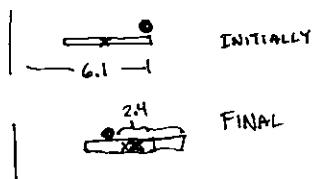


9.17 You know, this would have been an easy problem if they'd given us the length of the boat.

4.5kg dog 18kg boat



INITIAL $M_{\text{tot}} x_{\text{cm}}^i = m_{\text{dog}} x_{\text{dog}}^i + m_{\text{boat}} x_{\text{boat}}^i$ } distance measured from shoreline
 Final $M_{\text{tot}} x_{\text{cm}}^f = m_{\text{dog}} x_{\text{dog}}^f + m_{\text{boat}} x_{\text{boat}}^f$

Now subtract the two equations

$$0 = m_{\text{dog}} \Delta x_{\text{dog}} + m_{\text{boat}} \Delta x_{\text{boat}}$$

Negative number Positive number

$$\text{so } \Delta x_{\text{boat}} = -\frac{m_{\text{dog}}}{m_{\text{boat}}} \Delta x_{\text{dog}}$$

We are told how far the dog moves along the length of the boat

$$-\Delta x_{\text{dog}} + \Delta x_{\text{boat}} = 2.4$$

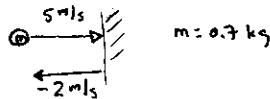
$$-\Delta x_{\text{dog}} + -\frac{m_{\text{dog}}}{m_{\text{boat}}} \Delta x_{\text{dog}} = 2.4$$

$$-\left[1 + \frac{m_{\text{dog}}}{m_{\text{boat}}}\right] \Delta x_{\text{dog}} = 2.4$$

$$-\left[1 + \frac{4.5}{18}\right] \Delta x_{\text{dog}} = 2.4$$

$$\Delta x_{\text{dog}} = -1.92 \text{ m}$$

9.18



$$\overrightarrow{\text{Impulse}} = \Delta \vec{p} = \vec{p}_f - \vec{p}_i$$

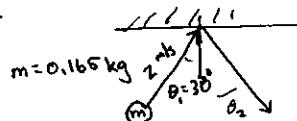
$$= m \vec{v}_f - m \vec{v}_i$$

Just do x-components

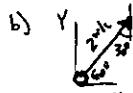
$$\begin{aligned} \Delta p_x &= m v_{fx} - m v_{ix} \\ &= 0.7(-2) - 0.7(5) \\ &= -4.9 \text{ kg m/s} \end{aligned}$$

$$|\Delta p_x| = 4.9 \text{ kg m/s}$$

9.22



$$\text{a) } \theta_2 = 30^\circ \text{ also}$$



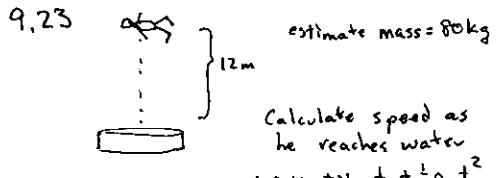
$$\vec{p}_{\text{init}} = m \vec{v}_{i\hat{x}}$$

$$\begin{aligned} \vec{p}_{\text{init}} &= m v_{ix} \hat{i} + m v_{iy} \hat{j} \\ &= (0.165) 2 \cos 60^\circ \hat{i} + (0.165) 2 \sin 60^\circ \hat{j} \\ &= 0.165 \hat{i} + 0.286 \hat{j} \text{ kg m/s} \end{aligned}$$

After the bounce

$$\vec{p}_{\text{final}} = 0.165 \hat{i} - 0.286 \hat{j}$$

$$\begin{aligned} \Delta \vec{p} &= \vec{p}_{\text{final}} - \vec{p}_{\text{init}} = 0 \hat{i} - 0.572 \hat{j} \text{ kg m/s} \end{aligned}$$



