Physics 262 Fall 2010 Exam 5 Solutions

$x' = \gamma(x - Vt)$

$ct' = \gamma(ct - \frac{Vx}{c})$

$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$f = f_0\sqrt{\frac{1-v/c}{1+v/c}}$

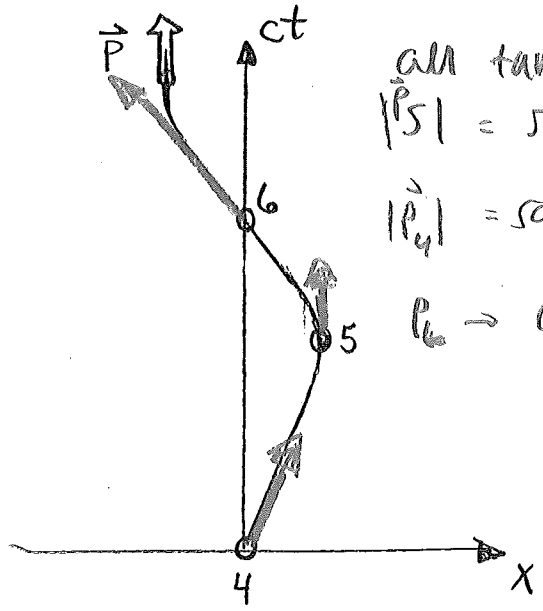
$\Delta s = \sqrt{c^2t^2 - x^2}$

$v_{o/a} = \frac{v_{o/b} + v_{b/a}}{1 + \frac{v_{o/b}v_{b/a}}{c^2}}$

1&2] A mass 2m collides and sticks to initially stationary mass m. The combined lump moves off at 0.8c. What was the initial speed of mass 2m?

3]By what % did the total mass increase? (enter 9 for anything > 9%)

4&5&6] Accurately draw energy momentum 4-vectors on the worldline shown, at the points indicated. (Dr. T will grade this part by hand.)



all tangent

$|\vec{P}_5|$ = same as given $|\vec{P}|$

$|\vec{P}_4|$ = same, but drawn longer.

P_6 → drawn longest.

Consider two charges in a spaceship, oriented at 45° to the direction of travel. In the spaceship, the electric force between the charges is 707 N. The spaceship is moving at 0.98c in the +x direction.

7&8] What is the magnitude of the x-component of the force on the upper charge in the earth frame?

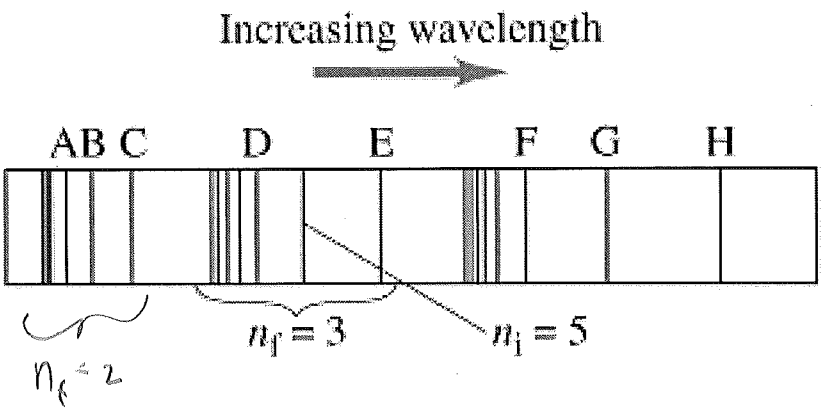
9&10] What is the magnitude of the y-component of the force on the upper charge in the earth frame?

11&12] A wire in the lab carries a current of electrons, with a linear charge density of 2×10^6 e/m, each moving at 0.1c. In the rest frame of the electrons, what is their linear charge density?

13] In the rest frame of the electrons, the linear charge density of the positive nuclei in the wire is
a) Bigger than their own density by a factor of γ
b) Bigger than their own density by a factor of γ^2
c) Bigger than their own density by a factor of γ^3
d) Smaller than their own density by a factor of γ
e) Smaller than their own density by a factor of γ^2
f) Smaller than their own density by a factor of γ^3
g) The same as their own density.

