Homework assignment 3

Due September 22, either at the start of class or in my physics department mailbox at noon.

1. The Planck law for the spectrum of a blackbody has two limits. One is for the case where f is a very small number, and it reduces to the classical case, which is called the Rayleigh-Jeans spectrum. The other is for the case where f is a large number, and it reduces to a power law times an exponential, and it is called a Wien spectrum. (a) Show how to derive these two limits – in the first case by taking a Taylor expansion and cancelling, and in the second by stating that if a number is an exponential term minus one, and that the exponential term is much larger than one, it is a good approximation to throw out the one.

2. Do book problem 3.14

3. Do book problem 3.17

4. Do book problem 3.29

5. This is the difficult problem for the week.

   In the standard discussion of Compton scattering, we consider the case of an energetic photon interacting with an electron which is at rest. When we do this, we get the result that the photon should have less energy and the electron should have more energy after the interaction than before.

   In some other cases in physics, notably in astrophysics, but also in some other circumstances, we deal with a different situation. We may have low energy photons interacting with more energetic electrons.

   (a) First, give a brief qualitative discussion what should happen in the following case: photons from a blackbody with temperature T_1 pass through a cloud of ionized gas with temperature T_2. T_2 is much larger than T_1. The primary means of interaction between the photons and electrons is Compton scattering. Explain why the photons should be *more* energetic after passing through the gas cloud, in terms of basic thermodynamics.

   (b) You may have been concerned that there is a contradiction between the results of part (a) and the equations you saw for Compton scattering above. The key to reconciling the two results is to remember that the result that the photon transfers energy to the electron is obtained *in the electron rest frame.* Doing a full calculation of what happens is more algebra than I want you all to be doing for this course. Instead, what we can do is the calculation of what happens just in one case, where, *in the electron rest frame*, the electron is scattered directly forward, and the photon is scattered directly backward. Assume that initially, the electron is moving toward the photon with a Lorentz factor of γ. Assume also that the photon has an initial energy of E_0. Calculate the final energy of the photon and of the electron after the Compton scattering takes place.