Assignment IX, HONS 157 (Honors Physics I)
Fall 2015
Due 10/30/15 at start of class

1. (This problem is adapted from problem 86 from chapter 9 of your text). Figure 9-75 in your text shows block 1 having mass m_1 sliding along the x axis on a frictionless floor with speed $v_{1i} = 4.00$ m/s. Then it undergoes an elastic collision with a stationary block of mass $m_2 = 0.500m_1$. Next, block 2 undergoes a one-dimensional elastic collision with stationary block 3 of mass $m_3 = 0.500m_2$.

   a) What then is the final speed of block 3?

   b) What fraction of the initial kinetic energy is transferred to block 3? (In other words, if the initial kinetic energy is K_i, you can write that the final kinetic energy of block 3 as $(K_f)_3 = \gamma K_i$ with γ some constant between 0 and 1. Find γ).

   c) What fraction of the initial momentum is transferred to block 3? (In other words, if the initial momentum is p_i, you can write the final momentum of block 3 as $(p_f)_3 = \beta p_i$ with β some constant. Find β).

2. A car engine idles at about 800 rpm (rotations per minute, or – equivalently – revolutions per minute). If, after turning your car off, the engine stops running completely in 0.7 seconds, what is the rotational acceleration of the engine during the "turning-off" process? You may assume α is constant.

3. A car tire with a 28 inch diameter is rolling (without slipping), helping to support a car that is driving down the road at an initial speed of 40 miles per hour. If the car decelerates with $a = -3$ m/s^2, what is the angular deceleration of the car tire on its axis?

4. A negligible thin rod of length $2L$ runs along the x-axis from the point $-L\hat{i}$ to the point $L\hat{i}$. The ends of this rod mark the midpoints of two solid spheres, each with radius $R < L$ (so that there's a sphere of radius R centered at each of the two end points $-L\hat{i}$ and $L\hat{i}$). (This system looks like an old-school "barbell"). Let the rod have mass m and each sphere have mass M. By construction, the center of mass is at the origin no matter what m and M are. For this system:

   a) Find the moment of inertia of the whole system through the axis that goes through the origin and points in the y direction.

   b) Find the moment of inertia of the whole system through the x-axis.

   c) [Extra Credit]: Introductory texts give the following simple approximation for the nuclear radius: $R \approx (1.2 \times 10^{-15}\ \text{m})A^{1/3}$ where A is the number of nucleons (protons and neutrons) in the atom. The bond-length of an N_2 molecule is approximately

145×10^{-12} m. Assuming that the bond itself has negligible mass, calculate I_y/I_x for an N_2 molecule using the basic theoretical model described above.

5. I once visited a data-center that used a giant flywheel to store kinetic energy that would enable the entire facility to keep running for a few seconds after a power-outage. The idea behind this is that you use a motor to get a system with a large amount of rotational inertia rotating while the power is still on and keep the thing rotating at all times when the power is on. If the power turns off, the flywheel will still keep turning for a little while and the motion of that flywheel can power your building's electricity through its motion (much like a turbine or water wheel). The details are unimportant for this problem, other than the fact that you can take the rotational kinetic energy of the flywheel and convert it back into electrical energy to power the thing you care about for a little while.

   Let's say that the building had to power 300 computers, each having requiring about 500 Watts to keep them running. You want your flywheel to power everything for 10 seconds – enough time for backup generators to kick on and start running and take over. The flywheel is constructed from a solid steel disk. (The density of the steel is 7600 kg/m^3). If the flywheel is 0.1 meters thick, and is rotated at a constant velocity of, say, 3 rotations per second about its center, what would its radius have to be in order to meet the energy requirements of keeping all the computers running for 10 seconds? (Recall that the moment of inertia of a solid disk is $\frac{1}{2}MR^2$). Assume that the energy stored in the flywheel can be completely converted back to electrical energy with perfect efficiency.

   (In case you are curious, they previously used a bank of several hundred car batteries to do this task for them. That ended up being impractical).