Physics 325 Quiz 1 Feb. 16, 2004

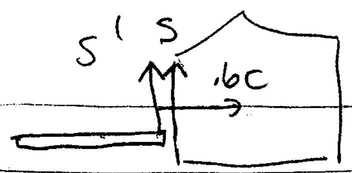
Open book and notes, calculator allowed. Show HOW you arrive at your answers. No credit for illegible work on the page. If you cannot get it to work out and want partial credit, explain in words how you are going about it. Total possible points = 110.

1. (20) Two very fast space ships approach each other, each moving at 0.6 c relative to the earth.
a) How fast does each ship see the other approaching?
b) If the left hand ship emits a burst of light, at what speed does the right hand ship see this light approach?

2. (40) In a certain linear accelerator electrons are accelerated to 20 GeV kinetic energy. (1 GeV = 10^9 eV; 1MeV = 10^6 eV; the rest mass energy of an electron is 0.51 MeV).
a) What is γ for this electron?
b) What is the velocity of this electron to two significant figures? (Do not do a lot of algebra! Think!)
c) If this electron crosses a target room 100 meters long, how long does this take in the rest frame of the electron?
d) How long is the room in the rest frame of the electron?

3. (20) We want to make π mesons (rest mass energy 140 MeV) by sending photons (rest mass zero) onto stationary protons (rest mass energy 938 MeV) , resulting in a proton plus a π meson. What minimum photon energy is needed?

4. (30) A runner enters a barn with a long pole, moving to the right at v=0.6c. The barn is 3 meters long, in its own rest frame, and the pole is 3 m long in its own rest frame. Consider two coordinate frames: S at rest with respect to the barn, and S' moving with the runner to the right at v=0.6c. The two systems are synchronized such that t=t'=x=x'=0 when the right hand end of the pole just enters the barn.
a) Find the coordinates (x,t) of the event corresponding to the right hand end of the pole just reaching the exit (right hand) end of the barn.
b) Find the coordinates (x',t') of this event.
c) If the entrance (left hand) barn door is slammed shut at this same t', will it cut the pole? Why? (No credit for answer only : you must explain.)
d) Find the location (x',t') of the left hand end of the barn at the t' of part c (i.e., the coordinates of the slam in S').
e) Find the coordinates (x,t) of this event.
f) Explain what an observer in S sees happen.



4. $\gamma = 1/\sqrt{1-.6^2} = 1.25 = \frac{5}{4}$

$ct = 5m$ a) Right hand end is there at $x = 3m$, and took time $\ell/v = 3m/(.6)(3(8)) = \underline{1.66(-8)\text{ sec} = t}$

$ct' = 4m$ b) In S', $\underline{x' = 0}$ still. Time is time dilated $1.66(-8)/\gamma = \underline{1.33\times10^{-8}s = t'}$

c) The runner sees a $3m/\gamma = \underline{2.4m}$ long barn passing a $\underline{3m}$ pole. So at $t' = 1.33\times10^{-8}s$, the pole still hangs out, cuts pole.

$x' = \cancel{3}\ -2.4,\ ct' = 4m$ d) $\underline{x'} = -\cancel{3}\ 2.4;\ \underline{t'} = 1.33\times10^{-8}s$

e) $\cancel{x} = \gamma(x' + vt') = \gamma(-\cancel{3}\ 2.4 + \underbrace{(.6)(3(8))(1.33^{-8})}) = 0.$

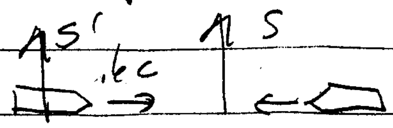
$x = 0, ct = \cancel{\ }$ Ok, of course. It must be.

$t = \gamma(t' + v/c^2 x') = \gamma(1.33(-8) + \frac{.6}{c}(\cancel{-3}\ -2.4)) = \underline{.73(-9)}$.

f) at time of slam, which is much earlier than time at which pole reaches end of barn, pole has not fully entered the barn. So it gets cut.

$ct = \gamma(4 - 1.44) = \frac{5}{4}(2.56) \approx \underline{3.0}$

Quiz 1



1. 4

a) $u_x' = \dfrac{u_x - v}{1 - u_x v/c^2} = \dfrac{-.6c-(.6c)}{1-\frac{(.6)(-.6)c^2}{c^2}} = \dfrac{-1.2c}{1+.36}$

$u_x' = \underline{-.88\,c} = \underline{-2.64\times10^{8}\ \text{m/s}}$ 2

b) approaches at $\underline{\underline{c}}$ in all systems. 10

2. $\xrightarrow{20\,\text{GeV}}$, $m_0c^2 = .51$ MeV

10 a) $\gamma = E/mc^2 = 20.00051/.00051 = \underline{3.9\times10^{4}}$ 4

10 b) $v/c = (1-1/\gamma^2)^{1/2} \simeq 1$, $v = c = \underline{3.0\times10^{8}\ \text{m/s}}$ 5

c) In lab. frame, takes $100\,\text{m}/c = 3.33(-7)$ s.
In electron frame, time dilated to
$3.33(-7)/\gamma = \underline{8.53\times10^{-12}\ \text{sec}}$ 5

d) Lorentz contracted to
$100\,\text{m}/\gamma = \underline{2.56\ \text{mm}}$ 3

3. $\underbrace{\gamma}_{p} + \underbrace{\text{proton}}_{m} \rightarrow \underbrace{\underset{m}{\text{proton}} + \underset{m_\pi}{\pi^0}}_{p}$ 4 Momentum

$p + m = \sqrt{p^2 + (m+m_\pi)^2}$ 8 Energy

Solve for p: $\cancel{p^2} + m^2 + 2mp = \cancel{p^2} + (m+m_\pi)^2$

$p = \dfrac{(m+m_\pi)^2 - m^2}{2m} = \dfrac{(938+140)^2 - (938)^2}{2(938)}$

$= 150$ MeV/c 4

$E_{photon} = pc = 150$ MeV. 4