# Chapter One

**P1.2** $5.52 \times 10^3\ \text{kg/m}^3$, between the densities of aluminum and iron, and greater than the densities of surface rocks.

**P1.4** 23.0 kg

**P1.6** 7.69 cm

**P1.8** (a) and (b) see the solution, $N_A = 6.022\ 137 \times 10^{23}$; (c) 18.0 g; (d) 44.0 g

**P1.10** (a) $9.83 \times 10^{-16}$ g; (b) $1.06 \times 10^7$ atoms

**P1.12** (a) $4.02 \times 10^{25}$ molecules; (b) $3.65 \times 10^4$ molecules

**P1.14** (a) ii; (b) iii; (c) i

**P1.16** (a) $\frac{\text{M} \cdot \text{L}}{\text{T}^2}$; (b) 1 newton = $1\ \text{kg} \cdot \text{m/s}^2$

**P1.18** $35.7\ \text{m}^2$

**P1.20** $1.39 \times 10^{-4}\ \text{m}^3$

**P1.22** (a) $3.39 \times 10^5\ \text{ft}^3$; (b) $2.54 \times 10^4$ lb

**P1.24** (a) 560 km = $5.60 \times 10^5$ m = $5.60 \times 10^7$ cm;
(b) 491 m = 0.491 km = $4.91 \times 10^4$ cm;
(c) 6.19 km = $6.19 \times 10^3$ m = $6.19 \times 10^5$ cm;
(d) 2.50 km = $2.50 \times 10^3$ m = $2.50 \times 10^5$ cm

**P1.26** $4.05 \times 10^3\ \text{m}^2$

**P1.28** (a) 1 mi/h = 1.609 km/h; (b) 88.5 km/h; (c) 16.1 km/h

**P1.30** $1.19 \times 10^{57}$ atoms

**P1.32** $2.57 \times 10^6\ \text{m}^3$

**P1.34** $1.3 \times 10^{21}$ kg

**P1.36** 200 km

**P1.38** (a) 13.4; (b) 49.1

**P1.40** $r_{\text{Al}} = r_{\text{Fe}} \left( \frac{\rho_{\text{Fe}}}{\rho_{\text{Al}}} \right)^{1/3}$

**P1.42** $\sim 10^7$ rev

**P1.44** $\sim 10^9$ raindrops

**P1.46** $\sim 10^{11}$ cans; $\sim 10^5$ tons

**P1.48** $(209 \pm 4)\ \text{cm}^2$

**P1.50** (a) 3; (b) 4; (c) 3; (d) 2

**P1.52** (a) 797; (b) 1.1; (c) 17.66

**P1.54** 115.9 m

**P1.56** 316 m

**P1.58** $4.50\ \text{m}^2$

**P1.60** see the solution; 24.6°

**P1.62** 3.64 cents; no

**P1.64** see the solution

**P1.66** (a) 1 000 kg; (b) $5.2 \times 10^{-16}$ kg; 0.27 kg; $1.3 \times 10^{-5}$ kg

**P1.68** $8.32 \times 10^{-4}$ m/s; a snail

**P1.70** see the solution

## Chapter Two

**P2.2** (a) $2\times10^{-7}$ m/s; $1\times10^{-6}$ m/s; (b) $5\times10^{8}$ yr

**P2.4** (a) 50.0 m/s; (b) 41.0 m/s

**P2.6** (a) 27.0 m; (b) $27.0\text{ m}+(18.0\text{ m/s})\Delta t+(3.00\text{ m/s}^2)(\Delta t)^2$; (c) 18.0 m/s

**P2.8** (a), (b), (c) see the solution; 4.6 $\text{m/s}^2$; (d) 0

**P2.10** 5.00 m

**P2.12** (a) 20.0 m/s; 5.00 m/s; (b) 262 m

**P2.14** (a) see the solution; (b) 1.60 $\text{m/s}^2$; 0.800 $\text{m/s}^2$

**P2.16** (a) 13.0 m/s; (b) 10.0 m/s; 16.0 m/s; (c) 6.00 $\text{m/s}^2$; (d) 6.00 $\text{m/s}^2$

**P2.18** see the solution

**P2.20** (a) 6.61 m/s; (b) $-0.448$ $\text{m/s}^2$

**P2.22** (a) $-21.8$ $\text{mi/h}\cdot\text{s}=-9.75$ $\text{m/s}^2$; (b) $-22.2$ $\text{mi/h}\cdot\text{s}=-9.94$ $\text{m/s}^2$; (c) $-22.8$ $\text{mi/h}\cdot\text{s}=-10.2$ $\text{m/s}^2$

**P2.24** (a) 1.88 km; (b) 1.46 km; (c) see the solution; (d) (i) $x_1=(1.67\text{ m/s}^2)t^2$; (ii) $x_2=(50\text{ m/s})t-375\text{ m}$; (iii) $x_3=(250\text{ m/s})t-(2.5\text{ m/s}^2)t^2-4\,375\text{ m}$; (e) 37.5 m/s

**P2.26** 958 m

**P2.28** (a) $x_f=(30.0t-t^2)$ m; $v_f=(30.0-2t)$ m/s; (b) 225 m

**P2.30** $x_f-x_i=v_{xf}t-\frac{1}{2}a_xt^2$; 3.10 m/s

**P2.32** (a) 35.0 s; (b) 15.7 m/s

**P2.34** (a) $1.12\times10^{11}$ $\text{m/s}^2$; (b) $4.67\times10^{-5}$ s

**P2.36** (a) False unless the acceleration is zero; see the solution; (b) True

**P2.38** Yes; 212 m; 11.4 s

**P2.40** (a) $-4.90$ m; $-19.6$ m; $-44.1$ m; (b) $-9.80$ m/s; $-19.6$ m/s; $-29.4$ m/s

**P2.42** 1.79 s

**P2.44** No; see the solution

**P2.46** The second ball is thrown at speed $v_i=\sqrt{gh}$

**P2.48** (a) 510 m; (b) 20.4 s

**P2.50** (a) 96.0 ft/s; (b) $a=3.07\times10^{3}$ $\text{ft/s}^2$ upward; (c) $\Delta t=3.13\times10^{-2}$ s

**P2.52** 38.2 m

**P2.54** (a) and (b) see the solution; (c) $-4$ $\text{m/s}^2$; (d) 34 m; (e) 28 m

**P2.56** 0.222 s

**P2.58** (a) see the solution; (b) 6.23 s

**P2.60** 1.60 $\text{m/s}^2$

**P2.62** (a) 41.0 s; (b) 1.73 km; (c) $-184$ m/s

**P2.64** $v_{xi}t+\frac{1}{2}a_xt^2$; displacements agree

**P2.66** 155 s; 129 s

**P2.68** (a) 5.44 s; (b) 131 m; (c) 50.8 m/s; (d) 95.3 $\text{m/s}^2$ upward

**P2.70** (a) 26.4 m; (b) 6.82%

**P2.72** see the solution

**P2.74** see the solution; $a_x=-1.63$ $\text{m/s}^2$

# Chapter Three

**P3.2** (a) $(2.17\text{ m}, 1.25\text{ m})$; $(-1.90\text{ m}, 3.29\text{ m})$; (b) 4.55 m

**P3.4** (a) 8.60 m; (b) 4.47 m at $-63.4°$; 4.24 m at $135°$

**P3.6** (a) $r$ at $180° - \theta$; (b) $2r$ at $180° + \theta$; (c) $3r$ at $-\theta$

**P3.8** 14 km at 65° north of east

**P3.10** (a) 6.1 at 112°; (b) 14.8 at 22°

**P3.12** 9.5 N at 57°

**P3.14** 7.9 m at 4° north of west

**P3.16** see the solution

**P3.18** 86.6 m and –50.0 m

**P3.20** 1.31 km north; 2.81 km east

**P3.22** $-25.0\text{ m }\hat{\mathbf{i}} + 43.3\text{ m }\hat{\mathbf{j}}$

**P3.24** $14.0\text{ m/s}$ at 11.3° west of north

**P3.26** 788 mi at 48.0° north of east

**P3.28** 7.21 m at 56.3°

**P3.30** $\mathbf{C} = 7.30\text{ cm }\hat{\mathbf{i}} - 7.20\text{ cm }\hat{\mathbf{j}}$

**P3.32** (a) 2.83 m at 315°; (b) 13.4 m at 117°

**P3.34** 42.7 yards

**P3.36** 4.64 m at 78.6°

**P3.38** (a) 10.4 cm; (b) 35.5°

**P3.40** $1.43 \times 10^4\text{ m}$ at 32.2° above the horizontal

**P3.42** $-220\hat{\mathbf{i}} + 57.6\hat{\mathbf{j}} = 227$ paces at 165°

**P3.44** (a) $(3.12\hat{\mathbf{i}} + 5.02\hat{\mathbf{j}} - 2.20\hat{\mathbf{k}})\text{ km}$; (b) 6.31 km

**P3.46** (a) $(15.1\hat{\mathbf{i}} + 7.72\hat{\mathbf{j}})\text{ cm}$; (b) $(-7.72\hat{\mathbf{i}} + 15.1\hat{\mathbf{j}})\text{ cm}$; (c) $(+7.72\hat{\mathbf{i}} + 15.1\hat{\mathbf{j}})\text{ cm}$

