Midterm Quiz: Modern Physics 201
March 9, 2007

Textbook and 2-sided formula sheet. Total 40 + 2 bonus points. Individual values follow each question. Do questions 1 and 2ab and **two of** 2c, 3, and 4. Usual conventions for frames S and S' apply.

1. Suppose that a particle with a mass of 2 MeV/c^2 is moving in the lab frame S with $u_x = 0.900\,c$, $u_y = 0.304\,c$, and $u_z = 0$. The mass of this particle in SI units is 3.56×10^{-30} kg. If you are using "MeV" units I won't be concerned with the "c" factors except in the answers.

   (a) Calculate u the speed of the electron as measured in the lab. Please give your answer in "c" units. (2)

   (b) Calculate E, p_x, and p_y from their definitions in terms of the particle velocity. (4)

   (c) Demonstrate numerically that $E^2 - p^2c^2 = m^2c^4$. (4)

   (d) Assuming that we should take the relativistic expressions for the momentum as correct what is the deBroglie wavelength of this particle? (3)

   (e) Now consider a frame S' with $v = 0.9\,c$ along the x-axis (the standard convention). Using the 4-vector formulation find E', p'_x, and p'_y. (First find the elements of the 4 by 4 Lorentz transform matrix and then it is simple arithmetic.) Note: in this question I have choosen $v = u_x$. This doesn't change the nature of the question but it does mean one of the answers will have a simple form. (6)

   (f) Briefly explain why $E'^2 - p'^2c^2 = E^2 - p^2c^2$. Don't need to derive this; it is a simple answer. (2)

2. A farmer has barn that is 8 m long and wants to enclose a pole that is 14 m long when measured at rest.

   (a) According to the farmer (at rest with respect to the barn) how fast must the pole be moving to be Lorentz contracted to fit into the barn. An answer in m/s or c units is fine. (3)

   (b) The farmer arranges for the doors to be shut at $t = 0$ when the back end of the pole enters the barn. Using Lorentz transforms calculate the x' and t' coordinates of the shutting doors. Usual conventions apply. (4)

   (c) An observer in the frame of the rod disagrees that the rod will fit in the barn as the farmer suggests. Use a couple of diagrams and information from the previous parts of the question to explain what happens. What is the key phenomenon that gets you out of the paradox? (6)

3. What is Compton scattering? Explain with a diagram. Which of the scattered particles is observed? Calculate the final wavelength if the initial wavelength is 0.050 Åand the scattering angle is 30 degrees. (6)

4. Use a sketch to describe the spectral energy density (either $\rho(\lambda)$ or $I(\lambda)$) of a blackbody radiator as a function of temperature and wavelength. What is a blackbody? Why is it said that the proper description of blackbody radiation ushered in quantum theory? (6)

5. Bonus: It takes me roughly 4000 seconds to drive home and I maintain of speed of 30 m/s. Using a binomial expansion estimate how much less time in picoseconds has elapsed on my clock relative to a clock at rest. (2)