Calculate speed as he reaches water

$$y = y_0 + v_{oy}t + \frac{1}{2}a_y t^2$$

$$v_{oy} = v_{oy} + a_y t$$

or we can use

$$v_{oy}^2 - v_{oy,i}^2 = 2a_y \Delta y$$

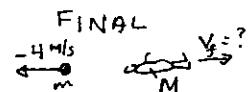
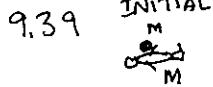
$$v_{oy,f}^2 - 0^2 = 2(-9.8)(-12)$$

$$|v_{oy,f}| = 15.3 \text{ m/s}$$

$$|\text{Impulse}| = |\Delta \vec{P}| \approx m \Delta v$$

$$\approx 80(15.3)$$

$$\approx 1227 \text{ kg m/s}$$



$$m = 0.068 \text{ kg}$$

$$M = 91 \text{ kg}$$

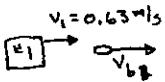
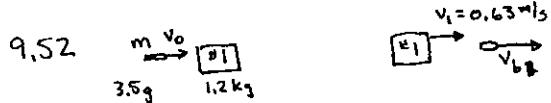
$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$\Delta = mv_{\text{stone}} + Mv_f$$

$$\Delta = 0.068(-4) + 91v_f$$

$$v_f = 0.0030 \text{ m/s}$$

Gee, he should have used a bigger rock.



$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$mv_0 = M_1 v_1 + mv_{b1}$$

$$0.0035 v_0 = 1.2(0.63) + 0.0035 v_{b1}$$

THEN



$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$mv_{b1} = (M_2 m) v_2$$

$$0.0035 v_{b1} = 1.8035(1.4)$$

$$v_{b1} = 721.4 \text{ m/s}$$

$$0.0035 v_0 = 1.2(0.63) + 0.0035(721.4)$$

$$v_0 = 937 \text{ m/s}$$

9.60



$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$m_A v_{A_i} + m_B v_{B_i} = m_A v_{A_f} + m_B v_{B_f}$$

$$1.6(5.5) + 2.4(2.5) = 1.6 v_{A_f} + 2.4(4.9)$$

$$v_{A_f} = 1.9 \text{ m/s}$$

this would be toward the right

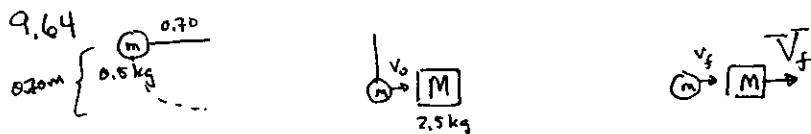
Is this elastic?

$$\begin{aligned} \text{KE before collision} &= \frac{1}{2} 1.6(5.5)^2 + \frac{1}{2} 2.4(2.5)^2 \\ &= 31.7 \text{ Joules} \end{aligned}$$

$$\begin{aligned} \text{KE after collision} &= \frac{1}{2} 1.6(1.9)^2 + \frac{1}{2} 2.4(4.9)^2 \\ &= 31.7 \text{ Joules} \end{aligned}$$

Yes, this was an elastic collision.

9.64



$$\text{Total Init Energy} = \text{Total Energy at bottom} \\ \text{at top of swing} \quad \text{or swing}$$

$$mgh = \frac{1}{2} mv_0^2$$

$$9.8(0.7) = \frac{1}{2} v_0^2$$

$$v_0 = 3.7 \text{ m/s}$$

$$\text{Total Momentum Before} = \text{Total Momentum After}$$

$$mv_0 = mv_f + M\bar{V}_f$$

$$0.5(3.7) = 0.5v_f + 2.5\bar{V}_f$$

$$1.85 = 0.5v_f + 2.5\bar{V}_f$$

$$1.85 - 2.5\bar{V}_f = 0.5v_f$$

$$3.7 - 5\bar{V}_f = v_f$$

Since perfectly elastic

$$\text{Energy before} = \text{Energy after}$$

$$\frac{1}{2}mv_0^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}M\bar{V}_f^2$$

$$\frac{1}{2}0.5(3.7)^2 = \frac{1}{2}0.5v_f^2 + \frac{1}{2}2.5\bar{V}_f^2$$

$$3.42 = 0.25v_f^2 + 1.25\bar{V}_f^2$$

$$\begin{aligned} 3.42 &= 0.25(3.7 - 5\bar{V}_f)^2 + 1.25\bar{V}_f^2 \\ &= 0.25[13.69 - 37.5\bar{V}_f + 25\bar{V}_f^2] + 1.25\bar{V}_f^2 \end{aligned}$$

