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DEPARTMENT OF PHYSICS
PHYSICS H7C
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Second Midterm Examination April 11, 2008

This examination is open book, notes or any other material you wish to use. Work all problems. They are of equal weight. Laptop computers are not allowed.

1 20
2 20
3 12

Total 52

1. Given two events with a four-vector interval between them [4,5,0,0].

Is the interval time like? If so, find the speed of the frame in which the two events occur at the same place and the time between them.

Is the interval space like? If so, find the speed of the frame in which the two events occur at the same time and the distance between them.

$s^2 = (ct)^2 - x^2 - y^2 - z^2$

$= 16 - 25 = -9 < 0 \Rightarrow$ spacelike

$\underset{\sim}{x}_A = \begin{pmatrix} c \\ 0 \\ 0 \\ 0 \end{pmatrix} = \underset{\sim}{x}'_A$

$\underset{\sim}{x}_B = \begin{pmatrix} 4 \\ 5 \\ 0 \\ 0 \end{pmatrix}$

$\underset{\sim}{x}'_B = \begin{pmatrix} \gamma(4 - 5\beta) \\ \gamma(5 - \beta 4) \\ 0 \\ 0 \end{pmatrix}$

$t_B = t_A$

$\gamma(4 - 5\beta) = 0$

$5\beta = 4$

$\beta = \frac{4}{5}$

$\boxed{v = \frac{4}{5}c}$

$\gamma = \frac{1}{\sqrt{1 - (\frac{4}{5})^2}} = \frac{5}{3}$

$x_B = \gamma(5 - \beta \cdot 4)$

$= \frac{5}{3}(5 - \frac{4}{5} \cdot 4)$

$= \boxed{3}$

$s^2 = -9 = \gamma^2(4c - 5\beta)^2 - \gamma^2(5 - \beta c \cdot 4)^2$

$\frac{-9}{\gamma^2} = 16c^2 + 25\beta^2 - 40\beta c - 25 - 16\beta^2 c^2 + 40\beta c$

$-(1 - \beta^2)9 = \beta^2(25 - 16c^2) + 16c^2$

$-9 + 16c^2 = \beta^2(16 - 16c^2)$

$\beta^2 = \frac{9 + 16c^2}{16(c^2 - 1)}$

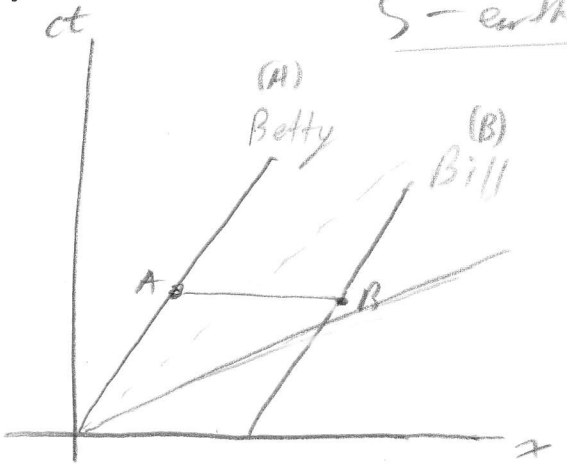
$v = \frac{c}{4}\sqrt{\frac{9 + 16c^2}{c^2 - 1}} =$

2. A rocket ship traveling in the plus x direction relative to the earth observers with a speed of βc. Bill is standing at the rear of the ship and Betty is standing at the font a distance ℓ_0 from Bill. On the earth, we observe Bill and Betty smile at each other at the same time.

   a. In the frame of the rocket who smiled first?
   b. By how much?

S – earth frame

S' – rocket frame



$x_A' = 0$ $\quad x_B' = \ell_0$ $\quad x_A = 0$ $\quad x_B = \gamma(\ell_0 - \beta c t_B')$

$t_A' = 0$ $\quad t_B' = ?$ $\quad t_A = 0$ $\quad t_B = 0 = \gamma(c t_B' - \beta \ell_0)$

$c t_B' = \beta \ell_0$

$t_B' = \frac{\beta \ell_0}{c}$

Since $t_B' > 0$

A happened first.

∴ Betty smiled first

3. A simple production reaction for antiprotons is using a gamma ray incident on a proton target at rest. That is: $\gamma + p \rightarrow p + p + \bar{p}$. Find the minimum energy of the gamma ray for the reaction to occur. Leave your answer in terms of m the mass of the proton.

Hints: Remember for a gamma ray E=pc and for threshold there is some frame in which the three final particles at rest relative to each other.

$$\underset{\sim}{p}_\gamma + \underset{\sim}{p}_i = \underset{\sim}{p}_f + \underset{\sim}{p}_f + \underset{\sim}{\bar{p}}$$

Choose frame where final particles at rest

$$\underset{\sim}{p}_i = \begin{pmatrix} E/c \\ \vec{p} \end{pmatrix}$$

$$\underset{\sim}{p}_f = \begin{pmatrix} m_p c \\ \vec{0} \end{pmatrix}$$

$$\underset{\sim}{p}_\gamma = \begin{pmatrix} E_\gamma/c \\ E_\gamma/c \\ 0 \\ 0 \end{pmatrix}$$

$$\underset{\sim}{\bar{p}} = \begin{pmatrix} m_p c \\ \vec{0} \end{pmatrix}$$

$$\left(\underset{\sim}{p}_i = 2\underset{\sim}{p}_f + \underset{\sim}{\bar{p}} - \underset{\sim}{p}_\gamma\right)^2$$

$$(m_p c)^2 = 4(m_p c)^2 + (m_p c)^2 + 0$$

$$-4\underset{\sim}{p}_\gamma \cdot \underset{\sim}{p}_f - 2\underset{\sim}{p}_\gamma \cdot \underset{\sim}{\bar{p}} - 4\underset{\sim}{p}_f \cdot \underset{\sim}{\bar{p}}$$

$$4(m_p c)^2 - 4(E_\gamma m_p) - 2(E_\gamma m_p) - 4(m_p c)^2 = 0$$

$$-6 E_\gamma m_p = 0$$

$$E_\gamma = 0\ ?$$

(-8)