Course 12.425. Problem Set 4. Due 1 Nov. 2007.

1. **Planet Albedos and Related Questions**

   a. Which body in our solar system has the highest albedo?

   b. One analogy for the brightness ratio of an Earth-twin is: looking for a firefly 6 feet away from a searchlight that is 2,600 miles distant. Come up with a similar analogy for a planet with $R_p = 2R_\oplus$ that is twice as close to a star that has a temperature two thirds that of the sun.

   c. If the Moon's albedo were 0.9 instead of 0.1, how would this affect the Earth?

2. **Black Body Radiation**.

   In class we discussed: black body radiation $B(\nu, T)$,

$$B(\nu, T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT} - 1}; \tag{1}$$

   planet flux F; and the Stefan-Boltzmann law,

$$F = \pi \int_0^\infty B(\nu, T) d\nu \equiv \sigma_R T_{\rm eff}^4. \tag{2}$$

   Derive the radiation constant

$$\sigma_R = \frac{2\pi^5}{15}\frac{h}{c^2}\left(\frac{k}{h}\right)^4, \tag{3}$$

   and give its value and units. Here h is Planck's constant, c is the speed of light, and k is Boltzmann's constant.

3. **Planet Temperature and Energy**

   For this problem we will assume stars and planets can be approximated by black bodies. We will use the equilibrium temperature derived in class

$$T_{\rm eq} = T_{\rm eff,*}\left(\frac{R_*}{a}\right)^{1/2}\left[(1 - A_{\rm B})\right]^{1/4}. \tag{4}$$

   Here a is the semi-major axis, and f' and $A_{\rm B}$ is the Bond albedo.

   a) Compute $T_{\rm eq}$ for a hot Jupiter orbiting a sun-like star. The hot Jupiter has $a = 0.04$ AU, $A_{\rm B} = 0.01$.

   b) Compare the energy Earth receives from the sun (using $T_{\rm eq}$ and the Stefan-Boltzmann law) to the energy emitted from Earth's interior, 55 terra Watts.