Chapter 1

عمل وانشاء :

مالك

تنقيح وتدقيق :

رياض

مؤيد

نواف

13. The position of a particle moving under uniform acceleration is some function of time and the acceleration. Suppose we write this position $s = ka^m t^n$, where k is a dimensionless constant. Show by dimensional analysis that this expression is satisfied if $m = 1$ and $n = 2$. Can this analysis give the value of k?

15. Which of the following equations are dimensionally correct?

(a) $v_f = v_i + ax$

(b) $y = (2\ \text{m})\cos(kx)$, where $k = 2\ \text{m}^{-1}$.

21. A rectangular building lot is 100 ft by 150 ft. Determine the area of this lot in m^2.

25. A solid piece of lead has a mass of 23.94 g and a volume of 2.10 cm^3. From these data, calculate the density of lead in SI units (kg/m^3).

31. One gallon of paint (volume $= 3.78 \times 10^{-3}\ \mathrm{m}^3$) covers an area of $25.0\ \mathrm{m}^2$. What is the thickness of the paint on the wall?

P1.13 The term x has dimensions of L, a has dimensions of LT^{-2}, and t has dimensions of T. Therefore, the equation $x = ka^m t^n$ has dimensions of

$$L = \left(LT^{-2}\right)^m (T)^n \text{ or } L^1T^0 = L^m T^{n-2m}.$$

P1.15 (a) $\boxed{\text{This is incorrect}}$ since the units of $[ax]$ are m^2/s^2, while the units of $[v]$ are m/s.

(b) $\boxed{\text{This is correct}}$ since the units of $[y]$ are m, and $\cos(kx)$ is dimensionless if $[k]$ is in m^{-1}.

P1.21 *Conceptualize*: We must calculate the area and convert units. Since a meter is about 3 feet, we should expect the area to be about $A \approx (30\text{ m})(50\text{ m}) = 1\,500\text{ m}^2$.

Categorize: We model the lot as a perfect rectangle to use Area = Length × Width. Use the conversion: $1\text{ m} = 3.281\text{ ft}$.

Analyze: $A = LW = (100\text{ ft})\left(\frac{1\text{ m}}{3.281\text{ ft}}\right)(150\text{ ft})\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 1\,390\text{ m}^2 = \boxed{1.39 \times 10^3\text{ m}^2}$.

Finalize: Our calculated result agrees reasonably well with our initial estimate and has the proper units of m^2. Unit conversion is a common technique that is applied to many problems.

P1.25 From Table 1.5, the density of lead is $1.13 \times 10^4\text{ kg/m}^3$, so we should expect our calculated value to be close to this number. This density value tells us that lead is about 11 times denser than water, which agrees with our experience that lead sinks.

Density is defined as mass per volume, in $\rho = \frac{m}{V}$. We must convert to SI units in the calculation.

$$\rho = \frac{23.94\text{ g}}{2.10\text{ cm}^3}\left(\frac{1\text{ kg}}{1\,000\text{ g}}\right)\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3 = \boxed{1.14 \times 10^4\text{ kg/m}^3}$$

At one step in the calculation, we note that *one million* cubic centimeters make one cubic meter. Our result is indeed close to the expected value. Since the last reported significant digit is not certain, the difference in the two values is probably due to measurement uncertainty and should not be a concern. One important common-sense check on density values is that objects which sink in water must have a density greater than 1 g/cm^3, and objects that float must be less dense than water.

P1.31 $V = At$ so $t = \frac{V}{A} = \frac{3.78 \times 10^{-3}\text{ m}^3}{25.0\text{ m}^2} = \boxed{1.51 \times 10^{-4}\text{ m (or 151 } \mu\text{m)}}$

Chapter 2

4. A particle moves according to the equation $x = 10t^2$ where x is in meters and t is in seconds. (a) Find the average velocity for the time interval from 2.00 s to 3.00 s. (b) Find the average velocity for the time interval from 2.00 to 2.10 s.

5. A person walks first at a constant speed of 5.00 m/s along a straight line from point A to point B and then back along the line from B to A at a constant speed of 3.00 m/s. What is (a) her average speed over the entire trip? (b) her average velocity over the entire trip?

11. A 50.0-g superball traveling at 25.0 m/s bounces off a brick wall and rebounds at 22.0 m/s. A high-speed camera records this event. If the ball is in contact with the wall for 3.50 ms, what is the magnitude of the average acceleration of the ball during this time interval? (*Note:* 1 ms = 10^{-3} s.)

15. A particle moves along the x axis according to the equation $x = 2.00 + 3.00t - 1.00t^2$, where x is in meters and t is in seconds. At $t = 3.00$ s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

16. An object moves along the x axis according to the equation $x(t) = (3.00t^2 - 2.00t + 3.00)$ m. Determine (a) the average speed between $t = 2.00$ s and $t = 3.00$ s, (b) the instantaneous speed at $t = 2.00$ s and at $t = 3.00$ s, (c) the average acceleration between $t = 2.00$ s and $t = 3.00$ s, and (d) the instantaneous acceleration at $t = 2.00$ s and $t = 3.00$ s.

20. A truck covers 40.0 m in 8.50 s while smoothly slowing down to a final speed of 2.80 m/s. (a) Find its original speed. (b) Find its acceleration.

21. An object moving with uniform acceleration has a velocity of 12.0 cm/s in the positive x direction when its x coordinate is 3.00 cm. If its x coordinate 2.00 s later is -5.00 cm, what is its acceleration?

22. A 745i BMW car can brake to a stop in a distance of 121 ft. from a speed of 60.0 mi/h. To brake to a stop from a speed of 80.0 mi/h requires a stopping distance of 211 ft. What is the average braking acceleration for (a) 60 mi/h to rest, (b) 80 mi/h to rest, (c) 80 mi/h to 60 mi/h? Express the answers in mi/h/s and in m/s^2.

23. A speedboat moving at 30.0 m/s approaches a no-wake buoy marker 100 m ahead. The pilot slows the boat with a constant acceleration of $-3.50\ \mathrm{m/s^2}$ by reducing the throttle. (a) How long does it take the boat to reach the buoy? (b) What is the velocity of the boat when it reaches the buoy?

25. A particle moves along the x axis. Its position is given by the equation $x = 2 + 3t - 4t^2$ with x in meters and t in seconds. Determine (a) its position when it changes direction and (b) its velocity when it returns to the position it had at $t = 0$.

27. A jet plane lands with a speed of 100 m/s and can accelerate at a maximum rate of $-5.00\ \mathrm{m/s^2}$ as it comes to rest. (a) From the instant the plane touches the runway, what is the minimum time interval needed before it can come to rest? (b) Can this plane land on a small tropical island airport where the runway is 0.800 km long?

28. A car is approaching a hill at 30.0 m/s when its engine suddenly fails just at the bottom of the hill. The car moves with a constant acceleration of $-2.00\ \mathrm{m/s^2}$ while coasting up the hill. (a) Write equations for the position along the slope and for the velocity as functions of time, taking $x = 0$ at the bottom of the hill, where $v_i = 30.0$ m/s. (b) Determine the maximum distance the car rolls up the hill.

29. The driver of a car slams on the brakes when he sees a tree blocking the road. The car slows uniformly with an acceleration of $-5.60\ \mathrm{m/s^2}$ for 4.20 s, making straight skid marks 62.4 m long ending at the tree. With what speed does the car then strike the tree?

32. A truck on a straight road starts from rest, accelerating at $2.00\ m/s^2$ until it reaches a speed of $20.0\ m/s$. Then the truck travels for 20.0 s at constant speed until the brakes are applied, stopping the truck in a uniform manner in an additional 5.00 s. (a) How long is the truck in motion? (b) What is the average velocity of the truck for the motion described?

33. An electron in a cathode ray tube (CRT) accelerates from 2.00×10^4 m/s to 6.00×10^6 m/s over 1.50 cm. (a) How long does the electron take to travel this 1.50 cm? (b) What is its acceleration?

40. A golf ball is released from rest from the top of a very tall building. Neglecting air resistance, calculate (a) the position and (b) the velocity of the ball after 1.00, 2.00, and 3.00 s.

Note: In all problems in this section, ignore the effects of air resistance.

42. A ball is thrown directly downward, with an initial speed of 8.00 m/s, from a height of 30.0 m. After what time interval does the ball strike the ground?

43. A student throws a set of keys vertically upward to her sorority sister, who is in a window 4.00 m above. The keys are caught 1.50 s later by the sister's outstretched hand. (a) With what initial velocity were the keys thrown? (b) What was the velocity of the keys just before they were caught?

46. A ball is dropped from rest from a height h above the ground. Another ball is thrown vertically upwards from the ground at the instant the first ball is released. Determine the speed of the second ball if the two balls are to meet at a height $h/2$ above the ground.

48. It is possible to shoot an arrow at a speed as high as 100 m/s. (a) If friction is neglected, how high would an arrow launched at this speed rise if shot straight up? (b) How long would the arrow be in the air?

51. The height of a helicopter above the ground is given by $h = 3.00t^3$, where h is in meters and t is in seconds. After 2.00 s, the helicopter releases a small mailbag. How long after its release does the mailbag reach the ground?

52. A freely falling object requires 1.50 s to travel the last 30.0 m before it hits the ground. From what height above the ground did it fall?

P2.4 $x = 10t^2$: For

$t(\text{s})$	=	2.0	2.1	3.0
$x(\text{m})$	=	40	44.1	90

(a) $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{50\text{ m}}{1.0\text{ s}} = \boxed{50.0\text{ m/s}}$

(b) $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{4.1\text{ m}}{0.1\text{ s}} = \boxed{41.0\text{ m/s}}$

P2.5 (a) Let d represent the distance between A and B. Let t_1 be the time for which the walker has the higher speed in $5.00\text{ m/s} = \dfrac{d}{t_1}$. Let t_2 represent the longer time for the return trip in $-3.00\text{ m/s} = -\dfrac{d}{t_2}$. Then the times are $t_1 = \dfrac{d}{(5.00\text{ m/s})}$ and $t_2 = \dfrac{d}{(3.00\text{ m/s})}$. The average speed is:

$$\bar{v} = \frac{\text{Total distance}}{\text{Total time}} = \frac{d+d}{\frac{d}{(5.00\text{ m/s})} + \frac{d}{(3.00\text{ m/s})}} = \frac{2d}{\frac{(8.00\text{ m/s})d}{(15.0\text{ m}^2/\text{s}^2)}}$$

$$\bar{v} = \frac{2(15.0\text{ m}^2/\text{s}^2)}{8.00\text{ m/s}} = \boxed{3.75\text{ m/s}}$$

P2.11 Choose the positive direction to be the outward direction, perpendicular to the wall.

$$v_f = v_i + at : a = \frac{\Delta v}{\Delta t} = \frac{22.0\text{ m/s} - (-25.0\text{ m/s})}{3.50\times10^{-3}\text{ s}} = \boxed{1.34\times10^4\text{ m/s}^2}.$$

P2.15 $x = 2.00 + 3.00t - t^2$, $v = \dfrac{dx}{dt} = 3.00 - 2.00t$, $a = \dfrac{dv}{dt} = -2.00$

At $t = 3.00$ s:

(a) $x = (2.00 + 9.00 - 9.00)\text{ m} = \boxed{2.00\text{ m}}$

(b) $v = (3.00 - 6.00)\text{ m/s} = \boxed{-3.00\text{ m/s}}$

(c) $a = \boxed{-2.00\text{ m/s}^2}$

P2.16 (a) At $t = 2.00$ s, $x = \left[3.00(2.00)^2 - 2.00(2.00) + 3.00\right]\text{ m} = 11.0\text{ m}$.

At $t = 3.00$ s, $x = \left[3.00(9.00)^2 - 2.00(3.00) + 3.00\right]\text{ m} = 24.0\text{ m}$

so

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{24.0\text{ m} - 11.0\text{ m}}{3.00\text{ s} - 2.00\text{ s}} = \boxed{13.0\text{ m/s}}.$$

(b) At all times the instantaneous velocity is

$$v = \frac{d}{dt}(3.00t^2 - 2.00t + 3.00) = (6.00t - 2.00)\text{ m/s}$$

At $t = 2.00$ s, $v = [6.00(2.00) - 2.00]\text{ m/s} = \boxed{10.0\text{ m/s}}$.
At $t = 3.00$ s, $v = [6.00(3.00) - 2.00]\text{ m/s} = \boxed{16.0\text{ m/s}}$.

(c) $\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{16.0\text{ m/s} - 10.0\text{ m/s}}{3.00\text{ s} - 2.00\text{ s}} = \boxed{6.00\text{ m/s}^2}$

(d) At all times $a = \dfrac{d}{dt}(6.00 - 2.00) = \boxed{6.00\text{ m/s}^2}$. (This includes both $t = 2.00$ s and $t = 3.00$ s).

P2.20 (a) $x_f - x_i = \dfrac{1}{2}(v_i + v_f)t$ becomes $40\text{ m} = \dfrac{1}{2}(v_i + 2.80\text{ m/s})(8.50\text{ s})$ which yields $v_i = \boxed{6.61\text{ m/s}}$.

(b) $a = \dfrac{v_f - v_i}{t} = \dfrac{2.80\text{ m/s} - 6.61\text{ m/s}}{8.50\text{ s}} = \boxed{-0.448\text{ m/s}^2}$

P2.21 Given $v_i = 12.0$ cm/s when $x_i = 3.00\text{ cm}(t = 0)$, and at $t = 2.00$ s, $x_f = -5.00$ cm,

$$x_f - x_i = v_i t + \frac{1}{2}at^2 : -5.00 - 3.00 = 12.0(2.00) + \frac{1}{2}a(2.00)^2$$

$$-8.00 = 24.0 + 2a \qquad a = -\frac{32.0}{2} = \boxed{-16.0\text{ cm/s}^2}.$$

***P2.22** (a) Let i be the state of moving at 60 mi/h and f be at rest

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$$

$$0 = (60\ \text{mi/h})^2 + 2a_x(121\ \text{ft} - 0)\left(\frac{1\ \text{mi}}{5\,280\ \text{ft}}\right)$$

$$a_x = \frac{-3\,600\ \text{mi}}{242\ \text{h}^2}\left(\frac{5\,280\ \text{ft}}{1\ \text{mi}}\right)\left(\frac{1\ \text{h}}{3\,600\ \text{s}}\right) = \boxed{-21.8\ \text{mi/h}\cdot\text{s}}$$

$$= -21.8\ \text{mi/h}\cdot\text{s}\left(\frac{1\,609\ \text{m}}{1\ \text{mi}}\right)\left(\frac{1\ \text{h}}{3\,600\ \text{s}}\right) = \boxed{-9.75\ \text{m/s}^2}.$$

(b) Similarly,

$$0 = (80\ \text{mi/h})^2 + 2a_x(211\ \text{ft} - 0)$$

$$a_x = -\frac{6\,400(5\,280)}{422(3\,600)}\ \text{mi/h}\cdot\text{s} = \boxed{-22.2\ \text{mi/h}\cdot\text{s} = -9.94\ \text{m/s}^2}.$$

(c) Let i be moving at 80 mi/h and f be moving at 60 mi/h.

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$$

$$(60\ \text{mi/h})^2 = (80\ \text{mi/h})^2 + 2a_x(211\ \text{ft} - 121\ \text{ft})$$

$$a_x = -\frac{2\,800(5\,280)}{2(90)(3\,600)}\ \text{mi/h}\cdot\text{s} = \boxed{-22.8\ \text{mi/h}\cdot\text{s} = -10.2\ \text{m/s}^2}.$$

***P2.23** (a) Choose the initial point where the pilot reduces the throttle and the final point where the boat passes the buoy:

$$x_i = 0,\ x_f = 100\ \text{m},\ v_{xi} = 30\ \text{m/s},\ v_{xf} = ?,\ a_x = -3.5\ \text{m/s}^2,\ t = ?$$

$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$:

$$100\ \text{m} = 0 + (30\ \text{m/s})t + \frac{1}{2}(-3.5\ \text{m/s}^2)t^2$$

$$(1.75\ \text{m/s}^2)t^2 - (30\ \text{m/s})t + 100\ \text{m} = 0.$$

We use the quadratic formula:

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{30\ \text{m/s} \pm \sqrt{900\ \text{m}^2/\text{s}^2 - 4(1.75\ \text{m/s}^2)(100\ \text{m})}}{2(1.75\ \text{m/s}^2)} = \frac{30\ \text{m/s} \pm 14.1\ \text{m/s}}{3.5\ \text{m/s}^2} = 12.6\ \text{s or } \boxed{4.53\ \text{s}}.$$

The smaller value is the physical answer. If the boat kept moving with the same acceleration, it would stop and move backward, then gain speed, and pass the buoy again at 12.6 s.

(b) $v_{xf} = v_{xi} + a_x t = 30\ \text{m/s} - (3.5\ \text{m/s}^2)4.53\ \text{s} = \boxed{14.1\ \text{m/s}}$

P2.25 (a) Compare the position equation $x = 2.00 + 3.00t - 4.00t^2$ to the general form

$$x_f = x_i + v_i t + \frac{1}{2}at^2$$

to recognize that $x_i = 2.00$ m, $v_i = 3.00$ m/s, and $a = -8.00\ \text{m/s}^2$. The velocity equation, $v_f = v_i + at$, is then

$$v_f = 3.00\ \text{m/s} - (8.00\ \text{m/s}^2)t.$$

The particle changes direction when $v_f = 0$, which occurs at $t = \frac{3}{8}$ s. The position at this time is:

$$x = 2.00\ \text{m} + (3.00\ \text{m/s})\left(\frac{3}{8}\ \text{s}\right) - (4.00\ \text{m/s}^2)\left(\frac{3}{8}\ \text{s}\right)^2 = \boxed{2.56\ \text{m}}.$$

(b) From $x_f = x_i + v_i t + \frac{1}{2}at^2$, observe that when $x_f = x_i$, the time is given by $t = -\frac{2v_i}{a}$. Thus, when the particle returns to its initial position, the time is

$$t = \frac{-2(3.00\ \text{m/s})}{-8.00\ \text{m/s}^2} = \frac{3}{4}\ \text{s}$$

and the velocity is $v_f = 3.00\ \text{m/s} - (8.00\ \text{m/s}^2)\left(\frac{3}{4}\ \text{s}\right) = \boxed{-3.00\ \text{m/s}}$.

P2.27 (a) $v_i = 100$ m/s, $a = -5.00\ \text{m/s}^2$, $v_f = v_i + at$ so $0 = 100 - 5t$, $v_f^2 = v_i^2 + 2a(x_f - x_i)$ so $0 = (100)^2 - 2(5.00)(x_f - 0)$. Thus $x_f = 1\,000$ m and $t = \boxed{20.0\ \text{s}}$.

(b) At this acceleration the plane would overshoot the runway: $\boxed{\text{No}}$.

