Physic 325:Astrophysics. HW 5 Due Wed Nov 29.

In general, I expect you to work problems out from first principles—the goal is to develop the skills of applying your basic physics to astrophysical situations, not to apply random formulas. I expect you to be clear and justify any assumptions you make in working out these problems. I expect you to show all steps. If you look up any quantities, you must provide references.

1. If the temperature of the matter at the core of the sun is 15 million Kelvin,
    a. What is the characteristic thermal energy associated with this temperature?
    b. What is the rms speed and kinetic energy of a hydrogen atom there?
    c. What is the rms speed and kinetic energy of a helium atom there?
    d. In order for fusion reactions to happen, two hydrogen nuclei (=protons) must get close enough together for nuclear forces (which are short range—approximately 1fm) to come into play. But the hydrogen nuclei are repelled by electrostatic forces. Given the energy you found for hydrogen above, what is the closest together (in an rms sense) that 2 such hydrogen nuclei come? Hint: Use energy principles. You likely got something reasonably bigger than 1fm, which seems to indicate we would have trouble getting nuclear reactions to happen. (Ch 7 will help supply a solution to this).
2. For the earth's atmosphere
    a. What fraction of the any hydrogen molecules in the atmosphere have a speed in excess of the escape speed? (assume uniform temperature to make life easy)
    b. If the entire atmosphere were hydrogen estimate how long it would take the hydrogen to all escape. As a simplifying assumption, assume that they "leave" as a result of the flux through the spherical surface of the earth's atmosphere with a (perpendicular) velocity equal to the escape speed. You may also assume the gas is always at thermodynamic equilibrium.
    c. Repeat a. and b. for nitrogen.
3. What is the wavelength of e-m radiation emitted if a hydrogen atom goes from the n=6 to n=4 level?
4. What is the wavelength of e-m radiation emitted if singly ionized helium goe from the n-6 to n=4 level?
5. A population inversion in a quantum system is when more of its population is in a higher energy state than in a low energy state. Is it possible to get a population inversion when in thermodynamic equilibrium? You may find it useful to make your argument in reference to Eqn. 6.16 or 6.18 in the textbook.