PHY152H1S – Practical 8: Sound Waves

Don't forget:

- List the NAMES of all participants on the first page of each day's write-up. Note if any participants arrived late or left early.
- Put the DATE (including year!) at the top of every page in your notebook.
- NUMBER the pages in your notebook, in case you need to refer back to previous work.

Note that the activities below have numbers which refer to numbers in the Waves Module at http://faraday.physics.utoronto.ca/Practicals/ .

Activity 4 (30 minutes)

Here is a Flash animation of a molecular view of a sound wave traveling through the air:

http://faraday.physics.utoronto.ca/IYearLab/Intros/StandingWaves/Flash/long_wave.swf

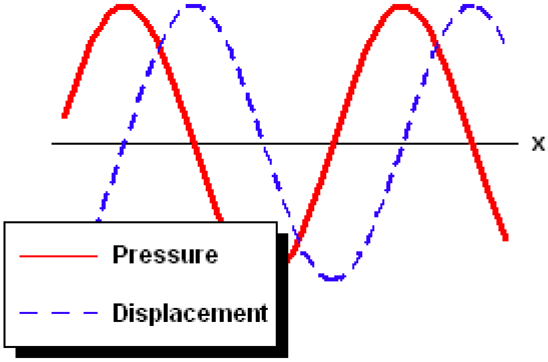
A. The bottom shows the motion of the air molecules. You may wish to imagine that the molecules are connected to their nearest neighbors by springs, which are not shown. There is a wave of increasing and decreasing density of the molecules. Is the wave moving to the right or to the left? Explain. Is the wave longitudinal or transverse? Explain.
B. Often instead of describing the wave as one of density we talk about a *pressure* wave. Does the higher density of molecules correspond to higher or lower pressure? Can you explain?
C. The top shows the displacement of the molecules from their equilibrium positions. It too is a wave, often called a *displacement* wave. Is the wave moving to the right or to the left? Explain. Is the wave longitudinal or transverse? Explain.
D. Use the *step* controls, pause the animation and position molecules 3 and 9 at their equilibrium position with molecule 6 at maximum displacement. The amplitude of the displacement wave is zero for molecules 3 and 9. Is the amplitude of the pressure wave at the position of molecule 3 also zero, or is it a maximum or a minimum? What about the pressure wave at the position of molecule 9?
E. Use the *step* controls to position molecules 3 and 9 at their equilibrium position with molecule 6 at minimum displacement. Is the amplitude of the pressure wave at the position of molecule 3 zero, or is it a maximum or a minimum? What about the pressure wave at the position of molecule 9?
F. From your results for Parts D and E, what is the phase angle between the pressure wave and the displacement wave?

Activity 9 (75 minutes including "If You Have Time" part)

As investigated in Activity 4, we can think of a sound wave two different ways:

1. A pressure wave. The pressure oscillates around atmospheric pressure.
2. A displacement wave. The displacements of the air molecules oscillate around their equilibrium positions.

These two waves are 90 degrees out of phase: when one has a maximum or minimum the other is at zero amplitude.



You will want to know that microphones measure the *pressure* wave. You will also want to know that the accepted value of the speed of sound is:

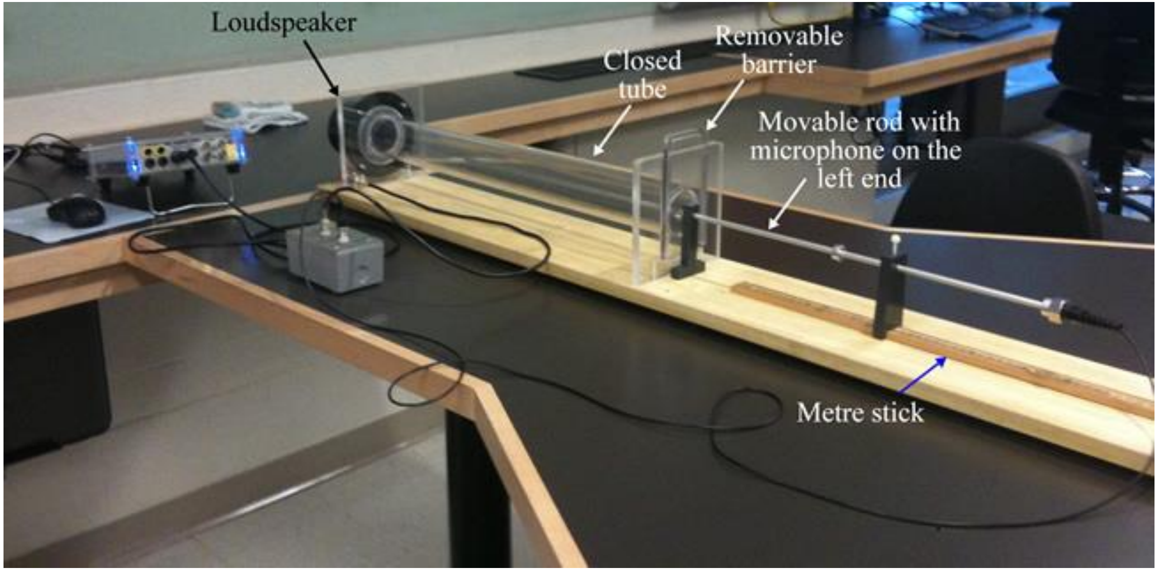
$$v_{accepted} = 331 + 0.61T \text{ (m/s)}$$

