Physics 171.201
Midterm Exam 1

October 12th, 2005

Answer all **three** problems. Be sure that you pace yourself so that you have enough time to work on each problem. Note that the problems do not have equal weight. Partial credit will be given, so be sure to **show your work** as clearly as possible**.** Good luck!

List of potentially useful formulae

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$$

$$y' = y$$

$$z' = z$$

$$t' = \frac{t - (v/c^2)x}{\sqrt{1 - v^2/c^2}}$$

$$u_x' = \frac{u_x - v}{1 - u_x v/c^2}$$

$$u_y' = \frac{u_y \sqrt{1 - v^2/c^2}}{1 - u_x v/c^2}$$

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

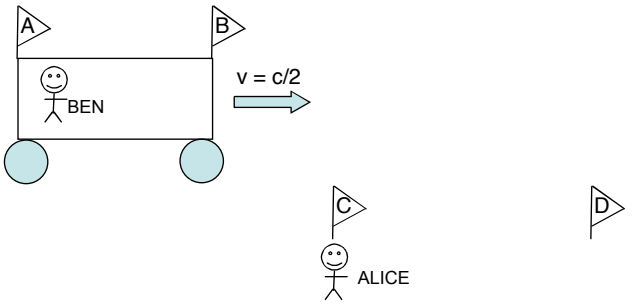
$$E = mc^2$$

$$\vec{p} = m\vec{v}$$

$$E^2 = m_0{}^2c^4 + p^2c^2$$

$$E^2 - p^2c^2 = E'^2 - p'^2c^2$$

Problem 1 (40 points)



Ben is standing at the rear end of a railroad car below a flag marked A. The front end of the car has a flag marked B. Ben measures the length of the car to be L'. Alice, standing on the station platform holding flag marked C, observes the car passing by her with a velocity of $\frac{1}{2}c$ in the positive-x direction. Farther down the platform is another flag marked D. As the car travels through the station, Ben measures that A passes C at the same instant that B passes D.

(a) Does Alice also measure that A passes C at the same instant that B passes D? If not, which does she measure to happen first?

(b) What does Alice measure to be the distance from C to D?

After Ben passes flag D he begins to throw baseballs back toward Alice. According to Ben the baseballs have a velocity of $\frac{3}{4}c$ in the negative-x direction, and he throws them at a rate of one per second.

(c) What velocity does Alice measure for the baseballs? Be sure to specify both the magnitude and direction.

(d) At what rate does Alice receive the baseballs?

Problem 2 (20 points)

Ben is flying in a rocket ship past Alice at a velocity of $\frac{1}{2}c$ in the positive-x direction. The two synchronize their coordinate systems so that the origins of space and time coincide. At t=0, two stars at rest in Alice's reference frame explode emitting huge pulses of light. One is of the stars at point F = $+6 \times 10^8$ meters in the (positive) x-direction from the origin in Alice's frame and the other is at point G = -3×10^8 meters in the (negative) x-direction. Recall that the speed of light c = 3×10^8 m/s.

(a) Carefully draw a Minkowski diagram for this situation from Alice's perspective to determine whether the light pulse from F or from G reaches Ben first.

(b) Using the Lorentz invariant property of the "4-length" s^2 discussed in class, construct a calibration curve on the diagram to determine the time that Ben measures when the pulse from F reaches him.

Problem 3 (40 points)

In the laboratory, an electron traveling in the x-direction with velocity $\frac{3}{5}c$ collides with a positron (anti-electron) traveling in the y-direction (i.e. perpendicular to the electron) also with velocity $\frac{3}{5}c$. Write the rest mass of the electron and positron as M_0.

(a) What is the total energy and total momentum of the pair in the lab frame?

(b) Imagine the electron and positron annihilate to form an exotic new particle X: $e^+ + e^- \rightarrow X$. What is the rest mass of X? [Hint: work in the center-of-mass frame and use invariants; otherwise, the math will get ugly!]

(c) What is particle X's kinetic energy in the lab frame?

(d) Imagine that X decays into a pair of photons: $X \rightarrow \gamma + \gamma$. Is it possible for the two photons to travel away in the same directions as the initial electron and positron? That is, can one photon have its velocity fully in the x-direction and the other fully in the y-direction? If so, what would be the energy of each photon?