$$3.42 = 3.375 - 4.625\bar{V}_f + 6.25\bar{V}_f^2 + 1.25\bar{V}_f^2$$

$$3.42 = 3.375 - 4.625\bar{V}_f + 7.75\bar{V}_f^2$$

$$0 = -0.045 - 4.625\bar{V}_f + 7.75\bar{V}_f^2$$

$$\bar{V}_f = \frac{4.625 \pm \sqrt{(4.625)^2 - 4(-0.045)(7.75)}}{2(7.75)}$$

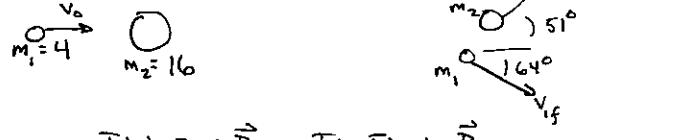
$$\bar{V}_f = \frac{4.625 \pm 4.773}{2(7.75)} = 0.606 \text{ m/s}$$

only need (+) option

$$3.7 - 5(0.606) = v_f$$

$$0.668 \text{ m/s} = v_f$$

9.71



$$\text{Total Init } \vec{P} = \text{Tot Final } \vec{P}$$

$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$m_1 v_0 = m_1 v_{1f} \cos 64^\circ + m_2 v_{2f} \cos 51^\circ$$

$$\text{Tot Init } P_y = \text{Tot Final } P_y$$

$$0 = m_1 v_{1f} \sin 64^\circ + m_2 v_{2f} \sin 51^\circ$$

$$0 = (-) 4 v_{1f} \sin 64^\circ + 16 (1.2 \times 10^5) \sin 51^\circ$$

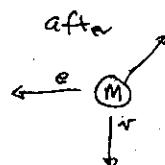
$$4 v_0 = 4 (4.15 \times 10^5) \cos 64^\circ + 16 (1.2 \times 10^5) \cos 51^\circ$$

$$v_0 = 4.84 \times 10^5 \text{ m/s}$$

$$v_{1f} = 4.15 \times 10^5 \text{ m/s}$$

9.90

before



Assume initial & final
nuclei have close
to the same mass

$$\text{Tot Init } \vec{P} = \text{Tot Final } \vec{P}$$

$$0 = \vec{P}_n + \vec{P}_e + \vec{P}_{\text{nucleus}}$$

$$0 = [-6.4 \times 10^{-22} \hat{i}] + [-1.2 \times 10^{-22} \hat{i}] + \vec{P}_{\text{nucleus}}$$

so

$$\vec{P}_{\text{nucleus}} = 1.2 \times 10^{-22} \hat{i} + 6.4 \times 10^{-22} \hat{j}$$

$$|\vec{P}| = \sqrt{P_x^2 + P_y^2} = 1.36 \times 10^{-22} \text{ kg m/s}$$

$$\tan \theta = \frac{P_y}{P_x} = \frac{0.64 \times 10^{-22}}{1.2 \times 10^{-22}}$$

$$\rightarrow \theta = 28.1^\circ$$

$$\text{If } M = 5.8 \times 10^{-26} \text{ kg}$$

$$|\vec{P}| = m v$$

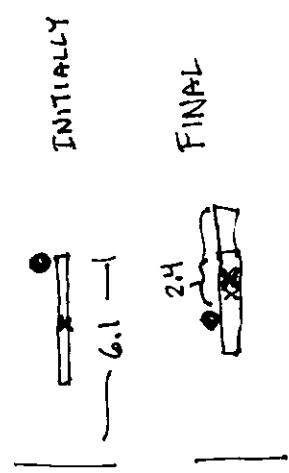
$$1.36 \times 10^{-22} = 5.8 \times 10^{-26}$$

$$|v| = 2345 \text{ m/s}$$

$$KE = \frac{1}{2} M v^2 = \frac{1}{2} (5.8 \times 10^{-26}) (2345)^2 = 1.59 \times 10^{-19} \text{ Joules}$$

9.17 You know this would have been an easy problem if they'd given us the length of the boat.

4.5 kg dog 18 kg boat



$$\text{INITIAL } M_{\text{tot}} x_{\text{cm}}^i = m_{\text{dog}} x_{\text{dog}}^i + m_{\text{boat}} x_{\text{boat}}^i$$

$$\text{Final } M_{\text{tot}} x_{\text{cm}}^f = m_{\text{dog}} x_{\text{dog}}^f + m_{\text{boat}} x_{\text{boat}}^f$$

