Midterm Quiz: Modern Physics 201
March 15, 2013

Formula sheet provided. Total 40 points. Individual values follow each question. Usual conventions for frames S and S' apply.

1. A train 100 m long is at rest in frame S' and lies along the x-axis. Relative to the S frame it is moving at $0.75c$ in the positive x-direction. The back of the train crosses the origin at $t = t' = 0$. Following our usual convention this is also when the origins of the frames coincide.

   (a) How long is the train as measured in S'? How long is the train as measured in S? What is this phenomenon called? Which length is the proper length? (3)

   (b) Draw a space-time diagram that includes the light cone, roughly correct scaling for the x' and ct' axes, and worldlines for the ends of the train. Give yourself some space since you need to put other things on later in the question. I suggest an x scale of -150 to 200 m and a ct scale of -150 to 150 m. (5)

   (c) Highlight how your answers in 1a can be found on the space-time diagram. (Hint: imagine that in S you measure the length of the train by locating the front and back of the train at $ct = 0$ using the worldlines.) (3)

   (d) Using the Lorentz transforms calculate x' and ct' if x and ct correspond to the event of measuring the position of the front end the train. You can use your answer from part 1a. Also calculate t' in microseconds ($c = 300$ m/μs). (3)

   (e) Compare/comment on the values of t' when the ends of the train are "located" in S in light of the relativity of simultaniety. Show how this agrees with the space-time diagram. (2)

2. (a) A proton has a rest mass of 938 MeV/c^2 and a relativistic energy of $E = 1400$ MeV. It is moving in the x-direction. Calculate p_x and u_x. You may use any method you want and any appropriate units. (4)

   (b) Now consider a frame S' with $\beta = -0.5$. If an object has $u_x = 0.74\,c$ calculate u'_x. If something has $u_x = c$ calculate u'_x. (4)

   (c) Give the energy and momentum of the proton in S'. Either use Lorentz transforms of E/c and p_x with the proper γ and β (but sloppy c) or use the relativistic formulas with u'_x. (You don't need to show this but if you want to check your answers remember that rest mass is invariant). (4)

3. (a) What feature distinguishes the twins in the twin paradox? (3)

   (b) Give the position 4-vector. (2)

   (c) Did Einstein invent relativity? Explain. (3)

   (d) A group of students in the Andromeda galaxy (200 000 light years away) just finished writing the same midterm that you did. Explain why they might have been able to send you the answers. Explain why they actually can't. (No need for equations. And no, it isn't because they don't know the answers!) (4)