where T is the temperature of the air in Celsius.

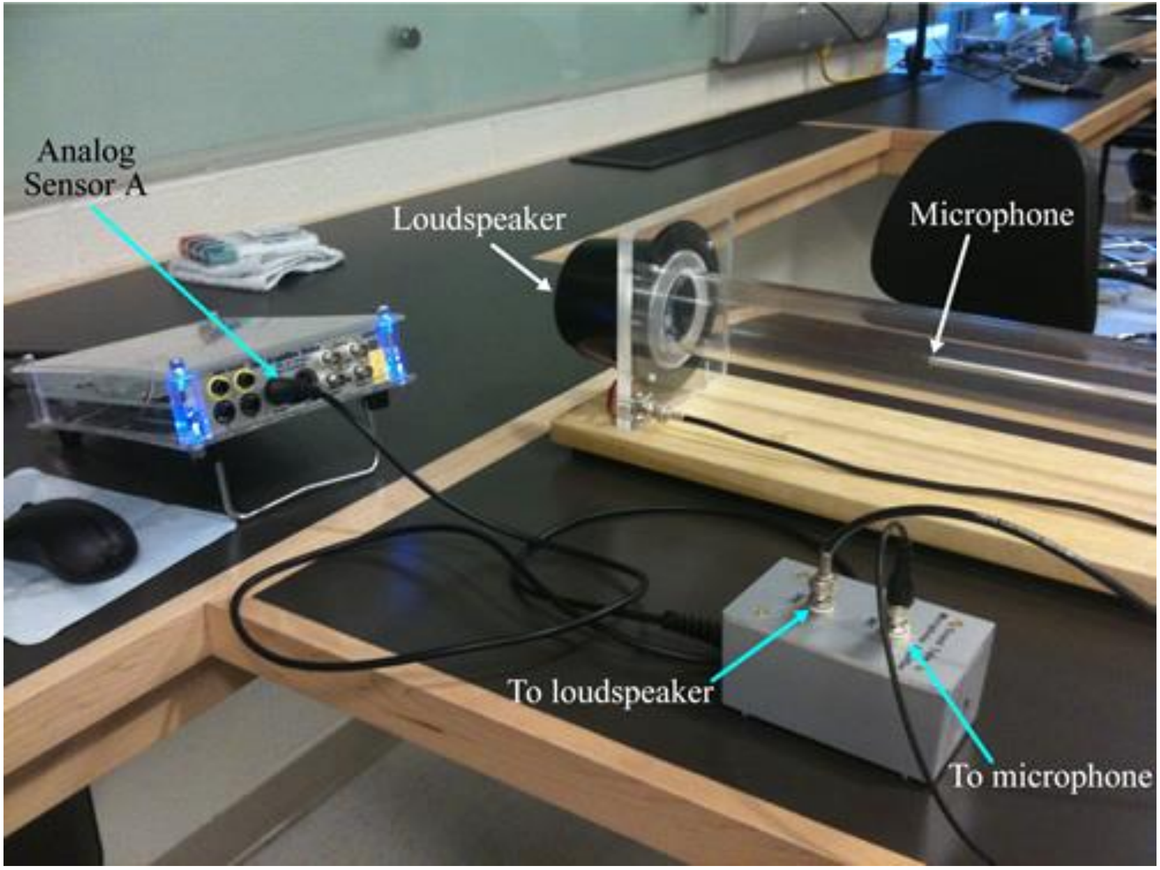
In this Activity you will set up standing sound waves in a tube filled with air and determine the speed of sound.

The Apparatus

The apparatus is shown on the next page. The loudspeaker generates the sound wave. The rod inside the tube has a small microphone mounted on the end, so the sound wave inside the tube can be measured at different positions.



