Goals

- To observe resonance and standing waves on strings and in air.
- To understand how wave properties are related.
- To experimentally determine the speed of sound in air.
- To present and analyze data using both lower-level and higher-level graphs.
- To practice writing the introduction of a lab report.

Reading:

- Chapter 2 (Presenting Data Graphically) and section 3.2.2 (The Introduction) of the lab reference manual
- Review chapter Q1 and the relevant wave chapter from your previous course (E15 if you used Unit E.)

Pre-Lab Problems (in WebAssign; note: it will direct you to do some of these in your lab notebook):

1. Exercise 2.1 – Put the graph in your lab notebook. The distances are in meters and the kinetic energies are in Joules.
2. Exercise 2.2.
3. How does the mass per unit length of the string relate to the speed of the wave?
4. For the experiment below with sound waves, is each end of the tube open or closed? Sketch the shape of the first three standing waves that fit in the tube.
5. For each of the three standing waves sketched, how does the length *L* of the tube relate to the wavelength of the sound?

Lab Procedures:

Waves on a String:

- Set up a string to go from the rod, over the table, over the pulley, and pulled down with a weight of approximately 200 g. See figure Q1.10 for the set up.
- Place the string in the wave driver (near the rod) and plug the wave driver into the function generator.
- Begin with the function generator set to produce a sine wave with a frequency in the single hertz range. Keep the amplitude low to avoid damaging the equipment.
    a. Things to know about using the Function Generator
        i. The WaveForm button in the middle brings up a menu that allows you to select sine wave, square wave,… The "Voltage" knob doubles as the menu select knob and button; to really 'select' a form, you push the "Voltage" knob.
        ii. The arrow buttons at the bottom of the function generator adjust the scale on which the Frequency and Voltage dials will operate.
- Adjust the frequency to get a standing wave on the string. Note that there are both a coarse and fine adjustment for frequency on the function generator. Record the driving frequency and distance between nodes. Determine the wavelength.
- Slowly increase the frequency to find several more standing waves.
- Plot the wavelength λ vs. $1/f$, where f is the driving frequency. Find the slope and intercept of the best-fit line. (Don't forget the units.) What do these quantities represent physically? Explain using a theoretical relation.
- Determine the mass per unit length of the string *while it is stretched by the weight*.
- Repeat for a different string (optional).

Sound Waves:

- Add water to the reservoir until it comes within 10 cm of the top of the tube. Place the speaker a few centimeters above the tube and connect it directly to the function generator. The water level in the calibrated tube can be adjusted by raising or lowering the supply tank.
- Set the frequency to some value between 500 and 1000 Hz. Keep it fixed for the following three steps.
- Determine the position of the resonance by raising and lowering the water level until you are sure that the sound is at maximum intensity.
- Repeat for the entire length of the glass tube. Note that at some point you may need to remove some of the water from the supply tank with a small beaker.
- Using relations between the length of the air column and the wavelength from the pre-lab, determine the wavelength for this frequency. Explain your method of arriving at a single wavelength.
- Repeat the previous three steps for more frequencies.
- Plot the wavelength λ vs. $1/f$, where f is the frequency of the sound wave. Find the slope and intercept of the best-fit line. (Don't forget the units.) What do they represent physically? Explain using a theoretical relation.

Post-Lab Assignment:

1. Write the introduction of a lab report for all of the experiments that you performed. This should be typed.
2. Make higher-level graphs for each of the lower-level graphs you made during lab. You may use the computer program *LinReg* for this. Attach these in your lab notebook with tape or staples.
3. Determine the speed of the wave on the string from the higher-level graph. Explain using a theoretical relation. Calculated the speed expected from the mass per length of the string. How do the two values of the speed compare?
4. Determine the speed of the sound waves from the higher-level graph. Explain using a theoretical relation. How does your measured speed compare to the value given in the textbook?

Note: For this lab only, don't worry about uncertainties in the quantities that you are asked to find here. In Lab 5, you'll learn about determining uncertainties from graphs (called *linear regression*).