Astronomy 421 – Problem set 2

Due Thursday, Sep 8

1. At what distance from a 100 W light bulb is the radiant flux equal to the solar irradiance?
2. A 1.2 x 10^4 kg spacecraft is launched from Earth and is to be accelerated radially away from the Sun using a circular solar sail. The initial acceleration of the spacecraft is to be 1g. Assuming a flat sail, determine the radius of the sail if it is:
    a. Black, so it absorbs all the Sun's light;
    b. Shiny, so it reflects all the Sun's light.

   Hint: The spacecraft, like Earth, is orbiting the Sun. Think about if you should include the Sun's gravity in your calculation.
3. The average person has 1.4 m^2 of skin at a temperature of roughly 306 K (92 F). Consider the average person to be an ideal radiator (blackbody) standing in a room at a temperature of 293 K (68 F).
    a. Calculate the energy per second radiated by the average person in watts.
    b. Determine the peak wavelength (λ_max) of the blackbody radiation emitted by an average person. What part of the spectrum is this?
    c. A blackbody also absorbs energy from its environment, in this case from the 293 K room. The equation describing the absorption is the same as the equation describing the emission (Eq. 3.16). Calculate the energy per second absorbed in watts.
    d. Calculate the net energy per second lost by the average person in watts.
4. Barnard's star is an orange star in the constellation Ophiuchus. It has the largest known proper motion (μ = 10.3577 arcsec/yr) and the fourth largest parallax (p = 0.54901 arcsec). In the spectrum of Barnard's star, the Hα absorption line is observed at 656.034 nm when measured from Earth.
    a. Determine the radial velocity of Barnard's star.
    b. Determine the transverse velocity of Barnard's star
    c. Calculate the speed of Barnard's star through space.
5. A one-electron atom is an atom with Z protons in the nucleus and all but one of its electrons stripped away by ionization.
    a. Starting from Coulomb's law, determine expressions for the orbital radii and energies using a Bohr model for the single electron atom with Z protons.
6. Find the radius of the ground-state orbit, the ground state energy. And the ionization energy of singly ionized helium (He II). Hint: results from problem 5 could be helpful.
7. Find the shortest vacuum-wavelength photon emitted by a downward electron transition for each of the Lyman, Balmer and Paschen series for a hydrogen atom in nm. These wavelengths are known as the *series limits*. Indicate the region of the electromagnetic spectrum for each.
8. An electron in a cathode ray tube (old style television) reaches a speed of about 5 x 10^7 m/s before it hits the screen. What is the wavelength of this electron?
9. An electron spends roughly 10^-8 s in the first excited state of the hydrogen atom before making a transition to the ground state.
    a. Use Heisenberg's uncertainty principle (Eq. 5.20) to determine the uncertainty in energy ΔE in the energy of the first excited state.
    b. Calculate the corresponding uncertainty in the wavelength ($\Delta\lambda$) involved in a transition to/from this first excited state from the ground state. This is called the "natural broadening" of the transition line. Is it safe to assume that ΔE = 0 for the ground state? Why?
10. The JWST has a 6.5 m primary mirror and wavelength coverage ranging from 0.6 to 28.5 micrometers. Calculate its corresponding range in angular resolution.