Now subtract the two equations

$$0 = m_{\text{dog}} \cancel{\Delta x_{\text{dog}}} + m_{\text{boat}} \cancel{\Delta x_{\text{boat}}} \quad \begin{array}{l} \text{positive number} \\ \text{negative number} \end{array}$$

$$\text{so } \Delta x_{\text{boat}} = - \frac{m_{\text{dog}}}{m_{\text{boat}}} \Delta x_{\text{dog}}$$

We are told how far the dog moves along the length of the boat

$$-\Delta x_{\text{dog}} + \Delta x_{\text{boat}} = 2.4$$

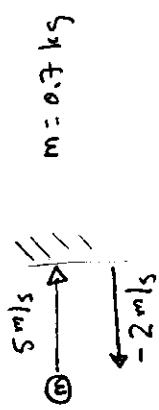
$$-\Delta x_{\text{dog}} + -\frac{m_{\text{dog}}}{m_{\text{boat}}} \Delta x_{\text{dog}} = 2.4$$

$$-\left[1 + \frac{m_{\text{dog}}}{m_{\text{boat}}} \right] \Delta x_{\text{dog}} = 2.4$$

$$-\left[1 + \frac{4.5}{18} \right] \Delta x_{\text{dog}} = 2.4$$

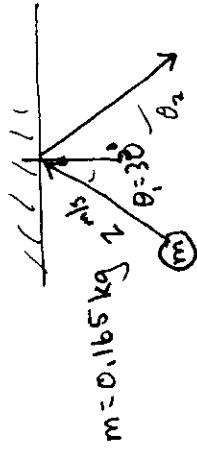
$$\Delta x_{\text{dog}} = -1.92 \text{ m}$$

9.18

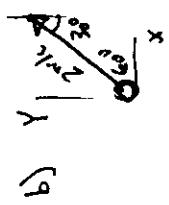


$$\begin{aligned} \text{Impulse} &= \Delta \vec{p} = \vec{p}_f - \vec{p}_i \\ &= m \vec{v}_f - m \vec{v}_i \\ &\quad \text{First do } x\text{-components} \\ \Delta p_x &= m v_{fx} - m v_{ix} \\ &= 0.7(-2) - 0.7(4.5) \\ &= -4.9 \text{ kg m/s} \\ |\Delta p_x| &= 4.9 \text{ kg m/s} \end{aligned}$$

9.22



$$a) \theta_2 = 30^\circ \text{ also}$$



$$\begin{aligned} \Delta p_x &= m v_{fx} - m v_{ix} \\ &= 0.165(2 \cos 60^\circ) - 0.165(2 \sin 60^\circ) \\ &= 0.165 \uparrow + 0.286 \uparrow \text{ kg m/s} \end{aligned}$$

After the bounce

$$\begin{aligned} \Delta \vec{p} &= \vec{p}_{final} - \vec{p}_{init} = 0 \uparrow - 0.572 \uparrow \text{ kg m/s} \end{aligned}$$

9.23

$$\text{estimate mass} = 80 \text{ kg}$$



Calculate speed as
he reaches water

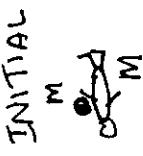
$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$v_{y_f} = v_{0y} + a_y t$$

or we can use

$$\begin{aligned} v_{y_f}^2 - v_{y_i}^2 &= 2 a_y \Delta y \\ v_{y_f}^2 - 0^2 &= 2(-9.8)(-12) \\ |v_{y_f}| &= 15.3 \text{ m/s} \end{aligned}$$

9.39



FINAL
~~12 m~~ $v_x = ?$

$$\begin{aligned} m &= 0.068 \text{ kg} \\ M &= 91 \text{ kg} \end{aligned}$$

$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$\Delta = m v_{\text{stone}} + M v_f$$

$$\Delta = 0.068(-4) + 91 v_f$$

$$\begin{aligned} v_f &= 0.0030 \text{ m/s} \\ v_f &= 0.0030 \text{ m/s} \end{aligned}$$

Gee, he should have used
a bigger rock.