P2.28 (a) Take $t_i = 0$ at the bottom of the hill where $x_i = 0$, $v_i = 30.0\ \text{m/s}$, $a = -2.00\ \text{m/s}^2$. Use these values in the general equation

$$x_f = x_i + v_i t + \frac{1}{2}at^2$$

to find

$$x_f = 0 + (30.0t\ \text{m/s}) + \frac{1}{2}(-2.00\ \text{m/s}^2)t^2$$

when t is in seconds

$$\boxed{x_f = (30.0t - t^2)\ \text{m}}.$$

To find an equation for the velocity, use $v_f = v_i + at = 30.0\ \text{m/s} + (-2.00\ \text{m/s}^2)t$,

$$\boxed{v_f = (30.0 - 2.00t)\ \text{m/s}}.$$

(b) The distance of travel x_f becomes a maximum, $x_{\max}$, when $v_f = 0$ (turning point in the motion). Use the expressions found in part (a) for v_f to find the value of t when x_f has its maximum value:

From $v_f = (3.00 - 2.00t)\ \text{m/s}$, $v_f = 0$ when $t = 15.0\ \text{s}$. Then

$$x_{\max} = (30.0t - t^2)\ \text{m} = (30.0)(15.0) - (15.0)^2 = \boxed{225\ \text{m}}.$$

P2.29 In the simultaneous equations:

$$\begin{Bmatrix} v_{xf} = v_{xi} + a_x t \\ x_f - x_i = \frac{1}{2}(v_{xi} + v_{xf})t \end{Bmatrix} \text{ we have } \begin{Bmatrix} v_{xf} = v_{xi} - (5.60\ \text{m/s}^2)(4.20\ \text{s}) \\ 62.4\ \text{m} = \frac{1}{2}(v_{xi} + v_{xf})(4.20\ \text{s}) \end{Bmatrix}.$$

So substituting for v_{xi} gives $62.4\ \text{m} = \frac{1}{2}\left[v_{xf} + (56.0\ \text{m/s}^2)(4.20\ \text{s}) + v_{xf}\right](4.20\ \text{s})$

$$14.9\ \text{m/s} = v_{xf} + \frac{1}{2}(5.60\ \text{m/s}^2)(4.20\ \text{s}).$$

Thus

$$v_{xf} = \boxed{3.10\ \text{m/s}}.$$

P2.32 (a) The time it takes the truck to reach $20.0\ \text{m/s}$ is found from $v_f = v_i + at$. Solving for t yields

$$t = \frac{v_f - v_i}{a} = \frac{20.0\ \text{m/s} - 0\ \text{m/s}}{2.00\ \text{m/s}^2} = 10.0\ \text{s}.$$

The total time is thus

$$10.0\ \text{s} + 20.0\ \text{s} + 5.00\ \text{s} = \boxed{35.0\ \text{s}}.$$

(b) The average velocity is the total distance traveled divided by the total time taken. The distance traveled during the first 10.0 s is

$$x_1 = \bar{v}t = \left(\frac{0 + 20.0}{2}\right)(10.0) = 100\ \text{m}.$$

With a being 0 for this interval, the distance traveled during the next 20.0 s is

$$x_2 = v_i t + \frac{1}{2}at^2 = (20.0)(20.0) + 0 = 400\ \text{m}.$$

The distance traveled in the last 5.00 s is

$$x_3 = \bar{v}t = \left(\frac{20.0 + 0}{2}\right)(5.00) = 50.0\ \text{m}.$$

The total distance $x = x_1 + x_2 + x_3 = 100 + 400 + 50 = 550\ \text{m}$, and the average velocity is given by $\bar{v} = \frac{x}{t} = \frac{550}{35.0} = \boxed{15.7\ \text{m/s}}$.

P2.33 We have $v_i = 2.00 \times 10^4\ \text{m/s}$, $v_f = 6.00 \times 10^6\ \text{m/s}$, $x_f - x_i = 1.50 \times 10^{-2}\ \text{m}$.

(a) $x_f - x_i = \frac{1}{2}(v_i + v_f)t : t = \frac{2(x_f - x_i)}{v_i + v_f} = \frac{2(1.50 \times 10^{-2}\ \text{m})}{2.00 \times 10^4\ \text{m/s} + 6.00 \times 10^6\ \text{m/s}} = \boxed{4.98 \times 10^{-9}\ \text{s}}$

(b) $v_f^2 = v_i^2 + 2a_x(x_f - x_i)$:

$$a_x = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{(6.00 \times 10^6\ \text{m/s})^2 - (2.00 \times 10^4\ \text{m/s})^2}{2(1.50 \times 10^{-2}\ \text{m})} = \boxed{1.20 \times 10^{15}\ \text{m/s}^2}$$

P2.40 Choose the origin ($y = 0$, $t = 0$) at the starting point of the ball and take upward as positive. Then $y_i = 0$, $v_i = 0$, and $a = -g = -9.80\ \text{m/s}^2$. The position and the velocity at time t become:

$$y_f - y_i = v_i t + \frac{1}{2}at^2 : y_f = -\frac{1}{2}gt^2 = -\frac{1}{2}(9.80\ \text{m/s}^2)t^2$$

and

$$v_f = v_i + at : v_f = -gt = -(9.80\ \text{m/s}^2)t.$$

(a) at $t = 1.00\ \text{s}$: $y_f = -\frac{1}{2}(9.80\ \text{m/s}^2)(1.00\ \text{s})^2 = \boxed{-4.90\ \text{m}}$

at $t = 2.00\ \text{s}$: $y_f = -\frac{1}{2}(9.80\ \text{m/s}^2)(2.00\ \text{s})^2 = \boxed{-19.6\ \text{m}}$

at $t = 3.00\ \text{s}$: $y_f = -\frac{1}{2}(9.80\ \text{m/s}^2)(3.00\ \text{s})^2 = \boxed{-44.1\ \text{m}}$

(b) at $t = 1.00\ \text{s}$: $v_f = -(9.80\ \text{m/s}^2)(1.00\ \text{s}) = \boxed{-9.80\ \text{m/s}}$

at $t = 2.00\ \text{s}$: $v_f = -(9.80\ \text{m/s}^2)(2.00\ \text{s}) = \boxed{-19.6\ \text{m/s}}$

at $t = 3.00\ \text{s}$: $v_f = -(9.80\ \text{m/s}^2)(3.00\ \text{s}) = \boxed{-29.4\ \text{m/s}}$

P2.42 We have $y_f = -\frac{1}{2}gt^2 + v_i t + y_i$

$$0 = -\left(4.90\ \text{m/s}^2\right)t^2 - (8.00\ \text{m/s})t + 30.0\ \text{m}.$$

Solving for t,

$$t = \frac{8.00 \pm \sqrt{64.0 + 588}}{-9.80}.$$

Using only the positive value for t, we find that $t = \boxed{1.79\ \text{s}}$.

P2.43 (a) $y_f - y_i = v_i t + \frac{1}{2}at^2$: $4.00 = (1.50)v_i - (4.90)(1.50)^2$ and $v_i = \boxed{10.0\ \text{m/s upward}}$.

(b) $v_f = v_i + at = 10.0 - (9.80)(1.50) = -4.68\ \text{m/s}$

$$v_f = \boxed{4.68\ \text{m/s downward}}$$

P2.46 At any time t, the position of the ball released from rest is given by $y_1 = h - \frac{1}{2}gt^2$. At time t, the position of the ball thrown vertically upward is described by $y_2 = v_i t - \frac{1}{2}gt^2$. The time at which the first ball has a position of $y_1 = \frac{h}{2}$ is found from the first equation as $\frac{h}{2} = h - \frac{1}{2}gt^2$, which yields $t = \sqrt{\frac{h}{g}}$. To require that the second ball have a position of $y_2 = \frac{h}{2}$ at this time, use the second equation to obtain $\frac{h}{2} = v_i\sqrt{\frac{h}{g}} - \frac{1}{2}g\left(\frac{h}{g}\right)$. This gives the required initial upward velocity of the second ball as $\boxed{v_i = \sqrt{gh}}$.

***P2.48** (a) Consider the upward flight of the arrow.

$$v_{yf}^2 = v_{yi}^2 + 2a_y\left(y_f - y_i\right)$$
$$0 = \left(100\ \text{m/s}\right)^2 + 2\left(-9.8\ \text{m/s}^2\right)\Delta y$$
$$\Delta y = \frac{10\,000\ \text{m}^2/\text{s}^2}{19.6\ \text{m/s}^2} = \boxed{510\ \text{m}}$$

(b) Consider the whole flight of the arrow.

$$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
$$0 = 0 + (100\ \text{m/s})t + \frac{1}{2}\left(-9.8\ \text{m/s}^2\right)t^2$$

The root $t = 0$ refers to the starting point. The time of flight is given by

$$t = \frac{100\ \text{m/s}}{4.9\ \text{m/s}^2} = \boxed{20.4\ \text{s}}.$$

P2.51 $y = 3.00t^3$: At $t = 2.00\ \text{s}$, $y = 3.00(2.00)^3 = 24.0\ \text{m}$ and

$$v_y = \frac{dy}{dt} = 9.00t^2 = 36.0\ \text{m/s}\uparrow.$$

If the helicopter releases a small mailbag at this time, the equation of motion of the mailbag is

$$y_b = y_{bi} + v_i t - \frac{1}{2}gt^2 = 24.0 + 36.0t - \frac{1}{2}(9.80)t^2.$$

Setting $y_b = 0$,

$$0 = 24.0 + 36.0t - 4.90t^2.$$

Solving for t, (only positive values of t count), $\boxed{t = 7.96\ \text{s}}$.

***P2.52** Consider the last 30 m of fall. We find its speed 30 m above the ground:

$$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
$$0 = 30\ \text{m} + v_{yi}(1.5\ \text{s}) + \frac{1}{2}\left(-9.8\ \text{m/s}^2\right)(1.5\ \text{s})^2$$
$$v_{yi} = \frac{-30\ \text{m} + 11.0\ \text{m}}{1.5\ \text{s}} = -12.6\ \text{m/s}.$$

Now consider the portion of its fall above the 30 m point. We assume it starts from rest

$$v_{yf}^2 = v_{yi}^2 + 2a_y\left(y_f - y_i\right)$$
$$\left(-12.6\ \text{m/s}\right)^2 = 0 + 2\left(-9.8\ \text{m/s}^2\right)\Delta y$$
$$\Delta y = \frac{160\ \text{m}^2/\text{s}^2}{-19.6\ \text{m/s}^2} = -8.16\ \text{m}.$$

Its original height was then $30\ \text{m} + \left|-8.16\ \text{m}\right| = \boxed{38.2\ \text{m}}$.

Chapter 3

1. The polar coordinates of a point are $r = 5.50$ m and $\theta = 240°$. What are the Cartesian coordinates of this point?

4. Two points in the *xy* plane have Cartesian coordinates (2.00, − 4.00) m and (− 3.00, 3.00) m. Determine (a) the distance between these points and (b) their polar coordinates.

19. A vector has an x component of -25.0 units and a y component of 40.0 units. Find the magnitude and direction of this vector.

21. Obtain expressions in component form for the position vectors having the following polar coordinates: (a) 12.8 m, 150° (b) 3.30 cm, 60.0° (c) 22.0 in., 215°.

27. Given the vectors $\mathbf{A} = 2.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}$ and $\mathbf{B} = 3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}$, (a) draw the vector sum $\mathbf{C} = \mathbf{A} + \mathbf{B}$ and the vector difference $\mathbf{D} = \mathbf{A} - \mathbf{B}$. (b) Calculate $\mathbf{C}$ and $\mathbf{D}$, first in terms of unit vectors and then in terms of polar coordinates, with angles measured with respect to the $+x$ axis.

30. Vector **A** has x and y components of -8.70 cm and 15.0 cm, respectively; vector **B** has x and y components of 13.2 cm and -6.60 cm, respectively. If $\mathbf{A} - \mathbf{B} + 3\mathbf{C} = 0$, what are the components of **C**?

31. Consider the two vectors $\mathbf{A} = 3\hat{\mathbf{i}} - 2\hat{\mathbf{j}}$ and $\mathbf{B} = -\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$. Calculate (a) $\mathbf{A} + \mathbf{B}$, (b) $\mathbf{A} - \mathbf{B}$, (c) $|\mathbf{A} + \mathbf{B}|$, (d) $|\mathbf{A} - \mathbf{B}|$, and (e) the directions of $\mathbf{A} + \mathbf{B}$ and $\mathbf{A} - \mathbf{B}$.

33. A particle undergoes the following consecutive displacements: 3.50 m south, 8.20 m northeast, and 15.0 m west. What is the resultant displacement?

39. Vector **B** has x, y, and z components of 4.00, 6.00, and 3.00 units, respectively. Calculate the magnitude of **B** and the angles that **B** makes with the coordinate axes.

49. Three displacement vectors of a croquet ball are shown in Figure P3.49, where $|\mathbf{A}| = 20.0$ units, $|\mathbf{B}| = 40.0$ units, and $|\mathbf{C}| = 30.0$ units. Find (a) the resultant in unit–vector notation and (b) the magnitude and direction of the resultant displacement.

Figure P3.49

50. If $\mathbf{A} = (6.00\hat{\mathbf{i}} - 8.00\hat{\mathbf{j}})$ units, $\mathbf{B} = (-8.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}})$ units, and $\mathbf{C} = (26.0\hat{\mathbf{i}} + 19.0\hat{\mathbf{j}})$ units, determine a and b such that $a\mathbf{A} + b\mathbf{B} + \mathbf{C} = 0$.

P3.1 $x = r\cos\theta = (5.50\text{ m})\cos 240° = (5.50\text{ m})(-0.5) = \boxed{-2.75\text{ m}}$

$y = r\sin\theta = (5.50\text{ m})\sin 240° = (5.50\text{ m})(-0.866) = \boxed{-4.76\text{ m}}$

P3.4 (a) $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} = \sqrt{(2.00 - [-3.00])^2 + (-4.00 - 3.00)^2}$

$d = \sqrt{25.0 + 49.0} = \boxed{8.60\text{ m}}$

(b) $r_1 = \sqrt{(2.00)^2 + (-4.00)^2} = \sqrt{20.0} = \boxed{4.47\text{ m}}$

$\theta_1 = \tan^{-1}\left(-\frac{4.00}{2.00}\right) = \boxed{-63.4°}$

$r_2 = \sqrt{(-3.00)^2 + (3.00)^2} = \sqrt{18.0} = \boxed{4.24\text{ m}}$

$\theta_2 = \boxed{135°}$ measured from the $+x$ axis.

P3.19 $A_x = -25.0$

$A_y = 40.0$

$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(-25.0)^2 + (40.0)^2} = \boxed{47.2\text{ units}}$

We observe that

$$\tan\phi = \frac{|A_y|}{|A_x|}.$$

FIG. P3.19

So

$$\phi = \tan^{-1}\left(\frac{A_y}{|A_x|}\right) = \tan\frac{40.0}{25.0} = \tan^{-1}(1.60) = 58.0°.$$

The diagram shows that the angle from the $+x$ axis can be found by subtracting from 180°:

$$\theta = 180° - 58° = \boxed{122°}.$$

P3.21 $x = r\cos\theta$ and $y = r\sin\theta$, therefore:

(a) $x = 12.8\cos 150°$, $y = 12.8\sin 150°$, and $(x, y) = \left(-11.1\hat{\mathbf{i}} + 6.40\hat{\mathbf{j}}\right)$ m

(b) $x = 3.30\cos 60.0°$, $y = 3.30\sin 60.0°$, and $(x, y) = \left(1.65\hat{\mathbf{i}} + 2.86\hat{\mathbf{j}}\right)$ cm

(c) $x = 22.0\cos 215°$, $y = 22.0\sin 215°$, and $(x, y) = \left(-18.0\hat{\mathbf{i}} - 12.6\hat{\mathbf{j}}\right)$ in

P3.27 (a) See figure to the right.

(b) $\mathbf{C} = \mathbf{A} + \mathbf{B} = 2.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}} + 3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}} = \boxed{5.00\hat{\mathbf{i}} + 4.00\hat{\mathbf{j}}}$

$\mathbf{C} = \sqrt{25.0 + 16.0}$ at $\tan^{-1}\left(\frac{4}{5}\right) = \boxed{6.40 \text{ at } 38.7°}$

$\mathbf{D} = \mathbf{A} - \mathbf{B} = 2.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}} - 3.00\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}} = \boxed{-1.00\hat{\mathbf{i}} + 8.00\hat{\mathbf{j}}}$

$\mathbf{D} = \sqrt{(-1.00)^2 + (8.00)^2}$ at $\tan^{-1}\left(\frac{8.00}{-1.00}\right)$

$\mathbf{D} = 8.06$ at $(180° - 82.9°) = \boxed{8.06 \text{ at } 97.2°}$

FIG. P3.27

P3.30 $\mathbf{A} = -8.70\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}$ and $\mathbf{B} = 13.2\hat{\mathbf{i}} - 6.60\hat{\mathbf{j}}$

$\mathbf{A} - \mathbf{B} + 3\mathbf{C} = 0$:

$$3\mathbf{C} = \mathbf{B} - \mathbf{A} = 21.9\hat{\mathbf{i}} - 21.6\hat{\mathbf{j}}$$
$$\mathbf{C} = 7.30\hat{\mathbf{i}} - 7.20\hat{\mathbf{j}}$$

or

$$C_x = \boxed{7.30\text{ cm}};\ C_y = \boxed{-7.20\text{ cm}}$$

P3.31 (a) $(\mathbf{A}+\mathbf{B}) = \left(3\hat{\mathbf{i}} - 2\hat{\mathbf{j}}\right) + \left(-\hat{\mathbf{i}} - 4\hat{\mathbf{j}}\right) = \boxed{2\hat{\mathbf{i}} - 6\hat{\mathbf{j}}}$

(b) $(\mathbf{A}-\mathbf{B}) = \left(3\hat{\mathbf{i}} - 2\hat{\mathbf{j}}\right) - \left(-\hat{\mathbf{i}} - 4\hat{\mathbf{j}}\right) = \boxed{4\hat{\mathbf{i}} + 2\hat{\mathbf{j}}}$

(c) $|\mathbf{A}+\mathbf{B}| = \sqrt{2^2 + 6^2} = \boxed{6.32}$

(d) $|\mathbf{A}-\mathbf{B}| = \sqrt{4^2 + 2^2} = \boxed{4.47}$

(e) $\theta_{|\mathbf{A}+\mathbf{B}|} = \tan^{-1}\left(-\frac{6}{2}\right) = -71.6° = \boxed{288°}$

$\theta_{|\mathbf{A}-\mathbf{B}|} = \tan^{-1}\left(\frac{2}{4}\right) = \boxed{26.6°}$

P3.33 $d_1 = \left(-3.50\hat{\mathbf{j}}\right)$ m

$d_2 = 8.20\cos 45.0°\,\hat{\mathbf{i}} + 8.20\sin 45.0°\,\hat{\mathbf{j}} = \left(5.80\hat{\mathbf{i}} + 5.80\hat{\mathbf{j}}\right)$ m

$d_3 = \left(-15.0\hat{\mathbf{i}}\right)$ m

$\mathbf{R} = d_1 + d_2 + d_3 = (-15.0 + 5.80)\hat{\mathbf{i}} + (5.80 - 3.50)\hat{\mathbf{j}} = \boxed{\left(-9.20\hat{\mathbf{i}} + 2.30\hat{\mathbf{j}}\right)\text{ m}}$

(or 9.20 m west and 2.30 m north)

The magnitude of the resultant displacement is

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-9.20)^2 + (2.30)^2} = \boxed{9.48\text{ m}}.$$

The direction is $\theta = \arctan\left(\frac{2.30}{-9.20}\right) = \boxed{166°}$.

