Midterm Quiz: Modern Physics 301
November 1, 2001

1. Value: 12 Points. An electron is travelling at a speed of $0.99c$ in the reference frame of the laboratory. We shall call the lab reference frame S and the electron reference frame S'.

   (a) The electron travels 1 m in S. How much time has passed in the laboratory? How much time has passed for the electron i.e for a clock in S' that is fixed at the position of the electron? (2)

   (b) According to an observer in S', how fast is the laboratory moving? Why does this not conflict with the different times that you determined in part (a)? (2)

   (c) What is the total relativistic energy of the electron in MeV? The rest mass of the electron is 0.511 MeV/c^2. What is the relativistic momentum of the electron? (2)

   (d) In S an anti-electron or *positron* approaches the initial electron with the same speed but in the opposite direction. According to an observer in S' what is the speed of the approaching positron? (2)

   (e) The electron and positron collide and produce two high energy photons that have equal energy in S. You know that photons have no rest mass and that electrons and positrons have the same rest mass. Give the energy and magnitude of the momentum of each photon using the units we established earlier. (2)

   (f) Why were the energies of the photons equal in the previous question? Why can't there be just one photon produced in this electron-positron collision? (2)

2. Value: 8 points. Consider a blackbody at 6000 K. You may find $hc = 1240$ eV-nm and $k = 8.62 \times 10^{-5}$ eV/K useful.

   (a) What is the energy of a photon with $\lambda = 590$ nm? What is the ratio of this energy to kT? (3)

   (b) Using Planck's formula for the energy density of a blackbody $u(\lambda)$ and your previous answer to calculate the *approximate* energy density between 580 nm and 600 nm. Give your answer in mJ/m^3. (5)

3. Value: 10 points. The probability distribution of the position of particle $f(x)$ is shaped like an isosceles triangle (think Bell curve but more "triangle"-like. Its highest point is at $x = 0$ and its lower corners, where the distribution approaches zero, are at $x = \pm W$.

   (a) What is $f(x = 0)$ such that $f(x)$ is normalized to 1? (2)

   (b) What is the probability that $x > W/2$ (i.e. that the particle is found with $x > W/2$)? (3)

   (c) Calculate $(< x^2 >)^{1/2}$. Hint: the integral is symmetric about $x = 0$. (5)