**Midterm Quiz: Modern Physics 201**
**February 15, 2011**

Formula sheet provided. Total 32 points. Individual values follow each question. Usual conventions for frames $S$ and $S'$ apply.

1. A particle is moving at $u_x = 0.9c$ in the lab frame. It has a rest mass of 0.8 MeV/$c^2$.
   (a) Calculate its energy and momentum and give your answers in MeV-style units. (2)
   (b) Another particle is coming from the right with $E = 2$ MeV and $p_x = -2$ MeV/$c$. What is its rest mass? What is its velocity? (2)
   (c) Calculate the rest mass of the two particles together as a system. (2)
   (d) An observer in another frame moving at $v = 0.7c$ relative to the first observes the same system. Knowing what you know about 4-vectors and 4-scalars what *must* they calculate for the rest mass of the system? Give an example of a 4-vector by stating its components. (2)

2. What is *relativity*? What types of frames are involved when we talk about "special" relativity? In *this* context explain why the Michelson-Morley experiment had a null result (i.e. no ether was detected). (3)

3. What is the principle of equivalence in the context of general relativity? Give an example of real world system where the effects of general relativity need to be included. (2)

4. A clock is at rest in reference frame $S'$. Consider that the frame $S'$ is moving at $v = 0.7c$ relative to the $S$ frame and the clock was at the origin at $t = t' = 0$. All of the usual conventions are in effect.
   (a) Draw a space-time diagram that includes the light cone, roughly correct scaling for the $x'$ and $ct'$ axes, and the worldline of the clock (Give yourself some space since you need to put other things on later in the question, maybe 3 units for the positive vertical and horizontal axes.) (2).
   (b) Imagine that 3.33 ns have elapsed on the clock at rest in $S'$ and this clock emits a light flash. Is the 3.33 ns a proper time? Why or why not? (2)
   (c) According to observers in the $S$ frame how much time has passed when $t' = 3.33$ ns. Where is the clock at this time? Show these results on the space-time diagram. (3)
   (d) Using the results in the previous questions calculate the space-time interval $(\Delta s)^2$ in both frames using the coincidence of the origins and the emission of the signal as the two events. Is this a space-like or time-like interval? (2)
   (e) Draw the worldline of the light flash as it heads toward the origin of $S$. At what time $t$ does it arrive? (Hint: between 5 and 10 ns.) Show that this time [equal to a period $T = (\nu_{\text{redshift}})^{-1}$] agrees with the prediction of the relativistic Doppler effect with $\nu_o = 300$ MHz (either symbolical or numerical proof). (3)

5. Make a sketch of the blackbody spectrum for 3 different temperatures. What law describes the area under the spectrum as a function of temperature. At what wavelengths is the "density of modes" highest? Convert $\lambda = 450$ nm into wavevector. (5)

6. In the context of the discovery of the electron as a fundamental constituent of matter what kind of experiments did Faraday do? (2)