P3.39 $\mathbf{B} = B_x\hat{\mathbf{i}} + B_y\hat{\mathbf{j}} + B_z\hat{\mathbf{k}} = 4.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}} + 3.00\hat{\mathbf{k}}$

$|\mathbf{B}| = \sqrt{4.00^2 + 6.00^2 + 3.00^2} = \boxed{7.81}$

$\alpha = \cos^{-1}\left(\frac{4.00}{7.81}\right) = \boxed{59.2°}$

$\beta = \cos^{-1}\left(\frac{6.00}{7.81}\right) = \boxed{39.8°}$

$\gamma = \cos^{-1}\left(\frac{3.00}{7.81}\right) = \boxed{67.4°}$

P3.49 (a) $R_x = 40.0\cos 45.0° + 30.0\cos 45.0° = 49.5$

$R_y = 40.0\sin 45.0° - 30.0\sin 45.0° + 20.0 = 27.1$

$\mathbf{R} = \boxed{49.5\hat{\mathbf{i}} + 27.1\hat{\mathbf{j}}}$

(b) $|\mathbf{R}| = \sqrt{(49.5)^2 + (27.1)^2} = \boxed{56.4}$

$\theta = \tan^{-1}\left(\frac{27.1}{49.5}\right) = \boxed{28.7°}$

FIG. P3.49

P3.50 Taking components along $\hat{\mathbf{i}}$ and $\hat{\mathbf{j}}$, we get two equations:

$$6.00a - 8.00b + 26.0 = 0$$

and

$$-8.00a + 3.00b + 19.0 = 0.$$

Solving simultaneously,

$$\boxed{a = 5.00,\ b = 7.00}.$$

Therefore,

$$5.00\mathbf{A} + 7.00\mathbf{B} + \mathbf{C} = 0.$$

Chapter 4

1. A motorist drives south at 20.0 m/s for 3.00 min, then turns west and travels at 25.0 m/s for 2.00 min, and finally travels northwest at 30.0 m/s for 1.00 min. For this 6.00-min trip, find (a) the total vector displacement, (b) the average speed, and (c) the average velocity. Let the positive x axis point east.

3. When the Sun is directly overhead, a hawk dives toward the ground with a constant velocity of 5.00 m/s at 60.0° below the horizontal. Calculate the speed of her shadow on the level ground.

5. At $t = 0$, a particle moving in the xy plane with constant acceleration has a velocity of $\mathbf{v}_i = (3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}})$ m/s and is at the origin. At $t = 3.00$ s, the particle's velocity is $\mathbf{v} = (9.00\hat{\mathbf{i}} + 7.00\hat{\mathbf{j}})$ m/s. Find (a) the acceleration of the particle and (b) its coordinates at any time t.

6. The vector position of a particle varies in time according to the expression $\mathbf{r} = (3.00\hat{\mathbf{i}} - 6.00t^2\hat{\mathbf{j}})$ m. (a) Find expressions for the velocity and acceleration as functions of time. (b) Determine the particle's position and velocity at $t = 1.00$ s.

8. A particle initially located at the origin has an acceleration of $\mathbf{a} = 3.00\hat{\mathbf{j}}\ \mathrm{m/s^2}$ and an initial velocity of $\mathbf{v}_i = 500\hat{\mathbf{i}}\ \mathrm{m/s}$. Find (a) the vector position and velocity at any time t and (b) the coordinates and speed of the particle at $t = 2.00$ s.

14. An astronaut on a strange planet finds that she can jump a maximum horizontal distance of 15.0 m if her initial speed is 3.00 m/s. What is the free-fall acceleration on the planet?

15. A projectile is fired in such a way that its horizontal range is equal to three times its maximum height. What is the angle of projection?

17. A ball is tossed from an upper-story window of a building. The ball is given an initial velocity of 8.00 m/s at an angle of 20.0° below the horizontal. It strikes the ground 3.00 s later. (a) How far horizontally from the base of the building does the ball strike the ground? (b) Find the height from which the ball was thrown. (c) How long does it take the ball to reach a point 10.0 m below the level of launching?

19. A place-kicker must kick a football from a point 36.0 m (about 40 yards) from the goal, and half the crowd hopes the ball will clear the crossbar, which is 3.05 m high. When kicked, the ball leaves the ground with a speed of 20.0 m/s at an angle of 53.0° to the horizontal. (a) By how much does the ball clear or fall short of clearing the crossbar? (b) Does the ball approach the crossbar while still rising or while falling?

20. A firefighter, a distance d from a burning building, directs a stream of water from a fire hose at angle θ_i above the horizontal as in Figure P4.20. If the initial speed of the stream is v_i, at what height h does the water strike the building?

Frederick McKinney/Getty Images

Figure P4.20

22. A dive bomber has a velocity of 280 m/s at an angle θ below the horizontal. When the altitude of the aircraft is 2.15 km, it releases a bomb, which subsequently hits a target on the ground. The magnitude of the displacement from the point of release of the bomb to the target is 3.25 km. Find the angle θ.

23. A soccer player kicks a rock horizontally off a 40.0-m high cliff into a pool of water. If the player hears the sound of the splash 3.00 s later, what was the initial speed given to the rock? Assume the speed of sound in air to be 343 m/s.

25. An archer shoots an arrow with a velocity of 45.0 m/s at an angle of 50.0° with the horizontal. An assistant standing on the level ground 150 m downrange from the launch point throws an apple straight up with the minimum initial speed necessary to meet the path of the arrow. (a) What is the initial speed of the apple? (b) At what time after the arrow launch should the apple be thrown so that the arrow hits the apple?

29. A tire 0.500 m in radius rotates at a constant rate of 200 rev/min. Find the speed and acceleration of a small stone lodged in the tread of the tire (on its outer edge).

P4.1

$x(m)$	$y(m)$
0	−3 600
−3 000	0
−1 270	1 270
−4 270 m	−2 330 m

FIG. P4.1

(a) Net displacement $= \sqrt{x^2 + y^2}$

$= \boxed{4.87 \text{ km at } 28.6° \text{ S of W}}$

(b) Average speed $= \dfrac{(20.0 \text{ m/s})(180 \text{ s}) + (25.0 \text{ m/s})(120 \text{ s}) + (30.0 \text{ m/s})(60.0 \text{ s})}{180 \text{ s} + 120 \text{ s} + 60.0 \text{ s}} = \boxed{23.3 \text{ m/s}}$

(c) Average velocity $= \dfrac{4.87 \times 10^3 \text{ m}}{360 \text{ s}} = \boxed{13.5 \text{ m/s along } \mathbf{R}}$

***P4.3** The sun projects onto the ground the x-component of her velocity:

$$5.00 \text{ m/s} \cos(-60.0°) = \boxed{2.50 \text{ m/s}}.$$

P4.5 (a) $\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t$

$$\mathbf{a} = \frac{\mathbf{v}_f - \mathbf{v}_i}{t} = \frac{(9.00\hat{\mathbf{i}} + 7.00\hat{\mathbf{j}}) - (3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}})}{3.00} = \boxed{(2.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}}) \text{ m/s}^2}$$

(b) $\mathbf{r}_f = \mathbf{r}_i + \mathbf{v}_i t + \frac{1}{2}\mathbf{a}t^2 = (3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}})t + \frac{1}{2}(2.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}})t^2$

$\boxed{x = (3.00t + t^2) \text{ m}}$ and $\boxed{y = (1.50t^2 - 2.00t) \text{ m}}$

P4.6 (a) $\mathbf{v} = \dfrac{d\mathbf{r}}{dt} = \left(\dfrac{d}{dt}\right)(3.00\hat{\mathbf{i}} - 6.00t^2\hat{\mathbf{j}}) = \boxed{-12.0t\,\hat{\mathbf{j}} \text{ m/s}}$

$\mathbf{a} = \dfrac{d\mathbf{v}}{dt} = \left(\dfrac{d}{dt}\right)(-12.0t\,\hat{\mathbf{j}}) = \boxed{-12.0\hat{\mathbf{j}} \text{ m/s}^2}$

(b) $\boxed{\mathbf{r} = (3.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}) \text{ m};\ \mathbf{v} = -12.0\hat{\mathbf{j}} \text{ m/s}}$

P4.8 $\mathbf{a} = 3.00\hat{\mathbf{j}} \text{ m/s}^2$; $\mathbf{v}_i = 5.00\hat{\mathbf{i}} \text{ m/s}$; $\mathbf{r}_i = 0\hat{\mathbf{i}} + 0\hat{\mathbf{j}}$

(a) $\mathbf{r}_f = \mathbf{r}_i + \mathbf{v}_i t + \frac{1}{2}\mathbf{a}t^2 = \boxed{\left[5.00t\hat{\mathbf{i}} + \frac{1}{2}3.00t^2\hat{\mathbf{j}}\right] \text{ m}}$

$\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t = \boxed{(5.00\hat{\mathbf{i}} + 3.00t\hat{\mathbf{j}}) \text{ m/s}}$

(b) $t = 2.00 \text{ s}$, $\mathbf{r}_f = 5.00(2.00)\hat{\mathbf{i}} + \frac{1}{2}(3.00)(2.00)^2\hat{\mathbf{j}} = (10.0\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}) \text{ m}$

so $x_f = \boxed{10.0 \text{ m}}$, $y_f = \boxed{6.00 \text{ m}}$

$\mathbf{v}_f = 5.00\hat{\mathbf{i}} + 3.00(2.00)\hat{\mathbf{j}} = (5.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}) \text{ m/s}$

$v_f = |\mathbf{v}_f| = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{(5.00)^2 + (6.00)^2} = \boxed{7.81 \text{ m/s}}$

P4.14 From Equation 4.14 with $R = 15.0$ m, $v_i = 3.00$ m/s, $\theta_{max} = 45.0°$

$$\therefore g = \frac{v_i^2}{R} = \frac{9.00}{15.0} = \boxed{0.600 \text{ m/s}^2}$$

P4.15 $h = \dfrac{v_i^2 \sin^2\theta_i}{2g}$; $R = \dfrac{v_i^2(\sin 2\theta_i)}{g}$; $3h = R$,

so $\dfrac{3v_i^2 \sin^2\theta_i}{2g} = \dfrac{v_i^2(\sin 2\theta_i)}{g}$

or $\dfrac{2}{3} = \dfrac{\sin^2\theta_i}{\sin 2\theta_i} = \dfrac{\tan\theta_i}{2}$

thus $\theta_i = \tan^{-1}\left(\dfrac{4}{3}\right) = \boxed{53.1°}$.

P4.17 (a) $x_f = v_{xi}\,t = 8.00\cos 20.0°\,(3.00) = \boxed{22.6\text{ m}}$

(b) Taking y positive downwards,

$$y_f = v_{yi}t + \frac{1}{2}gt^2$$

$$y_f = 8.00\sin 20.0°\,(3.00) + \frac{1}{2}(9.80)(3.00)^2 = \boxed{52.3\text{ m}}.$$

(c) $10.0 = 8.00(\sin 20.0°)t + \frac{1}{2}(9.80)t^2$

$$4.90t^2 + 2.74t - 10.0 = 0$$

$$t = \frac{-2.74 \pm \sqrt{(2.74)^2 + 196}}{9.80} = \boxed{1.18\text{ s}}$$

P4.19 (a) We use the trajectory equation:

$$y_f = x_f \tan\theta_i - \frac{gx_f^2}{2v_i^2\cos^2\theta_i}.$$

With

$$x_f = 36.0\text{ m},\ v_i = 20.0\text{ m/s, and } \theta = 53.0°$$

we find

$$y_f = (36.0\text{ m})\tan 53.0° - \frac{(9.80\text{ m/s}^2)(36.0\text{ m})^2}{2(20.0\text{ m/s})^2\cos^2(53.0°)} = 3.94\text{ m}.$$

The ball clears the bar by

$$(3.94 - 3.05)\text{ m} = \boxed{0.889\text{ m}}.$$

(b) The time the ball takes to reach the maximum height is

$$t_1 = \frac{v_i\sin\theta_i}{g} = \frac{(20.0\text{ m/s})(\sin 53.0°)}{9.80\text{ m/s}^2} = 1.63\text{ s}.$$

The time to travel 36.0 m horizontally is $t_2 = \dfrac{x_f}{v_{ix}}$

$$t_2 = \frac{36.0\text{ m}}{(20.0\text{ m/s})(\cos 53.0°)} = 2.99\text{ s}.$$

Since $t_2 > t_1$ $\boxed{\text{the ball clears the goal on its way down}}$.

P4.20 The horizontal component of displacement is $x_f = v_{xi}t = (v_i\cos\theta_i)t$. Therefore, the time required to reach the building a distance d away is $t = \dfrac{d}{v_i\cos\theta_i}$. At this time, the altitude of the water is

$$y_f = v_{yi}t + \frac{1}{2}a_y t^2 = v_i\sin\theta_i\left(\frac{d}{v_i\cos\theta_i}\right) - \frac{g}{2}\left(\frac{d}{v_i\cos\theta_i}\right)^2.$$

Therefore the water strikes the building at a height h above ground level of

$$h = y_f = \boxed{d\tan\theta_i - \frac{gd^2}{2v_i^2\cos^2\theta_i}}.$$

***P4.22** When the bomb has fallen a vertical distance 2.15 km, it has traveled a horizontal distance x_f given by

$$x_f = \sqrt{(3.25\text{ km})^2 - (2.15\text{ km})^2} = 2.437\text{ km}$$

$$y_f = x_f\tan\theta - \frac{gx_f^2}{2v_i^2\cos^2\theta_i}$$

$$-2\,150\text{ m} = (2\,437\text{ m})\tan\theta_i - \frac{(9.8\text{ m/s}^2)(2\,437\text{ m})^2}{2(280\text{ m/s})^2\cos^2\theta_i}$$

$$\therefore -2\,150\text{ m} = (2\,437\text{ m})\tan\theta_i - (371.19\text{ m})(1 + \tan^2\theta_i)$$

$$\therefore \tan^2\theta - 6.565\tan\theta_i - 4.792 = 0$$

$$\therefore \tan\theta_i = \frac{1}{2}\left(6.565 \pm \sqrt{(6.565)^2 - 4(1)(-4.792)}\right) = 3.283 \pm 3.945.$$

Select the negative solution, since θ_i is below the horizontal.

$$\therefore \tan\theta_i = -0.662,\ \boxed{\theta_i = -33.5°}$$

P4.23 The horizontal kick gives zero vertical velocity to the rock. Then its time of flight follows from

$$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
$$-40.0\text{ m} = 0 + 0 + \frac{1}{2}\left(-9.80\text{ m/s}^2\right)t^2$$
$$t = 2.86\text{ s}.$$

The extra time $3.00\text{ s} - 2.86\text{ s} = 0.143\text{ s}$ is the time required for the sound she hears to travel straight back to the player.

It covers distance

$$(343\text{ m/s})0.143\text{ s} = 49.0\text{ m} = \sqrt{x^2 + (40.0\text{ m})^2}$$

where x represents the horizontal distance the rock travels.

$$x = 28.3\text{ m} = v_{xi}t + 0t^2$$
$$\therefore v_{xi} = \frac{28.3\text{ m}}{2.86\text{ s}} = \boxed{9.91\text{ m/s}}$$

***P4.25** The arrow's flight time to the collision point is

$$t = \frac{x_f - x_i}{v_{xi}} = \frac{150\text{ m}}{(45\text{ m/s})\cos 50°} = 5.19\text{ s}.$$

The arrow's altitude at the collision is

$$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$$
$$= 0 + (45\text{ m/s})(\sin 50°)5.19\text{ s} + \frac{1}{2}\left(-9.8\text{ m/s}^2\right)(5.19\text{ s})^2 = 47.0\text{ m}.$$

(a) The required launch speed for the apple is given by

$$v_{yf}^2 = v_{yi}^2 + 2a_y\left(y_f - y_i\right)$$
$$0 = v_{yi}^2 + 2\left(-9.8\text{ m/s}^2\right)(47\text{ m} - 0)$$
$$v_{yi} = \boxed{30.3\text{ m/s}}.$$

(b) The time of flight of the apple is given by

$$v_{yf} = v_{yi} + a_y t$$
$$0 = 30.3\text{ m/s} - 9.8\text{ m/s}^2\, t$$
$$t = 3.10\text{ s}.$$

So the apple should be launched after the arrow by $5.19\text{ s} - 3.10\text{ s} = \boxed{2.09\text{ s}}$.

P4.29 $r = 0.500\text{ m};$

$$v_t = \frac{2\pi r}{T} = \frac{2\pi(0.500\text{ m})}{\frac{60.0\text{ s}}{200\text{ rev}}} = 10.47\text{ m/s} = \boxed{10.5\text{ m/s}}$$

$$a = \frac{v^2}{R} = \frac{(10.47)^2}{0.5} = \boxed{219\text{ m/s}^2\text{ inward}}$$

Chapter 5

3. A 3.00-kg object undergoes an acceleration given by $\mathbf{a} = (2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}})\ \mathrm{m/s^2}$. Find the resultant force acting on it and the magnitude of the resultant force.

7. An electron of mass 9.11×10^{-31} kg has an initial speed of 3.00×10^5 m/s. It travels in a straight line, and its speed increases to 7.00×10^5 m/s in a distance of 5.00 cm. Assuming its acceleration is constant, (a) determine the force exerted on the electron and (b) compare this force with the weight of the electron, which we neglected.

11. Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a 5.00-kg object. If $F_1 = 20.0$ N and $F_2 = 15.0$ N, find the accelerations in (a) and (b) of Figure P5.11.

Figure P5.11

16. A 3.00-kg object is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^3 + 2$, where x and y are in meters and t is in seconds. Find the magnitude of the net force acting on this object at $t = 2.00$ s.

18. A bag of cement of weight 325 N hangs from three wires as suggested in Figure P5.18. Two of the wires make angles $\theta_1 = 60.0°$ and $\theta_2 = 25.0°$ with the horizontal. If the system is in equilibrium, find the tensions T_1, T_2, and T_3 in the wires.

Figure P5.18 Problems 18 and 19.

24. A 5.00-kg object placed on a frictionless, horizontal table is connected to a string that passes over a pulley and then is fastened to a hanging 9.00-kg object, as in Figure P5.24. Draw free-body diagrams of both objects. Find the acceleration of the two objects and the tension in the string.

Figure P5.24 Problems 24 and 43.

25. A block is given an initial velocity of 5.00 m/s up a frictionless 20.0° incline (Fig. P5.22). How far up the incline does the block slide before coming to rest?

26. Two objects are connected by a light string that passes over a frictionless pulley, as in Figure P5.26. Draw free-body diagrams of both objects. If the incline is frictionless and if $m_1 = 2.00$ kg, $m_2 = 6.00$ kg, and $\theta = 55.0°$, find (a) the accelerations of the objects, (b) the tension in the string, and (c) the speed of each object 2.00 s after being released from rest.

28. Two objects with masses of 3.00 kg and 5.00 kg are connected by a light string that passes over a light frictionless pulley to form an Atwood machine, as in Figure 5.14a. Determine (a) the tension in the string, (b) the acceleration of each object, and (c) the distance each object will move in the first second of motion if they start from rest.

