Assignment 12

1. Black Body Curve
   a) Using a software package such as Excel, plot the energy density of black body radiation enclosed in a volume V for a gas of photons at temperatures a) 4000 K and b) 6000 K.
   b) What are the frequencies at which the energy density is maximum in the two cases?
   c) What are the corresponding wavelengths to the answers in b?
   d) What are the total energy densities i.e. summed over all frequencies in the two cases?

2. The surface of the sun is at a temperature of about 5800 K.
   a) Estimate the energy per second radiated by the sun.
   b) Estimate the amount of the sun's energy per second striking the Earth.
   c) Estimate the Earth's temperature by equating the energy per second of solar light striking the Earth to the energy per second the Earth radiates into space.
   d) Explain why the actual temperature of the Earth is different from that estimated in c.

3. Residual Radiation of Big Bang
   a) Derive the energy density of black body radiation as a function of wavelength.

$$\frac{dU}{d\lambda} = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{\beta hc/\lambda} - 1}$$

   b) Using a software package such as Excel, plot it for a temperature of 2.74 K.
   c) What is the wavelength at which the radiation is a maximum?

4. Efficiency of a Solar Cell
   a) Calculate the maximum photon wavelength λ_{max} that can be absorbed a material having a work function of 1 eV.
   b) What fraction of the solar spectrum consists of light having a wavelength less than λ_{max}? Assume the solar spectrum corresponds to a black body at a temperature of 5800 K.
   c) Most materials only generate a single photoelectron when they absorb an incoming photon. i.e. If the incoming photon has an energy of 2 eV, it only generates a single photoelectron with an energy of 1 eV, not 2 such photoelectrons. Calculate the average wavelength of the solar radiation satisfying $\lambda < \lambda_{max}$. Use this result and that of part b to estimate the maximum efficiency of an ideal solar cell.
   d) Present day solar cells have a maximum efficiency of about 15%. Cloudy days reduce the radiation that can be absorbed by a further factor of about 2. A school wishes to install solar panels having an area of 1000 m^2. Estimate how many kilowatt hours of electricity this will generate in 1 year.
   e) How much money will the school earn each year?