**P3.48** (a) 74.6° north of east; (b) 470 km

**P3.50** $a = 5.00$, $b = 7.00$

**P3.52** $2\tan^{-1}\left(\frac{1}{n}\right)$

**P3.54** 25.4 s

**P3.56** (a) 7.17 km; (b) 6.15 km

**P3.58** 7.87 N at 97.8° counterclockwise from a horizontal line to the right

**P3.60** $(-2.00\text{ m/s})\hat{\mathbf{j}}$; its velocity vector

**P3.62** (a) $(10.0\text{ m}, 16.0\text{ m})$; (b) see the solution

**P3.64** (a) $\mathbf{R}_1 = a\hat{\mathbf{i}} + b\hat{\mathbf{j}}$; $|\mathbf{R}_1| = \sqrt{a^2 + b^2}$; (b) $\mathbf{R}_2 = a\hat{\mathbf{i}} + b\hat{\mathbf{j}} + c\hat{\mathbf{k}}$; $|\mathbf{R}_2| = \sqrt{a^2 + b^2 + c^2}$

**P3.66** (a) 0.079 8N; (b) 57.9°; (c) 32.1°

## Chapter Four

**P4.2** (a) $\mathbf{r} = 18.0t\hat{\mathbf{i}} + \left(4.00t - 4.90t^2\right)\hat{\mathbf{j}}$;
(b) $\mathbf{v} = 18.0\hat{\mathbf{i}} + (4.00 - 9.80t)\hat{\mathbf{j}}$;
(c) $\mathbf{a} = \left(-9.80\ \text{m/s}^2\right)\hat{\mathbf{j}}$;
(d) $(54.0\ \text{m})\hat{\mathbf{i}} - (32.1\ \text{m})\hat{\mathbf{j}}$;
(e) $(18.0\ \text{m/s})\hat{\mathbf{i}} - (25.4\ \text{m/s})\hat{\mathbf{j}}$;
(f) $\left(-9.80\ \text{m/s}^2\right)\hat{\mathbf{j}}$

**P4.4** (a) $\mathbf{v} = \left(-5.00\omega\,\hat{\mathbf{i}} + 0\hat{\mathbf{j}}\right)\ \text{m/s}$;
$\mathbf{a} = \left(0\hat{\mathbf{i}} + 5.00\omega^2\hat{\mathbf{j}}\right)\ \text{m/s}^2$;
(b) $\mathbf{r} = 4.00\ \text{m}\ \hat{\mathbf{j}}\ + 5.00\ \text{m}\left(-\sin\omega t\,\hat{\mathbf{i}} - \cos\omega t\,\hat{\mathbf{j}}\right)$;
$\mathbf{v} = 5.00\ \text{m}\ \omega\left(-\cos\omega t\,\hat{\mathbf{i}} + \sin\omega t\,\hat{\mathbf{j}}\right)$;
$\mathbf{a} = 5.00\ \text{m}\ \omega^2\left(\sin\omega t\,\hat{\mathbf{i}} + \cos\omega t\,\hat{\mathbf{j}}\right)$;
(c) a circle of radius 5.00 m centered at $(0,\ 4.00\ \text{m})$

**P4.6** (a) $\mathbf{v} = -12.0t\hat{\mathbf{j}}\ \text{m/s}$; $\mathbf{a} = -12.0\hat{\mathbf{j}}\ \text{m/s}^2$;
(b) $\mathbf{r} = \left(3.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}\right)\text{m}$; $\mathbf{v} = -12.0\hat{\mathbf{j}}\ \text{m/s}$

**P4.8** (a) $\mathbf{r} = \left(5.00t\hat{\mathbf{i}} + 1.50t^2\hat{\mathbf{j}}\right)\text{m}$;
$\mathbf{v} = \left(5.00\hat{\mathbf{i}} + 3.00t\hat{\mathbf{j}}\right)\ \text{m/s}$;
(b) $\mathbf{r} = \left(10.0\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}\right)\text{m}$; 7.81 m/s

**P4.10** $\left(7.23\times10^3\ \text{m},\ 1.68\times10^3\ \text{m}\right)$

**P4.12** (a) $d\sqrt{\dfrac{g}{2h}}$ horizontally;
(b) $\tan^{-1}\left(\dfrac{2h}{d}\right)$ below the horizontal

**P4.14** $0.600\ \text{m/s}^2$

**P4.16** (a) 76.0°; (b) the same; (c) $\dfrac{17d}{8}$

**P4.18** 25.8 m/s

**P4.20** $d\tan\theta_i - \dfrac{gd^2}{\left(2v_i^2\cos^2\theta_i\right)}$

**P4.22** 33.5° below the horizontal

**P4.24** (a) 0.852 s; (b) 3.29 m/s; (c) 4.03 m/s;
(d) 50.8°; (e) 1.12 s

**P4.26** $\tan^{-1}\left(\dfrac{\sqrt{2gh}}{v}\right)$

**P4.28** $0.0337\ \text{m/s}^2$ toward the center of the Earth

**P4.30** 0.281 rev/s

**P4.32** $7.58\times10^3\ \text{m/s}$; $5.80\times10^3\ \text{s}$

**P4.34** (a) $0.600\ \text{m/s}^2$ forward;
(b) $0.800\ \text{m/s}^2$ inward;
(c) $1.00\ \text{m/s}^2$ forward and 53.1° inward

**P4.36** (a) see the solution; (b) $29.7\ \text{m/s}^2$;
(c) 6.67 m/s at 36.9° above the horizontal

**P4.38** (a) 26.9 m/s; (b) 67.3 m;
(c)

**P4.40** 18.0 s

**P4.42** 153 km/h at 11.3° north of west

**P4.44** (a) $10.1\ \text{m/s}^2$ at 14.3° south from the vertical; (b) $9.80\ \text{m/s}^2$ vertically downward

**P4.46** 27.7° east of north

**P4.48** $2v_it\cos\theta_i$

**P4.50** (a) see the solution;
(b) $\theta_i = 45° + \dfrac{\phi}{2}$; $d_{\max} = \dfrac{v_i^2(1-\sin\phi)}{g\cos^2\phi}$

**P4.52** (a) 1.69 km/s; (b) $6.47\times10^3$ s

**P4.54** 10.7 m/s

**P4.56** $\dfrac{R}{2}$

**P4.58** 7.50 m/s in the direction the ball was thrown

**P4.60** (a) 19.6 cm; (b) 0.0561°; (c) aim low 3.68 cm; (d) aim low 3.68 cm; (e) aim high 6.12 cm; (f) aim low; (g) aim low

