SOUND WAVES

Introduction:

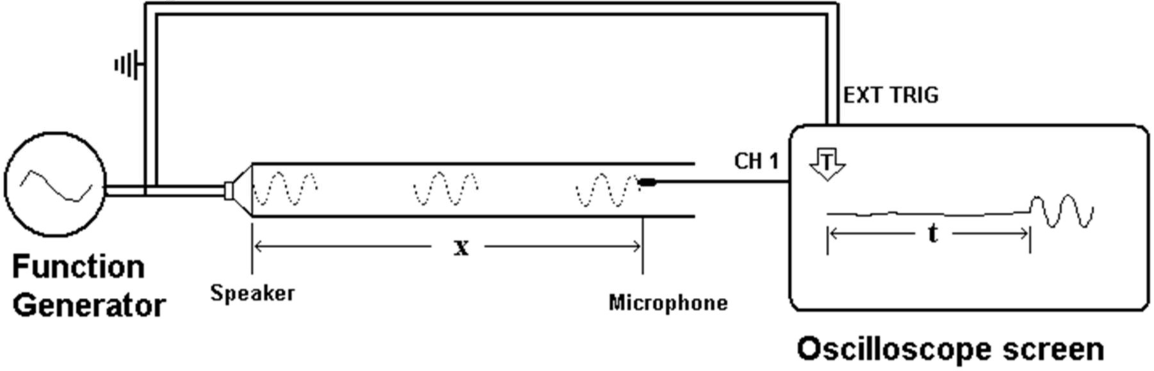
Sound is a longitudinal pressure wave that can travel at different speeds depending on the medium. In air, sound travels much faster than we can move (at 0 ºC, $v = 331 + 0.61T$ m/s, where T is temperature in ºC) providing us with means to react to danger, communicate at a distance, or alternatively, avoid sources of noise. It carries so much information that we have evolved very sophisticated organs to detect and interpret it. Our ears, paired up and separated, allow our brain to distinguish frequencies and correlate the phase difference so precisely that we are able to identify a source's character and location.

In this lab, you will:

1. Measure the speed of sound in air at room temperature.
2. Investigate sound's wave nature.
3. Observe resonance.

Speed of Sound:

In this part of the experiment you will use a microphone mounted on a moveable rod and connected to an oscilloscope to measure the time of travel of a sound pulse.



Referring to the figure above: When a signal from the function generator initiates a sound pulse from the speaker, it also triggers the oscilloscope to start a trace (the origin of the horizontal time axes on the Oscilloscope screen is signified by an icon with a 'T' in it.) As the sound travels through the air within the tube, the trace remains relatively flat and does not show a major deviation until the sound is detected by the microphone. The distance the sound pulse traveled is 'x' and the time it took to get to the microphone is 't'. Therefore, the speed of sound 'v' is simply x/t.

Setup:

- **Connect the microphone that is mounted on the narrow rod to the yellow channel (1) on the oscilloscope. Make sure the inline switch on the microphone is turned on.**
- **If the blue channel (2) is connected to anything, disconnect it.**
- **Connect the PULSE output of the function generator to both the speaker and the external trigger (EXT TRIG) connection of the oscilloscope. Make sure the side of the connector labeled GND is plugged into the receptacle marked low on the function generator; otherwise, the signal on the oscilloscope will not be stable.**
- **Set the function generator to a low frequency (f ~ 10 Hz).**
- **Turn on the oscilloscope and press 'Save/Recall' button. When the menu appears in the screen, choose 'Recall'. This should set all settings required for this section of the lab.**
- **If the automatic settings do not work, set up the oscilloscope manually by:**
    - **Using the Horizontal Scale knob to set the time/division to 500 µs (the value is shown on the bottom of the screen and corresponds to the major graticule divisions, not the small tick marks.)**
    - **Activating the external trigger source function on the oscilloscope by: pressing the Trigger 'Menu' button. When the trigger menu appears on the screen, press the button next to 'Source' and use the 'Multipurpose' knob to select 'Ext', and then press the'Multipurpose' knob set it.**
    - **Moving the origin to the left side of the screen. To do this, notice the small orange icon at the top of the screen with a T in it. This signifies the 0 position for the Horizontal time axis. Using the 'Horizontal Position' knob, move the icon to far left side of the screen so that it just touches the edge. Note: if you go too far, the icon points to the left to signify that the origin is buried off-screen**.

