Chapter 9 Solutions

P9.1 $m = 3.00\text{ kg}$, $\vec{\mathbf{v}} = \left(3.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}}\right)\text{ m/s}$

(a) $\vec{\mathbf{p}} = m\vec{\mathbf{v}} = \left(9.00\hat{\mathbf{i}} - 12.0\hat{\mathbf{j}}\right)\text{ kg}\cdot\text{m/s}$

Thus, $\boxed{p_x = 9.00\text{ kg}\cdot\text{m/s}}$

and $\boxed{p_y = -12.0\text{ kg}\cdot\text{m/s}}$

(b) $p = \sqrt{p_x^2 + p_y^2} = \sqrt{(9.00)^2 + (12.0)^2} = \boxed{15.0\text{ kg}\cdot\text{m/s}}$

$\theta = \tan^{-1}\left(\dfrac{p_y}{p_x}\right) = \tan^{-1}(-1.33) = \boxed{307°}$

*P9.4 (a) For the system of two blocks $\Delta p = 0$,

or $p_i = p_f$

Therefore, $0 = Mv_m + (3M)(2.00\text{ m/s})$

Solving gives $v_m = \boxed{-6.00\text{ m/s}}$ (motion toward the left).

(b) $\dfrac{1}{2}kx^2 = \dfrac{1}{2}Mv_M^2 + \dfrac{1}{2}(3M)v_{3M}^2 = \boxed{8.40\text{ J}}$

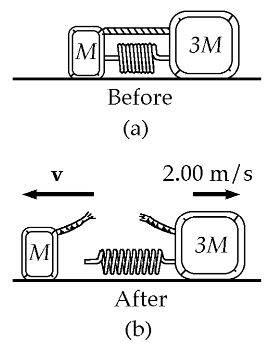

FIG. P9.4

(c) The original energy is in the spring. A force had to be exerted over a distance to compress the spring, transferring energy into it by work. The cord exerts force, but over no distance.

(d) System momentum is conserved with the value zero. The forces on the two blocks are of equal magnitude in opposite directions. Their impulses add to zero. The final momenta of the two blocks are of equal magnitude in opposite directions.

P9.5 (a) The momentum is $p = mv$, so $v = \dfrac{p}{m}$ and the kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \boxed{\frac{p^2}{2m}}$$

(b) $K = \dfrac{1}{2}mv^2$ implies $v = \sqrt{\dfrac{2K}{m}}$, so $p = mv = m\sqrt{\dfrac{2K}{m}} = \boxed{\sqrt{2mK}}$

P9.7 (a) $I = \int F dt =$ area under curve

$$I = \frac{1}{2}\left(1.50\times10^{-3}\text{ s}\right)\left(18\,000\text{ N}\right) = \boxed{13.5\text{ N}\cdot\text{s}}$$

(b) $$F = \frac{13.5\text{ N}\cdot\text{s}}{1.50\times10^{-3}\text{ s}} = \boxed{9.00\text{ kN}}$$

(c) From the graph, we see that $F_{\max} = \boxed{18.0\text{ kN}}$

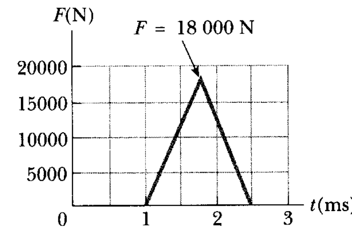

FIG. P9.7

P9.9 $\Delta\vec{\mathbf{p}} = \vec{\mathbf{F}}\Delta t$

$$\Delta p_y = m\left(v_{fy} - v_{iy}\right) = m\left(v\cos 60.0°\right) - mv\cos 60.0° = 0$$

$$\Delta p_x = m\left(-v\sin 60.0° - v\sin 60.0°\right) = -2mv\sin 60.0°$$

$$= -2\left(3.00\text{ kg}\right)\left(10.0\text{ m/s}\right)\left(0.866\right)$$

$$= -52.0\text{ kg}\cdot\text{m/s}$$

$$F_{\text{avg}} = \frac{\Delta p_x}{\Delta t} = \frac{-52.0\text{ kg}\cdot\text{m/s}}{0.200\text{ s}} = \boxed{-260\text{ N}}$$

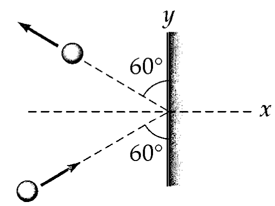

FIG. P9.9

*P9.14 After 3 s of pouring, the bucket contains (3s)(0.25 L/s) = 0.75 liter of water, with mass 0.75 L(1 kg/1 L) = 0.75 kg, and feeling gravitational force 0.75 kg(9.8 m/s^2) = 7.35 N. The scale through the bucket must exert 7.35 N upward on this stationary water to support its weight. The scale must exert another 7.35 N to support the 0.75-kg bucket itself.