$$|\text{Impulse}| = |\Delta \vec{P}| \approx m \Delta v$$

$$\begin{aligned} &\sim 80(15.3) \\ &\sim 1227 \text{ kg m/s} \end{aligned}$$

$$9.52 \quad m \xrightarrow{v_0} \boxed{\#1} \quad 3.5g \quad 1.2kg$$

$$v_1 = 0.63 \text{ m/s}$$

$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$m v_0 = M_1 v_1 + m v_{b1}$$

$$0.0035 v_0 = 1.2 (0.63) + 0.0035 v_{b1}$$

THEN

$$\boxed{\#2} \quad v_2 = 1.4 \text{ m/s}$$

$$\boxed{\#2} \quad 3.5g \quad 1.8kg$$

$$\text{Tot Init } P_x = \text{Tot Final } P_x$$

$$m v_{b1} = (M_2 + m) v_2$$

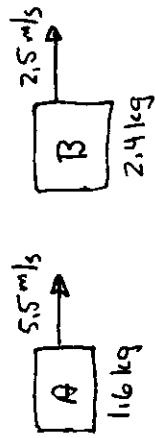
$$0.0035 v_{b1} = 1.8035 (1.4)$$

$$v_{b1} = 721.4 \text{ m/s}$$

$$0.0035 v_0 = 1.2 (0.63) + 0.0035 (721.4)$$

$$v_0 = 937 \text{ m/s}$$

9.60



$$\text{Total Initial } P_x = \text{Total Final } P_x$$

$$m_A v_{A_i} + m_B v_{B_i} = m_A v_{A_f} + m_B v_{B_f}$$

$$1.6(5.5) + 2.4(2.5) = 1.6 v_{A_f} + 2.4(4.9)$$

$$v_{A_f} = 1.9 \text{ m/s}$$

this would be toward the right

Is this elastic?

$$\begin{aligned} \text{KE before collision} &= \frac{1}{2} 1.6 (5.5)^2 + \frac{1}{2} 2.4 (2.5)^2 \\ &= 31.7 \text{ Joules} \end{aligned}$$

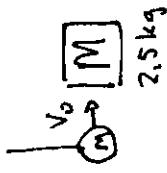
$$\begin{aligned} \text{KE after collision} &= \frac{1}{2} 1.6 (1.9)^2 + \frac{1}{2} 2.4 (4.9)^2 \\ &= 31.7 \text{ Joules} \end{aligned}$$

Yes, this was an elastic collision.



$$0.64 \quad \left\{ \begin{array}{l} m \\ 0.5 \text{ kg} \end{array} \right.$$

$$0.30 \text{ m}$$

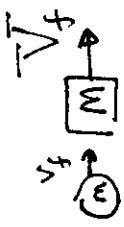


Total Int Energy = Tot Energy at bottom
at top of surface

$$\text{mgh} = \frac{1}{2} m v_0^2$$

$$0.8(0.7) = \frac{1}{2} v_0^2$$

$$v_0 = 3.7 \text{ m/s}$$



2.5 kg

Total Int Energy = Tot Energy at bottom
at top of surface

$$\text{mgh} = \frac{1}{2} m v_0^2$$

$$0.8(0.7) = \frac{1}{2} v_0^2$$

$$v_0 = 3.7 \text{ m/s}$$

Total Momentum Before = Total Momentum After

$$m v_0 = m v_f + M \bar{V}_f$$

$$0.5(3.7) = 0.5 v_f + 2.5 \bar{V}_f$$

$$1.85 = 0.5 v_f + 2.5 \bar{V}_f$$

$$1.85 - 2.5 \bar{V}_f = 0.5 v_f$$

$$3.7 - 5 \bar{V}_f = v_f$$

$$3.7 - 5(0.606) = v_f$$

$$0.668 m/s = v_f$$

Since perfectly elastic

Energy before = Energy after

$$\frac{1}{2} m v_0^2 = \frac{1}{2} m v_f^2 + \frac{1}{2} M \bar{V}_f^2$$

$$\frac{1}{2} 0.5 (3.7)^2 = \frac{1}{2} 0.5 v_f^2 + \frac{1}{2} 2.5 \bar{V}_f^2$$

