1) {*Sound properties*}

The loudest sound a human can hear without quickly having permanent hearing damage is about 100 dB.

a) What is the intensity of such a sound?

b) What is the total power of this sound over the area of an ear opening, about $0.5\,cm^2$?

c) What is the amplitude of the molecular vibration (which we called s_{max} in class) for a sound at 440 Hz and 100 dB? What about a sound at 20 Hz?

d) What would the amplitude of pressure variation for these sounds (in the previous part)?

2) {*Doppler & Shock Waves*}

While the details of how Doppler and shock waves occur with light are totally different from the case with sound, both phenomena exist and at "low" speeds, the sound formulas are a good enough approximation. The speed of light is $3 \cdot 10^8 \frac{\mathrm{m}}{\mathrm{s}}$, so "slow" includes pretty much any normal speed you would deal with.

a) If a car is traveling at 30m/s away from a stationary radar gun (which emits a wave of the exact same type as light), by what factor does the Doppler shift change the frequency it "observes"?

b) If a car going 30 m/s emits a radar signal, by what factor does the Doppler effect change the frequency observed by a detector sitting still on the ground?

c) Suppose our radar gun creates a 10 GHz wave. If a wave from a stationary source is reflected off a moving car and the resulting wave received again near the source, what frequency arrives back at the source?

d) Using the analogous phenomenon to "beats," what low frequency signal is obtained by adding the original and reflected signal?

e) The speed of light in water is 3/4 of the speed of light in air. How fast does a particle have to be moving to produce a shock wave of light in water?

3) {*Standing Waves*}

A standard diatonic harmonica has ten reeds on each of two plates. This gives a total of 20 notes it can play. The range of notes is about three octaves, which means a factor of eight in frequency. Each reed is a thin metal piece attached to the plate at one end and with the other end free to vibrate. It acts very similar to a wave on a string, but with one end attached and one end free. The interesting thing is that the range of lengths of these reeds is more like a factor of two than eight.

Figure 1: An actual photo of (one face of) the inside of an old harmonica

a) What is the range of wavelengths of sound from these reeds (as an overall factor)?

b) What is the range of wavelengths of the reed vibration if they really act exactly as waves on a string?

c, d) Since the answers to the previous two questions are not the same, there must be another difference between the reeds beside the length. Since one end is open, the tension is not easy to alter, so what must that difference be?

I want you to answer this last part twice: once with a wave property, and once with a property of the reed itself which makes the wave property that way.

4) {*Various short problems*}

a) What is the speed of sound in brass? (To answer this, it will help to know that the speed of sound in brass is 3475m/s.)

b) A pulse traveling on a string has waveform $y = \frac{1}{x^2+a^2}$ at the beginning of time ($t = 0$). The string has mass per unit length 3.3 g/m and is under a tension of 3 N.

What is the equation of this wave as a function of space and time as it moves in the positive x direction?

c) "Speed" of a wave is measured in the units _____.

d, e) A very thin metal bar vibrating has a few distinct types of normal modes, one set of which is similar to a string with both ends free (not fixed). In terms of the length of the bar, what is the wavelength of the fundamental mode of vibration of this bar? What is the wavelength of the next harmonic after the fundamental mode?

f) Verify by explicit substitution that our first example of a standing wave: $y = \mathcal{A}\sin(k\,x)\,\cos(\omega\,t)$ is a solution to the linear wave equation we saw in class.

g) If the higher harmonics of a sound produced by some instrument all fade away in time faster than the fundamental frequency does, does this make the sound seem more or less 'pure" as it fades?