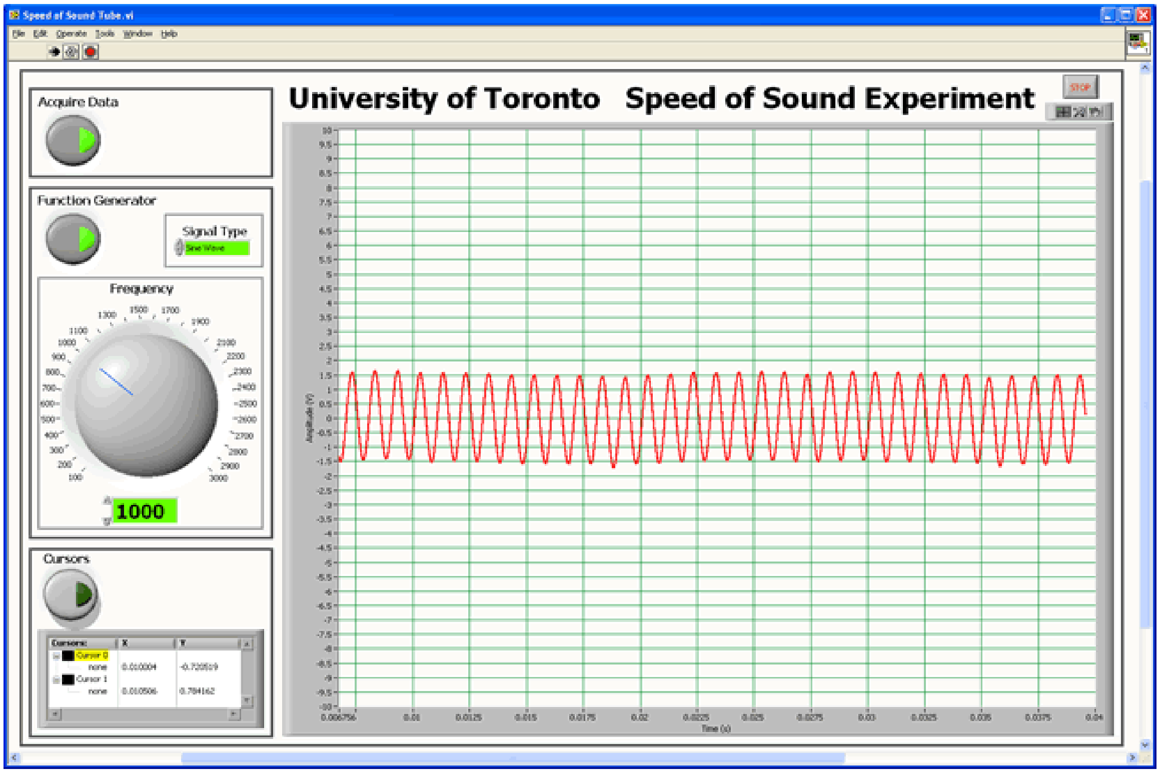
The figure below shows a close-up of the left side of the apparatus.



The gray box in the lower-right corner is the *Sound Tube Microphone Amplifier*. It is connected to the Analog Sensor A connection on the *Data Acquisition Device*. The connector on the top of the box labeled *SPK* is connected to the loudspeaker, and the connector labeled *MIC* is connected to the microphone.

The Software

The `Sound_vs_time` program both drives the loudspeaker and measures the output from the microphone. Here is a screen shot of the software.



Signal Type: Sine Wave

Frequency: 1000

To use the software for this Activity:

- Click on *Acquire Data* in the upper-left corner. The button will turn green as shown.
- Click on *Function Generator* just below the *Acquire Data* button. It too will turn green as shown. This causes the loudspeaker to begin generating a sound wave.
- Choose a *Sine Wave* as the *Signal Type*
- Adjust the frequency of the sound produced by the loudspeaker with the *Frequency* knob and the control just below the knob.

The plot on the right is what the microphone measures. It is a plot of wave displacement versus time. You will be interested in the amplitude of the wave, which is about 1.5 V in the screen shot.

Getting a Standing Wave in the Tube

The most challenging part of this Activity is getting a standing wave set up in the tube. The actual tube differs from the ideal case because of a number of factors:

- The cone of the loudspeaker is moving back and forth, so is only approximately a closed end.
- The sound wave will reflect off the rod, the hole in the right hand side barrier, etc. This means that you are unlikely to measure nodes that have exactly zero amplitude. Instead the amplitude at the nodes will only be close to zero but will be much less than the amplitude at the antinodes.

Here are some tips for getting a standing wave. You may wish to repeat some of the steps as you get closer and closer to a good standing wave.