14&15] Light shines on a metal with a work function of 1.4 eV. What is the longest wavelength that can still eject electrons from the metal (in nm)?

16] If the intensity of light (at a wavelength that can emit electrons) is increased:
A] the energy of the emitted electrons increases
B] the rate at which electrons are emitted increases
C] both increase
D] neither increases



17] The spectrum of a Bohr atom (hydrogen) is spread out with a prism. Red is to the right. Which letter corresponds to the transition $n_i = 5$ to $n_f = 2$? (A)

18] If the ionization energy of hydrogen is 13.6 ev, what is the energy (in eV) of the photon emitted?

Since $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ and $E = \frac{hc}{\lambda}$ $E = hcR\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Ionization $\rightarrow$ $n_i = \infty$, $n_f = 1$ $E_i = hcR$

so $E = 13.6\,eV \cdot \left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 2.86\,eV$ Visible.

[8.2] $\vec{P}_i = \vec{P}_f$

t) $\gamma_i 2mc + mc = \gamma_f Mc$

x) $\gamma_i 2mv_i = \gamma_f Mv_f$

$\frac{v_f}{c} = \frac{v_i}{c} \cdot \frac{2\gamma_i}{2\gamma_i + 1}$ $\quad \frac{v_f}{c} = 0.8$ Drop cs, add back later.

$0.8(2\gamma_i + 1) = v_i \cdot 2\gamma_i$

$1.6\gamma_i + 0.8 = v_i \cdot 2\gamma_i$

$(1.6 - 2v_i)\gamma_i = -0.3$

$\gamma_i = \frac{0.3}{2v_i - 1.6} = \frac{0.4}{v_i - 0.8}$

$\gamma_i^2 = \frac{0.16}{v_i^2 - 1.6v_i + 0.64} = \frac{1}{1 - v_i^2}$

$0.16 - 0.16v_i^2 = v_i^2 - 1.6v_i + 0.64$

$0 = 1.16v_i^2 - 1.6v_i + 0.48$

$v_i = \frac{1.6 \pm \sqrt{1.6^2 - 4 \cdot 1.16 \cdot 0.48}}{2 \cdot 1.16} = 0.689 \pm 0.249$

$v_i = 0.938c$. (4 roots)

$= 2.8 \times 10^8$ m/s

Check $\gamma_i = 2.88$

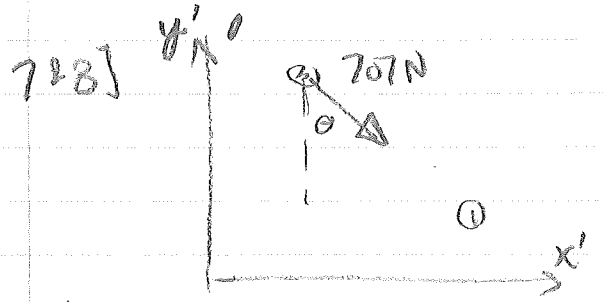
$0.8 \stackrel{?}{=} 0.938 \cdot \frac{2 \cdot 2.88}{2 \cdot 2.88 + 1} = 0.938 \cdot \frac{5.77}{6.77}$ ✓

3.) $\gamma_f = 1.67$

$(2\gamma_i + 1)mc = \gamma_f Mc$

$4.047\,m = M$

Mass increased from 3m to 4.047 m, a 34.9% increase.

7 & 8] 

$v/c = 0.98$

$\gamma = 5.025$

$F_x = F_x' = 707 \sin 45° = 500\,N$

$F_y = F_y'/\gamma$ y-component of force is lower in lab frame (when ptcl at rest in spaceship)

9 & 10] $F_y = 500\,N/5.025 = 99.5\,N$

11 & 12] In their own frame, they are farther apart.

$\lambda_- = \lambda_+/\gamma = 1.99 \times 10^6$ e/m.

13] (b) They are Lorentz contracted to higher density

14 & 15] 886 nm. $\frac{hc}{\lambda} = W$

16] B.

17]