Chapter 4

Conceptual 3) Yes, an object can only travel as fast as the speed of light

5) You would probably catch fire due to all of the friction and heat so it probably wouldn't look too nice. You would see just the same. The speed of light is a maximum and if you hold a mirror light in your relative space is still the same.

7) i) a) Speed of light is upper limit.

ii) a) Speed of light.

iii) b) $\frac{1}{0} m_e c$

9) i) The orbiting clock runs faster

ii) b) it is ahead a certain amount

Problems 14) .70c, 15 yr in rest frame

spaceship proper time

a) how long as from earth time

$t_p = \frac{\Delta t}{\gamma}$ $t_p = \frac{15}{\sqrt{\frac{1}{1-.7^2}}}$

proper length from earth

$.7c \cdot 15yr$

$10.5 = L$ in light years

$L \gamma = L_p$ $\boxed{t_p = 10.71 \text{ years}}$

b) $L_p = \frac{L}{\gamma}$ $L_p = \frac{10.71}{\sqrt{\frac{1}{1-\frac{v^2}{c^2}}}} = \boxed{7.64 ly}$

$\Delta t = \frac{1}{\gamma} t_p$

c. $.7c \cdot 15 = 10.5$ ly

d.) $\frac{10.71 x}{0 -}$

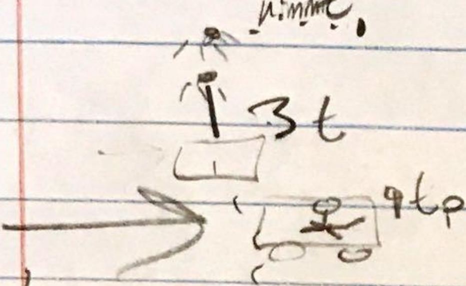
10.71

$10.71 + 7.64 = \boxed{18.35 \text{ years}}$

μ means micro in this context, not to be confused with other μ for friction

$\Delta t = 3\mu s \quad \gamma t' = 9\mu s$

16. two light pulses separate by $3.00\ \mu s$



$x' = \gamma(x - vt) \qquad \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$t' = \gamma\left(t - \frac{vx}{c^2}\right)$

(a) $\frac{t_{prop}}{t} = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}/t$

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

$\frac{t^2}{t_p^2} = 1 - v^2/c^2$

$+v^2/c \quad -t^2/t_p^2$

$\frac{v^2}{c^2} = 1 - t^2/t_p^2 \quad \cdot c^2$

$v = \sqrt{1 - t^2/t_p^2} \quad \cdot c$

$v = \sqrt{1 - \frac{3^2}{9^2}} = .94c$

(b) ~~Length Δtime $\cdot$ Speed of light~~

1 microsecond $= 1\times10^{-6}$ sec

$x = ct'$

$x = c \cdot 9$

$x = 3.00\times10^{8} \cdot 9\times10^{-6}$

$\boxed{x = 2700\ m}$

27.

1.6×10^{-27}

25×10^{-28}

$.843c$

$v_f = 0$

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

$p = \frac{m\vec{v}_1}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}} = \frac{m_2 v_2}{\sqrt{1-\frac{v^2}{c^2}}}$

$p = \frac{25\times10^{-28} \cdot .843c}{\sqrt{1 - .843 \cdot .843}}$

we want this

$4.96\times10^{-28}\ (p) = \frac{m_2 v_2}{\sqrt{1-\frac{v^2}{c^2}}}$

momentum

$\boxed{4.96\times10^{-28}c}^2$

$m_2 \cdot$

$p^2\left(1-\frac{v^2}{c^2}\right) = m^2 v_2^2$

$p^2 = m^2 v^2$

$p^2\left(1-\frac{v^2}{c^2}\right) = m^2 v^2$

$m^2 v^2\left(1-\frac{v^2}{c^2}\right) = p^2$

$v^2\left(m^2 + \frac{p^2}{c^2}\right) = p^2$

$v^2 = \frac{p^2}{m^2 + \frac{p^2}{c^2}}$

$\frac{(4.46\times10^{-26}c)}{\sqrt{(1.6\times10^{-27})^2 + (4.96\times10^{-28})^2}}$

$= \boxed{29.6c}$

33 Rest electron $.511\ MeV$ Rest proton $938\ MeV$

$KE = 2.00\ MeV$

Find proton + electron

(a) Electron $.511\ MeV$ $KE\ 2.00$

$K = \int_{x_1}^{x_2} F\,dx = \int_{x_1}^{x_2} \frac{dp}{dt}\,dx$

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

Rest energy $.511 = mc^2$

$\frac{.511}{c^2} = m$

(a)

