NYU General Physics 1—Problem set 6

Problem 1: A standard-sized and typically able college-age human walks into a building for an appointment on the 10th story. The elevator is broken. She walks up the 9 stories. Roughly speaking:

(a) How much mechanical energy does she need to expend to climb those 9 stories?

(b) How much time do you think it takes her to climb those stairs? Assume she is at least somewhat motivated to get to her appointment. If you are having trouble estimating this, hire a friend to time themselves climbing stairs. Use that time and the total energy from part *(a)* to get a power, and express the power in horsepower. Are you surprised? Why is horsepower defined as it is?

(c) Now convert the energy you got in part *(a)* to what dieticians call "Calories", which are really SI kcal units. What fraction of a standard human 2000 kcal diet was this stair climbing exercise? Does this make sense given what you know about programs of "exercise"?

(d) How many flights of stairs could our subject climb in a day if all her body did was convert a 2000 kcal input of food into stair-climbing energy? Why is that not at all a realistic description of the body? On what bodily processes is energy spent in forms *other* than mechanical forms?

Problem 2: 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 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, I think, because biofuel is made from things like olive oil!

(c) Now assume that a car moving at speed $v = 75\,\mathrm{mi\,h^{-1}}$ encounters an air resistance force of $\rho\,A\,v^2$, where ρ is the density of air and A is the cross-sectional area of the car, about $2\,\mathrm{m}^2$ How much work does it take to move the car 30 mi at this speed?

(d) If a car with these properties was *perfectly efficient*, how many miles per gallon would it get? What does this make you think about the future of energy-efficient cars?

Problem 3: A (magical) perfect ball of mass $m = 0.7\,\mathrm{kg}$ is dropped from a height $h = 0.9\,\mathrm{m}$ onto a hard surface, off of which it bounces perfectly. It then continues to bounce forever. Make a plot, labeling carefully the time and energy axes, of the kinetic energy of the ball as a function of time, and of the gravitational potential energy of the ball as a function of time. Assume that the bounces (the times in contact with the floor) are extremely short (negligible). Now also plot the sum of the kinetic energy and the potential energy (the total energy) as a function of time. For all three plots, label relevant times and energies. You have to make a choice about the "zero" of potential energy, right?

For extra fun: Make the bounces last a short time Δt and plot also the "elastic" potential energy in the ball!

Sanity check: This problem is impossible because in real life, each bounce will be shorter than the previous bounce. Why? Where does that energy go?