Homework 4, HONS 280 (Physics of Sound and Music)
Spring 2020
Due Date – Friday, January 24th, 2020 at beginning of class

As always, turn your legible and complete answers in on separate paper. Remember, I can't give partial credit unless I can follow what you've done. Including words is usually a good thing for you.

Note that I'm going to give you a few equations that appear in your textbook. This will be the last homework assignment where I give you that material; after that, I am going to assume you have access to the book to help you attack these problems.

- The natural frequency of oscillation 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 of kg/s^2) and m the mass of the attached mass (in kg).

- The natural frequency of small oscillations for a mass at the end of a pendulum of length ℓ is given by:

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

  where g is the gravitational acceleration near the surface of the Earth ($g \approx 9.81\ \frac{\mathrm{m}}{\mathrm{s}^2}$), and ℓ is the length of the pendulum (in meters).

- The fundamental frequency of a Helmholtz resonator is given by:

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

  with c_s 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.

- The fundamental (lowest) resonant frequency for strings can be found via:

$$f = \frac{c_s}{2L} = \frac{1}{2L}\sqrt{\frac{T}{\rho}}$$

  with c_s the speed of wave propagation on the string (in m/s), L the length of the string (in m), T the tension on the string (in N), and ρ the mass per unit length of the string (in kg/m).

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 0.15 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 is a box having 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. If you wanted your speaker in the previous problem to have a lower resonant frequency but had to make it inside the same enclosure and operate at the same temperature, how could you do it? (Explain two different methods you could use).