**P4.62** (a) $\sqrt{gR}$; (b) $\left(\sqrt{2}-1\right)R$

**P4.64** (18.8 m; −17.3 m)

**P4.66** see the solution; $\sim10^2\ \text{m/s}^2$

**P4.68** $x = -D$

**P4.70** (a) at 90° to the bank; (b) 133 m;
(c) upstream at 53.1° to the bank; (d) 107 m

**P4.72** see the solution

# Chapter Five

**P5.2** $1.66 \times 10^6$ N forward

**P5.4** (a) $\frac{vt}{2}$; (b) $\left(\frac{F_g v}{gt}\right)\hat{\mathbf{i}} + F_g\hat{\mathbf{j}}$

**P5.6** (a) $4.47 \times 10^{15}$ m/s$^2$ away from the wall; (b) $2.09 \times 10^{-10}$ N toward the wall

**P5.8** (a) 534 N down; (b) 54.5 kg

**P5.10** 2.55 N for an 88.7 kg person

**P5.12** $(16.3\hat{\mathbf{i}} + 14.6\hat{\mathbf{j}})$ N

**P5.14** (a) 181°; (b) 11.2 kg; (c) 37.5 m/s; (d) $(-37.5\hat{\mathbf{i}} - 0.893\hat{\mathbf{j}})$ m/s

**P5.16** 112 N

**P5.18** $T_1 = 296$ N; $T_2 = 163$ N; $T_3 = 325$ N

**P5.20** (a) see the solution; (b) 1.79 N

**P5.22** (a) 2.54 m/s$^2$ down the incline; (b) 3.18 m/s

**P5.24** see the solution; 6.30 m/s$^2$; 31.5 N

**P5.26** (a) 3.57 m/s$^2$; (b) 26.7 N; (c) 7.14 m/s

**P5.28** (a) 36.8 N; (b) 2.45 m/s$^2$; (c) 1.23 m

**P5.30** (a) 0.529 m; (b) 7.40 m/s upward

**P5.32** (a) 2.22 m; (b) 8.74 m/s

**P5.34** (a) $a_1 = 2a_2$;
(b) $T_1 = \frac{m_1 m_2 g}{2m_1 + \frac{m_2}{2}}$; $T_2 = \frac{m_1 m_2 g}{m_1 + \frac{m_2}{4}}$;
(c) $a_1 = \frac{m_2 g}{2m_1 + \frac{m_2}{2}}$; $a_2 = \frac{m_2 g}{4m_1 + m_2}$

**P5.36** $\mu_s = 0.306$; $\mu_k = 0.245$

**P5.38** (a) 3.34; (b) Time would increase

**P5.40** (a) 55.2°; (b) 167 N

**P5.42** 152 ft

**P5.44** (a) 2.31 m/s$^2$ down for $m_1$, left for $m_2$ and up for $m_3$; (b) 30.0 N and 24.2 N

**P5.46** Any value between 31.7 N and 48.6 N

**P5.48** 72.0 N

**P5.50** 6.84 m

**P5.52** (a) 3.00 s; (b) 20.1 m; (c) $(18.0\hat{\mathbf{i}} - 9.00\hat{\mathbf{j}})$ m

**P5.54** (a) 2.00 m/s$^2$ to the right;
(b) 8.00 N right on 4 kg;
6.00 N right on 3 kg; 4 N right on 2 kg;
(c) 8.00 N between 4 kg and 3 kg;
14.0 N between 2 kg and 3 kg;
(d) see the solution

**P5.56** 1.18 kN

**P5.58** (a) 4.90 m/s$^2$; (b) 3.13 m/s at 30.0° below the horizontal; (c) 1.35 m; (d) 1.14 s; (e) No

**P5.60** (a) and (b) see the solution; (c) 357 N; (d) see the solution; (e) 1.20

**P5.62** see the solution; 0.143 m/s$^2$ agrees with 0.137 m/s$^2$

**P5.64** (a) see the solution;
(b) on block one:
$49.0\text{ N }\hat{\mathbf{j}} - 49.0\text{ N }\hat{\mathbf{j}} + 14.7\text{ N }\hat{\mathbf{i}}$;
on block two: $-49.0\text{ N }\hat{\mathbf{j}} - 14.7\text{ N }\hat{\mathbf{i}} - 147\text{ N }\hat{\mathbf{j}} + 196\text{ N }\hat{\mathbf{j}} - 98.0\text{ N }\hat{\mathbf{i}} + 113\text{ N }\hat{\mathbf{i}}$;
(c) for block one: $0.980\hat{\mathbf{i}}$ m/s$^2$;
for block two: 1.96 m/s$^2$ $\hat{\mathbf{i}}$

**P5.66** 61.1 N

**P5.68** (a) 2.20 m/s$^2$; (b) 27.4 N

**P5.70** $mg\cos\theta\sin\theta$ to the right $+(M + m\cos^2\theta)g$ upward

**P5.72** see the solution

# Chapter Six

**P6.2** 215 N horizontally inward

**P6.4** $6.22 \times 10^{-12}$ N

**P6.6** (a) 1.65 km/s; (b) $6.84 \times 10^3$ s

**P6.8** 0.966 $g$

**P6.10** (a) $(-0.233\,\hat{\mathbf{i}} + 0.163\,\hat{\mathbf{j}})$ m/s$^2$; (b) 6.53 m/s; (c) $(-0.181\,\hat{\mathbf{i}} + 0.181\,\hat{\mathbf{j}})$ m/s$^2$

**P6.12** $2.06 \times 10^3$ rev/min

**P6.14** (a) $\sqrt{R\left(\frac{2T}{m} - g\right)}$; (b) $2T$ upward

**P6.16** (a) 1.33 m/s$^2$; (b) 1.79 m/s$^2$ forward and 48.0° inward

**P6.18** 8.88 N

**P6.20** (a) 8.62 m; (b) $Mg$ downward; (c) 8.45 m/s$^2$, Unless they are belted in, the riders will fall from the cars.

**P6.22** 15.3 m/s Straight across the dashboard to the left

**P6.24** 0.527°

**P6.26** (a) 1.41 h; (b) 17.1

**P6.28** $\mu_k = \dfrac{2(vt - L)}{(g + a)t^2}$

**P6.30** (a) $2.38 \times 10^5$ m/s$^2$ horizontally inward $= 2.43 \times 10^4 g$; (b) 360 N inward perpendicular to the cone; (c) $47.5 \times 10^4$ m/s$^2$

**P6.32** (a) 6.27 m/s$^2$ downward; (b) 784 N up; (c) 283 N up

**P6.34** (a) 53.8 m/s; (b) 148 m

**P6.36** 1.40

**P6.38** $-0.212$ m/s$^2$

**P6.40** see the solution

**P6.42** 36.5 m/s

**P6.44** (a) 0.980 m/s; (b) see the solution

**P6.46** (a) $7.70 \times 10^{-4}$ kg/m; (b) 0.998 N; (c) The ball reaches maximum height 49 m. Its flight lasts 6.3 s and its impact speed is 27 m/s.