30. In the Atwood machine shown in Figure 5.14a, $m_1 = 2.00$ kg and $m_2 = 7.00$ kg. The masses of the pulley and string are negligible by comparison. The pulley turns without friction and the string does not stretch. The lighter object is released with a sharp push that sets it into motion at $v_i = 2.40$ m/s downward. (a) How far will m_1 descend below its initial level? (b) Find the velocity of m_1 after 1.80 seconds.

31. In the system shown in Figure P5.31, a horizontal force $\mathbf{F}_x$ acts on the 8.00-kg object. The horizontal surface is frictionless. (a) For what values of F_x does the 2.00-kg object accelerate upward? (b) For what values of F_x is the tension in the cord zero? (c) Plot the acceleration of the 8.00-kg object versus F_x. Include values of F_x from -100 N to $+100$ N.

37. A car is traveling at 50.0 mi/h on a horizontal highway. (a) If the coefficient of static friction between road and tires on a rainy day is 0.100, what is the minimum distance in which the car will stop? (b) What is the stopping distance when the surface is dry and $\mu_s = 0.600$?

41. A 3.00-kg block starts from rest at the top of a 30.0° incline and slides a distance of 2.00 m down the incline in 1.50 s. Find (a) the magnitude of the acceleration of the block, (b) the coefficient of kinetic friction between block and plane, (c) the friction force acting on the block, and (d) the speed of the block after it has slid 2.00 m.

44. Three objects are connected on the table as shown in Figure P5.44. The table is rough and has a coefficient of kinetic friction of 0.350. The objects have masses of 4.00 kg, 1.00 kg, and 2.00 kg, as shown, and the pulleys are frictionless. Draw free-body diagrams of each of the objects. (a) Determine the acceleration of each object and their directions. (b) Determine the tensions in the two cords.

Figure P5.44

45. Two blocks connected by a rope of negligible mass are being dragged by a horizontal force **F** (Fig. P5.45). Suppose that $F = 68.0$ N, $m_1 = 12.0$ kg, $m_2 = 18.0$ kg, and the coefficient of kinetic friction between each block and the surface is 0.100. (a) Draw a free-body diagram for each block.

(b) Determine the tension T and the magnitude of the acceleration of the system.

Figure P5.45

46. A block of mass 3.00 kg is pushed up against a wall by a force **P** that makes a 50.0° angle with the horizontal as shown in Figure P5.46. The coefficient of static friction between the block and the wall is 0.250. Determine the possible values for the magnitude of **P** that allow the block to remain stationary.

Figure P5.46

68. Two blocks of mass 3.50 kg and 8.00 kg are connected by a massless string that passes over a frictionless pulley (Fig. P5.68). The inclines are frictionless. Find (a) the magnitude of the acceleration of each block and (b) the tension in the string.

Figure P5.68

P5.3 $m = 3.00 \text{ kg}$

$$\mathbf{a} = \left(2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}}\right) \text{ m/s}^2$$

$$\sum \mathbf{F} = m\mathbf{a} = \boxed{\left(6.00\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}\right) \text{ N}}$$

$$\left|\sum \mathbf{F}\right| = \sqrt{(6.00)^2 + (15.0)^2} \text{ N} = \boxed{16.2 \text{ N}}$$

P5.7 (a) $\sum F = ma$ and $v_f^2 = v_i^2 + 2ax_f$ or $a = \dfrac{v_f^2 - v_i^2}{2x_f}$.

Therefore,

$$\sum F = m\frac{\left(v_f^2 - v_i^2\right)}{2x_f}$$

$$\sum F = 9.11 \times 10^{-31} \text{ kg}\frac{\left[\left(7.00 \times 10^5 \text{ m/s}^2\right)^2 - \left(3.00 \times 10^5 \text{ m/s}^2\right)^2\right]}{2(0.050\,0 \text{ m})} = \boxed{3.64 \times 10^{-18} \text{ N}}.$$

(b) The weight of the electron is

$$F_g = mg = \left(9.11 \times 10^{-31} \text{ kg}\right)\left(9.80 \text{ m/s}^2\right) = 8.93 \times 10^{-30} \text{ N}$$

The accelerating force is $\boxed{4.08 \times 10^{11} \text{ times the weight of the electron.}}$

P5.11 (a) $\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = \left(20.0\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}\right) \text{ N}$

$$\sum \mathbf{F} = m\mathbf{a}: \quad 20.0\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}} = 5.00\mathbf{a}$$

$$\mathbf{a} = \left(4.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}}\right) \text{ m/s}^2$$

or

$$\boxed{a = 5.00 \text{ m/s}^2 \text{ at } \theta = 36.9^\circ}$$

FIG. P5.11

(b) $F_{2x} = 15.0 \cos 60.0^\circ = 7.50 \text{ N}$

$F_{2y} = 15.0 \sin 60.0^\circ = 13.0 \text{ N}$

$$\mathbf{F}_2 = \left(7.50\hat{\mathbf{i}} + 13.0\hat{\mathbf{j}}\right) \text{ N}$$

$$\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = \left(27.5\hat{\mathbf{i}} + 13.0\hat{\mathbf{j}}\right) \text{ N} = m\mathbf{a} = 5.00\mathbf{a}$$

$$\mathbf{a} = \boxed{\left(5.50\hat{\mathbf{i}} + 2.60\hat{\mathbf{j}}\right) \text{ m/s}^2 = 6.08 \text{ m/s}^2 \text{ at } 25.3^\circ}$$

P5.16 $v_x = \dfrac{dx}{dt} = 10t$, $v_y = \dfrac{dy}{dt} = 9t^2$

$a_x = \dfrac{dv_x}{dt} = 10$, $a_y = \dfrac{dv_y}{dt} = 18t$

At $t = 2.00$ s, $a_x = 10.0 \text{ m/s}^2$, $a_y = 36.0 \text{ m/s}^2$

$\sum F_x = ma_x$: $3.00 \text{ kg}\left(10.0 \text{ m/s}^2\right) = 30.0 \text{ N}$

$\sum F_y = ma_y$: $3.00 \text{ kg}\left(36.0 \text{ m/s}^2\right) = 108 \text{ N}$

$$\sum F = \sqrt{F_x^2 + F_y^2} = \boxed{112 \text{ N}}$$

P5.18 $T_3 = F_g$ (1)

$T_1 \sin\theta_1 + T_2 \sin\theta_2 = F_g$ (2)

$T_1 \cos\theta_1 = T_2 \cos\theta_2$ (3)

Eliminate T_2 and solve for T_1

$$T_1 = \frac{F_g \cos\theta_2}{\left(\sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2\right)} = \frac{F_g \cos\theta_2}{\sin\left(\theta_1 + \theta_2\right)}$$

$$T_3 = F_g = \boxed{325 \text{ N}}$$

$$T_1 = F_g\left(\frac{\cos 25.0^\circ}{\sin 85.0^\circ}\right) = \boxed{296 \text{ N}}$$

$$T_2 = T_1\left(\frac{\cos\theta_1}{\cos\theta_2}\right) = 296 \text{ N}\left(\frac{\cos 60.0^\circ}{\cos 25.0^\circ}\right) = \boxed{163 \text{ N}}$$

FIG. P5.18

***P5.24** First, consider the block moving along the horizontal. The only force in the direction of movement is T. Thus, $\sum F_x = ma$

$$T = (5\text{ kg})a \qquad (1)$$

Next consider the block that moves vertically. The forces on it are the tension T and its weight, 88.2 N.

We have $\sum F_y = ma$

$$88.2\text{ N} - T = (9\text{ kg})a \qquad (2)$$

FIG. P5.24

Note that both blocks must have the same magnitude of acceleration. Equations (1) and (2) can be added to give $88.2\text{ N} = (14\text{ kg})a$. Then

$$\boxed{a = 6.30\text{ m/s}^2 \text{ and } T = 31.5\text{ N}}.$$

P5.25 After it leaves your hand, the block's speed changes only because of one component of its weight:

$$\sum F_x = ma_x \quad -mg\sin 20.0° = ma$$
$$v_f^2 = v_i^2 + 2a(x_f - x_i).$$

Taking $v_f = 0$, $v_i = 5.00$ m/s, and $a = -g\sin(20.0°)$ gives

$$0 = (5.00)^2 - 2(9.80)\sin(20.0°)(x_f - 0)$$

or

$$x_f = \frac{25.0}{2(9.80)\sin(20.0°)} = \boxed{3.73\text{ m}}.$$

FIG. P5.25

P5.26 $m_1 = 2.00$ kg, $m_2 = 6.00$ kg, $\theta = 55.0°$

(a) $\sum F_x = m_2 g\sin\theta - T = m_2 a$

and

$$T - m_1 g = m_1 a$$
$$a = \frac{m_2 g\sin\theta - m_1 g}{m_1 + m_2} = \boxed{3.57\text{ m/s}^2}$$

(b) $T = m_1(a + g) = \boxed{26.7\text{ N}}$

(c) Since $v_i = 0$, $v_f = at = (3.57\text{ m/s}^2)(2.00\text{ s}) = \boxed{7.14\text{ m/s}}$.

FIG. P5.26

P5.28 First, consider the 3.00 kg rising mass. The forces on it are the tension, T, and its weight, 29.4 N. With the upward direction as positive, the second law becomes

$$\sum F_y = ma_y: T - 29.4\text{ N} = (3.00\text{ kg})a \qquad (1)$$

The forces on the falling 5.00 kg mass are its weight and T, and its acceleration is the same as that of the rising mass. Calling the positive direction down for this mass, we have

$$\sum F_y = ma_y: 49\text{ N} - T = (5.00\text{ kg})a \qquad (2)$$

FIG. P5.28

Equations (1) and (2) can be solved simultaneously by adding them:

$$T - 29.4\text{ N} + 49.0\text{ N} - T = (3.00\text{ kg})a + (5.00\text{ kg})a$$

(b) This gives the acceleration as

$$a = \frac{19.6\text{ N}}{8.00\text{ kg}} = \boxed{2.45\text{ m/s}^2}.$$

(a) Then

$$T - 29.4\text{ N} = (3.00\text{ kg})(2.45\text{ m/s}^2) = 7.35\text{ N}.$$

The tension is

$$T = \boxed{36.8\text{ N}}.$$

(c) Consider either mass. We have

$$y = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(2.45\text{ m/s}^2)(1.00\text{ s})^2 = \boxed{1.23\text{ m}}.$$

***P5.30** Both blocks move with acceleration $a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right)g$:

$$a = \left(\frac{7\text{ kg} - 2\text{ kg}}{7\text{ kg} + 2\text{ kg}}\right)9.8\text{ m/s}^2 = 5.44\text{ m/s}^2.$$

(a) Take the upward direction as positive for m_1.

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i): \quad 0 = (-2.4\text{ m/s})^2 + 2(5.44\text{ m/s}^2)(x_f - 0)$$

$$x_f = -\frac{5.76\text{ m}^2/\text{s}^2}{2(5.44\text{ m/s}^2)} = -0.529\text{ m}$$

$$x_f = \boxed{0.529\text{ m below its initial level}}$$

(b) $v_{xf} = v_{xi} + a_x t$: $\quad v_{xf} = -2.40\text{ m/s} + (5.44\text{ m/s}^2)(1.80\text{ s})$

$$v_{xf} = \boxed{7.40\text{ m/s upward}}$$

P5.31 Forces acting on 2.00 kg block:

$$T - m_1 g = m_1 a \qquad (1)$$

Forces acting on 8.00 kg block:

$$F_x - T = m_2 a \qquad (2)$$

(a) Eliminate T and solve for a:

$$a = \frac{F_x - m_1 g}{m_1 + m_2}$$

$$\boxed{a > 0 \text{ for } F_x > m_1 g = 19.6\text{ N}}.$$

(b) Eliminate a and solve for T:

$$T = \frac{m_1}{m_1 + m_2}(F_x + m_2 g)$$

$$\boxed{T = 0 \text{ for } F_x \le -m_2 g = -78.4\text{ N}}.$$

FIG. P5.31

(c)

F_x, N	−100	−78.4	−50.0	0	50.0	100
a_x, m/s²	−12.5	−9.80	−6.96	−1.96	3.04	8.04

P5.37 $\sum F_y = ma_y$: $\quad +n - mg = 0$

$$f_s \le \mu_s n = \mu_s mg$$

This maximum magnitude of static friction acts so long as the tires roll without skidding.

$$\sum F_x = ma_x: \quad -f_s = ma$$

The maximum acceleration is

$$a = -\mu_s g.$$

The initial and final conditions are: $x_i = 0$, $v_i = 50.0\text{ mi/h} = 22.4\text{ m/s}$, $v_f = 0$

$$v_f^2 = v_i^2 + 2a(x_f - x_i): \quad -v_i^2 = -2\mu_s g x_f$$

(a) $x_f = \frac{v_i^2}{2\mu g}$

$$x_f = \frac{(22.4\text{ m/s})^2}{2(0.100)(9.80\text{ m/s}^2)} = \boxed{256\text{ m}}$$

(b) $x_f = \frac{v_i^2}{2\mu g}$

$$x_f = \frac{(22.4\text{ m/s})^2}{2(0.600)(9.80\text{ m/s}^2)} = \boxed{42.7\text{ m}}$$

P5.41 $m = 3.00\text{ kg},\ \theta = 30.0°,\ x = 2.00\text{ m},\ t = 1.50\text{ s}$

FIG. P5.41

(a) $x = \frac{1}{2}at^2$:

$$2.00\text{ m} = \frac{1}{2}a(1.50\text{ s})^2$$
$$a = \frac{4.00}{(1.50)^2} = \boxed{1.78\text{ m/s}^2}$$

$\sum \mathbf{F} = \mathbf{n} + \mathbf{f} + m\mathbf{g} = m\mathbf{a}$:

$$\text{Along } x\text{:}\quad 0 - f + mg\sin 30.0° = ma$$
$$f = m(g\sin 30.0° - a)$$
$$\text{Along } y\text{:}\quad n + 0 - mg\cos 30.0° = 0$$
$$n = mg\cos 30.0°$$

(b) $\mu_k = \frac{f}{n} = \frac{m(g\sin 30.0° - a)}{mg\cos 30.0°},\ \mu_k = \tan 30.0° - \frac{a}{g\cos 30.0°} = \boxed{0.368}$

(c) $f = m(g\sin 30.0° - a),\ f = 3.00(9.80\sin 30.0° - 1.78) = \boxed{9.37\text{ N}}$

(d) $v_f^2 = v_i^2 + 2a(x_f - x_i)$

where

$$x_f - x_i = 2.00\text{ m}$$

$$v_f^2 = 0 + 2(1.78)(2.00) = 7.11\text{ m}^2/\text{s}^2$$
$$v_f = \sqrt{7.11\text{ m}^2/\text{s}^2} = \boxed{2.67\text{ m/s}}$$

P5.44 Let a represent the positive magnitude of the acceleration $-a\hat{\mathbf{j}}$ of m_1, of the acceleration $-a\hat{\mathbf{i}}$ of m_2, and of the acceleration $+a\hat{\mathbf{j}}$ of m_3. Call T_{12} the tension in the left rope and T_{23} the tension in the cord on the right.

FIG. P5.44

For m_1, $\sum F_y = ma_y$ $\quad +T_{12} - m_1 g = -m_1 a$

For m_2, $\sum F_x = ma_x$ $\quad -T_{12} + \mu_k n + T_{23} = -m_2 a$

and $\sum F_y = ma_y$ $\quad n - m_2 g = 0$

for m_3, $\sum F_y = ma_y$ $\quad T_{23} - m_3 g = +m_3 a$

we have three simultaneous equations

$$-T_{12} + 39.2\text{ N} = (4.00\text{ kg})a$$
$$+T_{12} - 0.350(9.80\text{ N}) - T_{23} = (1.00\text{ kg})a$$
$$+T_{23} - 19.6\text{ N} = (2.00\text{ kg})a.$$

(a) Add them up:

$$+39.2\text{ N} - 3.43\text{ N} - 19.6\text{ N} = (7.00\text{ kg})a$$

$$a = \boxed{2.31\text{ m/s}^2\text{, down for } m_1\text{, left for } m_2\text{, and up for } m_3}.$$

(b) Now $-T_{12} + 39.2\text{ N} = (4.00\text{ kg})(2.31\text{ m/s}^2)$

$$\boxed{T_{12} = 30.0\text{ N}}$$

and $T_{23} - 19.6\text{ N} = (2.00\text{ kg})(2.31\text{ m/s}^2)$

$$\boxed{T_{23} = 24.2\text{ N}}.$$

P5.45 (a) See Figure to the right

FIG. P5.45

(b) $68.0 - T - \mu m_2 g = m_2 a$ (Block #2)
$T - \mu m_1 g = m_1 a$ (Block #1)

Adding,

$$68.0 - \mu(m_1 + m_2)g = (m_1 + m_2)a$$
$$a = \frac{68.0}{(m_1 + m_2)} - \mu g = \boxed{1.29\text{ m/s}^2}$$
$$T = m_1 a + \mu m_1 g = \boxed{27.2\text{ N}}$$

P5.46 (Case 1, impending upward motion)
Setting

$$\sum F_x = 0: \quad P\cos 50.0° - n = 0$$
$$f_{s,\max} = \mu_s n: \quad f_{s,\max} = \mu_s P\cos 50.0° = 0.250(0.643)P = 0.161P$$

Setting

$$\sum F_y = 0: \quad P\sin 50.0° - 0.161P - 3.00(9.80) = 0$$
$$P_{\max} = \boxed{48.6\text{ N}}$$

(Case 2, impending downward motion)
As in Case 1,

$$f_{s,\max} = 0.161P$$

Setting

$$\sum F_y = 0: \quad P\sin 50.0° + 0.161P - 3.00(9.80) = 0$$
$$P_{\min} = \boxed{31.7\text{ N}}$$

FIG. P5.46

P5.68 Since it has a larger mass, we expect the 8.00-kg block to move down the plane. The acceleration for both blocks should have the same magnitude since they are joined together by a non-stretching string. Define up the left hand plane as positive for the 3.50-kg object and down the right hand plane as positive for the 8.00-kg object.

FIG. P5.68

$$\sum F_1 = m_1 a_1: \quad -m_1 g\sin 35.0° + T = m_1 a$$
$$\sum F_2 = m_2 a_2: \quad m_2 g\sin 35.0° - T = m_2 a$$

and

$$-(3.50)(9.80)\sin 35.0° + T = 3.50a$$
$$(8.00)(9.80)\sin 35.0° - T = 8.00a.$$

Adding, we obtain

$$+45.0\text{ N} - 19.7\text{ N} = (11.5\text{ kg})a.$$

(b) Thus the acceleration is

$$\boxed{a = 2.20\text{ m/s}^2}.$$

By substitution,

$$-19.7\text{ N} + T = (3.50\text{ kg})(2.20\text{ m/s}^2) = 7.70\text{ N}.$$

(a) The tension is

$$\boxed{T = 27.4\text{ N}}.$$

Chapter 6

1. A light string can support a stationary hanging load of 25.0 kg before breaking. A 3.00-kg object attached to the string rotates on a horizontal, frictionless table in a circle of radius 0.800 m, while the other end of the string is held fixed. What range of speeds can the object have before the string breaks?

2. A curve in a road forms part of a horizontal circle. As a car goes around it at constant speed 14.0 m/s, the total force on the driver has magnitude 130 N. What is the total vector force on the driver if the speed is 18.0 m/s instead?