Water is entering the bucket with speed given by $mgy_{top} = (1/2)mv_{impact}^2$

$v_{impact} = (2\,g\,y_{top})^{1/2} = [2(9.8\text{ m/s}^2)2.6\text{ m}]^{1/2} = 7.14$ m/s downward

The scale exerts an extra upward force to stop the downward motion of this additional water, as described by

$mv_{impact} + F_{extra}\,t = mv_f$

The rate of change of momentum is the force itself: $(dm/dt)\,v_{impact} + F_{extra} = 0$

$F_{extra} = -(dm/dt)\,v_{impact} = -(0.25\text{ kg/s})(-7.14\text{ m/s}) = +1.78$ N

Altogether the scale must exert 7.35 N + 7.35 N + 1.78 N = $\boxed{16.5\text{ N}}$

P9.15 Momentum is conserved for the bullet-block system

$$\left(10.0\times10^{-3}\text{ kg}\right)v = \left(5.01\text{ kg}\right)\left(0.600\text{ m/s}\right)$$

$$v = \boxed{301\text{ m/s}}$$

P9.16 (a) $mv_{1i} + 3mv_{2i} = 4mv_f$ where $m = 2.50\times10^4$ kg

$$v_f = \frac{4.00 + 3(2.00)}{4} = \boxed{2.50\text{ m/s}}$$

(b) $K_f - K_i = \frac{1}{2}(4m)v_f^2 - \left[\frac{1}{2}mv_{1i}^2 + \frac{1}{2}(3m)v_{2i}^2\right] = (2.50\times10^4)(12.5 - 8.00 - 6.00) = -3.75\times10^4 \text{ J}$

$K_i = K_f + \Delta E_{int}$ $\Delta E_{int} = \boxed{+37.5 \text{ kJ}}$

P9.19 First we find v_1, the speed of m_1 at B before collision.

$$\frac{1}{2}m_1 v_1^2 = m_1 g h$$

$$v_1 = \sqrt{2(9.80)(5.00)} = 9.90 \text{ m/s}$$

Now we use the text's analysis of one-dimensional elastic collisions to find v_{1f}, the speed of m_1 at B just after collision.

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_1 = -\frac{1}{3}(9.90) \text{ m/s} = -3.30 \text{ m/s}$$

Now the 5-kg block bounces back up to its highest point after collision according to

$$m_1 g h_{max} = \frac{1}{2}m_1(-3.30)^2 \qquad h_{max} = \frac{(-3.30 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = \boxed{0.556 \text{ m}}$$

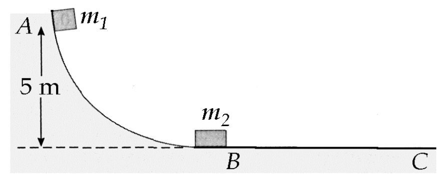

FIG. P9.19

P9.21 (a), (b) Let v_g and v_p be the x-components of velocity of the girl and the plank relative to the ice surface. Then we may say that $v_g - v_p$ is the velocity of the girl relative to the plank, so that

$$v_g - v_p = 1.50 \qquad (1)$$

But also we must have $m_g v_g + m_p v_p = 0$, since total momentum of the girl-plank system is zero relative to the ice surface. Therefore

$$45.0v_g + 150v_p = 0, \text{ or } v_g = -3.33v_p$$

Putting this into the equation (1) above gives

$-3.33v_p - v_p = 1.50$ or $v_p = \boxed{-0.346\,\hat{\mathbf{i}} \text{ m/s}}$ (answer b)

Then $v_g = -3.33(-0.346) = \boxed{1.15\,\hat{\mathbf{i}} \text{ m/s}}$ (answer a)

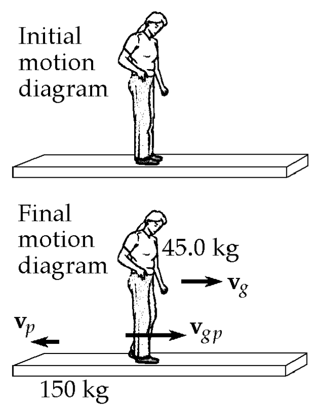

FIG. P9.21

P9.23 (a) From the text's analysis of a one-dimensional elastic collision with an originally stationary target, the x-component of the neutron's velocity changes from v_i to $v_{1f} = (1 - 12)v_i/13 = -11v_i/13$. The x-component of the target nucleus velocity is $v_{2f} = 2v_i/13$.