**P6.48** (a) see the solution; (b) 81.8 m; (c) 15.9°

**P6.50** 0.835 rev/s

**P6.52** (a) $mg - \dfrac{mv^2}{R}$; (b) $v = \sqrt{gR}$

**P6.54** (a) 2.63 m/s$^2$; (b) 201 m; (c) 17.7 m/s

**P6.56** (a) 106 N; (b) 0.396

**P6.58** (a) $m_2 g$; (b) $m_2 g$; (c) $\sqrt{\left(\frac{m_2}{m_1}\right) gR}$

**P6.60** 62.2 rev/min

**P6.62** 2.14 rev/min

**P6.64** (a) $v = \sqrt{\pi R g}$; (b) $m\pi g$

**P6.66** (a) 8.04 s; (b) 379 m/s; (c) 1.19 cm/s; (d) 9.55 cm

**P6.68** (a) either 70.4° or 0°; (b) 0°

**P6.70** (a) 78.3 m/s; (b) 11.1 s; (c) 121 m

**P6.72** (a) and (b) see the solution; (c) 53.0 m/s

# Chapter Seven

**P7.2** $1.59\times10^{3}$ J

**P7.4** (a) $3.28\times10^{-2}$ J; (b) $-3.28\times10^{-2}$ J

**P7.6** see the solution

**P7.8** 5.33 W

**P7.10** 16.0

**P7.12** (a) see the solution; (b) $-12.0$ J

**P7.14** 50.0 J

**P7.16** (a) 575 N/m; (b) 46.0 J

**P7.18** (a) 9.00 kJ; (b) 11.7 kJ, larger by 29.6%

**P7.20** (a) see the solution; (b) $mgR$

**P7.22** (a) $\frac{mg}{k_1}+\frac{mg}{k_2}$; (b) $\left(\frac{1}{k_1}+\frac{1}{k_2}\right)^{-1}$

**P7.24** (a) 1.20 J; (b) 5.00 m/s; (c) 6.30 J

**P7.26** (a) 60.0 J; (b) 60.0 J

**P7.28** (a) 1.94 m/s; (b) 3.35 m/s; (c) 3.87 m/s

**P7.30** (a) $3.78\times10^{-16}$ J; (b) $1.35\times10^{-14}$ N; (c) $1.48\times10^{+16}$ m/s$^2$; (d) 1.94 ns

**P7.32** (a) 0.791 m/s; (b) 0.531 m/s

**P7.34** (a) 329 J; (b) 0; (c) 0; (d) 185 J; (e) 144 J

**P7.36** 8.01 W

**P7.38** $\sim 10^{4}$ W

**P7.40** (a) 5.91 kW; (b) 11.1 kW

**P7.42** No. (a) 582; (b) 90.5 W = 0.121 hp

**P7.44** 5.92 km/L

**P7.46** 90.0 J

**P7.48** (a) $\cos\alpha=\frac{A_x}{A}$; $\cos\beta=\frac{A_y}{A}$; $\cos\gamma=\frac{A_z}{A}$; (b) see the solution

**P7.50** (a) $a=\frac{40.1\text{ kN}}{m^{1.8}}$; $b=1.80$; (b) 294 J

**P7.52** (a) $\frac{mgnhh_s}{v+nh_s}$; (b) $\frac{mgvh}{v+nh_s}$

**P7.54** $1.53\times10^{5}$ N upward

**P7.56** see the solution

**P7.58** (a) see the solution; (b) $2kL^2+kA^2-2kL\sqrt{A^2+L^2}$

**P7.60** (a) $\mathbf{F}_1=(20.5\hat{\mathbf{i}}+14.3\hat{\mathbf{j}})$ N; $\mathbf{F}_2=(-36.4\hat{\mathbf{i}}+21.0\hat{\mathbf{j}})$ N;
(b) $(-15.9\hat{\mathbf{i}}+35.3\hat{\mathbf{j}})$ N;
(c) $(-3.18\hat{\mathbf{i}}+7.07\hat{\mathbf{j}})$ m/s$^2$;
(d) $(-5.54\hat{\mathbf{i}}+23.7\hat{\mathbf{j}})$ m/s;
(e) $(-2.30\hat{\mathbf{i}}+39.3\hat{\mathbf{j}})$ m; (f) 1.48 kJ; (g) 1.48 kJ

**P7.62** (a) see the solution; (b) 125 N/m ± 2%; (c) 13.1 N

**P7.64** (a) 5.60 J; (b) 0.152; (c) 2.28 rev

**P7.66** see the solution

**P7.68** (a) 2.17 kW; (b) 58.6 kW

**P7.70** (a) $x=-4.0$ mm; (b) $-1.0$ cm

# Chapter Eight

**P8.2** (a) 800 J; (b) 107 J; (c) 0

**P8.4** (a) $1.11\times10^9$ J; (b) 0.2

**P8.6** 1.84 m

**P8.8** (a) 10.2 kW; (b) 10.6 kW; (c) $5.82\times10^6$ J

**P8.10** $d=\dfrac{kx^2}{2mg\sin\theta}-x$

**P8.12** (a) see the solution; (b) 60.0°

**P8.14** (a) $\sqrt{\dfrac{2(m_1-m_2)gh}{(m_1+m_2)}}$; (b) $\dfrac{2m_1h}{m_1+m_2}$

**P8.16** 160 L/min

**P8.18** 40.8°

**P8.20** $\left(\dfrac{8gh}{15}\right)^{1/2}$

**P8.22** (a) see the solution; (b) 35.0 J

**P8.24** (a) $v_B=5.94$ m/s; $v_C=7.67$ m/s; (b) 147 J

**P8.26** (a) $U_f=22.0$ J; $E=40.0$ J; (b) Yes. The total mechanical energy changes.

**P8.28** 194 m

**P8.30** 2.06 kN up

**P8.32** 168 J

**P8.34** (a) 24.5 m/s; (b) yes; (c) 206 m; (d) Air drag depends strongly on speed.

**P8.36** 3.92 kJ

**P8.38** 44.1 kW

**P8.40** (a) $\dfrac{Ax^2}{2}-\dfrac{Bx^3}{3}$;
(b) $\Delta U=\dfrac{5A}{2}-\dfrac{19B}{3}$; $\Delta K=\dfrac{19B}{3}-\dfrac{5A}{2}$

**P8.42** $\left(7-9x^2y\right)\hat{\mathbf{i}}-3x^3\hat{\mathbf{j}}$

**P8.44** see the solution

**P8.46** (a) $r=1.5$ mm and 3.2 mm, stable; 2.3 mm and unstable; $r\to\infty$ neutral;
(b) $-5.6\text{ J}\le E<1\text{ J}$; (c) $0.6\text{ mm}\le r\le3.6\text{ mm}$; (d) 2.6 J; (e) 1.5 mm; (f) 4 J

**P8.48** see the solution

**P8.50** 33.4 kW

**P8.52** (a) 0.588 J; (b) 0.588 J; (c) 2.42 m/s;
(d) 0.196 J; 0.392 J

**P8.54** 0.115

**P8.56** (a) 100 J; (b) 0.410 m; (c) 2.84 m/s;
(d) −9.80 mm; (e) 2.85 m/s

**P8.58** (a) $\left(3x^2-4x-3\right)\hat{\mathbf{i}}$; (b) 1.87; −0.535;
(c) see the solution

**P8.60** (a) 0.378 m; (b) 2.30 m/s; (c) 1.08 m

**P8.62** (a) see the solution; (b) 7.42 m/s

**P8.64** (a) see the solution; (b) 1.35 m/s;
(c) 0.958 m/s; (d) see the solution

**P8.66** 0.923 m/s

**P8.68** $2m$

**P8.70** 100.6°

**P8.72** see the solution

**P8.74** (a) 14.1 m/s; (b) −7.90 J; (c) 800 N;
(d) 771 N; (e) 1.57 kN up

# Chapter Nine

**P9.2** (a) 0; (b) $1.06\ \text{kg}\cdot\text{m/s}$; upward

**P9.4** (a) $6.00\ \text{m/s}$ to the left; (b) 8.40 J

**P9.6** The force is 6.44 kN

**P9.8** $1.39\ \text{kg}\cdot\text{m/s}$ upward

**P9.10** (a) $5.40\ \text{N}\cdot\text{s}$ toward the net; (b) $-27.0$ J

**P9.12** $\sim 10^3$ N upward

**P9.14** (a) and (c) see the solution; (b) small; (d) large; (e) no difference

**P9.16** $1.67\ \text{m/s}$

**P9.18** (a) $2.50\ \text{m/s}$; (b) $3.75\times 10^4$ J

**P9.20** 0.556 m

**P9.22** 1.78 kN on the truck driver; 8.89 kN in the opposite direction on the car driver

**P9.24** $v = \dfrac{4M}{m}\sqrt{g\ell}$

**P9.26** 7.94 cm

**P9.28** (a) $2.88\ \text{m/s}$ at 32.3°; (b) 783 J becomes internal energy

**P9.30** $v_Y = v_i \sin\theta$; $v_O = v_i\cos\theta$

**P9.32** No; his speed was $41.5\ \text{mi/h}$

**P9.34** (a) $v = \dfrac{v_i}{\sqrt{2}}$; (b) 45.0° and −45.0°

**P9.36** (a) $\sqrt{2}v_i$; $\sqrt{\dfrac{2}{3}}v_i$; (b) 35.3°

**P9.38** $(0,\ 1.00\ \text{m})$

**P9.40** $4.67\times 10^6$ m from the Earth's center

**P9.42** (a) see the solution; (b) $3.57\times 10^8$ J

**P9.44** 0.063 5$L$

**P9.46** (a) see the solution;
(b) $(-2.00\ \text{m},\ -1.00\ \text{m})$;
(c) $(3.00\hat{\mathbf{i}} - 1.00\hat{\mathbf{j}})\ \text{m/s}$;
(d) $(15.0\hat{\mathbf{i}} - 5.00\hat{\mathbf{j}})\ \text{kg}\cdot\text{m/s}$

**P9.48** (a) $-0.780\hat{\mathbf{i}}\ \text{m/s}$; $1.12\hat{\mathbf{i}}\ \text{m/s}$; (b) $0.360\hat{\mathbf{i}}\ \text{m/s}$

**P9.50** (a) $787\ \text{m/s}$; (b) $138\ \text{m/s}$

**P9.52** see the solution

**P9.54** (a) $\dfrac{m_1\mathbf{v}_1 + m_2\mathbf{v}_2}{m_1+m_2}$;
(b) $(v_1 - v_2)\sqrt{\dfrac{m_1m_2}{k(m_1+m_2)}}$;
(c) $\mathbf{v}_{1f} = \left(\dfrac{m_1-m_2}{m_1+m_2}\right)\mathbf{v}_1 + \left(\dfrac{2m_2}{m_1+m_2}\right)\mathbf{v}_2$;
$\mathbf{v}_{2f} = \left(\dfrac{2m_1}{m_1+m_2}\right)\mathbf{v}_1 + \left(\dfrac{m_2-m_1}{m_1+m_2}\right)\mathbf{v}_2$

**P9.56** 291 N

**P9.58** $\left(\dfrac{M+m}{m}\right)\sqrt{\dfrac{gd^2}{2h}}$

**P9.60** (a) $-0.667\ \text{m/s}$; (b) 0.952 m

**P9.62** (a) $6.81\ \text{m/s}$; (b) 1.00 m

**P9.64** (a) $-3.54\ \text{m/s}$; (b) 1.77 m; (c) 35.4 kN; (d) No. The rails exert a vertical force to change the momentum

**P9.66** 0.312 N to the right

**P9.68** $0.179\ \text{m/s}$

**P9.70** (a) $3.7\ \text{km/s}$; (b) 153 km

**P9.72** (a) 3.75 N to the right; (b) 3.75 N to the right; (c) 3.75 N; (d) 2.81 J; (e) 1.41 J; (f) Friction between sand and belt converts half of the input work into extra internal energy.