5. A coin placed 30.0 cm from the center of a rotating, horizontal turntable slips when its speed is 50.0 cm/s. (a) What force causes the centripetal acceleration when the coin is stationary relative to the turntable? (b) What is the coefficient of static friction between coin and turntable?

7. A crate of eggs is located in the middle of the flat bed of a pickup truck as the truck negotiates an unbanked curve in the road. The curve may be regarded as an arc of a circle of radius 35.0 m. If the coefficient of static friction between crate and truck is 0.600, how fast can the truck be moving without the crate sliding?

59. The pilot of an airplane executes a constant-speed loop-the-loop maneuver in a vertical circle. The speed of the airplane is 300 mi/h, and the radius of the circle is 1 200 ft. (a) What is the pilot's apparent weight at the lowest point if his true weight is 160 lb? (b) What is his apparent weight at the highest point? (c) **What If?** Describe how the pilot could experience weightlessness if both the radius and the speed can be varied. (*Note:* His apparent weight is equal to the magnitude of the force exerted by the seat on his body.)

P6.1 $m = 3.00\text{ kg}$, $r = 0.800\text{ m}$. The string will break if the tension exceeds the weight corresponding to 25.0 kg, so

$$T_{\max} = Mg = 25.0(9.80) = 245\text{ N}.$$

When the 3.00 kg mass rotates in a horizontal circle, the tension causes the centripetal acceleration,

so $\quad T = \dfrac{mv^2}{r} = \dfrac{(3.00)v^2}{0.800}.$

Then $\quad v^2 = \dfrac{rT}{m} = \dfrac{(0.800)T}{3.00} \le \dfrac{(0.800)T_{\max}}{3.00} = \dfrac{0.800(245)}{3.00} = 65.3\text{ m}^2/\text{s}^2$

and $\quad 0 \le v \le \sqrt{65.3}$

or $\quad \boxed{0 \le v \le 8.08\text{ m/s}}.$

FIG. P6.1

P6.2 In $\sum F = m\dfrac{v^2}{r}$, both m and r are unknown but remain constant. Therefore, $\sum F$ is proportional to v^2 and increases by a factor of $\left(\dfrac{18.0}{14.0}\right)^2$ as v increases from 14.0 m/s to 18.0 m/s. The total force at the higher speed is then

$$\sum F_{\text{fast}} = \left(\frac{18.0}{14.0}\right)^2 (130\text{ N}) = 215\text{ N}.$$

Symbolically, write $\sum F_{\text{slow}} = \left(\dfrac{m}{r}\right)(14.0\text{ m/s})^2$ and $\sum F_{\text{fast}} = \left(\dfrac{m}{r}\right)(18.0\text{ m/s})^2$.

Dividing gives $\dfrac{\sum F_{\text{fast}}}{\sum F_{\text{slow}}} = \left(\dfrac{18.0}{14.0}\right)^2$, or

$$\sum F_{\text{fast}} = \left(\frac{18.0}{14.0}\right)^2 \sum F_{\text{slow}} = \left(\frac{18.0}{14.0}\right)^2 (130\text{ N}) = \boxed{215\text{ N}}.$$

This force must be $\boxed{\text{horizontally inward}}$ to produce the driver's centripetal acceleration.

P6.5 (a) $\boxed{\text{static friction}}$

(b) $ma\hat{\mathbf{i}} = f\hat{\mathbf{i}} + n\hat{\mathbf{j}} + mg\left(-\hat{\mathbf{j}}\right)$

$\sum F_y = 0 = n - mg$

thus $n = mg$ and $\sum F_r = m\dfrac{v^2}{r} = f = \mu n = \mu mg$.

Then $\mu = \dfrac{v^2}{rg} = \dfrac{(50.0\text{ cm/s})^2}{(30.0\text{ cm})(980\text{ cm/s}^2)} = \boxed{0.085\,0}.$

P6.7 $n = mg$ since $a_y = 0$

The force causing the centripetal acceleration is the frictional force f.

From Newton's second law $f = ma_c = \dfrac{mv^2}{r}$.

But the friction condition is $f \le \mu_s n$

i.e., $\dfrac{mv^2}{r} \le \mu_s mg$

$v \le \sqrt{\mu_s rg} = \sqrt{0.600(35.0\text{ m})(9.80\text{ m/s}^2)} \qquad v \le \boxed{14.3\text{ m/s}}$

FIG. P6.7

P6.59 (a) $v = (300\text{ mi/h})\left(\dfrac{88.0\text{ ft/s}}{60.0\text{ mi/h}}\right) = 440\text{ ft/s}$

At the lowest point, his seat exerts an upward force; therefore, his weight seems to increase. His apparent weight is

$$F_g' = mg + m\frac{v^2}{r} = 160 + \left(\frac{160}{32.0}\right)\frac{(440)^2}{1\,200} = \boxed{967\text{ lb}}.$$

(b) At the highest point, the force of the seat on the pilot is directed down and

$$F_g' = mg - m\frac{v^2}{r} = \boxed{-647\text{ lb}}.$$

Since the plane is upside down, the seat exerts this downward force.

(c) When $F_g' = 0$, then $mg = \dfrac{mv^2}{R}$. If we vary the aircraft's R and v such that the above is true, then the pilot feels weightless.

Chapter 7

1. A block of mass 2.50 kg is pushed 2.20 m along a frictionless horizontal table by a constant 16.0-N force directed 25.0° below the horizontal. Determine the work done on the block by (a) the applied force, (b) the normal force exerted by the table, and (c) the gravitational force. (d) Determine the total work done on the block.

4. A raindrop of mass 3.35×10^{-5} kg falls vertically at constant speed under the influence of gravity and air resistance. Model the drop as a particle. As it falls 100 m, what is the work done on the raindrop (a) by the gravitational force and (b) by air resistance?

7. A force $\mathbf{F} = (6\hat{\mathbf{i}} - 2\hat{\mathbf{j}})$ N acts on a particle that undergoes a displacement $\Delta\mathbf{r} = (3\hat{\mathbf{i}} + \hat{\mathbf{j}})$ m. Find (a) the work done by the force on the particle and (b) the angle between $\mathbf{F}$ and $\Delta\mathbf{r}$.

13. A particle is subject to a force F_x that varies with position as in Figure P7.13. Find the work done by the force on the particle as it moves (a) from $x = 0$ to $x = 5.00$ m, (b) from $x = 5.00$ m to $x = 10.0$ m, and (c) from $x = 10.0$ m to $x = 15.0$ m. (d) What is the total work done by the force over the distance $x = 0$ to $x = 15.0$ m?

Figure P7.13 Problems 13 and 28.

14. A force $\mathbf{F} = (4x\hat{\mathbf{i}} + 3y\hat{\mathbf{j}})$ N acts on an object as the object moves in the x direction from the origin to $x = 5.00$ m. Find the work $W = \int \mathbf{F} \cdot d\mathbf{r}$ done on the object by the force.

15. When a 4.00-kg object is hung vertically on a certain light spring that obeys Hooke's law, the spring stretches 2.50 cm. If the 4.00-kg object is removed, (a) how far will the spring stretch if a 1.50-kg block is hung on it, and (b) how much work must an external agent do to stretch the same spring 4.00 cm from its unstretched position?

16. An archer pulls her bowstring back 0.400 m by exerting a force that increases uniformly from zero to 230 N. (a) What is the equivalent spring constant of the bow? (b) How much work does the archer do in pulling the bow?

19. If it takes 4.00 J of work to stretch a Hooke's-law spring 10.0 cm from its unstressed length, determine the extra work required to stretch it an additional 10.0 cm.

21. A light spring with spring constant 1 200 N/m is hung from an elevated support. From its lower end a second light spring is hung, which has spring constant 1 800 N/m. An object of mass 1.50 kg is hung at rest from the lower end of the second spring. (a) Find the total extension distance of the pair of springs. (b) Find the effective spring constant of the pair of springs as a system. We describe these springs as *in series*.

24. A 0.600-kg particle has a speed of 2.00 m/s at point Ⓐ and kinetic energy of 7.50 J at point Ⓑ. What is (a) its kinetic energy at Ⓐ? (b) its speed at Ⓑ? (c) the total work done on the particle as it moves from Ⓐ to Ⓑ?

25. A 0.300-kg ball has a speed of 15.0 m/s. (a) What is its kinetic energy? (b) **What If?** If its speed were doubled, what would be its kinetic energy?

26. A 3.00-kg object has a velocity $(6.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}})$ m/s. (a) What is its kinetic energy at this time? (b) Find the total work done on the object if its velocity changes to $(8.00\hat{\mathbf{i}} + 4.00\hat{\mathbf{j}})$ m/s. (*Note:* From the definition of the dot product, $v^2 = \mathbf{v} \cdot \mathbf{v}$.)

28. A 4.00-kg particle is subject to a total force that varies with position as shown in Figure P7.13. The particle starts from rest at $x = 0$. What is its speed at (a) $x = 5.00$ m, (b) $x = 10.0$ m, (c) $x = 15.0$ m?

31. A 40.0-kg box initially at rest is pushed 5.00 m along a rough, horizontal floor with a constant applied horizontal force of 130 N. If the coefficient of friction between box and floor is 0.300, find (a) the work done by the applied force, (b) the increase in internal energy in the box-floor system due to friction, (c) the work done by the normal force, (d) the work done by the gravitational force, (e) the change in kinetic energy of the box, and (f) the final speed of the box.

32. A 2.00-kg block is attached to a spring of force constant 500 N/m as in Figure 7.10. The block is pulled 5.00 cm to the right of equilibrium and released from rest. Find the speed of the block as it passes through equilibrium if (a) the horizontal surface is frictionless and (b) the coefficient of friction between block and surface is 0.350.

33. A crate of mass 10.0 kg is pulled up a rough incline with an initial speed of 1.50 m/s. The pulling force is 100 N parallel to the incline, which makes an angle of 20.0° with the horizontal. The coefficient of kinetic friction is 0.400, and the crate is pulled 5.00 m. (a) How much work is done by the gravitational force on the crate? (b) Determine the increase in internal energy of the crate–incline system due to friction. (c) How much work is done by the 100-N force on the crate? (d) What is the change in kinetic energy of the crate? (e) What is the speed of the crate after being pulled 5.00 m?

35. A sled of mass m is given a kick on a frozen pond. The kick imparts to it an initial speed of 2.00 m/s. The coefficient of kinetic friction between sled and ice is 0.100. Use energy considerations to find the distance the sled moves before it stops.

37. A 700-N Marine in basic training climbs a 10.0-m vertical rope at a constant speed in 8.00 s. What is his power output?

40. A 650-kg elevator starts from rest. It moves upward for 3.00 s with constant acceleration until it reaches its cruising speed of 1.75 m/s. (a) What is the average power of the elevator motor during this period? (b) How does this power compare with the motor power when the elevator moves at its cruising speed?

P7.1 (a) $W = F\Delta r\cos\theta = (16.0\text{ N})(2.20\text{ m})\cos 25.0° = \boxed{31.9\text{ J}}$

(b), (c) The normal force and the weight are both at 90° to the displacement in any time interval. Both do $\boxed{0}$ work.

(d) $\sum W = 31.9\text{ J} + 0 + 0 = \boxed{31.9\text{ J}}$

P7.4 (a) $W = mgh = \left(3.35\times10^{-5}\right)(9.80)(100)\text{ J} = \boxed{3.28\times10^{-2}\text{ J}}$

(b) Since $R = mg$, $W_{\text{air resistance}} = \boxed{-3.28\times10^{-2}\text{ J}}$

P7.7 (a) $W = \mathbf{F}\cdot\Delta\mathbf{r} = F_x x + F_y y = (6.00)(3.00)\text{ N}\cdot\text{m} + (-2.00)(1.00)\text{ N}\cdot\text{m} = \boxed{16.0\text{ J}}$

(b) $\theta = \cos^{-1}\left(\dfrac{\mathbf{F}\cdot\Delta\mathbf{r}}{F\Delta r}\right) = \cos^{-1}\dfrac{16}{\sqrt{\left((6.00)^2+(-2.00)^2\right)\left((3.00)^2+(1.00)^2\right)}} = \boxed{36.9°}$

P7.13 $W = \int F_x dx$

and W equals the area under the Force-Displacement curve

FIG. P7.13

(a) For the region $0 \le x \le 5.00\text{ m}$,

$$W = \frac{(3.00\text{ N})(5.00\text{ m})}{2} = \boxed{7.50\text{ J}}$$

(b) For the region $5.00 \le x \le 10.0$,

$$W = (3.00\text{ N})(5.00\text{ m}) = \boxed{15.0\text{ J}}$$

(c) For the region $10.0 \le x \le 15.0$,

$$W = \frac{(3.00\text{ N})(5.00\text{ m})}{2} = \boxed{7.50\text{ J}}$$

(d) For the region $0 \le x \le 15.0$

$$W = (7.50 + 7.50 + 15.0)\text{ J} = \boxed{30.0\text{ J}}$$

P7.14 $W = \int_i^f \mathbf{F}\cdot d\mathbf{r} = \int_0^{5\text{ m}} \left(4x\hat{\mathbf{i}} + 3y\hat{\mathbf{j}}\right)\text{ N}\cdot dx\hat{\mathbf{i}}$

$$\int_0^{5\text{ m}} (4\text{ N/m})x\,dx + 0 = (4\text{ N/m})\left.\frac{x^2}{2}\right|_0^{5\text{ m}} = \boxed{50.0\text{ J}}$$

P7.15 $k = \dfrac{F}{y} = \dfrac{Mg}{y} = \dfrac{(4.00)(9.80)\text{ N}}{2.50\times10^{-2}\text{ m}} = 1.57\times10^3\text{ N/m}$

(a) For 1.50 kg mass $y = \dfrac{mg}{k} = \dfrac{(1.50)(9.80)}{1.57\times10^3} = \boxed{0.938\text{ cm}}$

(b) Work $= \dfrac{1}{2}ky^2$

Work $= \dfrac{1}{2}\left(1.57\times10^3\text{ N}\cdot\text{m}\right)\left(4.00\times10^{-2}\text{ m}\right)^2 = \boxed{1.25\text{ J}}$

P7.16 (a) Spring constant is given by $F = kx$

$$k = \frac{F}{x} = \frac{(230\text{ N})}{(0.400\text{ m})} = \boxed{575\text{ N/m}}$$

(b) Work $= F_{\text{avg}}x = \dfrac{1}{2}(230\text{ N})(0.400\text{ m}) = \boxed{46.0\text{ J}}$

P7.19 $4.00\text{ J} = \dfrac{1}{2}k(0.100\text{ m})^2$

$\therefore k = 800\text{ N/m}$ and to stretch the spring to 0.200 m requires

$$\Delta W = \frac{1}{2}(800)(0.200)^2 - 4.00\text{ J} = \boxed{12.0\text{ J}}$$

***P7.21** The same force makes both light springs stretch.

(a) The hanging mass moves down by

$$x = x_1 + x_2 = \frac{mg}{k_1} + \frac{mg}{k_2} = mg\left(\frac{1}{k_1} + \frac{1}{k_2}\right)$$
$$= 1.5 \text{ kg } 9.8 \text{ m/s}^2\left(\frac{1 \text{ m}}{1\,200 \text{ N}} + \frac{1 \text{ m}}{1\,800 \text{ N}}\right) = \boxed{2.04 \times 10^{-2} \text{ m}}$$

(b) We define the effective spring constant as

$$k = \frac{F}{x} = \frac{mg}{mg(1/k_1 + 1/k_2)} = \left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1}$$
$$= \left(\frac{1 \text{ m}}{1\,200 \text{ N}} + \frac{1 \text{ m}}{1\,800 \text{ N}}\right)^{-1} = \boxed{720 \text{ N/m}}$$

P7.24 (a) $K_A = \frac{1}{2}(0.600 \text{ kg})(2.00 \text{ m/s})^2 = \boxed{1.20 \text{ J}}$

(b) $\frac{1}{2}mv_B^2 = K_B$: $v_B = \sqrt{\frac{2K_B}{m}} = \sqrt{\frac{(2)(7.50)}{0.600}} = \boxed{5.00 \text{ m/s}}$

(c) $\sum W = \Delta K = K_B - K_A = \frac{1}{2}m\left(v_B^2 - v_A^2\right) = 7.50 \text{ J} - 1.20 \text{ J} = \boxed{6.30 \text{ J}}$

P7.25 (a) $K = \frac{1}{2}mv^2 = \frac{1}{2}(0.300 \text{ kg})(15.0 \text{ m/s})^2 = \boxed{33.8 \text{ J}}$

(b) $K = \frac{1}{2}(0.300)(30.0)^2 = \frac{1}{2}(0.300)(15.0)^2(4) = 4(33.8) = \boxed{135 \text{ J}}$

P7.26 $\mathbf{v}_i = \left(6.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}\right) = \text{ m/s}$

(a) $v_i = \sqrt{v_{ix}^2 + v_{iy}^2} = \sqrt{40.0} \text{ m/s}$

$K_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(3.00 \text{ kg})\left(40.0 \text{ m}^2/\text{s}^2\right) = \boxed{60.0 \text{ J}}$

(b) $\mathbf{v}_f = 8.00\hat{\mathbf{i}} + 4.00\hat{\mathbf{j}}$

$v_f^2 = \mathbf{v}_f \cdot \mathbf{v}_f = 64.0 + 16.0 = 80.0 \text{ m}^2/\text{s}^2$

$\Delta K = K_f - K_i = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \frac{3.00}{2}(80.0) - 60.0 = \boxed{60.0 \text{ J}}$

P7.28 (a) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W =$ (area under curve from $x = 0$ to $x = 5.00$ m)

$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(7.50 \text{ J})}{4.00 \text{ kg}}} = \boxed{1.94 \text{ m/s}}$

(b) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W =$ (area under curve from $x = 0$ to $x = 10.0$ m)

$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(22.5 \text{ J})}{4.00 \text{ kg}}} = \boxed{3.35 \text{ m/s}}$

(c) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W =$ (area under curve from $x = 0$ to $x = 15.0$ m)

$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(30.0 \text{ J})}{4.00 \text{ kg}}} = \boxed{3.87 \text{ m/s}}$

P7.31 $\sum F_y = ma_y$: $n - 392 \text{ N} = 0$

$n = 392 \text{ N}$

$f_k = \mu_k n = (0.300)(392 \text{ N}) = 118 \text{ N}$

FIG. P7.31

(a) $W_F = F\Delta r\cos\theta = (130)(5.00)\cos 0° = \boxed{650 \text{ J}}$

(b) $\Delta E_{\text{int}} = f_k \Delta x = (118)(5.00) = \boxed{588 \text{ J}}$

(c) $W_n = n\Delta r\cos\theta = (392)(5.00)\cos 90° = \boxed{0}$

(d) $W_g = mg\Delta r\cos\theta = (392)(5.00)\cos(-90°) = \boxed{0}$

(e) $\Delta K = K_f - K_i = \sum W_{\text{other}} - \Delta E_{\text{int}}$

$\frac{1}{2}mv_f^2 - 0 = 650 \text{ J} - 588 \text{ J} + 0 + 0 = \boxed{62.0 \text{ J}}$

(f) $v_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2(62.0 \text{ J})}{40.0 \text{ kg}}} = \boxed{1.76 \text{ m/s}}$

