Homework 11 Solutions

39.2 (a) $v = v_T + v_B = \boxed{60.0\text{ m/s}}$

(b) $v = v_T - v_B = \boxed{20.0\text{ m/s}}$

(c) $v = \sqrt{v_T^2 + v_B^2} = \sqrt{20^2 + 40^2} = \boxed{44.7\text{ m/s}}$

39.3 The first observer watches some object accelerate under applied forces. Call the instantaneo velocity of the object v_1. The second observer has constant velocity v_{21} relative to the fir and measures the object to have velocity $v_2 = v_1 - v_{21}$.

The second observer measures an acceleration of $a_2 = \frac{dv_2}{dt} = \frac{dv_1}{dt}$

This is the same as that measured by the first observer. In this nonrelativistic case, th measure the same forces as well. Thus, the second observer also confirms that $\Sigma F = ma$.

39.6 $\Delta t = \frac{\Delta t_p}{\left[1-(v/c)^2\right]^{1/2}}$ so $v = c\left[1-\left(\frac{\Delta t_p}{\Delta t}\right)^2\right]^{1/2}$

For $\Delta t = 2\Delta t_p \Rightarrow v = c\left[1-\left(\frac{\Delta t_p}{2\Delta t_p}\right)^2\right]^{1/2} = c\left[1-\frac{1}{4}\right]^{1/2} = \boxed{0.866c}$

*39.13 For $\frac{v}{c} = 0.990,\ \gamma = 7.09$

(a) The muon's lifetime as measured in the Earth's rest frame is $\Delta t = \frac{4.60\text{ km}}{0.990c}$

and the lifetime measured in the muon's rest frame is

$$\Delta t_p = \frac{\Delta t}{\gamma} = \frac{1}{7.09}\left[\frac{4.60\times10^3\text{ m}}{0.990\left(3.00\times10^8\text{ m/s}\right)}\right] = \boxed{2.18\ \mu\text{s}}$$

(b) $L = L_p\sqrt{1-(v/c)^2} = \frac{L_p}{\gamma} = \frac{4.60\times10^3\text{ m}}{7.09} = \boxed{649\text{ m}}$

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*39.17 (a) Since your ship is identical to his, and you are at rest with respect to your own ship, its length is $\boxed{20.0\text{ m}}$.

(b) His ship is in motion relative to you, so you see its length contracted to $\boxed{19.0\text{ m}}$.

(c) We have $L = L_p\sqrt{1-v^2/c^2}$

from which $\frac{L}{L_p} = \frac{19.0\text{ m}}{20.0\text{ m}} = 0.950 = \sqrt{1-\frac{v^2}{c^2}}$ and $\boxed{v = 0.312c}$

*39.26 (a) From Equation 39.13,

$$\Delta x' = \gamma(\Delta x - v\Delta t),$$

$$0 = \gamma\left[2.00\text{ m} - v\left(8.00\times10^{-9}\text{ s}\right)\right]$$

$$v = \frac{2.00\text{ m}}{8.00\times10^{-9}\text{ s}} = \boxed{2.50\times10^{8}\text{ m/s}}$$

$$\gamma = \frac{1}{\sqrt{1-\left(2.50\times10^{8}\text{ m/s}\right)^2/\left(3.00\times10^{8}\text{ m/s}\right)^2}} = 1.81$$

(b) From Equation 39.11,

$$x' = \gamma(x - vt) = 1.81\left[3.00\text{ m} - \left(2.50\times10^{8}\text{ m/s}\right)\left(1.00\times10^{-9}\text{ s}\right)\right] = \boxed{4.97\text{ m}}$$

(c)

$$t' = \gamma\left(t - \frac{v}{c^2}x\right) = 1.81\left[1.00\times10^{-9}\text{ s} - \frac{\left(2.50\times10^{8}\text{ m/s}\right)}{\left(3.00\times10^{8}\text{ m/s}\right)^2}(3.00\text{ m})\right]$$

$$t' = \boxed{-1.33\times10^{-8}\text{ s}}$$

*39.31 Relativistic momentum must be conserved:

For total momentum to be zero after as it was before, we must have, with subscript 2 referring to the heavier fragment, and subscript 1 to the lighter, $p_2 = p_1$

or $$\gamma_2 m_2 u_2 = \gamma_1 m_1 u_1 = \frac{2.50\times10^{-28}\text{ kg}}{\sqrt{1-(0.893)^2}} \times (0.893c)$$

or $$\frac{(1.67\times10^{-27}\text{ kg})u_2}{\sqrt{1-(u_2/c)^2}} = (4.960\times10^{-28}\text{ kg})c$$

and $u_2 = \boxed{0.285c}$

39.35 (a) $E_R = mc^2 = (1.67\times10^{-27}\text{ kg})(2.998\times10^8\text{ m/s})^2 = 1.50\times10^{-10}\text{ J} = \boxed{938\text{ MeV}}$

(b) $E = \gamma mc^2 = \dfrac{1.50\times10^{-10}\text{ J}}{[1-(0.95c/c)^2]^{1/2}} = 4.81\times10^{-10}\text{ J} = \boxed{3.00\times10^3\text{ MeV}}$

(c) $K = E - mc^2 = 4.81\times10^{-10}\text{ J} - 1.50\times10^{-10}\text{ J} = 3.31\times10^{-10}\text{ J} = \boxed{2.07\times10^3\text{ MeV}}$

39.41 (a) $q(\Delta V) = K = (\gamma - 1)m_e c^2$

Thus, $\gamma = \frac{1}{\sqrt{1-(u/c)^2}} = 1 + \frac{q(\Delta V)}{m_e c^2}$ from which $\boxed{u = 0.302c}$

(b) $K = (\gamma - 1)m_e c^2 = q(\Delta V) = (1.60 \times 10^{-19}\ \text{C})(2.50 \times 10^4\ \text{J/C}) = \boxed{4.00 \times 10^{-15}\ \text{J}}$

39.47 $\Delta m = \frac{E}{c^2} = \frac{\mathcal{P}t}{c^2} = \frac{0.800(1.00 \times 10^9\ \text{J/s})(3.00\ \text{yr})(3.16 \times 10^7\ \text{s/yr})}{(3.00 \times 10^8\ \text{m/s})^2} = \boxed{0.842\ \text{kg}}$

39.49 $\mathcal{P} = \frac{dE}{dt} = \frac{d(mc^2)}{dt} = c^2 \frac{dm}{dt} = 3.77 \times 10^{26}\ \text{W}$

Thus, $\frac{dm}{dt} = \frac{3.77 \times 10^{26}\ \text{J/s}}{(3.00 \times 10^8\ \text{m/s})^2} = \boxed{4.19 \times 10^9\ \text{kg/s}}$

***39.64** (a) $f_{\text{observed}} = f_{\text{source}}\sqrt{\frac{1+v/c}{1-v/c}}$ implies $\frac{c}{\lambda + \Delta\lambda} = \frac{c}{\lambda}\sqrt{\frac{1+v/c}{1-v/c}}$,

or $\sqrt{\frac{1-v/c}{1+v/c}} = \frac{\lambda + \Delta\lambda}{\lambda}$

and $\boxed{1 + \frac{\Delta\lambda}{\lambda} = \sqrt{\frac{1-v/c}{1+v/c}}}$

(b) $1 + \frac{550\ \text{nm} - 650\ \text{nm}}{650\ \text{nm}} = \sqrt{\frac{1-v/c}{1+v/c}} = 0.846$

$1 - \frac{v}{c} = (0.846)^2\left(1 + \frac{v}{c}\right) = 0.716 + 0.716\left(\frac{v}{c}\right)$

$v = 0.166c = \boxed{4.97 \times 10^7\ \text{m/s}}$