Physics 225

Homework Assignment 1

Due 14 January 2008

1 Speed of sound in other gases

Calculate the speed of sound in Helium, at standard temperature and pressure. Useful data: The factor $\gamma \equiv c_p/c_v$ for Helium is 5/3, whereas for ordiary air it is 7/5. The molecular weight for Helium is 4, while the mean molecular weight for air is about 29. The speed of sound in air is 344 m/s.

The period (inverse frequency) of sound produced by a wind instrument is proportional to the time it takes sound to travel the length of the instrument's tube. If a wind instrument plays at 220 Hertz when filled with normal air, what frequency will it play if it were filled with Helium?

Musicians describe frequency differences on a logarithmic scale based on the *half-step*. Two notes differ by a half-step if their frequencies differ by a factor of $f_2/f_1 = 2^{1/12}$. (Two notes differ by 12 half-steps, or an *octave*, if their frequencies differ by a factor of $f_2/f_1 = 2$.) How many musical half-steps higher is the frequency of the instrument when filled with Helium?

2 How loud is conversation?

This problem is to give you some practice with intensity, the $1/r^2$ law, and the relation between intensity, pressure, and air speed.

In North America it is customary to stand about 1 meter from someone during conversation, and to speak so that the sound intensity at their ear is about 10^{-6} W/m^2. Since people are more than 1 meter tall, and since most of the sound is at frequencies below 2000 Hertz, take the sound to radiate out in all directions (in a sphere) from the speaker's mouth.

First, what is the power in Watts of sound, that a speaker must produce in order to carry out normal conversation? What is the sound intensity, in Watts per square meter, at the speaker's mouth? (All the sound energy goes out through the mouth. You will have to measure the area of the mouth opening during speech.)

What is the speed of the air due to the sound v_{air} at the speaker's mouth, and what is it at the listener's ear? Give either the peak speed assuming a sine wave, or the RMS (root mean squared, the thing which if you square it you get $\langle v_{\text{air}}^2 \rangle$ over the period) speed, whichever you are comfortable with, but state clearly which you are giving.

Using that the eardrum is about .00008 square meters, and that people speak about 3 words per second, how much sound energy per word are your ears actually receiving when you hold a conversation?

Suppose a spoken sound is sinusoidal with a fequency of 1000 Hertz. At the listener's ear, how far back and forth (peak-to-peak) is the air moving?

3 Speed of sound in solids

When I look up the speed of sound in Aluminium (Aluminum) in a table, I find that it lists two numbers, roughly 3400 m/s and 5000 m/s. How can there be *two* speeds of sound in Aluminium (and other solids)?