P7.32 (a) $W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 = \frac{1}{2}(500)\left(5.00\times10^{-2}\right)^2 - 0 = 0.625\text{ J}$

$W_s = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 - 0$

so $v_f = \sqrt{\frac{2\left(\sum W\right)}{m}} = \sqrt{\frac{2(0.625)}{2.00}}\text{ m/s} = \boxed{0.791\text{ m/s}}$

(b) $\frac{1}{2}mv_i^2 - f_k\Delta x + W_s = \frac{1}{2}mv_f^2$

$0 - (0.350)(2.00)(9.80)(0.050\,0)\text{ J} + 0.625\text{ J} = \frac{1}{2}mv_f^2$

$0.282\text{ J} = \frac{1}{2}(2.00\text{ kg})v_f^2$

$v_f = \sqrt{\frac{2(0.282)}{2.00}}\text{ m/s} = \boxed{0.531\text{ m/s}}$

FIG. P7.32

P7.33 (a) $W_g = mg\ell\cos(90.0°+\theta)$

$W_g = (10.0\text{ kg})\left(9.80\text{ m/s}^2\right)(5.00\text{ m})\cos 110° = \boxed{-168\text{ J}}$

(b) $f_k = \mu_k n = \mu_k mg\cos\theta$

$\Delta E_{\text{int}} = \ell f_k = \ell\mu_k mg\cos\theta$

$\Delta E_{\text{int}} = (5.00\text{ m})(0.400)(10.0)(9.80)\cos 20.0° = \boxed{184\text{ J}}$

(c) $W_F = F\ell = (100)(5.00) = \boxed{500\text{ J}}$

(d) $\Delta K = \sum W_{\text{other}} - \Delta E_{\text{int}} = W_F + W_g - \Delta E_{\text{int}} = \boxed{148\text{ J}}$

(e) $\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$v_f = \sqrt{\frac{2(\Delta K)}{m} + v_i^2} = \sqrt{\frac{2(148)}{10.0} + (1.50)^2} = \boxed{5.65\text{ m/s}}$

FIG. P7.33

P7.35 $v_i = 2.00\text{ m/s}$ $\qquad \mu_k = 0.100$

$K_i - f_k\Delta x + W_{\text{other}} = K_f:$ $\qquad \frac{1}{2}mv_i^2 - f_k\Delta x = 0$

$\frac{1}{2}mv_i^2 = \mu_k mg\Delta x$ $\qquad \Delta x = \frac{v_i^2}{2\mu_k g} = \frac{(2.00\text{ m/s})^2}{2(0.100)(9.80)} = \boxed{2.04\text{ m}}$

P7.37 $\text{Power} = \frac{W}{t}$ $\qquad \mathcal{P} = \frac{mgh}{t} = \frac{(700\text{ N})(10.0\text{ m})}{8.00\text{ s}} = \boxed{875\text{ W}}$

P7.40 (a) The distance moved upward in the first 3.00 s is

$$\Delta y = \bar{v}t = \left[\frac{0+1.75\text{ m/s}}{2}\right](3.00\text{ s}) = 2.63\text{ m}.$$

The motor and the earth's gravity do work on the elevator car:

$$\frac{1}{2}mv_i^2 + W_{\text{motor}} + mg\Delta y\cos 180° = \frac{1}{2}mv_f^2$$

$$W_{\text{motor}} = \frac{1}{2}(650\text{ kg})(1.75\text{ m/s})^2 - 0 + (650\text{ kg})g(2.63\text{ m}) = 1.77\times10^4\text{ J}$$

Also, $W = \bar{\mathcal{P}}t$ so $\bar{\mathcal{P}} = \frac{W}{t} = \frac{1.77\times10^4\text{ J}}{3.00\text{ s}} = \boxed{5.91\times10^3\text{ W}} = 7.92\text{ hp}.$

(b) When moving upward at constant speed $(v = 1.75\text{ m/s})$ the applied force equals the weight $= (650\text{ kg})\left(9.80\text{ m/s}^2\right) = 6.37\times10^3\text{ N}$. Therefore,

$$\mathcal{P} = Fv = \left(6.37\times10^3\text{ N}\right)(1.75\text{ m/s}) = \boxed{1.11\times10^4\text{ W}} = 14.9\text{ hp}.$$

Chapter 8

2. A 400-N child is in a swing that is attached to ropes 2.00 m long. Find the gravitational potential energy of the child–Earth system relative to the child's lowest position when (a) the ropes are horizontal, (b) the ropes make a 30.0° angle with the vertical, and (c) the child is at the bottom of the circular arc.

5. A bead slides without friction around a loop-the-loop (Fig. P8.5). The bead is released from a height $h = 3.50R$. (a) What is its speed at point Ⓐ? (b) How large is the normal force on it if its mass is 5.00 g?

Figure P8.5

6. Dave Johnson, the bronze medalist at the 1992 Olympic decathlon in Barcelona, leaves the ground at the high jump with vertical velocity component 6.00 m/s. How far does his center of mass move up as he makes the jump?

11. A block of mass 0.250 kg is placed on top of a light vertical spring of force constant 5 000 N/m and pushed downward so that the spring is compressed by 0.100 m. After the block is released from rest, it travels upward and then leaves the spring. To what maximum height above the point of release does it rise?

13. Two objects are connected by a light string passing over a light frictionless pulley as shown in Figure P8.13. The object of mass 5.00 kg is released from rest. Using the principle of conservation of energy, (a) determine the speed of the 3.00-kg object just as the 5.00-kg object hits the ground. (b) Find the maximum height to which the 3.00-kg object rises.

Figure P8.13 Problems 13 and 14.

17. A 20.0-kg cannon ball is fired from a cannon with muzzle speed of 1 000 m/s at an angle of 37.0° with the horizontal. A second ball is fired at an angle of 90.0°. Use the conservation of energy principle to find (a) the maximum height reached by each ball and (b) the total mechanical energy at the maximum height for each ball. Let $y = 0$ at the cannon.

31. The coefficient of friction between the 3.00-kg block and the surface in Figure P8.31 is 0.400. The system starts from rest. What is the speed of the 5.00-kg ball when it has fallen 1.50 m?

Figure P8.31

33. A 5.00-kg block is set into motion up an inclined plane with an initial speed of 8.00 m/s (Fig. P8.33). The block comes to rest after traveling 3.00 m along the plane, which is inclined at an angle of 30.0° to the horizontal. For this motion determine (a) the change in the block's kinetic energy, (b) the change in the potential energy of the block–Earth system, and (c) the friction force exerted on the block (assumed to be constant). (d) What is the coefficient of kinetic friction?

Figure P8.33

36. A 50.0-kg block and a 100-kg block are connected by a string as in Figure P8.36. The pulley is frictionless and of

Figure P8.36

38. A 75.0-kg skysurfer is falling straight down with terminal speed 60.0 m/s. Determine the rate at which the skysurfer–Earth system is losing mechanical energy.

42. A potential-energy function for a two-dimensional force is of the form $U = 3x^3y - 7x$. Find the force that acts at the point (x, y).

55. **Review problem.** Suppose the incline is frictionless for the system described in Problem 54 (Fig. P8.54). The block is released from rest with the spring initially unstretched. (a) How far does it move down the incline before coming to rest? (b) What is its acceleration at its lowest point? Is the acceleration constant? (c) Describe the energy transformations that occur during the descent.

57. A 10.0-kg block is released from point Ⓐ in Figure P8.57. The track is frictionless except for the portion between points Ⓑ and Ⓒ, which has a length of 6.00 m. The block travels down the track, hits a spring of force constant 2 250 N/m, and compresses the spring 0.300 m from its equilibrium position before coming to rest momentarily. Determine the coefficient of kinetic friction between the block and the rough surface between Ⓑ and Ⓒ.

Figure P8.57

59. A 20.0-kg block is connected to a 30.0-kg block by a string that passes over a light frictionless pulley. The 30.0-kg block is connected to a spring that has negligible mass and a force constant of 250 N/m, as shown in Figure P8.59. The spring is unstretched when the system is as shown in the figure, and the incline is frictionless. The 20.0-kg block is pulled 20.0 cm down the incline (so that the 30.0-kg block is 40.0 cm above the floor) and released from rest. Find the speed of each block when the 30.0-kg block is 20.0 cm above the floor (that is, when the spring is unstretched).

Figure P8.59

60. A 1.00-kg object slides to the right on a surface having a coefficient of kinetic friction 0.250 (Fig. P8.60). The object has a speed of $v_i = 3.00$ m/s when it makes contact with a light spring that has a force constant of 50.0 N/m. The object comes to rest after the spring has been compressed a distance d. The object is then forced toward the left by the spring and continues to move in that direction beyond the spring's unstretched position. Finally, the object comes to rest a distance D to the left of the unstretched spring. Find (a) the distance of compression d, (b) the speed v at the unstretched position when the object is moving to the left, and (c) the distance D where the object comes to rest.

P8.2 (a) We take the zero configuration of system potential energy with the child at the lowest point of the arc. When the string is held horizontal initially, the initial position is 2.00 m above the zero level. Thus,

$$U_g = mgy = (400\text{ N})(2.00\text{ m}) = \boxed{800\text{ J}}.$$

FIG. P8.2

(b) From the sketch, we see that at an angle of 30.0° the child is at a vertical height of (2.00 m)(1 − cos 30.0°) above the lowest point of the arc. Thus,

$$U_g = mgy = (400\text{ N})(2.00\text{ m})(1-\cos 30.0°) = \boxed{107\text{ J}}.$$

(c) The zero level has been selected at the lowest point of the arc. Therefore, $\boxed{U_g = 0}$ at this location.

P8.5 $U_i + K_i = U_f + K_f$:

$$mgh + 0 = mg(2R) + \frac{1}{2}mv^2$$
$$g(3.50R) = 2g(R) + \frac{1}{2}v^2$$
$$\boxed{v = \sqrt{3.00gR}}$$

$\sum F = m\frac{v^2}{R}$:

$$n + mg = m\frac{v^2}{R}$$
$$n = m\left[\frac{v^2}{R} - g\right] = m\left[\frac{3.00gR}{R} - g\right] = 2.00mg$$
$$n = 2.00\left(5.00\times10^{-3}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)$$
$$= \boxed{0.098\,0\text{ N downward}}$$

FIG. P8.5

P8.6 From leaving ground to the highest point,

$$K_i + U_i = K_f + U_f$$
$$\frac{1}{2}m(6.00\text{ m/s})^2 + 0 = 0 + m\left(9.80\text{ m/s}^2\right)y$$

The mass makes no difference:

$$\therefore y = \frac{(6.00\text{ m/s})^2}{(2)\left(9.80\text{ m/s}^2\right)} = \boxed{1.84\text{ m}}$$

P8.11 From conservation of energy for the block-spring-Earth system,

$$U_{gf} = U_{si},$$

or

$$(0.250\text{ kg})\left(9.80\text{ m/s}^2\right)h = \left(\frac{1}{2}\right)(5\,000\text{ N/m})(0.100\text{ m})^2$$

This gives a maximum height $h = \boxed{10.2\text{ m}}$.

FIG. P8.11

P8.17 (a) $K_i + U_{gi} = K_f + U_{gf}$

$$\frac{1}{2}mv_i^2 + 0 = \frac{1}{2}mv_f^2 + mgy_f$$
$$\frac{1}{2}mv_{xi}^2 + \frac{1}{2}mv_{yi}^2 = \frac{1}{2}mv_{xf}^2 + mgy_f$$

But $v_{xi} = v_{xf}$, so for the first ball

$$y_f = \frac{v_{yi}^2}{2g} = \frac{(1\,000\sin 37.0°)^2}{2(9.80)} = \boxed{1.85\times10^4\text{ m}}$$

and for the second

$$y_f = \frac{(1\,000)^2}{2(9.80)} = \boxed{5.10\times10^4\text{ m}}$$

(b) The total energy of each is constant with value

$$\frac{1}{2}(20.0\text{ kg})(1\,000\text{ m/s})^2 = \boxed{1.00\times10^7\text{ J}}.$$

P8.13 Using conservation of energy for the system of the Earth and the two objects

(a) $(5.00\text{ kg})g(4.00\text{ m}) = (3.00\text{ kg})g(4.00\text{ m}) + \frac{1}{2}(5.00+3.00)v^2$

$v = \sqrt{19.6} = \boxed{4.43\text{ m/s}}$

(b) Now we apply conservation of energy for the system of the 3.00 kg object and the Earth during the time interval between the instant when the string goes slack and the instant at which the 3.00 kg object reaches its highest position in its free fall.

$$\frac{1}{2}(3.00)v^2 = mg\,\Delta y = 3.00g\Delta y$$
$$\Delta y = 1.00\text{ m}$$
$$y_{max} = 4.00\text{ m} + \Delta y = \boxed{5.00\text{ m}}$$

FIG. P8.13

P8.31 $U_i + K_i + \Delta E_{\text{mech}} = U_f + K_f$:

$$m_2gh - fh = \frac{1}{2}m_1v^2 + \frac{1}{2}m_2v^2$$

$$f = \mu n = \mu m_1 g$$

$$m_2gh - \mu m_1 gh = \frac{1}{2}(m_1 + m_2)v^2$$

$$v^2 = \frac{2(m_2 - \mu m_1)(hg)}{m_1 + m_2}$$

$$v = \sqrt{\frac{2(9.80\ \text{m/s}^2)(1.50\ \text{m})[5.00\ \text{kg} - 0.400(3.00\ \text{kg})]}{8.00\ \text{kg}}} = \boxed{3.74\ \text{m/s}}$$

FIG. P8.31

P8.33 (a) $\Delta K = \frac{1}{2}m(v_f^2 - v_i^2) = -\frac{1}{2}mv_i^2 = \boxed{-160\ \text{J}}$

(b) $\Delta U = mg(3.00\ \text{m})\sin 30.0° = \boxed{73.5\ \text{J}}$

(c) The mechanical energy converted due to friction is 86.5 J

$$f = \frac{86.5\ \text{J}}{3.00\ \text{m}} = \boxed{28.8\ \text{N}}$$

(d) $f = \mu_k n = \mu_k mg\cos 30.0° = 28.8\ \text{N}$

$$\mu_k = \frac{28.8\ \text{N}}{(5.00\ \text{kg})(9.80\ \text{m/s}^2)\cos 30.0°} = \boxed{0.679}$$

FIG. P8.33

P8.36 $\sum F_y = n - mg\cos 37.0° = 0$

$\therefore n = mg\cos 37.0° = 400\ \text{N}$

$f = \mu n = 0.250(400\ \text{N}) = 100\ \text{N}$

$-f\Delta x = \Delta E_{\text{mech}}$

$(-100)(20.0) = \Delta U_A + \Delta U_B + \Delta K_A + \Delta K_B$

$\Delta U_A = m_A g(h_f - h_i) = (50.0)(9.80)(20.0\sin 37.0°) = 5.90 \times 10^3$

$\Delta U_B = m_B g(h_f - h_i) = (100)(9.80)(-20.0) = -1.96 \times 10^4$

$\Delta K_A = \frac{1}{2}m_A(v_f^2 - v_i^2)$

$\Delta K_B = \frac{1}{2}m_B(v_f^2 - v_i^2) = \frac{m_B}{m_A}\Delta K_A = 2\Delta K_A$

Adding and solving, $\Delta K_A = \boxed{3.92\ \text{kJ}}$.

FIG. P8.36

P8.38 The total mechanical energy of the skysurfer-Earth system is

$$E_{\text{mech}} = K + U_g = \frac{1}{2}mv^2 + mgh.$$

Since the skysurfer has constant speed,

$$\frac{dE_{\text{mech}}}{dt} = mv\frac{dv}{dt} + mg\frac{dh}{dt} = 0 + mg(-v) = -mgv.$$

The rate the system is losing mechanical energy is then

$$\left|\frac{dE_{\text{mech}}}{dt}\right| = mgv = (75.0\ \text{kg})(9.80\ \text{m/s}^2)(60.0\ \text{m/s}) = \boxed{44.1\ \text{kW}}.$$

P8.42 $F_x = -\frac{\partial U}{\partial x} = -\frac{\partial(3x^3y - 7x)}{\partial x} = -(9x^2y - 7) = 7 - 9x^2y$

$F_y = -\frac{\partial U}{\partial y} = -\frac{\partial(3x^3y - 7x)}{\partial y} = -(3x^3 - 0) = -3x^3$

Thus, the force acting at the point $(x,\ y)$ is $\mathbf{F} = F_x\hat{\mathbf{i}} + F_y\hat{\mathbf{j}} = \boxed{(7 - 9x^2y)\hat{\mathbf{i}} - 3x^3\hat{\mathbf{j}}}$.

P8.55 (a) Since no nonconservative work is done, $\Delta E = 0$

Also $\Delta K = 0$

therefore, $U_i = U_f$

where $U_i = (mg\sin\theta)x$

and $U_f = \frac{1}{2}kx^2$

FIG. P8.55

Substituting values yields $(2.00)(9.80)\sin 37.0° = (100)\frac{x}{2}$ and solving we find

$$x = \boxed{0.236\text{ m}}$$

(b) $\sum F = ma$. Only gravity and the spring force act on the block, so

$$-kx + mg\sin\theta = ma$$

For $x = 0.236$ m,

$a = \boxed{-5.90\text{ m/s}^2}$. The negative sign indicates a is up the incline.

The $\boxed{\text{acceleration depends on position}}$.

(c) U(gravity) decreases monotonically as the height decreases.
U(spring) increases monotonically as the spring is stretched.
K initially increases, but then goes back to zero.

P8.57

$$\Delta E_{\text{mech}} = -f\Delta x$$
$$E_f - E_i = -f \cdot d_{BC}$$
$$\frac{1}{2}kx^2 - mgh = -\mu mgd_{BC}$$
$$\mu = \frac{mgh - \frac{1}{2}kx^2}{mgd_{BC}} = \boxed{0.328}$$

FIG. P8.57

P8.59

$$(K+U)_i = (K+U)_f$$
$$0 + (30.0\text{ kg})(9.80\text{ m/s}^2)(0.200\text{ m}) + \frac{1}{2}(250\text{ N/m})(0.200\text{ m})^2$$
$$= \frac{1}{2}(50.0\text{ kg})v^2 + (20.0\text{ kg})(9.80\text{ m/s}^2)(0.200\text{ m})\sin 40.0°$$
$$58.8\text{ J} + 5.00\text{ J} = (25.0\text{ kg})v^2 + 25.2\text{ J}$$
$$\boxed{v = 1.24\text{ m/s}}$$

FIG. P8.59

P8.60 (a) Between the second and the third picture, $\Delta E_{\text{mech}} = \Delta K + \Delta U$

$$-\mu mgd = -\frac{1}{2}mv_i^2 + \frac{1}{2}kd^2$$
$$\frac{1}{2}(50.0\text{ N/m})d^2 + 0.250(1.00\text{ kg})(9.80\text{ m/s}^2)d - \frac{1}{2}(1.00\text{ kg})(3.00\text{ m/s}^2) = 0$$
$$d = \frac{[-2.45 \pm 21.25]\text{ N}}{50.0\text{ N/m}} = \boxed{0.378\text{ m}}$$

(b) Between picture two and picture four, $\Delta E_{\text{mech}} = \Delta K + \Delta U$

$$-f(2d) = \frac{1}{2}mv^2 - \frac{1}{2}mv_i^2$$
$$v = \sqrt{(3.00\text{ m/s})^2 - \frac{2}{(1.00\text{ kg})}(2.45\text{ N})(2)(0.378\text{ m})}$$
$$= \boxed{2.30\text{ m/s}}$$

(c) For the motion from picture two to picture five, $\Delta E_{\text{mech}} = \Delta K + \Delta U$

$$-f(D + 2d) = -\frac{1}{2}(1.00\text{ kg})(3.00\text{ m/s})^2$$
$$D = \frac{9.00\text{ J}}{2(0.250)(1.00\text{ kg})(9.80\text{ m/s}^2)} - 2(0.378\text{ m}) = \boxed{1.08\text{ m}}$$

FIG. P8.60

Chapter 9

1. A 3.00-kg particle has a velocity of $(3.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}})$ m/s. (a) Find its x and y components of momentum. (b) Find the magnitude and direction of its momentum.

