Physics of Human Energy Use
Assignment 10

Due December 6, 2010

1) Consider the energy budgets for different car designs. For fiducial numbers, suppose that a typical sedan weighs 1.5 metric tons and has an effective cross sectional area of 0.75 m^2 (i.e., $C_d A$), while a typical SUV weighs 2.5 tons and has an effective cross sectional area 1.4 m^2 (these actually are fairly representative). Also suppose that half a car's mileage is done on long road-trips at an average speed of 100 km/hr, and half on short trips in which the average speed (while moving) is 50 km/hr, but the car stops once every km.

a) Which contributions scale in proportion to mass and which in proportion to area?

b) What fraction of the total energy can be attributed to each contribution for sedans? For SUVs?

c) What fraction of the total energy might be recouped with regenerative brakes, as in hybrids?

2) Imagine an idealized electrical regenerative braking system on a vehicle. A dual purpose electric motor/generator is connected by mechanical linkages to the drive axle. Inside that motor/generator a magnet rotates inside a coil of wire. For the purposes of calculation, suppose that the magnetic field strength is 1 Tesla and that the coil radius is 3 cm.

a) If the vehicle is moving at 30m/s, its wheels have a diameter of 0.75 m, and there are no gears in the mechanical linkage (so that the magnet rotates at the same rate the wheels do), how many loops of wire must run around the coil in order for the generator to create an electrical potential of 500 V? This number is, by the way, the actual operating voltage in a Toyota Prius.

b) If the mass of the car is 1.5 metric ton, and you wish to stop the vehicle in 10 s, how much current must flow through the circuit?

3) Consider a gravitational regenerative braking system for subway cars.

a) If each subway car weighs 40T and can carry 250 people (packed), does the weight of the people exceed the weight of the empty car?

b) How far must the tunnel drop in order to accelerate the car from a standing start to 50 km/hr?

4) The lift/drag ratio in an airplane is $[A_w/(C_d A_p)]^{1/2}$, where the effective cross section for drag presented by the plane's fuselage and wings is $C_d A_p$ and the area of the wings (viewed from above) is A_w. Both effects involve pushing air aside. How is it, then, that air passing through a cross section as large as A_w can be deflected to make lift, while the effective cross section for drag is so much smaller?