Assignment III, PHYS 150 (Physics of Sound and Music)
Basic Resonances for Helmholtz Resonantors, Strings, and Pipes
Due 1/24/14 at start of class

Reminders (in case you still haven't picked up the book; this will be the last homework I give you information that can be found in the book).

The natural frequency for a mass on a spring is given by:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

with k the stiffness of the spring (in SI units), and m the mass of the mass (in kg).

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The natural frequency of small oscillations of a pendulum is given by:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$$

with g the gravitational acceleration near the planet you are on (for earth, nominally 9.81 m/(s^2)), and ℓ the length of the pendulum (in meters).

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The fundamental frequency of a Helmholtz resonator is given by:

$$f = \frac{c}{2\pi}\sqrt{\frac{a}{V\ell}}$$

with c the speed of sound (in air), a the area of the opening, ℓ the length of the neck, and V the volume of the resonating cavity.

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The fundamental resonant frequency for strings can be found via:

$$f_1 = \frac{c}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\rho}}$$

with c the speed of wave propagation on the string, L the length of the string, T the tension on the string, and ρ the mass per unit length of the string.

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1. On Earth, a pendulum undergoes small oscillations with a period of 2.7 seconds.
   a) What is the frequency of small oscillations for this pendulum?
   b) How long is this pendulum?
   c) What would the frequency of small oscillations for this pendulum be on the moon? (on the moon, $g \approx 1.62$ m/s^2).
   d) The coolest pendulum I ever saw in person was the Foucault pendulum at Fermilab near Chicago. I found an old youtube video of it moving back and forth and it looks like the period of oscillation was right around 15 seconds. How long was the pendulum?
2. A typical car has a mass of about 1800 kg. Let's say that after going over a bump in the road, I notice that I bounce with a frequency of around 1.2 Hz. (Yeah, I'm a nerd). If I was alone in the car and I weigh about 100 kg (we'll pretend), what is the approximate spring constant of my car's suspension?

3. Piano wire (according to Wikipedia) can vary in diameter from about .15 to 4.8 mm (1.5×10^{-4} m to 4.8×10^{-3} m). The piano wire for C4 is typically around 62.5 cm long and 261.6 Hz. If you wanted to make a Piano that used pure aluminum as the wire (density 2700 kg/m^3) with a diameter of 2 mm, what tension would C4 have to be under for the length given?

4. I have a bottle Helmholtz resonator with fundamental frequency 300 Hz. If I cut its volume down to 2/3 of the value it used to be (by filling the bottom 1/3 with water, for example), what would the new fundamental frequency be? (Assume the opening, area, etc. are all left unchanged).

5. Let's design a hypothetical speaker. This speaker (which has dimensions 30 cm x 30 cm x 20 cm) has a bass reflex port drilled in of circular area. The radius of this port is 2 cm. How long of a tube (extending into the speaker) would you need in order for this speaker to have a resonant frequency of 65 Hz (about C2)? (Technically the Helmholtz resonator shown in your text and described in class has the tube extending out of the volume, but here we're going to talk about a similar geometry where the thin-necked tube actually goes into the resonator. If you have a hard time visualizing it, see the following webpage: http://tinyurl.com/reflexport

6. Why do low frequency sound waves from a subwoofer spread out in all directions, but high-frequency sound waves from a tweeter travel pretty much straight ahead?