$$3.42 = 0.25 v_f^2 + 1.25 \bar{V}_f^2$$

$$3.42 = 0.25 (3.7 - 5 \bar{V}_f)^2 + 1.25 \bar{V}_f^2$$

$$= 0.25 [13.69 - 30 \bar{V}_f + 25 \bar{V}_f^2] + 1.25 \bar{V}_f^2$$

$$= 3.375 - 4.625 \bar{V}_f + 6.25 \bar{V}_f^2 + 1.25 \bar{V}_f^2$$

$$= 3.375 - 4.625 \bar{V}_f + 7.75 \bar{V}_f^2$$

$$0 = 4.625 \frac{\partial}{\partial \bar{V}_f} (4.625 \bar{V}_f^2 - 4(7.75) \bar{V}_f^2)$$

$$0 = 4.625 \frac{\partial}{\partial \bar{V}_f} (4.625 \bar{V}_f^2 - 4(7.75) \bar{V}_f^2)$$

$$0 = -0.045 - 4.625 \bar{V}_f + 7.75 \bar{V}_f^2$$

$$0 = 4.625 \frac{\partial}{\partial \bar{V}_f} (4.625 \bar{V}_f^2 - 4(7.75) \bar{V}_f^2)$$

$$\bar{V}_f = \frac{4.625 \pm \sqrt{4(7.75)^2 - 4(4.625)(-0.045)}}{2(7.75)}$$

$$\bar{V}_f = \frac{4.625 \pm 2(7.75)}{2(7.75)} = 0.606 \text{ m/s}$$

only need (+) option

9.71



$$\text{Total Init } \vec{P} = \text{Total Final } \vec{P}$$

$$\text{Total Init } P_x = \text{Total Final } P_x$$

$$m_1 v_0 = m_1 v_{1,f} \cos 64^\circ + m_2 v_{2,f} \cos 51^\circ$$

$$4 v_0 = 4 (4.15 \times 10^5) \cos 64^\circ + 16 (1.2 \times 10^5) \cos 51^\circ$$

$$v_0 = 4.84 \times 10^5 \text{ m/s}$$

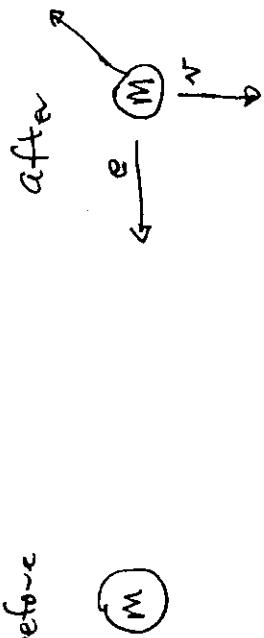
$$\text{Total Init } P_y = \text{Total Final } P_y$$

$$0 = m_1 v_{1,f} \sin 64^\circ + m_2 v_{2,f} \sin 51^\circ$$

$$0 = (-) 4 v_{1,f} \sin 64^\circ + 16 (1.2 \times 10^5) \sin 51^\circ$$

$$v_{1,f} = 4.15 \times 10^5 \text{ m/s}$$

9.90 before



Assume initial & final
nuclei have close
to the same mass

$$\text{Tot Init } \vec{P} = \text{Tot Final } \vec{P}$$

$$0 = \vec{P}_N + \vec{P}_e + \vec{P}_{\text{nucleus}}$$

$$0 = [-6.4 \times 10^{-23} \hat{i}] + [-1.2 \times 10^{-22} \hat{c}] + \vec{P}_{\text{nucleus}}$$

so

$$\vec{P}_{\text{nucleus}} = 1.2 \times 10^{-22} \hat{c} + 6.4 \times 10^{-23} \hat{i}$$

$$|\vec{P}| = \sqrt{P_x^2 + P_y^2} = 1.36 \times 10^{-22} \text{ kg m/s}$$

$$\tan \theta = \frac{P_y}{P_x} = \frac{0.64 \times 10^{-22}}{1.2 \times 10^{-22}}$$

$$\rightarrow \theta = 28.1^\circ$$

$$\text{If } M = 5.8 \times 10^{-26} \text{ kg}$$

$$|\vec{P}| = m|V|$$

$$1.36 \times 10^{-22} = 5.8 \times 10^{-26}$$

$$|V| = 2345 \text{ m/s}$$

$$KE = \frac{1}{2} M V^2 = \frac{1}{2} (5.8 \times 10^{-26}) (2345)^2 = 1.59 \times 10^{-19} \text{ Joules}$$