# Chapter Ten

**P10.2** (a) $822\ \text{rad/s}^2$; (b) $4.21\times10^3$ rad

**P10.4** (a) $1.20\times10^2\ \text{rad/s}$; (b) 25.0 s

**P10.6** $-226\ \text{rad/s}^2$

**P10.8** $13.7\ \text{rad/s}^2$

**P10.10** (a) 2.88 s; (b) 12.8 s

**P10.12** (a) $0.180\ \text{rad/s}$;
(b) $8.10\ \text{m/s}^2$ toward the center of the track

**P10.14** (a) $0.605\ \text{m/s}$; (b) $17.3\ \text{rad/s}$; (c) $5.82\ \text{m/s}$;
(d) The crank length is unnecessary

**P10.16** (a) 54.3 rev; (b) $12.1\ \text{rev/s}$

**P10.18** 0.572

**P10.20** (a) $92.0\ \text{kg}\cdot\text{m}^2$; 184 J;
(b) $6.00\ \text{m/s}$; $4.00\ \text{m/s}$; $8.00\ \text{m/s}$; 184 J

**P10.22** see the solution

**P10.24** $1.28\ \text{kg}\cdot\text{m}^2$

**P10.26** $\sim10^0\ \text{kg}\cdot\text{m}^2$

**P10.28** $\frac{1}{2}ML^2$

**P10.30** $168\ \text{N}\cdot\text{m}$ clockwise

**P10.32** $882\ \text{N}\cdot\text{m}$

**P10.34** (a) 1.03 s; (b) 10.3 rev

**P10.36** (a) $21.6\ \text{kg}\cdot\text{m}^2$; (b) $3.60\ \text{N}\cdot\text{m}$; (c) 52.4 rev

**P10.38** 0.312

**P10.40** $1.04\times10^{-3}$ J

**P10.42** $149\ \text{rad/s}$

**P10.44** (a) 6.90 J; (b) $8.73\ \text{rad/s}$; (c) $2.44\ \text{m/s}$;
(d) 1.043 2 times larger

**P10.46** $2.36\ \text{m/s}$

**P10.48** 276 J

**P10.50** (a) 74.3 W; (b) 401 W

**P10.52** $\frac{7Mv^2}{10}$

**P10.54** The disk; $\sqrt{\frac{4gh}{3}}$ versus $\sqrt{gh}$

**P10.56** (a) $2.38\ \text{m/s}$; (b) $4.31\ \text{m/s}$;
(c) It will not reach the top of the loop.

**P10.58** (a) 0.992 W; (b) 827 W

**P10.60** see the solution

**P10.62** (a) $12.5\ \text{rad/s}$; (b) 128 rad

**P10.64** $\frac{g(h_2-h_1)}{2\pi R^2}$

**P10.66** (a) $2.57\times10^{29}$ J; (b) $-1.63\times10^{17}$ J/day

**P10.68** $139\ \text{m/s}$

**P10.70** (a) $\sqrt{\frac{2mgd\sin\theta+kd^2}{I+mR^2}}$; (b) $1.74\ \text{rad/s}$

**P10.72** see the solution

**P10.74** (a) $-794\ \text{N}\cdot\text{m}$; $-2\,510\ \text{N}\cdot\text{m}$; 0;
$-1160\ \text{N}\cdot\text{m}$; $-2\,940\ \text{N}\cdot\text{m}$;
(b) see the solution

**P10.76** $\sqrt{\frac{10Rg(1-\cos\theta)}{7r^2}}$

**P10.78** see the solution

**P10.80** (a) $35.0\ \text{m/s}^2$; $7.35\hat{\mathbf{i}}$ N;
(b) $17.5\ \text{m/s}^2$; $-3.68\hat{\mathbf{i}}$ N;
(c) At 0.827 m from the top.

**P10.82** 54.0°

**P10.84** (a) $\sqrt{\frac{4g(R^3-r^3)}{3r^2}}$; (b) $5.31\times10^4\ \text{m/s}$;
(c) It becomes internal energy.

**P10.86** (a) $0.800\ \text{m/s}^2$; $0.400\ \text{m/s}^2$;
(b) 0.600 N between each cylinder and the plank; 0.200 N forward on each cylinder by the ground

**P10.88** see the solution

**P10.90** see the solution; to the left

# Chapter Eleven

**P11.2** (a) $740\ \text{cm}^2$; (b) 59.5 cm

**P11.4** (a) 168°; (b) 11.9° principal value; (c) Only the first is unambiguous.

**P11.6** No; see the solution

**P11.8** (a) $(-7.00\ \text{N}\cdot\text{m})\hat{\mathbf{k}}$; (b) $(11.0\ \text{N}\cdot\text{m})\hat{\mathbf{k}}$

**P11.10** see the solution

**P11.12** $(-22.0\ \text{kg}\cdot\text{m}^2/\text{s})\hat{\mathbf{k}}$

**P11.14** see the solution

**P11.16** (a) $3.14\ \text{N}\cdot\text{m}$; (b) $(0.400\ \text{kg}\cdot\text{m})v$; (c) $7.85\ \text{m/s}^2$

**P11.18** (a) $(+9.03\times 10^9\ \text{kg}\cdot\text{m}^2/\text{s})$ south; (b) No; (c) 0

**P11.20** $103\ \text{N}\cdot\text{m}$

**P11.22** $(4.50\ \text{kg}\cdot\text{m}^2/\text{s})$ up

**P11.24** $1.20\ \text{kg}\cdot\text{m}^2/\text{s}$ perpendicularly into the clock face

**P11.26** $8.63\ \text{m/s}^2$

**P11.28** (a) $\dfrac{I_1\omega_i}{I_1+I_2}$; (b) $\dfrac{K_f}{K_i}=\dfrac{I_1}{I_1+I_2}$

**P11.30** (a) $1.91\ \text{rad/s}$; (b) 2.53 J; 6.44 J

**P11.32** $8.54\ \text{rad/s}$

**P11.34** (a) $7.20\times 10^{-3}\ \text{kg}\cdot\text{m}^2/\text{s}$; (b) $9.47\ \text{rad/s}$

**P11.36** $12.3\ \text{m/s}^2$

**P11.38** (a) $2.35\ \text{rad/s}$; (b) $0.498\ \text{rad/s}$; (c) 5.58°

**P11.40** 131 s

**P11.42** (a) $2.19\times 10^6\ \text{m/s}$; (b) $2.18\times 10^{-18}\ \text{J}$; (c) $4.13\times 10^{16}\ \text{rad/s}$

**P11.44** (a) $11.1\ \text{m/s}$; (b) $5.32\times 10^3\ \text{kg}\cdot\text{m}^2/\text{s}$; (c) see the solution; (d) $12.0\ \text{m/s}$; (e) 1.08 kJ; (f) $5.34\ \text{m/s}$; (g) 1.46 m; (h) 1.43 s; (i) see the solution

**P11.46** (a) $(0.005\,89\ \text{W})t$; (b) $2.59\ \text{N}\cdot\text{m}$; (c) $(0.092\,5\ \text{W/s})t$; (d) $40.7\ \text{W}$; (e) $(3.70\ \text{N/s})t$; (f) $8.96\ \text{kJ}$; (g) $-4.48\ \text{kJ}$ (h) $+4.48\ \text{kJ}$

