examine Figure 3 again). Find these distances and then determine the average  $\lambda$  found. From the wavelength and frequency you can now find the speed of sound,  $v_{\text{experimental}}$  in the room. Make sure your answers seem reasonable.

Repeat the process above with a second tuning fork.

# When finished with your lab please make sure your lab station is cleaned up.

## Homework

1. For part I, why was the graph of  $v_{experimental}^2$  vs. *T* made rather than a graph of  $v_{experimental}$  vs. *T*?

2. The speed of sound in air at 0°C is 331.4 m/s. To compare your values from part II to this value you will need to adjust the values you found since they were measured at a different temperature. The speed of sound at 0°C can be calculated using:

$$v_{\rm o} = v_{\rm experimental} \sqrt{\frac{273}{273 + T}}$$

where  $v_o$  is the speed at 0°C, *T* is the temperature in Celsius of the room, and  $v_{\text{experimental}}$  is the speed you found for one of the tuning forks in part II. Find the adjusted speeds for each tuning fork and compare (% difference) your results to the accepted value of 331.4 m/s.