The neutron started with kinetic energy $(1/2)\, m_1 v_i^2$

The target nucleus ends up with kinetic energy $(1/2)\,(12\, m_1)(2v_i/13)^2$

Then the fraction transferred is

$$\frac{\frac{1}{2}12m_1(2v_i/13)^2}{\frac{1}{2}m_1v_i^2}=\frac{48}{169}=\boxed{0.284}$$ Because the collision is elastic, the other 71.6% of the original energy stays with the neutron. The carbon is functioning as a moderator in the reactor, slowing down neutrons to make them more likely to produce reactions in the fuel.

(b) $$K_n=(0.716)\left(1.6\times10^{-13}\text{ J}\right)=\boxed{1.15\times10^{-13}\text{ J}}$$

$$K_C=(0.284)\left(1.6\times10^{-13}\text{ J}\right)=\boxed{4.54\times10^{-14}\text{ J}}$$

Then, either (1) or (2) gives $V=\boxed{2.88\text{ m/s}}$

(c) $$K_i=\frac{1}{2}(90.0\text{ kg})(5.00\text{ m/s})^2+\frac{1}{2}(95.0\text{ kg})(3.00\text{ m/s})^2=1.55\times10^3\text{ J}$$

$$K_f=\frac{1}{2}(185\text{ kg})(2.88\text{ m/s})^2=7.67\times10^2\text{ J}$$

Thus, the kinetic energy lost is $\boxed{786\text{ J into internal energy}}$.

P9.27 By conservation of momentum for the system of the two billiard balls (with all masses equal), in the x and y directions separately,

$$5.00\text{ m/s}+0=(4.33\text{ m/s})\cos30.0°+v_{2fx}$$

$$v_{2fx}=1.25\text{ m/s}$$

$$0=(4.33\text{ m/s})\sin30.0°+v_{2fy}$$

$$v_{2fy}=-2.16\text{ m/s}$$

$$\vec{\mathbf{v}}_{2f}=\boxed{2.50\text{ m/s at }-60.0°}$$

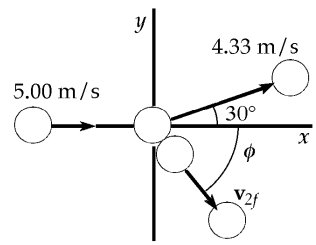

FIG. P9.27

P9.31 $m_1\vec{\mathbf{v}}_{1i}+m_2\vec{\mathbf{v}}_{2i}=(m_1+m_2)\vec{\mathbf{v}}_f$: $3.00(5.00)\hat{\mathbf{i}}-6.00\hat{\mathbf{j}}=5.00\vec{\mathbf{v}}$

$$\vec{\mathbf{v}}=\boxed{\left(3.00\hat{\mathbf{i}}-1.20\hat{\mathbf{j}}\right)\text{ m/s}}$$

P9.33 $m_0=17.0\times10^{-27}\text{ kg}$ $\vec{\mathbf{v}}_i=0$ (the parent nucleus)

$m_1=5.00\times10^{-27}\text{ kg}$ $\vec{\mathbf{v}}_1=6.00\times10^6\hat{\mathbf{j}}\text{ m/s}$

$m_2=8.40\times10^{-27}\text{ kg}$ $\vec{\mathbf{v}}_2=4.00\times10^6\hat{\mathbf{i}}\text{ m/s}$

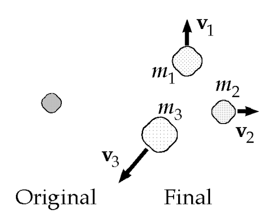

FIG. P9.33

(a) $m_1\vec{\mathbf{v}}_1+m_2\vec{\mathbf{v}}_2+m_3\vec{\mathbf{v}}_3=0$

where $m_3=m_0-m_1-m_2=3.60\times10^{-27}\text{ kg}$

$$\left(5.00\times10^{-27}\right)\left(6.00\times10^6\hat{\mathbf{j}}\right)+\left(8.40\times10^{-27}\right)\left(4.00\times10^6\hat{\mathbf{i}}\right)+\left(3.60\times10^{-27}\right)\vec{\mathbf{v}}_3=0$$

$$\vec{\mathbf{v}}_3=\boxed{\left(-9.33\times10^6\hat{\mathbf{i}}-8.33\times10^6\hat{\mathbf{j}}\right)\text{ m/s}}$$

(b) $$E=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2+\frac{1}{2}m_3v_3^2$$

$$E=\frac{1}{2}\left[\left(5.00\times10^{-27}\right)\left(6.00\times10^{6}\right)^2+\left(8.40\times10^{-27}\right)\left(4.00\times10^{6}\right)^2+\left(3.60\times10^{-27}\right)\left(12.5\times10^{6}\right)^2\right]$$

$$\boxed{E=4.39\times10^{-13}\text{ J}}$$