Physics 225b Homework 3 (Show your work!) Due Feb. 17, 2003

1) At the website http://www.siliconsolar.com, there is a solar panel, Model number OP-1215200, that outputs 3.75 W of electrical power when it is placed normal to direct sunlight. It is 12.2 inches by 6 inches in size.

a) If you assume this solar cell is 100 percent efficient at converting the radiation incident on its surface into electrical power, what is your estimate for the total power output of the sun? (Assume the earth has no atmosphere for your calculation.)

b) Check your result: Assume the sun is a blackbody and it has a maximum in the distribution of energy density per unit wavelength:

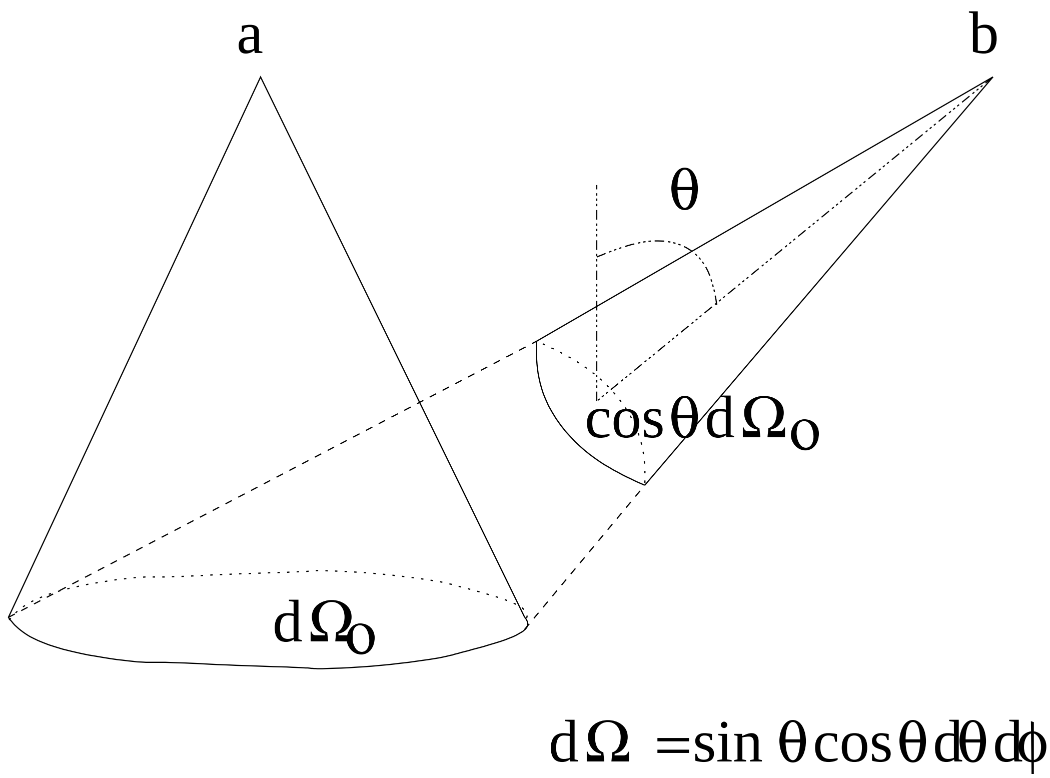
$$u(\lambda) \propto \frac{1}{\lambda^5} \frac{1}{e^{hc/\lambda k_B T} - 1}$$

corresponding to a wavelength of 500 nm. Please derive the relationship between the peak (max) wavelength and the temperature of a blackbody using this relationship. You will get something that is VERY hard to solve. An easy way to estimate (very well) a solution in to plot both sides of the equation on the same plot. Here is what I mean. Suppose the solution to a problem you are working on is x-cos(x)=0. You can find the solution to this problem by plotting y=x and y=cos(x) on the same plot. Where they cross is likely your result. (for x=cos(x), x= 0.739 or so). Sometimes you may get more than one result, and you have to choose the one that makes sense. After you find your solution, you can integrate equation 10.30 in your book (Krane) and determine the energy density. If you multiply this by c/4 you will get the intensity of the radiation at the surface of the sun. Now you can find the total power radiated by the sun to check your answer in a). (note: crack open a book and check out Wien's displacement Law and the Stefan–Boltzmann formula, you just derived them...)

c) Really good solar cells are 20 percent efficient. How about the cell in part a)?

In your book there is a mysterious c/4 factor you need to multiply by that we used in part b). You can derive this. If the intensity coming from a single part of the surface of an object is distributed isotropically about the 4π of a sphere, the bit going through a small solid angle $d\Omega$ is $\frac{U}{V}c\frac{d\Omega_o}{4\pi}$ (This is the piece from point a below). Now if you consider another part of the surface, say at point b of the figure below, the solid angle subtended is smaller as we've drawn it. If you integrate over all possible angles considering a location very near the surface, you get:

$$Intensity = \frac{U}{V}\frac{c}{4\pi}\int_0^{\pi/2}\cos\theta\sin\theta d\theta\int_0^{2\pi}d\phi = \frac{U}{V}\frac{c}{4\pi}2\pi\frac{1}{2}\sin^2\theta|_0^{\pi/2} = \frac{U}{V}\frac{c}{4}$$



2) Estimate the fermi energy for electrons in gold at room temperature, treating the electrons as a fermi gas with 1 electron for each gold atom. Use your result to determine the mean free path of the electrons in the gold. (See section 27-4 of Fishbane for a conduction refresher. You can also crack open most any intro text to get this info.)

3) As we did for our solid, consider a simpler system of N particles that can occupy 2 energy levels, 0 and ϵ. Use the Boltzmann distribution as we did in class to determine the average energy. Show what the average energy is at the 2 extremes of temperature (T very small and T very large). Find the heat capacity too.