Phys 242 Exam 1

This is a closed book, closed note exam. Calculators are permitted. An equation sheet is provided on the last page. If you have difficulty with one problem, move on to the next one and come back to the one you are having trouble with later. For full credit please show all work. Good luck!

Problem 1. (Short answer)

a. Briefly explain the barn and pole paradox and its resolution.

b. Consider Newton's second law. Write down the relativistically correct form of this equation in frame K' moving with velocity V with respect to frame K.

c. Is it possible to accelerate a proton to the speed of light? Explain.

c. Apply the binomial expansion to the relativistic expression for kinetic energy and show it reduces to the non-relativistic expectation.

e. Show explicitly that the spacetime interval $s^2 = x^2 + y^2 + z^2 - (ct)^2$ is invariant.

Problem 2.

a. Use the Lorentz transformations to show the length contraction relation.

b. Consider two clocks at different positions that read the same time in frame K. Use the Lorentz transformation to find the time difference between the clocks as measured in K'.

c. A meter stick moves with velocity $v = 0.8c$ relative to you. How long does it take the meter stick to pass you?

Problem 3.

Consider the reaction $\gamma p \rightarrow \pi^0 p$. The π^0 has a rest mass of 135 MeV/c^2 and the proton has a rest mass of 938 MeV/c^2.

a) What energy must the photon have in the laboratory frame to produce this reaction? In the laboratory frame the photon is the beam and the proton target is at rest.

b) Explain why the photon energy is not just simply the rest mass of the π^0 in this frame.

Problem 4.

Phys 242 students are traveling on Rocket A moving towards earth with $v = 0.6c$. A Phys 242 professor is traveling on Rocket B moving towards Rocket A with $v = 0.3c$ away from the earth. Both velocities are with respect to the earth.

a. What is the velocity of Rocket B as measured by Rocket A?

b. If the time interval on Rocket B shows 50 minutes have passed, how much time has passed as measured by the students on Rocket A?

c. If the time interval on Rocket B shows 50 minutes have passed, how much time as passed as measured by someone on earth?

Equations and Constants

Lorentz transformation
$x' = \gamma(x - Vt)$
$y' = y$
$z' = z$
$t' = \gamma(t - Vx/c^2)$

Addition of velocity
$u'_x = \frac{u_x - V}{1 - Vu_x/c^2}$

Doppler effect
$f = \frac{\sqrt{1+\beta}}{\sqrt{1-\beta}} f_0$

Energy and momentum relations
$p = \gamma mu$
$E = \gamma mc^2 = T + mc^2$
$T = \gamma mc^2 - mc^2$

Four vectors
spacetime (ct, x, y, z)
energy-momentum $(E/c, p_x, p_y, p_z)$

speed of light
$c = 3 \times 10^8 m/s$