Physics 200 Problem Set 3

Due at the end of class, Wed Sept 29th

1. Length contraction. In this question you will re-derive the length contraction result using Lorentz transformations. Let frame B move w.r.t. frame A with speed v along the positive x direction, and assume that the origins of the two frames line up at $t_A = t_B = 0$. A rod of length L is stationary w.r.t. frame B, with its left end at $x_B = 0$ and its right end at $x_B = L$.

(a) In frame A, where is the left end at $t_A = 0$?

(b) In frame A, where is the right end at $t_A = 0$?

(c) What is the length of the rod as measured in frame A?

(d) Does a moving object appear shorter or longer than its (proper) length?

2. Magical rulers. We will re-examine question 3 from Tutorial 2. Two parallel rulers, one (ruler A) stationary and one (ruler B) moving with velocity $v = \sqrt{3}c/2$ in the positive x direction, appear to be the same length, L. (See picture in the Tutorial sheet.) Define two events:

I - the left ends of the rulers line up
II - the right ends of the rulers line up

(a) In the frame in which ruler A is stationary, let event I be at $(t, x) = (0, 0)$. What are the space-time coordinates of event II in this frame?

(b) Use Lorentz transformations to figure out the space-time coordinates of the two events I and II in the frame in which ruler B is stationary.

(c) How long does it take, in the frame in which ruler B is stationary, between event I and event II?

Now that you have solved the problem, you might want to compare with solutions to the Tutorial.

3. A spaceship traveling with speed $v = c/2$ leaves the Earth for a star ten light years away. You can assume that the star is stationary w.r.t. the Earth. When the ship is half way to its destination, in the Earth's frame of reference, the star goes supernova (blows up).

(a) In the ship's frame of reference: how far from the Earth is the ship when the supernova occurs?

(b) How much time passes in the spaceships frame of reference between when the ship leaves the Earth and when the light from the supernova explosion is seen on the ship?

Challenge (not for credit, bragging rights only). Re-do the question with $v = (\sqrt{3}/2)c$.

4. A Rebel Alliance starship is cruising at $v = (3/5)c$ at an altitude of 10km above flat ground. The ship's laser gun is jammed so that it points exactly downwards, perpendicular (in the ship's frame) to the direction of motion of the ship. Jar Jar Binks is standing on the ground. When a ship is directly over Jar Jar, the pilot fires the gun. The laser hits a nearby tree.

(a) How far away is was the tree from Jar Jar?

(b) In the ground frame of reference, what are the horizontal and vertical components of the velocity of the laser pulse?