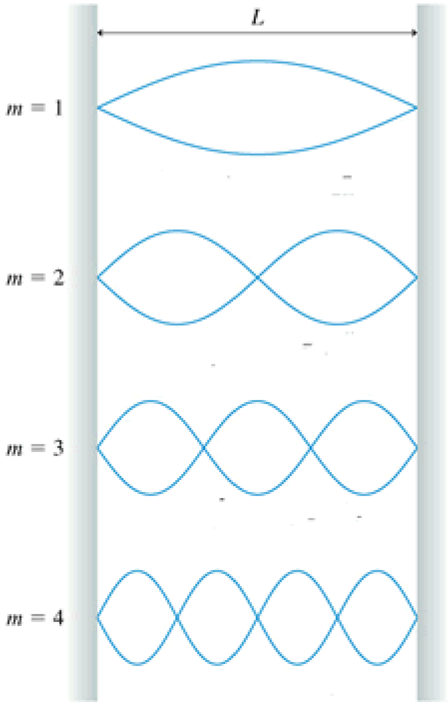
- Step 1: When a standing wave is established, this is called *resonance*, and you will be able to hear that the sound that leaks out of the tube is louder than for a non-resonant condition.
- Step 2: Place the microphone at the closed end of the tube. Slowly adjust the frequency so that you get a maximum amplitude from the microphone.
- Step 3: Place the microphone at a node, and slowly adjust the frequency so that you get a minimum amplitude from the microphone.

For each standing wave that you study, be sure to record the range of frequencies for which you cannot see any difference in the quality of the standing wave. This will determine the error in your value of the frequency.

Be careful not to push the Sound Sensor all the way into the speaker, as the speaker is made of paper!

Preliminary Parts

When the tube is closed at both ends, the possible *displacement* standing waves are the same as those for a standing waves on a string that is fixed at both ends: there is a node at each end of the tube. The figure to the right shows the first four possible standing waves. These are the same standing waves that for a string we called *normal modes* in Activity 7, and in fact this is the same figure that appears there!



A. What are the wavelengths of the shown standing waves? What is the wavelength of the $m = 5$ standing wave which is not shown? Generalise to a formula for the wavelengths for any value of m.
B. For the first two or three displacement standing waves, sketch the corresponding *pressure* standing wave.

Here is a link to a simple Flash animation that shows the displacement wave for the first three standing waves:

http://faraday.physics.utoronto.ca/IYearLab/Intros/StandingWaves/Flash/sta2fix.html

The Main Part

With the removable barrier in place so that the tube is effectively closed at both ends, get a standing wave in the tube. The stand that supports the rod straddles the metre stick. As you move the microphone from the nodes and antinodes of the standing wave, the distances between them can be determined by the position of the stand relative to the metre stick.

For a given node or antinode you will want to note how much you can vary the position of the microphone and not see any difference in the amplitude of the standing wave. This will allow you to determine the error in the position, which will allow you to determine the error in your determination of the wavelength λ of the sound wave.

Knowing the wavelength and frequency f of the standing wave you can calculate the speed of sound v from

$$\lambda f = v$$

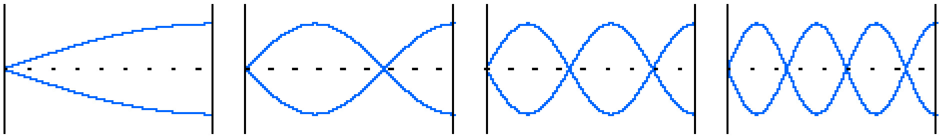
In your determination of the wavelength, you should think about how to get the most precise value, i.e. how to minimize the error in your value. Should you just measure the distance from an antinode to the next node, or from an antinode to the next antinode, or from the first antinode on the right of the tube to the furthest antinode on the left or the tube or …?

Determine the speed of sound for a few different standing waves of different frequency.

C. What is your final value of the speed of sound?
D. How does your value for the speed of sound compare to the accepted value which is given near the beginning of this Activity?

Tube Open on One End (If You Have Time)

When one end of the tube is open to the air, the standing waves that are possible are the same as those for a vibrating string with one loose end. Here are some of these displacement standing waves for a tube closed on the left and open on the right:



These standing waves occur because part of the incident sound wave is reflected from the open end of the tube. However, the effective reflection point of the wave is not the exact position of the open end of the tube but is slightly beyond it, and so the effective length of the tube is greater than its real length:

$$L_{effective} = L_{real} + \Delta L$$

where:

$$\Delta L \approx 0.3D$$

and D is the diameter of the tube. Sometimes $L_{effective}$ is called the *acoustic length*.

Here is a link to a simple animation that shows the first three standing waves:

http://faraday.physics.utoronto.ca/IYearLab/Intros/StandingWaves/Flash/sta1fix.html

Remove the barrier from the end of the tube and establish a standing wave.

E. Determine the effective length of the tube. How well do your measurements agree with the above equation?
F. If someone designs a pipe organ without being aware of the acoustic length, what will be the consequences?

This Student Guide was written by David M. Harrison, Dept. of Physics, Univ. of Toronto in the Fall of 2008.

Last revision: March 10, 2014 by Jason J.B. Harlow.