**P11.48** (a) 0; (b) 0; no

**P11.50** (a) $\dfrac{6mv_i}{Md+3md}$; (b) $\dfrac{M}{M+3m}$

**P11.52** (a) $Mvd$; (b) $Mv^2$; (c) $Mvd$; (d) $2v$; (e) $4Mv^2$; (f) $3Mv^2$

**P11.54** $\dfrac{M}{m}\sqrt{3ga\left(\sqrt{2}-1\right)}$

**P11.56** (a) $\dfrac{\omega_i}{3}$; (b) $\dfrac{\Delta E}{E}=-\dfrac{2}{3}$

# Chapter Twelve

**P12.2** $F_y + R_y - F_g = 0$; $F_x - R_x = 0$;
$F_y \ell \cos\theta - F_g\left(\frac{\ell}{2}\right)\cos\theta - F_x \ell \sin\theta = 0$

**P12.4** see the solution

**P12.6** 0.750 m

**P12.8** $(2.54 \text{ m}, 4.75 \text{ m})$

**P12.10** (a) 9.00 g; (b) 52.5 g; (c) 49.0 g

**P12.12** (a) 392 N; (b) $(339\hat{\mathbf{i}} + 0\hat{\mathbf{j}})$ N

**P12.14** (a) $f = \left[\frac{m_1 g}{2} + \frac{m_2 g x}{L}\right]\cot\theta$; $n_g = (m_1 + m_2)g$;
(b) $\mu = \frac{\left(\frac{m_1}{2} + \frac{m_2 d}{L}\right)\cot\theta}{m_1 + m_2}$

**P12.16** see the solution; 0.643 m

**P12.18** 36.7 N to the left; 31.2 N to the right

**P12.20** (a) 35.5 kN; (b) 11.5 kN to the right; (c) 4.19 kN down

**P12.22** (a) 859 N; (b) 104 kN at 36.9° above the horizontal to the left

**P12.24** $\frac{3L}{4}$

**P12.26** (a) see the solution; (b) $\theta$ decreases; (c) $R$ decreases

**P12.28** (a) 73.6 kN; (b) 2.50 mm

**P12.30** ~ 1 cm

**P12.32** $9.85 \times 10^{-5}$

**P12.34** 0.029 3 mm

**P12.36** (a) $-0.053\,8 \text{ m}^3$; (b) $1.09 \times 10^3 \text{ kg/m}^3$; (c) Yes, in most practical circumstances

**P12.38** (a) 53.1°; (b) 1.04 kN; (c) 0.126 m, 51.2°; (d) 1.07 kN; (e) 0.129 m, 51.1°; (f) 51.1°

**P12.40** (a) 0.400 mm; (b) 40.0 kN; (c) 2.00 mm; (d) 2.40 mm; (e) 48.0 kN

**P12.42** at $A$: $Mg\frac{\sin\beta}{\sin(\alpha + \beta)}$; at $B$: $Mg\frac{\sin\alpha}{\sin(\alpha + \beta)}$

**P12.44** (a) 160 N to the right; (b) 13.2 N to the right; (c) 292 N up; (d) 192 N

**P12.46** 1.46 kN; $(1.33\hat{\mathbf{i}} + 2.58\hat{\mathbf{j}})$ kN

**P12.48** 0.789

**P12.50** $T = 1.68$ kN; $R = 2.34$ kN; $\theta = 21.2°$

**P12.52** (a) see the solution; (b) 60.0°

**P12.54** (a) 120 N; (b) 0.300; (c) 103 N at 31.0° above the horizontal to the right

**P12.56** (a), (b) see the solution; (c) $C_{AB} = 732$ N; $T_{AC} = 634$ N; $C_{BC} = 897$ N

**P12.58** (a) $(9.09 \text{ m}, 10.9 \text{ m})$; (b) $(10.0 \text{ m}, 10.9 \text{ m})$; (c) 0.114 m/s to the right

**P12.60** $\frac{3}{8}F_g$

**P12.62** (a) $P_1 = 1.67$ N; $P_2 = 3.33$ N; $P_3 = 1.67$ N; (b) 2.36 N

**P12.64** 4.90 cm

**P12.66** 16.7 cm above the center of the bottom

**P12.68** $C_{AB} = 10.4$ kN; $T_{AC} = 7.94$ kN; $T_{BC} = 10.4$ kN; $C_{BD} = 15.9$ kN; $C_{DE} = 10.4$ kN; $T_{DC} = 10.4$ kN; $T_{EC} = 7.94$ kN

**P12.70** $\frac{2}{5}R$

**P12.72** $2.35 \text{ m/s}^2$

# Chapter Thirteen

**P13.2** $2.67 \times 10^{-7}\ \text{m/s}^2$

**P13.4** 3.00 kg and 2.00 kg

**P13.6** (a) $4.39 \times 10^{20}$ N toward the Sun;
(b) $1.99 \times 10^{20}$ N toward the Earth;
(c) $3.55 \times 10^{22}$ N toward the Sun

**P13.8** see the solution; either 1 m − 61.3 nm or $2.74 \times 10^{-4}$ m

**P13.10** $\frac{2}{3}$

**P13.12** (a) 1.02 km/s; (b) 1.35 mm

**P13.14** see the solution

**P13.16** 1.27

**P13.18** Planet $Y$ has turned through 1.30 revolutions

**P13.20** $1.63 \times 10^4$ rad/s

**P13.22** 18.2 ms

**P13.24** (a) $1.31 \times 10^{17}$ N toward the center;
(b) $2.62 \times 10^{12}$ N/kg

**P13.26** (a) $-4.77 \times 10^9$ J; (b) 569 N down;
(c) 569 N up

**P13.28** $2.52 \times 10^7$ m

**P13.30** $2.82 \times 10^9$ J

**P13.32** (a) see the solution; (b) 340 s

**P13.34** (a) 42.1 km/s; (b) $2.20 \times 10^{11}$ m

**P13.36** $1.58 \times 10^{10}$ J

**P13.38** (a) $2\pi(R_E + h)^{3/2}(GM_E)^{-1/2}$;
(b) $(GM_E)^{1/2}(R_E + h)^{-1/2}$;
(c) $GM_E m\left[\frac{R_E + 2h}{2R_E(R_E + h)}\right] - \frac{2\pi^2 R_E^2 m}{(86\,400\ \text{s})^2}$

The satellite should be launched from the Earth's equator toward the east.

**P13.40** (a) $10.0\ \text{m/s}^2$; (b) 21.8 km/s

**P13.42** 11.8 km/s

**P13.44** $\frac{GM_E m}{12R_E}$

**P13.46** (a) $v_0 = \left(\frac{GM_E}{r}\right)^{1/2}$; (b) $v_i = \frac{5\left(\frac{GM_E}{r}\right)^{1/2}}{4}$;
(c) $r_f = \frac{25r}{7}$

**P13.48** $2.26 \times 10^{-7}$

**P13.50** $\frac{2}{3}\sqrt{\frac{GM}{R}}$; $\frac{1}{3}\sqrt{\frac{GM}{R}}$

**P13.52** (a), (b) see the solution;
(c) $1.85 \times 10^{-5}\ \text{m/s}^2$

**P13.54** 492 m/s

**P13.56** see the solution

**P13.58** (a) $G^{1/2}c^{-3/2}h^{1/2}$; (b) $\sim 10^{-34}$ m

**P13.60** (a) 7.79 km/s; (b) 7.85 km/s; (c) −3.04 GJ;
(d) −3.08 GJ; (e) loss = 46.9 MJ;
(f) A component of the Earth's gravity pulls forward on the satellite in its downward banking trajectory.

