**Assignment XII, HONS 157 (Honors Physics I) (LAST ONE! Woo-Hoo!)**
**Fall 2015 Due Friday, 12/4/15 at start of class**

1. Since we are coving some of this material relatively briefly, please make sure to read chapter 15, chapter 16 (at least sections 1,2,5,7), and chapter 17 (at least sections 1,2,3,5,6,7).

2. An undamped, undriven oscillator reaches maximal displacement from equilibrium $A$ and has maximal velocity $v_\circ$. In terms of these two variables *only*, what is:

   a) The period of oscillation?

   b) The frequency of oscillation?

   c) The angular frequency of oscillation?

3. A mass-spring system of mass $M$ and spring constant $k$ is oscillating on a horizontal table-top at its natural (angular) frequency $\omega_\circ$ with amplitude $A$. At the instant the mass is stretched its furthest, you clip on a second mass $M$ onto the top of the first mass, so now a mass of $2M$ is being oscillated by a spring of spring constant $k$.

   a) What is the ratio $\frac{E(\text{before new mass added})}{E(\text{after new mass added})}$?

   b) What is the ratio $\frac{v_{\max}(\text{before new mass added})}{v_{\max}(\text{after new mass added})}$? ($v_{\max}$ indicates maximal velocity).

   c) What is the ratio $\frac{\text{Oscillation period before new mass added}}{\text{Oscillation period after new mass added}}$?

4. A classic example of an oscillatory system is someone on a swing on a swing set. We will explore this as a damped (but not driven) simple harmonic oscillator. If you go back and solve the appropriate differential equation for this system, you obtain (assuming it starts at maximum displacement)

$$\theta(t) = \theta_m e^{\frac{-bt}{2L}} \cos(\omega' t)$$
$$\omega' = \sqrt{\frac{4gL - b^2}{4L^2}}$$

   a) Briefly explain how you could estimate the damping coefficient $b$ of a swing-set. Explain – in detail – how you could find $b$ if you made some measurements of the system. You are only allowed to measure lengths, masses, and times.)

   b) Use realistic values for lengths, masses, and times to estimate $b$ for a realistic swing-set.

   c) What would the ratio $\frac{\omega'}{\omega_\circ}$ be for the values you assumed in part (b)? (You may assume that the system both with and without damping is well-approximated as a simple harmonic oscillator. You should not need to calculate any moments of inertia).

   d) (Extra credit). Actually do it. Go find a swing. Measure the values. Calculate $b$. Find $\omega'$ and compare it to $\omega_\circ$ for the system. (Again, you may assume that the system without damping is well approximated by a simple harmonic oscillator – no need to treat it as a physical pendulum).

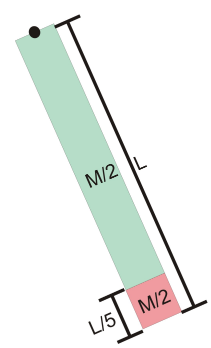
5. The ballistic pendulum lab you did earlier this semester ended up with us (erroneously) assuming that the pendulum could be well modeled as a simple pendulum. Let us envision a physical pendulum with a similar geometry and see how things change.

   We will use the figure below as a simplified version of the system we explored. The physical pendulum will be made up of two equal-mass components, each having mass $M/2$. The black circle indicates the pivot point. The center of mass of this system is designed to be at the intersection of the two pieces of this Physical pendulum, and exists at a distance $4L/5$ from the pivot.

   a) If all the mass were assumed to be at the center of mass of this system (like we did in the lab at the time), what would be the angular frequency of small oscillations of this system? (In terms of $L$, $M$, $g$, and any other necessary natural constants).

   b) If we now treat this system like the Physical pendulum that it is, what is the angular frequency of small oscillations of this system? (You may assume that the pendulum is a very thin rod, so you don't have to worry about the "width" of the arm; just its length. Again, leave your answer in terms of $L$, $M$, $g$, and any other necessary natural constants).

   c) Which of your answers to (a) or (b) is greater?



6. I googled some random string and found that a spool of this string weighs 0.3 ounces and has a length of 475 feet. Assume, for the sake of this problem, that the string is inextensible.

   a) If I use this string in a pulley/mass/standing wave setup like what we did in lab, and I attach a mass of 135 g to the free end of the string, what is the speed of wave transmission down the string?

   b) If I use this string in a pulley/mass/standing wave setup like what we did in lab, and I attach a mass of 135 g to the free end of the string, what is the lowest frequency for a stable state if the distance between the post and the pulley is 1.24 meters?

   c) If I use this string in a pulley/mass/standing wave setup like what we did in lab, and I attach a mass of 135 g to the free end of the string, what is the frequency associated with a standing wave pattern that has 4 nodes *between* the post and the pulley if the distance between the post and the pulley is 1.24 meters?

7. The speed of sound in (dry) air can be approximated with the equation:

$$v_{\text{air}} \approx (331.3 \text{ m/s})\sqrt{\left(1 + \frac{\theta}{273.15^\circ\text{C}}\right)}$$

   where $\theta$ is the air temperature (in degrees Celcius).

   a) In a 10 degree Celcius room, what is the wavelength of the main tuning note for most Orchestras (A-440, which has a frequency of 440 Hz)?

   b) How long would a tube closed at one end need to be so that it would have its lowest resonant frequency at A-440 in a 10 degree Celcius room?

8. A train horn has many frequencies (that's why you hear this weird cluster of sounds when you hear a train horn). I did some homework and broke down the real sound into its component frequencies. Turns out, one train has two main frequencies at 439 Hz and 523 Hz. For this problem, assume that the air is dry and the temperature outside is 20°C.

   a) Let's say you are stationary and the train is coming at you moving at 20 m/s. What two frequencies do you hear?

   b) As soon as the train passes by you and heads in the other direction, you hear a new pair of frequencies. As the train moves away from you at 20 m/s, what frequency do you hear now?

   c) The musical interval made by the pitches in the train whistle result from the ratio of frequencies. Do you hear a larger interval (larger ratio) when the train is coming toward you, when the train is going away from you, or is it essentially the same ratio?

   d) Let's say the train is stationary, but blows its whistle indicating it is about to start. You are moving towards the train at 20 m/s. What pitches do you hear?

   e) Same as part (d), but now you are moving away from the train at 20 m/s. What pitches do you hear now?