$2 = (\gamma - 1)mc^2$

$2 = \frac{\frac{.511}{c^2} \cdot c^2}{\sqrt{1-\frac{v^2}{c^2}}} - \frac{.511}{c^2} c^2$

$2 = \frac{.511}{\sqrt{1-\frac{v^2}{c^2}}} - .511$

$-.511 \quad -.511$

$1.489 = \frac{.511}{\sqrt{1-\frac{v^2}{c^2}}}$

$2.217 = \frac{.2611}{(1-\frac{v^2}{c^2})}$

$2.217 \cdot (1-\frac{v^2}{c^2}) = \frac{.2611}{2.217}$

$1 - v^2/c^2 = .1177$

$-1 \quad -1$

$-v^2/c^2 = .8822$

$v = \sqrt{.8822}$

$\boxed{v = .939c}$

(b)

$2 = (\gamma - 1)mc^2$

$2 = \frac{938\,MeV}{c^2} \cdot c^2 - \frac{938}{c^2} c^2$

$+938 \quad +938$

$940 = \frac{938\ MeV}{\sqrt{1-\frac{v^2}{c^2}}}$

$\sqrt{1-\frac{v^2}{c^2}}\ 940 = 938$

$1 - \frac{v^2}{c^2} = \left(\frac{938}{940}\right)^2 - 1$

-1

$v = \sqrt{\left(\frac{938}{940}\right)^2 - 1}$

$v = 1.412c$

(c) by 1.5 x

38 $\cancel{9}00$kg at .850 c
colllides with 1400kg @ 0c
perfectly inelastic
Speed: $u'_x = \dfrac{u_x - V}{\sqrt{1 - \frac{u_x V}{c^2}}}$
Before
900kg .850c 1400kg
After
2300

$P = \gamma m \vec{u}$

$P_{mi} = P_{mf}$

$\gamma_i m u_i = \gamma_f M_f u_f \Rightarrow \gamma_f = \dfrac{\gamma_i m u_i}{m_f u_f}$

$\gamma_i mc^2 + Mc^2 = \gamma_f M_f c^2$

$\gamma_i mc^2 + Mc^2 = \left[\dfrac{\gamma_i m u_i}{\cancel{M_f} u_f}\right] \cancel{M_f} c^2$

$\gamma_i m c^2 + M c^2 = \dfrac{\gamma_i m u_i}{u_f} c^2$

$\gamma_i m + M = \dfrac{\gamma_i m u_i}{u_f}$

$\gamma = \sqrt{\dfrac{1}{1 - \frac{v^2}{c^2}}} = 1.898$

$u_f = \dfrac{\gamma_i m u}{\gamma_i m + M}$

$u_f = \dfrac{1.898 \cdot 900 \cdot .85}{1.898 \cdot 900 + 2300}$

$\boxed{u_f = .36c}$ $\boxed{\text{Mass} = 2300}$

Andromeda! 95. 30yr spaceship FOR. 2.00×10^6 ly away
Howfast? γ 30 1 yr

$\gamma = \dfrac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$

$V = \dfrac{d}{\Delta t} = \dfrac{2 \times 10^6 c}{30 \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}}$

$1.5 \times 10^{-5} \frac{v}{c} =$

45 Cont'd $d = \frac{V \text{ (speed)}}{t \text{ (time)}}$ $\gamma \overset{30}{\Delta t_p} = 30 \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ new this

1 $v = \frac{d}{t}$ $\frac{2 \times 10^6 c}{30 \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}}$

$15 \times 10^{-4} \left(\frac{v}{c}\right) = \sqrt{1-\left(\frac{v}{c}\right)^2}$ $\gamma = \frac{1}{\sqrt{1-1+1.13 \times 10^{-10}}}$

$= 94072.08$

$\left(15 \times 10^{-4}\left(\frac{v}{c}\right)\right)^2 = 1 - \frac{v^2}{c^2}$

$\sqrt{\left(-\left(15 \times 10^{-4}\left(\frac{v}{c}\right)^2\right)+1\right)} = \frac{v^2}{c^2} = 1 - 1.13 \times 10^{-10}$

$\frac{v}{c} = \boxed{.499c}$ (Near speed of light)

~~$KE = (\gamma - 1)mc^2$~~

$E = \gamma mc^2$ ~~$= 31.62$~~ ~~$KE = 1000.62 mc^2$~~

$E = 94072 \cdot 900 \cdot 3.00 \times 10^8$

$\boxed{2.54 \times 10^{16} J}$ ~~100,000 W~~

$= 2.54 \times 10^{16} J \; \frac{2.77 \times 10^{-7}}{1 J} \times \$0.11$

$= \$ 773{,}421{,}651$

$\boxed{\$7.7 \times 10^8}$