Homework #4: More Practice

1. (Fermi Problem) Without looking, estimate the number of hairs on your scalp (not counting eyebrows and facial hair).

I think my hairs are about 1 mm apart, so that would be 1 hair/mm^2 or 100 hairs/cm^2. If my head is a sphere of about 10 cm radius, then the surface area of half the sphere would be about 600 cm^2. This yields about 6×10^4 hairs, or 10^5, to zero sig figs.

2. Estimate the number of electrons in the Earth.

If I take the earth's mass to be about 10^{25} kg, and I know the mass of a proton (or neutron) to be about 10^{-27} kg, then there are about 10^{52} protons and neutrons in the Earth. Since for every proton there are going to be roughly two neutrons, I need to divide by 3 (considering the mass of the electron to be negligible), that gets me down to about 10^{51} electrons in the Earth.

3. In HW Set 2, you calculated how small the volume of a nucleus is compared to the volume of an atom. How small is the volume of the sun compared to the volume of the solar system? (Use 100 AU as the radius of the solar system.) This is not a Fermi Problem – you can look stuff up.

The radius of the sun is 6.955×10^7 m ($\sim 10^8$ m), and the distance to the "edge" of the solar system is about 10^{13} m, so the ratio of these is about 10^5. If you then cube the ratio, you get about 10^{15} suns will fit in the solar system. That means the nucleus is actually 1000 times bigger than the sun, relative to its "space", since we argued you could fit 10^{12} nuclei in an atom.

4. Ford, E2.2. More practice with sig figs.

a) Express 100 km/hr in mph. Well, if I take 1 mile to be 1.609 km, then I get 621.5 mph, which to one sig fig is 600 mph.

b) 100 m in yards. 100 m is 109.36133 yards, but to one sig fig, it's still 100 yards.

c) 880 yards is 804.672 m, which to two sig figs is 8.0×10^2 m (there's no way to avoid scientific notation with this one, because you need a way to indicate that the zero *is* signficant.

d) 10^6 erg is 10^{-1} J, to zero sig figs.

5. Ford, E2.11. More fun with dimensional analysis. We want to end up with a force, which is mass times length over time^2. On the right side we have some dimensionless constants times a length (r) and a speed (v), which is length over time. So to get the dimensions to work out, the viscosity must have dimensions of mass over the product of (length times time). The SI unit for this quantity is called the Poiseuille, or Ns/m^2.

6. Ford, E2.25. If an electron (Rest energy 0.511 MeV) is moving at $v = 3 \times 10^7$ m/s ($0.1c$), then I can use our handy KE formula to get 4×10^{-16} J, or 2 keV. If I have a mass of about 100 kg, I would need a speed of 3×10^{-9} m/s to have 2 keV of energy (there are a lot of electrons in me, so I don't have to move as fast as a single electron). It would take me 10 years to walk a meter at that rate.

7. Ford, E3.8

The point here was just to estimate without measuring and then do a measurement to see how precise you think you can be without some measuring mechanism. Counting or pacing counts as a measuring mechanism.