2. A 0.100-kg ball is thrown straight up into the air with an initial speed of 15.0 m/s. Find the momentum of the ball (a) at its maximum height and (b) halfway up to its maximum height.

4. Two blocks of masses M and $3M$ are placed on a horizontal, frictionless surface. A light spring is attached to one of them, and the blocks are pushed together with the spring between them (Fig. P9.4). A cord initially holding the blocks together is burned; after this, the block of mass $3M$ moves to the right with a speed of 2.00 m/s. (a) What is the speed of the block of mass M? (b) Find the original elastic potential energy in the spring if $M = 0.350$ kg.

Figure P9.4

5. (a) A particle of mass m moves with momentum p. Show that the kinetic energy of the particle is $K = p^2/2m$. (b) Express the magnitude of the particle's momentum in terms of its kinetic energy and mass.

7. An estimated force–time curve for a baseball struck by a bat is shown in Figure P9.7. From this curve, determine (a) the impulse delivered to the ball, (b) the average force exerted on the ball, and (c) the peak force exerted on the ball.

Figure P9.7

8. A ball of mass 0.150 kg is dropped from rest from a height of 1.25 m. It rebounds from the floor to reach a height of 0.960 m. What impulse was given to the ball by the floor?

0

9. A 3.00-kg steel ball strikes a wall with a speed of 10.0 m/s at an angle of 60.0° with the surface. It bounces off with the same speed and angle (Fig. P9.9). If the ball is in contact with the wall for 0.200 s, what is the average force exerted by the wall on the ball ?

Figure P9.9

10. A tennis player receives a shot with the ball (0.060 0 kg) traveling horizontally at 50.0 m/s and returns the shot with the ball traveling horizontally at 40.0 m/s in the opposite direction. (a) What is the impulse delivered to the ball by the racquet? (b) What work does the racquet do on the ball?

13. A garden hose is held as shown in Figure P9.13. The hose is originally full of motionless water. What additional force is necessary to hold the nozzle stationary after the water flow is turned on, if the discharge rate is 0.600 kg/s with a speed of 25.0 m/s?

Figure P9.13

15. High-speed stroboscopic photographs show that the head of a golf club of mass 200 g is traveling at 55.0 m/s just before it strikes a 46.0-g golf ball at rest on a tee. After the collision, the club head travels (in the same direction) at 40.0 m/s. Find the speed of the golf ball just after impact.

16. An archer shoots an arrow toward a target that is sliding toward her with a speed of 2.50 m/s on a smooth, slippery surface. The 22.5-g arrow is shot with a speed of 35.0 m/s and passes through the 300-g target, which is stopped by the impact. What is the speed of the arrow after passing through the target?

17. A 10.0-g bullet is fired into a stationary block of wood (m = 5.00 kg). The relative motion of the bullet stops inside the block. The speed of the bullet-plus-wood combination immediately after the collision is 0.600 m/s. What was the original speed of the bullet?

18. A railroad car of mass 2.50×10^4 kg is moving with a speed of 4.00 m/s. It collides and couples with three other coupled railroad cars, each of the same mass as the single car and moving in the same direction with an initial speed of 2.00 m/s. (a) What is the speed of the four cars after the collision? (b) How much mechanical energy is lost in the collision?

21. A 45.0-kg girl is standing on a plank that has a mass of 150 kg. The plank, originally at rest, is free to slide on a frozen lake, which is a flat, frictionless supporting surface. The girl begins to walk along the plank at a constant speed of 1.50 m/s relative to the plank. (a) What is her speed relative to the ice surface? (b) What is the speed of the plank relative to the ice surface?

25. A 12.0-g wad of sticky clay is hurled horizontally at a 100-g wooden block initially at rest on a horizontal surface. The clay sticks to the block. After impact, the block slides 7.50 m before coming to rest. If the coefficient of friction between the block and the surface is 0.650, what was the speed of the clay immediately before impact?

27. (a) Three carts of masses 4.00 kg, 10.0 kg, and 3.00 kg move on a frictionless horizontal track with speeds of 5.00 m/s, 3.00 m/s, and 4.00 m/s, as shown in Figure P9.27. Velcro couplers make the carts stick together after colliding. Find the final velocity of the train of three carts. (b) **What If?** Does your answer require that all the carts collide and stick together at the same time? What if they collide in a different order?

Figure P9.27

32. Two automobiles of equal mass approach an intersection. One vehicle is traveling with velocity 13.0 m/s toward the east, and the other is traveling north with speed v_{2i}. Neither driver sees the other. The vehicles collide in the intersection and stick together, leaving parallel skid marks at an angle of 55.0° north of east. The speed limit for both roads is 35 mi/h, and the driver of the northward-moving vehicle claims he was within the speed limit when the collision occurred. Is he telling the truth?

33. A billiard ball moving at 5.00 m/s strikes a stationary ball of the same mass. After the collision, the first ball moves, at 4.33 m/s, at an angle of 30.0° with respect to the original line of motion. Assuming an elastic collision (and ignoring friction and rotational motion), find the struck ball's velocity after the collision.

35. An object of mass 3.00 kg, moving with an initial velocity of $5.00\hat{\mathbf{i}}$ m/s, collides with and sticks to an object of mass 2.00 kg with an initial velocity of $-3.00\hat{\mathbf{j}}$ m/s. Find the final velocity of the composite object.

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

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

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

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

P9.2 (a) At maximum height $\mathbf{v} = 0$, so $\mathbf{p} = \boxed{0}$.

(b) Its original kinetic energy is its constant total energy,

$$K_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(0.100)\text{kg}(15.0\text{ m/s})^2 = 11.2\text{ J}.$$

At the top all of this energy is gravitational. Halfway up, one-half of it is gravitational and the other half is kinetic:

$$K = 5.62\text{ J} = \frac{1}{2}(0.100\text{ kg})v^2$$

$$v = \sqrt{\frac{2\times 5.62\text{ J}}{0.100\text{ kg}}} = 10.6\text{ m/s}$$

Then $\mathbf{p} = m\mathbf{v} = (0.100\text{ kg})(10.6\text{ m/s})\hat{\mathbf{j}}$

$$\mathbf{p} = \boxed{1.06\text{ kg}\cdot\text{m/s}\,\hat{\mathbf{j}}}.$$

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

FIG. P9.4

P9.5 (a) The momentum is $p = mv$, so $v = \frac{p}{m}$ 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) $K = \frac{1}{2}mv^2$ implies $v = \sqrt{\frac{2K}{m}}$, so $p = mv = m\sqrt{\frac{2K}{m}} = \boxed{\sqrt{2mK}}$.

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

$I = \frac{1}{2}\left(1.50\times 10^{-3}\text{ s}\right)(18\,000\text{ N}) = \boxed{13.5\text{ N}\cdot\text{s}}$

(b) $F = \dfrac{13.5\text{ N}\cdot\text{s}}{1.50\times 10^{-3}\text{ s}} = \boxed{9.00\text{ kN}}$

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

FIG. P9.7

***P9.8** The impact speed is given by $\frac{1}{2}mv_1^2 = mgy_1$. The rebound speed is given by $mgy_2 = \frac{1}{2}mv_2^2$. The impulse of the floor is the change in momentum,

$$\begin{aligned} mv_2\text{ up} - mv_1\text{ down} &= m(v_2 + v_1)\text{ up} \\ &= m\left(\sqrt{2gh_2} + \sqrt{2gh_1}\right)\text{ up} \\ &= 0.15\text{ kg}\sqrt{2(9.8\text{ m/s}^2)}\left(\sqrt{0.960\text{ m}} + \sqrt{1.25\text{ m}}\right)\text{ up} \\ &= \boxed{1.39\text{ kg}\cdot\text{m/s upward}} \end{aligned}$$

P9.10 Assume the initial direction of the ball in the $-x$ direction.

(a) Impulse, $\mathbf{I} = \Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = (0.060\,0)(40.0)\hat{\mathbf{i}} - (0.060\,0)(50.0)\left(-\hat{\mathbf{i}}\right) = \boxed{5.40\hat{\mathbf{i}}\text{ N}\cdot\text{s}}$

(b) Work $= K_f - K_i = \frac{1}{2}(0.060\,0)\left[(40.0)^2 - (50.0)^2\right] = \boxed{-27.0\text{ J}}$

P9.13 The force exerted on the water by the hose is

$$F = \frac{\Delta p_{\text{water}}}{\Delta t} = \frac{mv_f - mv_i}{\Delta t} = \frac{(0.600\ \text{kg})(25.0\ \text{m/s}) - 0}{1.00\ \text{s}} = \boxed{15.0\ \text{N}}.$$

According to Newton's third law, the water exerts a force of equal magnitude back on
Thus, the gardener must apply a 15.0 N force (in the direction of the velocity of the e
stream) to hold the hose stationary.

P9.9

$$\Delta \mathbf{p} = \mathbf{F}\Delta t$$

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

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

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

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

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

FIG. P9.9

P9.15

$$(200\ \text{g})(55.0\ \text{m/s}) = (46.0\ \text{g})v + (200\ \text{g})(40.0\ \text{m/s})$$

$$v = \boxed{65.2\ \text{m/s}}$$

***P9.16**

$$(m_1v_1 + m_2v_2)_i = (m_1v_1 + m_2v_2)_f$$

$$22.5\ \text{g}(35\ \text{m/s}) + 300\ \text{g}(-2.5\ \text{m/s}) = 22.5\ \text{g}v_{1f} + 0$$

$$v_{1f} = \frac{37.5\ \text{g}\cdot\text{m/s}}{22.5\ \text{g}} = \boxed{1.67\ \text{m/s}}$$

FIG. P9.16

P9.17 Momentum is conserved

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

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

P9.18 (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) $K_f - K_i = \frac{1}{2}(4m)v_f^2 - \left[\frac{1}{2}mv_{1i}^2 + \frac{1}{2}(3m)v_{2i}^2\right] = \left(2.50\times10^4\right)(12.5 - 8.00 - 6.00) = \boxed{-3.75\times10^4\ \text{J}}$

P9.21 (a), (b) Let v_g and v_p be the 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 $m_gv_g + m_pv_p = 0$, 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

$$-3.33v_p - v_p = 1.50 \text{ or } v_p = \boxed{-0.346\ \text{m/s}}$$

Then $v_g = -3.33(-0.346) = \boxed{1.15\ \text{m/s}}$

FIG. P9.21

P9.25 At impact, momentum of the clay-block system is conserved, so:

$$mv_1 = (m_1 + m_2)v_2$$

After impact, the change in kinetic energy of the clay-block-surface system is equal to the increase in internal energy:

$$\frac{1}{2}(m_1 + m_2)v_2^2 = f_fd = \mu(m_1 + m_2)gd$$

$$\frac{1}{2}(0.112\ \text{kg})v_2^2 = 0.650(0.112\ \text{kg})\left(9.80\ \text{m/s}^2\right)(7.50\ \text{m})$$

$$v_2^2 = 95.6\ \text{m}^2/\text{s}^2 \qquad v_2 = 9.77\ \text{m/s}$$

$$\left(12.0\times10^{-3}\ \text{kg}\right)v_1 = (0.112\ \text{kg})(9.77\ \text{m/s}) \qquad v_1 = \boxed{91.2\ \text{m/s}}$$

FIG. P9.25

***P9.27** (a) Using conservation of momentum, $\left(\sum \mathbf{p}\right)_{\text{after}} = \left(\sum \mathbf{p}\right)_{\text{before}}$, gives

$$\left[(4.0 + 10 + 3.0)\ \text{kg}\right]v = (4.0\ \text{kg})(5.0\ \text{m/s}) + (10\ \text{kg})(3.0\ \text{m/s}) + (3.0\ \text{kg})(-4.0\ \text{m/s}).$$

Therefore, $v = +2.24$ m/s, or $\boxed{2.24\ \text{m/s toward the right}}$.

(b) $\boxed{\text{No}}$. For example, if the 10-kg and 3.0-kg mass were to stick together first, they would move with a speed given by solving

$$(13\ \text{kg})v_1 = (10\ \text{kg})(3.0\ \text{m/s}) + (3.0\ \text{kg})(-4.0\ \text{m/s}), \text{ or } v_1 = +1.38\ \text{m/s}.$$

Then when this 13 kg combined mass collides with the 4.0 kg mass, we have

$$(17\ \text{kg})v = (13\ \text{kg})(1.38\ \text{m/s}) + (4.0\ \text{kg})(5.0\ \text{m/s}), \text{ and } v = +2.24\ \text{m/s}$$

just as in part (a). Coupling order makes no difference.

P9.32 We use conservation of momentum for the system of two vehicles for both northward and eastward components.

FIG. P9.32

For the eastward direction:

$$M(13.0\ \text{m/s}) = 2MV_f \cos 55.0°$$

For the northward direction:

$$Mv_{2i} = 2MV_f \sin 55.0°$$

Divide the northward equation by the eastward equation to find:

$$v_{2i} = (13.0\ \text{m/s})\tan 55.0° = 18.6\ \text{m/s} = \boxed{41.5\ \text{mi/h}}$$

Thus, the driver of the north bound car was untruthful.

P9.33 By conservation of momentum for the system of the two billiard balls (with all masses equal),

FIG. P9.33

$$5.00\ \text{m/s} + 0 = (4.33\ \text{m/s})\cos 30.0° + v_{2fx}$$
$$v_{2fx} = 1.25\ \text{m/s}$$
$$0 = (4.33\ \text{m/s})\sin 30.0° + v_{2fy}$$
$$v_{2fy} = -2.16\ \text{m/s}$$
$$\mathbf{v}_{2f} = \boxed{2.50\ \text{m/s at } -60.0°}$$

P9.35 $m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = (m_1 + m_2)\mathbf{v}_f$: $\quad 3.00(5.00)\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}} = 5.00\mathbf{v}$

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

Chapter 10

1. During a certain period of time, the angular position of a swinging door is described by $\theta = 5.00 + 10.0t + 2.00t^2$, where θ is in radians and t is in seconds. Determine the angular position, angular speed, and angular acceleration of the door (a) at $t = 0$ (b) at $t = 3.00$ s.

3. A wheel starts from rest and rotates with constant angular acceleration to reach an angular speed of 12.0 rad/s in 3.00 s. Find (a) the magnitude of the angular acceleration of the wheel and (b) the angle in radians through which it rotates in this time.

5. An electric motor rotating a grinding wheel at 100 rev/min is switched off. With constant negative angular acceleration of magnitude 2.00 rad/s^2, (a) how long does it take the wheel to stop? (b) Through how many radians does it turn while it is slowing down?

6. A centrifuge in a medical laboratory rotates at an angular speed of 3 600 rev/min. When switched off, it rotates 50.0 times before coming to rest. Find the constant angular acceleration of the centrifuge.

8. A rotating wheel requires 3.00 s to rotate through 37.0 revolutions. Its angular speed at the end of the 3.00-s interval is 98.0 rad/s. What is the constant angular acceleration of the wheel?

12. A racing car travels on a circular track of radius 250 m. If the car moves with a constant linear speed of 45.0 m/s, find (a) its angular speed and (b) the magnitude and direction of its acceleration.

13. A wheel 2.00 m in diameter lies in a vertical plane and rotates with a constant angular acceleration of 4.00 rad/s^2. The wheel starts at rest at $t = 0$, and the radius vector of a certain point P on the rim makes an angle of 57.3° with the horizontal at this time. At $t = 2.00$ s, find (a) the angular speed of the wheel, (b) the tangential speed and the total acceleration of the point P, and (c) the angular position of the point P.

16. A car accelerates uniformly from rest and reaches a speed of 22.0 m/s in 9.00 s. If the diameter of a tire is 58.0 cm, find (a) the number of revolutions the tire makes during this motion, assuming that no slipping occurs. (b) What is the final angular speed of a tire in revolutions per second?

17. A disk 8.00 cm in radius rotates at a constant rate of 1 200 rev/min about its central axis. Determine (a) its angular speed, (b) the tangential speed at a point 3.00 cm from its center, (c) the radial acceleration of a point on the rim, and (d) the total distance a point on the rim moves in 2.00 s.

18. A car traveling on a flat (unbanked) circular track accelerates uniformly from rest with a tangential acceleration of $1.70\ m/s^2$. The car makes it one quarter of the way around the circle before it skids off the track. Determine the coefficient of static friction between the car and track from these data.

20. Rigid rods of negligible mass lying along the y axis connect three particles (Fig. P10.20). If the system rotates about the x axis with an angular speed of 2.00 rad/s, find (a) the moment of inertia about the x axis and the total rotational kinetic energy evaluated from $\frac{1}{2}I\omega^2$ and (b) the tangential speed of each particle and the total kinetic energy evaluated from $\Sigma\frac{1}{2}m_i v_i^2$.

Figure P10.20

21. The four particles in Figure P10.21 are connected by rigid rods of negligible mass. The origin is at the center of the rectangle. If the system rotates in the xy plane about the z axis with an angular speed of 6.00 rad/s, calculate (a) the moment of inertia of the system about the z axis and (b) the rotational kinetic energy of the system.

Figure P10.21

31. Find the net torque on the wheel in Figure P10.31 about the axle through O if $a = 10.0$ cm and $b = 25.0$ cm.

Figure P10.31

35. A model airplane with mass 0.750 kg is tethered by a wire so that it flies in a circle 30.0 m in radius. The airplane engine provides a net thrust of 0.800 N perpendicular to the tethering wire. (a) Find the torque the net thrust produces about the center of the circle. (b) Find the angular acceleration of the airplane when it is in level flight. (c) Find the linear acceleration of the airplane tangent to its flight path.

37. A block of mass $m_1 = 2.00$ kg and a block of mass $m_2 = 6.00$ kg are connected by a massless string over a pulley in the shape of a solid disk having radius $R = 0.250$ m and mass $M = 10.0$ kg. These blocks are allowed to move on a fixed block-wedge of angle $\theta = 30.0°$ as in Figure P10.37. The coefficient of kinetic friction is 0.360 for both blocks. Draw free-body diagrams of both blocks and of the pulley. Determine (a) the acceleration of the two blocks and (b) the tensions in the string on both sides of the pulley.

Figure P10.37

46. A 15.0-kg object and a 10.0-kg object are suspended, joined by a cord that passes over a pulley with a radius of 10.0 cm and a mass of 3.00 kg (Fig. P10.46). The cord has a negligible mass and does not slip on the pulley. The pulley rotates on its axis without friction. The objects start from rest 3.00 m apart. Treat the pulley as a uniform disk, and determine the speeds of the two objects as they pass each other.