- **If the wave on the screen is jittery, adjust the trigger level knob to stabilize it.**

Note: Because it is difficult to determine the exact location of the sound source (speaker surface) and the exact location of the detector (microphone surface), it is not easy to determine 'x' accurately in a single measurement.

However, if we change the position of the microphone and plot all of the data, these unknowns remain constant and can be ignored. So, for analysis, plot the measured values of 'x' vs 't' for 10 different positions of the microphone and determine the slope. This should yield an accurate measure of v_s ($x = v_s t + x_o$).

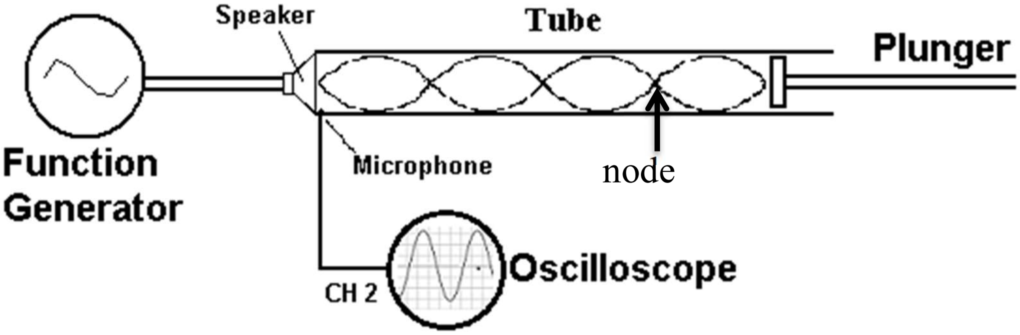
- **For 6 – 10 different positions of the microphone (ranging from the far end of the tube to as close as possible to the speaker, measure and record x and t values.**
- **Using Logger Pro software, plot this data and fit a straight line to it (using the 'm*x+b' function at the bottom of the list, not the 'straight line' function).**
- **Answer the following questions:**

    1. **Is the fit a good one? (Is the rmse roughly the same size as the measurement error of 'x'?)**
    2. **What is the meaning of the variable 'b' (the y-intercept)?**

Resonance and Standing Waves:

By using the plastic plunger provided with the apparatus, you will adjust the length of the closed cavity within the tube to create the conditions for standing waves; a phenomenon known as resonance. This is similar to the standing waves observed in the previous exercise (which you may want to review), but in this case it is not vibrations on a string, but sound waves in air. During resonance, you will notice that the amplitude signal on the oscilloscope screen will expand to a maximum.

The apparatus should be connected as follows:



Procedure:

- **Disconnect the microphone connected to the yellow channel (1).**
- **Move the connector on the function generator, from the pulse output to the signal output.**
- **Connect the microphone that is mounted into the side of the tube with the blue channel (2) on the oscilloscope.**

- **Set the function generator frequency to about 1000 Hz.**
- **Press the Autoset button on the oscilloscope.**
- **While keeping the frequency constant, slide the plunger within the tube and listen for the sound to get louder and watch for the amplitude of signal on the oscilloscope to get larger. When you reach a maximum, resonance is established. Record the plungers position at each resonance point along with its resonance number (e.g, 1,2,3…).**
- **Use the Logger Pro software to make a graph of x vs. n.**
  Note: since the distance between nodes (resonance points) is half the wavelength λ of the sound wave, the slope of this curve should be λ/2.
- **From the slope of this line and its uncertainty, find the wavelength and its uncertainty $\lambda \pm \Delta\lambda$.**
- **Answer the following questions:**

  1. **Is the fit a good one? (Is the rmse of the fit roughly the same size as the uncertainty of the position x?)**
  2. **From $\lambda \pm \Delta\lambda$, and the frequency $f \pm \Delta f$, find the velocity of sound, $v_f \pm \Delta v_f = \lambda f$.**
  3. **Compare this measurement with the value you found earlier in this experiment, and with the value given by $v = 331 + 0.61T$ m/s, (where T is the gas temperature in ^{o}C)? (Illustrate your answer by drawing a linear comparison graph.)**

- **Summarize your results and conclusions.**