Physics 321 Quiz #1 solutions Fall 2008

1: If the frequency ν_{max} at which radiance has a maximum is doubled, by what factor the total emitted power will change ?

$\nu_{max}/T = const$ => $\nu/T = \nu'/T'$ => $T'/T = \nu'/\nu = 2$

$R'_T/R_T'' = (\sigma T'^4)/(\sigma T^4) = (T'/T)^4 = (2)^4 = 16$

2. The average energy reaching Earth from the sun at the top of the atmosphere is 338 W/m^2, called the *solar constant*. Assuming that Earth radiates like a blackbody at uniform temperature, what do you conclude is the equilibrium temperature of the Earth ?

At equilibrium the power absorbed has to be equal to power emitted:

$$R_{TE} = R_{TA} = \sigma T^4 \Rightarrow T = \sqrt[4]{R_{TA}/\sigma} = \sqrt[4]{\frac{338 W/m^2}{5.6710^{-8} W/m^2/K^4}} = 277.86\ K$$

3. Use the Stefan-Boltzmann law to calculate the energy density (not radiance!) of the cosmic microwave background radiation (T = 2.74 K). Hint: $R_T = c/4\ \rho_T$

$\rho_T = 4R_T/c = 4\sigma T^4/c = 4 * 5.6710^{-8} W/m^2/K^4 (2.74K)^4/(3x10^8\ m/s) = 4.21x10^{-14}\ J/m^3$