**P13.62** (a) 29.3 km/s; (b) $K_p = 2.74 \times 10^{33}$ J; $U_p = -5.40 \times 10^{33}$ J; (c) $K_a = 2.57 \times 10^{33}$ J; $U_a = -5.22 \times 10^{33}$ J; yes

**P13.64** 119 km

**P13.66** (a) −36.7 MJ; (b) $9.24 \times 10^{10}\ \text{kg} \cdot \text{m}^2/\text{s}$;
(c) 5.58 km/s; 10.4 Mm; (d) 8.69 Mm;
(e) 134 min

**P13.68** see the solution

**P13.70** (a) $2.77\ \text{m/s}^2$; (b) $3.70\ \text{m/s}^2$

# Chapter Fourteen

**P14.2** $\sim 10^{18}\ \text{kg/m}^3$; matter is mostly empty space

**P14.4** $1.92\times 10^4\ \text{N}$

**P14.6** (a) $1.01\times 10^7\ \text{Pa}$; (b) $7.09\times 10^5\ \text{N}$ outward

**P14.8** 255 N

**P14.10** (a) 65.1 N; (b) 275 N

**P14.12** $5.88\times 10^6\ \text{N}$ down; 196 kN outward; 588 kN outward

**P14.14** (a) 29.4 kN to the right; (b) $16.3\ \text{kN}\cdot\text{m}$ counterclockwise

**P14.16** (a) 10.3 m; (b) zero

**P14.18** (a) 20.0 cm; (b) 0.490 cm

**P14.20** 12.6 cm

**P14.22** (a) 444 kg; (b) 480 kg

**P14.24** $\dfrac{m}{(\rho_w-\rho_s)h}$

**P14.26** (a) see the solution; (b) 25.0 N up; (c) horizontally inward; (d) tension increases; see the solution; (e) 62.5%; (f) 18.7%

**P14.28** $\sim 10^4$ balloons of 25-cm diameter

**P14.30** (a) 6.70 cm; (b) 5.74 cm

**P14.32** (a) 11.6 cm; (b) $0.963\ \text{g/cm}^3$; (c) no; see the solution

**P14.34** 0.611 kg

**P14.36** $2.67\times 10^3\ \text{kg}$

**P14.38** $12.8\ \text{kg/s}$

**P14.40** (a) 27.9 N; (b) $3.32\times 10^4\ \text{kg}$; (c) $7.26\times 10^4\ \text{Pa}$

**P14.42** (a) see the solution; (b) 616 MW

**P14.44** (a) 2.28 N toward Holland; (b) $1.74\times 10^6\ \text{s}$

**P14.46** (a), (b) $28.0\ \text{m/s}$; (c) 2.11 MPa

**P14.48** $6.80\times 10^4\ \text{Pa}$

**P14.50** $347\ \text{m/s}$

**P14.52** (a) 489 N outward; (b) 1.96 kN outward

**P14.54** 2.25 m above the level where the water emerges

**P14.56** 455 kPa

**P14.58** $709\ \text{kg/m}^3$

**P14.60** 8.01 km; yes

**P14.62** (a) see the solution; (b) $2.58\times 10^4\ \text{N}$

**P14.64** top scale: $\left(1-\dfrac{\rho_0}{\rho_{\text{Fe}}}\right)m_{\text{Fe}}g$;

bottom scale: $\left(m_b+m_0+\dfrac{\rho_0 m_{\text{Fe}}}{\rho_{\text{Fe}}}\right)g$

**P14.66** (a) $0.461\ \text{m/s}^2$; (b) 4.06 s

**P14.68** see the solution

**P14.70** (a) 18.3 mm; (b) 14.3 mm; (c) 8.56 mm

**P14.72** (a) $2.65\ \text{m/s}$; (b) $2.31\times 10^4\ \text{Pa}$

**P14.74** (a) see the solution; (b) 44.6 s

# Chapter Fifteen

**P15.2** (a) 4.33 cm; (b) $-5.00\ \text{cm/s}$; (c) $-17.3\ \text{cm/s}^2$; (d) 3.14 s; 5.00 cm

**P15.4** (a) 15.8 cm; (b) $-15.9$ cm; (c) see the solution; (d) 51.1 m; (e) 50.7 m

**P15.6** see the solution

**P15.8** 12.0 Hz

**P15.10** $18.8\ \text{m/s}$; $7.11\ \text{km/s}^2$

**P15.12** (a) 1.26 s; (b) $0.150\ \text{m/s}$; $0.750\ \text{m/s}^2$; (c) $x = -3\ \text{cm}\cos 5t$; $v = \left(\frac{15\ \text{cm}}{\text{s}}\right)\sin 5t$; $a = \left(\frac{75\ \text{cm}}{\text{s}^2}\right)\cos 5t$

**P15.14** (a) $\frac{v}{\omega}$; (b) $x = -\left(\frac{v}{\omega}\right)\sin\omega t$

**P15.16** (a) $126\ \text{N/m}$; (b) 0.178 m

**P15.18** (a) 0.153 J; (b) $0.784\ \text{m/s}$; (c) $17.5\ \text{m/s}^2$

**P15.20** (a) $100\ \text{N/m}$; (b) 1.13 Hz; (c) $1.41\ \text{m/s}$ at $x = 0$; (d) $10.0\ \text{m/s}^2$ at $x = \pm A$; (e) 2.00 J; (f) $1.33\ \text{m/s}$; (g) $3.33\ \text{m/s}^2$

**P15.22** (a) 1.50 s; (b) $73.4\ \text{N/m}$; (c) 19.7 m below the bridge; (d) $1.06\ \text{rad/s}$; (e) 2.01 s; (f) 3.50 s

**P15.24** (a) 0.218 s and 1.09 s; (b) 14.6 mW

**P15.26** The position of the piston is given by $x = A\cos\omega t$.

**P15.28** $\frac{g_C}{g_T} = 1.001\,5$

**P15.30** 1.42 s; 0.499 m

**P15.32** (a) 3.65 s; (b) 6.41 s; (c) 4.24 s

**P15.34** (a) see the solution; (b), (c) $9.85\ \text{m/s}^2$; agreeing with the accepted value within 0.5%

**P15.36** (a) 2.09 s; (b) 4.08%

**P15.38** $203\ \mu\text{N}\cdot\text{m}$

**P15.40** see the solution

**P15.42** see the solution

**P15.44** (a) 2.95 Hz; (b) 2.85 cm

**P15.46** see the solution

**P15.48** either 1.31 Hz or 0.641 Hz

**P15.50** 1.56 cm

**P15.52** (a) $0.500\ \text{m/s}$; (b) 8.56 cm

**P15.54** $A = \frac{\mu_s g}{4\pi^2 f^2}$

**P15.56** see the solution

**P15.58** (a) $k = \frac{4\pi^2 m}{T^2}$; (b) $m' = m\left(\frac{T'}{T}\right)^2$

**P15.60** (a) $x = (-2\ \text{m})\sin(10t)$; (b) at $x \pm 1.73\ \text{m}$; (c) 98.0 mm; (d) 52.4 ms

**P15.62** (a) decreased by 0.735 m; (b) increased by 0.730 s; (c) decreased by 120 J; (d) see the solution

**P15.64** (a) 3.56 Hz; (b) 2.79 Hz; (c) 2.10 Hz

**P15.66** (a) $\frac{1}{2}\left(M + \frac{m}{3}\right)v^2$; (b) $T = 2\pi\sqrt{\frac{M + \frac{m}{3}}{k}}$

**P15.68** see the solution; (a) $k = 1.74\ \text{N/m} \pm 6\%$; (b) $1.82\ \text{N/m} \pm 3\%$; they agree; (c) $8\ \text{g} \pm 12\%$; it agrees

**P15.70** (a) 5.20 s; (b) 2.60 s; (c) see the solution

**P15.72** see the solution; $T = \left(\frac{2}{r}\right)\sqrt{\frac{\pi M}{\rho g}}$

**P15.74** see the solution; (f) 0.281 Hz; (g) decreases; (h) increases; (i) increases; (j) decreases

# Chapter Sixteen

**P16.2** see the solution

**P16.4** (a) the P wave; (b) 665 s

**P16.6** $0.800\ \text{m/s}$

**P16.8** $2.40\ \text{m/s}$

**P16.10** 0.300 m in the positive $x$-direction

**P16.12** ±6.67 cm

**P16.14** (a) see the solution; (b) 0.125 s; in agreement with the example

**P16.16** (a) see the solution; (b) $18.0/\text{m}$; $83.3\ \text{ms}$; $75.4\ \text{rad/s}$; $4.20\ \text{m/s}$;
(c) $(0.2\ \text{m})\sin(18x + 75.4t - 0.151)$

**P16.18** (a) $0.021\,5\ \text{m}$; (b) 1.95 rad; (c) $5.41\ \text{m/s}$;
(d) $y(x,\ t) = (0.021\,5\ \text{m})\sin(8.38x + 80.0\pi t + 1.95)$

