NYU Physics I—Problem Set 4

Due Thursday 2017 October 05 at the beginning of lecture.

Problem 1: A normal, healthy NYU student climbs 10 stories of stairs at a reasonable, steady pace. Compute the potential-energy gain of the student. Compute also the kinetic energy of the student during this climb. You will have to estimate the mass of the student, the pace of stair climbing, and the height of a story of a building. Make reasonable and explicit assumptions. Give a simple explanation for why it is reasonable that one energy far larger than the other?

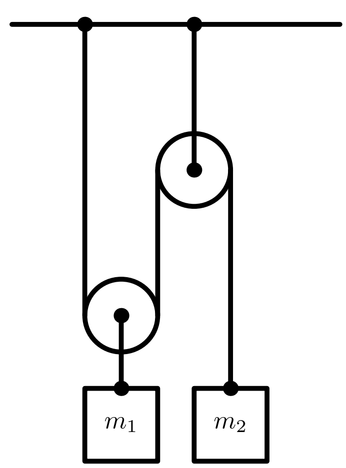
Problem 2: Let's complete the problem that Prof Hogg nearly completed in lecture on 2017-09-21: Consider a car driving around a circular banked turn at constant altitude with the bank set at $15\,\mathrm{deg}$ to the horizontal, and the car traveling at $55\,\mathrm{mi\,h^{-1}}$.

(a) Draw the free-body diagrams and compute the magnitude of the normal force in the case that the car is going around the curve at exactly the speed such that no lateral friction force is required at all, and the car neither loses nor gains altitude (it goes in a perfect, level, circle). That is, draw the free-body diagram for the frictionless, perfect-driving case.

(b) What is the radius of curvature R of the turn in this case?

(c) Now imagine that the car came into this same turn—with the same bank angle and same radius of turn R—but at $70\,\mathrm{mi\,h^{-1}}$. That is, a speeder. And, further, assume that there is plenty of static frictional force for the car to rely on. (Note, it is *static* friction that keeps a car on the road, not sliding friction!). What is the magnitude of the frictional force required to keep the car driving in the level, circular turn? Be very careful with your coordinate system and your diagrams.

Problem 3: Here is a non-trivial machine that delivers a kind of mechanical advantage:



(a) Draw free-body diagrams for all the masses and pulleys in this mechanism. Assume that the strings and pulleys are light and frictionless, so that the strings are perfect tension-transmitters.

(b) What is the kinematic constraint—the relationship between the accelerations of block 1 and block 2? Be very careful with this one. Treat all the strings as inextensible for simplicity.

(c) Find the tensions in all three strings and the accelerations of the two blocks.

(d) Now set the mass m_2 to the value it must have if the system is to be perfectly "balanced"; that is, for there to be no net acceleration of either block. In this situation, if block m_1 is lowered a small distance h, what is the net change in potential energy, accounting for the displacements of both blocks?

Problem 4: Gasoline and olive oil are both substances with great chemical energy content per unit mass.

(a) In the case of gasoline, the chemical energy is mainly in carbon bonds. If you assume that gasoline is *entirely* carbon atoms, and each one releases $4\,\mathrm{eV}$ of energy when it is combusted, how much energy per unit mass is there in gasoline? Get an answer in MJ per kg and compare to what you find on *Wikipedia*. How far off are our assumptions?

(b) Now convert your answer to kcal per g and compare it to what is written on the "Nutrition Facts" label on an olive oil bottle. How close are you? It should be close, (Prof Hogg thinks), because biofuel is made from things like olive oil!

Extra Problem (will not be graded for credit): *(a)* Assume that a car moving at speed $v = 75\,\mathrm{mi\,h^{-1}}$ encounters an air resistance force of $\frac{1}{2}\,\rho\,A\,v^2$, where ρ is the density of air and A is the cross-sectional area of the car, about $2.5\,\mathrm{m}^2$ How much work does it take to move the car $30\,\mathrm{mi}$ at this speed?

(b) If a car with these properties was *perfectly efficient*, how many miles per gallon would it get? You need to use a value for the energy density in gasoline.

(c) What does this make you think about the future of cars that are *far more efficient* than cars we have today? For example, could we have cars that are 100 times more efficient than today's cars?