Figure P10.46

70. The reel shown in Figure P10.70 has radius R and moment of inertia I. One end of the block of mass m is connected to a spring of force constant k, and the other end is fastened to a cord wrapped around the reel. The reel axle and the incline are frictionless. The reel is wound counterclockwise so that the spring stretches a distance d from its unstretched position and is then released from rest. (a) Find the angular speed of the reel when the spring is again unstretched. (b) Evaluate the angular speed numerically at this point if $I = 1.00\ \text{kg}\cdot\text{m}^2$, $R = 0.300$ m, $k = 50.0$ N/m, $m = 0.500$ kg, $d = 0.200$ m, and $\theta = 37.0°$.

Figure P10.70

71. Two blocks, as shown in Figure P10.71, are connected by a string of negligible mass passing over a pulley of radius 0.250 m and moment of inertia I. The block on the frictionless incline is moving up with a constant acceleration of 2.00 m/s^2. (a) Determine T_1 and T_2, the tensions in the two parts of the string. (b) Find the moment of inertia of the pulley.

Figure P10.71

P10.1 (a) $\theta|_{t=0} = \boxed{5.00 \text{ rad}}$

$$\omega|_{t=0} = \left.\frac{d\theta}{dt}\right|_{t=0} = 10.0 + 4.00t|_{t=0} = \boxed{10.0 \text{ rad/s}}$$

$$\alpha_{t=0} = \left.\frac{d\omega}{dt}\right|_{t=0} = \boxed{4.00 \text{ rad/s}^2}$$

(b) $\theta|_{t=3.00 \text{ s}} = 5.00 + 30.0 + 18.0 = \boxed{53.0 \text{ rad}}$

$$\omega|_{t=3.00 \text{ s}} = \left.\frac{d\theta}{dt}\right|_{t=3.00 \text{ s}} = 10.0 + 4.00t|_{t=3.00 \text{ s}} = \boxed{22.0 \text{ rad/s}}$$

$$\alpha|_{t=3.00 \text{ s}} = \left.\frac{d\omega}{dt}\right|_{t=3.00 \text{ s}} = \boxed{4.00 \text{ rad/s}^2}$$

P10.3 (a) $\alpha = \dfrac{\omega - \omega_i}{t} = \dfrac{12.0 \text{ rad/s}}{3.00 \text{ s}} = \boxed{4.00 \text{ rad/s}^2}$

(b) $\theta = \omega_i t + \dfrac{1}{2}\alpha t^2 = \dfrac{1}{2}\left(4.00 \text{ rad/s}^2\right)(3.00 \text{ s})^2 = \boxed{18.0 \text{ rad}}$

P10.5 $\omega_i = \dfrac{100 \text{ rev}}{1.00 \text{ min}}\left(\dfrac{1 \text{ min}}{60.0 \text{ s}}\right)\left(\dfrac{2\pi \text{ rad}}{1.00 \text{ rev}}\right) = \dfrac{10\pi}{3} \text{ rad/s}, \ \omega_f = 0$

(a) $t = \dfrac{\omega_f - \omega_i}{\alpha} = \dfrac{0 - \frac{10\pi}{3}}{-2.00} \text{ s} = \boxed{5.24 \text{ s}}$

(b) $\theta_f = \bar{\omega} t = \left(\dfrac{\omega_f + \omega_i}{2}\right)t = \left(\dfrac{10\pi}{6} \text{ rad/s}\right)\left(\dfrac{10\pi}{6} \text{ s}\right) = \boxed{27.4 \text{ rad}}$

P10.6 $\omega_i = 3\,600 \text{ rev/min} = 3.77 \times 10^2 \text{ rad/s}$

$\theta = 50.0 \text{ rev} = 3.14 \times 10^2 \text{ rad and } \omega_f = 0$

$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

$0 = \left(3.77 \times 10^2 \text{ rad/s}\right)^2 + 2\alpha\left(3.14 \times 10^2 \text{ rad}\right)$

$\alpha = \boxed{-2.26 \times 10^2 \text{ rad/s}^2}$

P10.8 $\theta_f - \theta_i = \omega_i t + \dfrac{1}{2}\alpha t^2$ and $\omega_f = \omega_i + \alpha t$ are two equations in two unknowns ω_i and α

$\omega_i = \omega_f - \alpha t$: $\quad \theta_f - \theta_i = \left(\omega_f - \alpha t\right)t + \dfrac{1}{2}\alpha t^2 = \omega_f t - \dfrac{1}{2}\alpha t^2$

$$37.0 \text{ rev}\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right) = 98.0 \text{ rad/s}(3.00 \text{ s}) - \frac{1}{2}\alpha(3.00 \text{ s})^2$$

$232 \text{ rad} = 294 \text{ rad} - \left(4.50 \text{ s}^2\right)\alpha$: $\quad \alpha = \dfrac{61.5 \text{ rad}}{4.50 \text{ s}^2} = \boxed{13.7 \text{ rad/s}^2}$

P10.12 (a) $v = r\omega; \ \omega = \dfrac{v}{r} = \dfrac{45.0 \text{ m/s}}{250 \text{ m}} = \boxed{0.180 \text{ rad/s}}$

(b) $a_r = \dfrac{v^2}{r} = \dfrac{(45.0 \text{ m/s})^2}{250 \text{ m}} = \boxed{8.10 \text{ m/s}^2 \text{ toward the center of track}}$

P10.13 Given $r = 1.00\text{ m}$, $\alpha = 4.00\text{ rad/s}^2$, $\omega_i = 0$ and $\theta_i = 57.3° = 1.00\text{ rad}$

(a) $\omega_f = \omega_i + \alpha t = 0 + \alpha t$

At $t = 2.00\text{ s}$, $\omega_f = 4.00\text{ rad/s}^2(2.00\text{ s}) = \boxed{8.00\text{ rad/s}}$

(b) $v = r\omega = 1.00\text{ m}(8.00\text{ rad/s}) = \boxed{8.00\text{ m/s}}$

$|a_r| = a_c = r\omega^2 = 1.00\text{ m}(8.00\text{ rad/s})^2 = 64.0\text{ m/s}^2$

$a_t = r\alpha = 1.00\text{ m}(4.00\text{ rad/s}^2) = 4.00\text{ m/s}^2$

The magnitude of the total acceleration is:

$$a = \sqrt{a_r^2 + a_t^2} = \sqrt{(64.0\text{ m/s}^2)^2 + (4.00\text{ m/s}^2)^2} = \boxed{64.1\text{ m/s}^2}$$

The direction of the total acceleration vector makes an angle ϕ with respect to the radius to point P:

$$\phi = \tan^{-1}\left(\frac{a_t}{a_c}\right) = \tan^{-1}\left(\frac{4.00}{64.0}\right) = \boxed{3.58°}$$

(c) $\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2 = (1.00\text{ rad}) + \frac{1}{2}(4.00\text{ rad/s}^2)(2.00\text{ s})^2 = \boxed{9.00\text{ rad}}$

P10.16 (a) $s = \bar{v}t = (11.0\text{ m/s})(9.00\text{ s}) = 99.0\text{ m}$

$$\theta = \frac{s}{r} = \frac{99.0\text{ m}}{0.290\text{ m}} = 341\text{ rad} = \boxed{54.3\text{ rev}}$$

(b) $\omega_f = \frac{v_f}{r} = \frac{22.0\text{ m/s}}{0.290\text{ m}} = 75.9\text{ rad/s} = \boxed{12.1\text{ rev/s}}$

P10.17 (a) $\omega = 2\pi f = \frac{2\pi\text{ rad}}{1\text{ rev}}\left(\frac{1\,200\text{ rev}}{60.0\text{ s}}\right) = \boxed{126\text{ rad/s}}$

(b) $v = \omega r = (126\text{ rad/s})(3.00 \times 10^{-2}\text{ m}) = \boxed{3.77\text{ m/s}}$

(c) $a_c = \omega^2 r = (126)^2(8.00 \times 10^{-2}) = 1\,260\text{ m/s}^2$ so $\mathbf{a}_r = \boxed{1.26\text{ km/s}^2\text{ toward the center}}$

(d) $s = r\theta = \omega r t = (126\text{ rad/s})(8.00 \times 10^{-2}\text{ m})(2.00\text{ s}) = \boxed{20.1\text{ m}}$

P10.18 The force of static friction must act forward and then more and more inward on the tires, to produce both tangential and centripetal acceleration. Its tangential component is $m(1.70\text{ m/s}^2)$. Its radially inward component is $\frac{mv^2}{r}$. This takes the maximum value

$$m\omega_f^2 r = mr(\omega_i^2 + 2\alpha\Delta\theta) = mr\left(0 + 2\alpha\frac{\pi}{2}\right) = m\pi r\alpha = m\pi a_t = m\pi(1.70\text{ m/s}^2).$$

With skidding impending we have $\sum F_y = ma_y$, $+n - mg = 0$, $n = mg$

$$f_s = \mu_s n = \mu_s mg = \sqrt{m^2(1.70\text{ m/s}^2)^2 + m^2\pi^2(1.70\text{ m/s}^2)^2}$$

$$\mu_s = \frac{1.70\text{ m/s}^2}{g}\sqrt{1+\pi^2} = \boxed{0.572}$$

P10.20 $m_1 = 4.00\text{ kg},\ r_1 = |y_1| = 3.00\text{ m};$

$m_2 = 2.00\text{ kg},\ r_2 = |y_2| = 2.00\text{ m};$

$m_3 = 3.00\text{ kg},\ r_3 = |y_3| = 4.00\text{ m};$

$\omega = 2.00\text{ rad/s}$ about the x-axis

FIG. P10.20

(a) $I_x = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2$

$I_x = 4.00(3.00)^2 + 2.00(2.00)^2 + 3.00(4.00)^2 = \boxed{92.0\text{ kg}\cdot\text{m}^2}$

$K_R = \frac{1}{2} I_x \omega^2 = \frac{1}{2}(92.0)(2.00)^2 = \boxed{184\text{ J}}$

(b) $v_1 = r_1\omega = 3.00(2.00) = \boxed{6.00\text{ m/s}}$ $\quad K_1 = \frac{1}{2} m_1 v_1^2 = \frac{1}{2}(4.00)(6.00)^2 = 72.0\text{ J}$

$v_2 = r_2\omega = 2.00(2.00) = \boxed{4.00\text{ m/s}}$ $\quad K_2 = \frac{1}{2} m_2 v_2^2 = \frac{1}{2}(2.00)(4.00)^2 = 16.0\text{ J}$

$v_3 = r_3\omega = 4.00(2.00) = \boxed{8.00\text{ m/s}}$ $\quad K_3 = \frac{1}{2} m_3 v_3^2 = \frac{1}{2}(3.00)(8.00)^2 = 96.0\text{ J}$

$K = K_1 + K_2 + K_3 = 72.0 + 16.0 + 96.0 = \boxed{184\text{ J}} = \frac{1}{2} I_x \omega^2$

P10.21 (a) $I = \sum_j m_j r_j^2$

In this case,

$r_1 = r_2 = r_3 = r_4$

$r = \sqrt{(3.00\text{ m})^2 + (2.00\text{ m})^2} = \sqrt{13.0}\text{ m}$

$I = \left[\sqrt{13.0}\text{ m}\right]^2 [3.00 + 2.00 + 2.00 + 4.00]\text{ kg}$

$= \boxed{143\text{ kg}\cdot\text{m}^2}$

(b) $K_R = \frac{1}{2} I\omega^2 = \frac{1}{2}(143\text{ kg}\cdot\text{m}^2)(6.00\text{ rad/s})^2$

$= \boxed{2.57 \times 10^3\text{ J}}$

FIG. P10.21

P10.31 $\sum \tau = 0.100\text{ m}(12.0\text{ N}) - 0.250\text{ m}(9.00\text{ N}) - 0.250\text{ m}(10.0\text{ N}) = \boxed{-3.55\text{ N}\cdot\text{m}}$

The thirty-degree angle is unnecessary information.

FIG. P10.31

P10.35 $m = 0.750\text{ kg},\ F = 0.800\text{ N}$

(a) $\tau = rF = 30.0\text{ m}(0.800\text{ N}) = \boxed{24.0\text{ N}\cdot\text{m}}$

(b) $\alpha = \frac{\tau}{I} = \frac{rF}{mr^2} = \frac{24.0}{0.750(30.0)^2} = \boxed{0.035\,6\text{ rad/s}^2}$

(c) $a_t = \alpha r = 0.035\,6(30.0) = \boxed{1.07\text{ m/s}^2}$

FIG. P10.35

P10.37 For m_1,

$\sum F_y = ma_y$: $\quad +n - m_1 g = 0$

$n_1 = m_1 g = 19.6\text{ N}$

$f_{k1} = \mu_k n_1 = 7.06\text{ N}$

$\sum F_x = ma_x$: $\quad -7.06\text{ N} + T_1 = (2.00\text{ kg})a \qquad (1)$

For the pulley,

$\sum \tau = I\alpha$: $\quad -T_1 R + T_2 R = \frac{1}{2}MR^2\left(\frac{a}{R}\right)$

$-T_1 + T_2 = \frac{1}{2}(10.0\text{ kg})a$

$-T_1 + T_2 = (5.00\text{ kg})a \qquad (2)$

For m_2, $\quad +n_2 - m_2 g\cos\theta = 0$

$n_2 = 6.00\text{ kg}(9.80\text{ m/s}^2)(\cos 30.0°)$

$= 50.9\text{ N}$

$f_{k2} = \mu_k n_2$

$= 18.3\text{ N}$: $\quad -18.3\text{ N} - T_2 + m_2 \sin\theta = m_2 a$

$-18.3\text{ N} - T_2 + 29.4\text{ N} = (6.00\text{ kg})a \qquad (3)$

FIG. P10.37

(a) Add equations (1), (2), and (3):

$$-7.06\text{ N} - 18.3\text{ N} + 29.4\text{ N} = (13.0\text{ kg})a$$

$$a = \frac{4.01\text{ N}}{13.0\text{ kg}} = \boxed{0.309\text{ m/s}^2}$$

(b) $T_1 = 2.00\text{ kg}(0.309\text{ m/s}^2) + 7.06\text{ N} = \boxed{7.67\text{ N}}$

$T_2 = 7.67\text{ N} + 5.00\text{ kg}(0.309\text{ m/s}^2) = \boxed{9.22\text{ N}}$

P10.46 Choose the zero gravitational potential energy at the level where the masses pass.

$$K_f + U_{gf} = K_i + U_{gi} + \Delta E$$

$$\frac{1}{2}m_1 v^2 + \frac{1}{2}m_2 v^2 + \frac{1}{2}I\omega^2 = 0 + m_1 g h_{1i} + m_2 g h_{2i} + 0$$

$$\frac{1}{2}(15.0 + 10.0)v^2 + \frac{1}{2}\left[\frac{1}{2}(3.00)R^2\right]\left(\frac{v}{R}\right)^2 = 15.0(9.80)(1.50) + 10.0(9.80)(-1.50)$$

$$\frac{1}{2}(26.5\text{ kg})v^2 = 73.5\text{ J} \Rightarrow v = \boxed{2.36\text{ m/s}}$$

P10.71 (a) $m_2 g - T_2 = m_2 a$

$T_2 = m_2(g - a) = 20.0\text{ kg}(9.80\text{ m/s}^2 - 2.00\text{ m/s}^2) = \boxed{156\text{ N}}$

$T_1 - m_1 g\sin 37.0° = m_1 a$

$T_1 = (15.0\text{ kg})(9.80\sin 37.0° + 2.00)\text{ m/s}^2 = \boxed{118\text{ N}}$

(b) $(T_2 - T_1)R = I\alpha = I\left(\frac{a}{R}\right)$

$I = \frac{(T_2 - T_1)R^2}{a} = \frac{(156\text{ N} - 118\text{ N})(0.250\text{ m})^2}{2.00\text{ m/s}^2} = \boxed{1.17\text{ kg}\cdot\text{m}^2}$

FIG. P10.71

P10.72 For the board just starting to move,

$\sum \tau = I\alpha$: $\quad mg\left(\frac{\ell}{2}\right)\cos\theta = \left(\frac{1}{3}m\ell^2\right)\alpha$

$\alpha = \frac{3}{2}\left(\frac{g}{\ell}\right)\cos\theta$

FIG. P10.72

The tangential acceleration of the end is $\quad a_t = \ell\alpha = \frac{3}{2}g\cos\theta$

The vertical component is $\quad a_y = a_t\cos\theta = \frac{3}{2}g\cos^2\theta$

If this is greater than g, the board will pull ahead of the ball falling:

(a) $\frac{3}{2}g\cos^2\theta \geq g$ gives $\cos^2\theta \geq \frac{2}{3}$ so $\quad \cos\theta \geq \sqrt{\frac{2}{3}}$ $\quad$ and $\quad \boxed{\theta \leq 35.3°}$

(b) When $\theta = 35.3°$, the cup will land underneath the release-point of the ball if $\quad r_c = \ell\cos\theta$

When $\ell = 1.00\text{ m}$, and $\theta = 35.3°$ $\quad r_c = 1.00\text{ m}\sqrt{\frac{2}{3}} = 0.816\text{ m}$

so the cup should be $(1.00\text{ m} - 0.816\text{ m}) = \boxed{0.184\text{ m from the moving end}}$

Course outline for 103 Physics
(Mechanics)

Text book:

Physics for Scientists and Engineers
6th Edition
Raymond A. **Serway**

Chapter	Title	Section	Hours	Suggested problems
1	Physics and measurement	1.1, 1.4, 1.5	2	13,15,21,25,31
2	Motion in One Dimension	2.1, 2.2, 2.3, 2.5, 2.6	4	4,5,11,15,16,20,21,22,23,25,27,28,29,32,33,40,42,43,46,48,51,52
3	Vectors	3.1--to--3.4	4	1,4,19,21,27,30,31,33,39,49,50
4	Motion in Two Dimensions	4.1--to--4.5	4	1,3,5,6,8,14,15,17,19,20,22,23,25,29
5	The Laws of Motion	5.1--to--5.8	6	3,7,11,16,18,24,25,26,28,30,31,37,41,44,45,46,68
6	Circular Motion and Other Applications of Newton's Laws	6.1	2	1,2,5,7,59
7	Energy and Energy Transfer	7.2--to--7.8	4	1,4,7,13,14,15,16,19,21,24,25,26,28,31,32,33,35,37,40
8	Potential Energy	8.1--to--8.5	4	2,5,6,11,13,17,31,33,36,38,42,55,57,59,60
9	Linear Momentum and Collisions	9.1--to--9.4	5	1,2,4,5,7,8,9,10,13,15,16,17,18,21,25,27,32,33,35
10	Rotation of a Rigid Object About a Fixed Axis	10.1--to--10.8	6	1,3,5,6,8,12,13,16,17,18,20,21,31,35,37,46,70,71

Marks distribution:

1) Two midterm exams each 15 marks----------= 30 marks
2) Practical work (Lab.)----------= 30 marks
3) Final exam----------= 40 marks

Total------= 100 marks

N.B. ***The students must know how to solve these suggested problems in addition to all the examples under supervision of the teacher.***