
Problem Set 4Due **in class** Monday 27 April 2009**Homework Problems:**

1. **Cost of Raiding the Fridge** [Student problem]: “When I was little my Dad used to yell at me for opening the refrigerator too many times. He said it costs \$0.25 every time I open it. Is this true...?”
2. **Wind power**
 - a) Give an expression for the power P that can be extracted from wind of speed v in air of density ρ by a wind turbine of rotor radius R .
 - b) The largest commercial wind turbines for electricity generation have rotor diameters of $\sim 100\text{m}$. They are placed in locations where the median wind speed is $\sim 5\text{m s}^{-1}$ (10mph). Estimate the dollar value of the electricity such a turbine produces in a year.
 - c) The reality of weather is that in locations where there are steady winds of $\sim 5\text{m s}^{-1}$, 15% of the time the wind speed is above 10m s^{-1} , and 1% of the time it is above 20m s^{-1} . What fractional amount do these stormy periods add to the total energy production?
 - d) If a line of such turbines were placed all along the eastern seaboard of the USA, what fraction of the total US electricity consumption could they generate?
 - e) Would it make sense to have ranks of turbines, not just a single line? What might limit the number of ranks and the turbine spacing along the wind direction?
3. **Freeway Physics**
 - a) Estimate the number of cars per hour which can travel along a 3-lane freeway. With reasonable assumptions about safety requirements, estimate how this flux depends on the speed at which the cars are travelling. Discuss LA’s freeway problem.
 - b) Estimate the mass of rubber liberated from car tires each year by the cars travelling along the stretch of the 210 freeway passing through Pasadena.
 - c) In units of atoms, how thick on average is the layer of rubber left on the road behind a car. What do you think is the variance, and what causes it?
4. **House lights** A 100 watt light bulb is powered by household current flowing in a pair of parallel copper wires, 1mm in radius, separated by 2mm, and 2m in length. In parts a-c, pretend that the current is 110V DC, as in the original Edison electrical distribution systems.
 - a) How much power is dissipated in the wires?
 - b) At what velocity do the current-carrying electrons drift?
 - c) What is the magnetic field generated by the current 1 meter away from the wires
 - d) How, if at all, are your answers to the previous parts affected by the fact that modern household power is AC, rather than DC?

5. **City Heat Islands** How much warmer is a big city [say 10^7 people in a square 20km on a side] than the surrounding countryside? (Hint: the average American uses 10kWatt) Treat two cases:
- a) The city is trapped under a breeze-less inversion layer, so all heat must be radiated.
 - b) The heat is convected up into the atmosphere and carried away by horizontal winds.
6. **Invent your own** Invent a problem of your own (you don't have to know the answer). The most interesting problems submitted will be done in class, or assigned as homework in subsequent problem sets. Your problem can be like those above, or more general.