3.2: Activities

Equipment

- sound sensor with Pasco software
- metal bar & "bang weight"
- hanging string
- tape measure

The General Idea

We are given a bar made of an unknown metal, and are tasked with determining is composition. It is silver in color, which doesn't narrow things down a lot, but let's just say we have whittled the possibilities down to aluminum and titanium. Titanium is significantly more dense than aluminum, which suggests a quick way to answer this question, but we can't be certain that the bar isn't hollow. A hollow bar of titanium could have the same average density of a solid bar of aluminum. So our (perhaps convoluted) approach will instead be to measure the speed of sound through the bar, and match it to the proper metal (within uncertainty).

To determine the theoretical speed of sound in these metals, we need to know a couple of their properties. A short Google search reveals the following about these metals:

	Young's modulus	mass density
aluminum	$7.80 \times 10^{10} \pm 13\% \frac{N}{m^2}$	$2.70 \times 10^3 \pm 0.1\% \frac{kg}{m^3}$
titanium	$1.03 \times 10^{11} \pm 2\% \frac{N}{m^2}$	$4.51 \times 10^3 \pm 0.1\% \frac{kg}{m^3}$

To measure the speed of sound in our lab, we can employ a method similar to Lab #1: Create standing waves and use the length of the bar and the measured frequencies of the harmonics excited to compute the speed of the traveling wave that comprises that standing wave. What is different from the previous lab is that we will just dump energy into the system haphazardly, exciting several harmonics at once, and use a sound-sensing device to sort out the harmonics (which, due to constructive interference, get almost all the energy).

Some Things to Think About

We use the Pasco equipment in both parts of this experiment, so advice for each part is includes pointers for using the software as well as hints about methods for data acquisition and analysis. In terms of the software, the startup is the same for both parts. As with the previous lab, the Pasco box laptop have to be started from scratch (with the power off, and with the Pasco box turned on before the laptop).

The application to run from the 9B folder on the laptop is called "Sound_1". The sensor will start displaying data as soon as you click the "Monitor" button. Clicking the same button to stop very nicely freezes the screen in place for you to analyze at your leisure.

This program displays the the sound detected by the sound sensor, organized according to energy detected (technically, it is voltage coming from the sensor) as a function of frequency. So each little vertical bar indicates how much energy from the sound entering the detector comes from a thin range of frequencies. So for example, a monotone, having only one frequency, is represented in the display by a single thin monolith. Ambient sound has no particular preference for a single frequency, which is why you see a whole wide spectrum of vertical bars when the detector is just picking up noise.

When struck by the metal weight (this should be done by striking the bar end-wise – we are creating compression waves along the length of the bar), at first the bar vibrates with more-or-less random frequencies, but thanks to the constructive interference inherent in standing waves, it doesn't take long for the harmonic frequencies to account for most of the vibrational energy in the bar (the wave bounces back-and-forth between the ends thousands of times in the first second, so you won't even notice a lag time for the peaks to occur).

- As always, you want as much data as you can get, for the most accurate result possible, so you should measure the frequencies of at least 4 different harmonics, and not all of them can be odd-numbered.

- The bar has to be held somewhere, but doing so squelches some of the vibrations, so we want to grip it as little as possible. One thing that will help is use of the string provided, which maintains far less contact than human fingers.
- Useful as the string is, it still has its limitations, and in fact *where* the string holds the bar will be critical. No single placement will allow you to see all the harmonic resonances (peaks in the vertical bars) that you want – you will need to support the bar in two different manners to get clear views of both odd and even harmonics. Thinking about what the standing waves look like in this bar (in terms of its nodes and antinodes) should help you determine where the support points should be.
- When you adjust your string and begin measuring the frequencies of some even harmonics, you may observe a couple of odd occurrences. First, the fundamental may not squelch-out as fast as you expect. Be sure to wait long enough for this to happen, so that you get the correct resonance peaks. And second, you may not be able to find the fourth harmonic at all. To answer this puzzle, you may want to sketch the standing wave of the fourth harmonic. Unlike the odd harmonics, which are all manifest with a single string placement, the same is not true of the even harmonics.
- You can most easily read the value of the frequency for a given peak by using the coordinate tool. To activate this, click the button that looks like this: . Then just drag the cursor over the peak, and the horizontal component shown is the value of the frequency. You can print/screen-capture/photo the output for your lab report.
- Armed with the frequencies of several harmonics, and your knowledge of the wavelengths of these standing waves in terms of the length of the metal bar, you have many separate measurements of the speed of the traveling sound wave in the bar, and you can average them for your official measurement of the speed of sound in the metal bar.
- All that remains is to determine which metal the bar is made from. We are given uncertainties in the measurements of Young's modulus and mass density to use as our bounds. There is one thing to keep in mind here, however. The speed calculation uses the *square root* of these values, and the uncertainty of the square root of a quantity is not the same as the uncertainty of the quantity itself. You can review this (as well as the "weakest link rule", which you should also use here) in the Background Material of Lab #4 from Physics 9A.

Lab Report

Craft a lab report for these activities and analysis, making sure to include every contributing group member's name on the front page. You are ***strongly encouraged*** to refer back to the Read Me as you do this, to make sure that you are not leaving out anything important. You should also feel free to get feedback from your lab TA whenever you find that your group is at an impasse.

Every member of the group must upload a separate digital copy of the report to their lab assignment in Canvas *prior to leaving the lab classroom*. These reports are not to be written outside the lab setting.