**P16.20** (a) see the solution; (b) $3.18\ \text{Hz}$

**P16.22** 30.0 N

**P16.24** (a) $y = (0.2\ \text{mm})\sin(16x - 3\,140t)$;
(b) 158 N

**P16.26** 631 N

**P16.28** $v = \dfrac{Tg}{2\pi}\sqrt{\dfrac{M}{m}}$

**P16.30** (a) $v = \left(30.4\ \dfrac{\text{m}}{\text{s}\cdot\sqrt{\text{kg}}}\right)\sqrt{m}$; (b) $3.89\ \text{kg}$

**P16.32** $\sqrt{\dfrac{mL\tan\theta}{4Mg}}$

**P16.34** 1.07 kW

**P16.36** (a), (b), (c) $\mathcal{P}$ is constant;
(d) $\mathcal{P}$ is quadrupled

**P16.38** (a) $y = (0.075\,0)\sin(4.19x - 314t)$;
(b) 625 W

**P16.40** (a) $15.1\ \text{W}$; (b) $3.02\ \text{J}$

**P16.42** The amplitude increases by 5.00 times

**P16.44** see the solution

**P16.46** (a) see the solution;
(b) $\dfrac{1}{2}(x+vt)^2 + \dfrac{1}{2}(x-vt)^2$;
(c) $\dfrac{1}{2}\sin(x+vt) + \dfrac{1}{2}\sin(x-vt)$

**P16.48** (a) $0.040\,0\ \text{m}$; (b) $0.031\,4\ \text{m}$;
(c) $0.477\ \text{Hz}$; (d) $2.09\ \text{s}$;
(e) positive $x$-direction

**P16.50** (a) $21.0\ \text{ms}$; (b) $1.68\ \text{m}$

**P16.52** $\Delta t = \sqrt{\dfrac{mL}{Mg\sin\theta}}$

**P16.54** (a) $2Mg$; (b) $L_0 + \dfrac{2Mg}{k}$;
(c) $\sqrt{\dfrac{2Mg}{m}\left(L_0 + \dfrac{2Mg}{k}\right)}$

**P16.56** 14.7 kg

**P16.58** (a) $v = \sqrt{\dfrac{T}{\rho\left(10^{-7}x + 10^{-6}\right)}}$ in SI units;
(b) $94.3\ \text{m/s}$; $66.7\ \text{m/s}$

**P16.60** see the solution

**P16.62** (a) $5.00\hat{\mathbf{i}}\ \text{m/s}$; (b) $-5.00\hat{\mathbf{i}}\ \text{m/s}$;
(c) $-7.50\hat{\mathbf{i}}\ \text{m/s}$; (d) $24.0\hat{\mathbf{i}}\ \text{m/s}$

**P16.64** (a) $\mu v_0^2$; (b) $v_0$;
(c) One travels 2 rev and the other does not move around the loop.

**P16.66** (a) $v = \left(\dfrac{2T_0}{\mu_0}\right)^{1/2} = v_0\sqrt{2}$;
$v' = \left(\dfrac{2T_0}{3\mu_0}\right)^{1/2} = v_0\sqrt{\dfrac{2}{3}}$; (b) $0.966\Delta t_0$

**P16.68** $130\ \text{m/s}$; 1.73 km

# Chapter Seventeen

**P17.2** 1.43 km/s

**P17.4** (a) 27.2 s; (b) longer than 25.7 s, because the air is cooler

**P17.6** (a) 153 m/s ; (b) 614 m

**P17.8** (a) 4.16 m; (b) 0.455 $\mu$s ; (c) 0.157 mm

**P17.10** $1.55\times10^{-10}$ m

**P17.12** (a) 1.27 Pa ; (b) 170 Hz ; (c) 2.00 m; (d) 340 m/s

**P17.14** $s = 22.5 \text{ nm} \cos\left(62.8x - 2.16\times10^4 t\right)$

**P17.16** (a) 4.63 mm; (b) 14.5 m/s ; (c) $4.73\times10^9$ W/m$^2$

**P17.18** (a) $5.00\times10^{-17}$ W ; (b) $5.00\times10^{-5}$ W

**P17.20** (a) $1.00\times10^{-5}$ W/m$^2$ ; (b) 90.7 mPa

**P17.22** (a) $I_2 = \left(\frac{f'}{f}\right)^2 I_1$; (b) $I_2 = I_1$

**P17.24** 21.2 W

**P17.26** (a) 4.51 times larger in water than in air and 18.0 times larger in iron;
(b) 5.60 times larger in water than in iron and 331 times larger in air;
(c) 59.1 times larger in water than in air and 331 times larger in iron;
(d) 0.331 m; 1.49 m; 5.95 m; 10.9 nm; 184 pm; 32.9 pm; 29.2 mPa; 1.73 Pa; 9.67 Pa

**P17.28** see the solution

**P17.30** 10.0 m; 100 m

**P17.32** 86.6 m

**P17.34** (a) 1.76 kJ ; (b) 108 dB

**P17.36** no

**P17.38** (a) 2.17 cm/s ; (b) 2 000 028.9 Hz ; (c) 2 000 057.8 Hz

**P17.40** (a) 441 Hz; 439 Hz; (b) 54.0 dB

**P17.42** (a) 325 m/s ; (b) 29.5 m/s

**P17.44** 48.2°

**P17.46** 46.4°

**P17.48** (a) 7; (b) and (c) see the solution

**P17.50** (a) 0.642 W ; (b) 0.004 28 = 0.428%

**P17.52** (a) 0.232 m ; (b) 84.1 nm ; (c) 13.8 mm

**P17.54** (a) 0.515/min ; (b) 0.614/min

**P17.56** (a) 5.04 km/s ; (b) 159 $\mu$s ; (c) 1.90 mm; (d) 0.002 38; (e) 476 MPa; (f) see the solution

**P17.58** (a) see the solution; (b) 85.9 Hz

**P17.60** The gap between bat and insect is closing at 1.69 m/s .

**P17.62** (a) see the solution; (b) 0.343 m; (c) 0.303 m; (d) 0.383 m; (e) 1.03 kHz

**P17.64** 80.0°

**P17.66** 67.0 dB

**P17.68** $\Delta t = \frac{eE}{4\pi d^2 I_0 10^{\beta/10}}$

**P17.70** see the solution

**P17.72** $\sim 10^{11}$ Hz

## Chapter Eighteen

**P18.2** see the solution

**P18.4** 5.66 cm

**P18.6** 0.500 s

**P18.8** (a) 3.33 rad; (b) 283 Hz

**P18.10** (a) The number is the greatest integer $\le d\left(\frac{f}{v}\right)+\frac{1}{2}$;

(b) $L_n = \frac{d^2 - (n-1/2)^2(v/f)^2}{2(n-1/2)(v/f)}$ where $n = 1, 2, \ldots, n_{\max}$

**P18.12** (a) $\Delta x = \frac{\lambda}{2}$;
(b) along the hyperbola $9x^2 - 16y^2 = 144$

**P18.14** (a) $(2n+1)\pi$ m for $n = 0, 1, 2, 3, \ldots$;
(b) 0.029 4 m

**P18.16** see the solution

**P18.18** see the solution

**P18.20** 15.7 Hz

**P18.22** (a) 257 Hz; (b) 6

**P18.24** (a) 495 Hz; (b) 990 Hz

**P18.26** 19.976 kHz

**P18.28** 3.84%

**P18.30** 291 Hz

**P18.32** 0.352 Hz

**P18.34** see the solution

**P18.36** (a) 531 Hz; (b) 42.5 mm

**P18.38** 0.656 m; 1.64 m

**P18.40** 3 kHz; see the solution

**P18.42** $\Delta t = \frac{\pi r^2 v}{2Rf}$

**P18.44** $L = 0.252$ m, 0.504 m, 0.757 m, $\ldots$, $n(0.252)$ m for $n = 1, 2, 3, \ldots$

**P18.46** 0.502 m; 0.837 m

**P18.48** (a) 0.195 m; (b) 841 m

**P18.50** 1.16 m

**P18.52** (a) 521 Hz or 525 Hz; (b) 526 Hz;
(c) reduce by 1.14%

**P18.54** 4-foot and $2\frac{2}{3}$-foot ; $2\frac{2}{3}$ and 2-foot ; and all three together

**P18.56** see the solution

**P18.58** (a) and (b) 3.99 beats/s

**P18.60** 4.85 m

**P18.62** 31.1 N

**P18.64** (a) $\frac{1}{2}Mg$; (b) $3h$; (c) $\frac{m}{3h}$; (d) $\sqrt{\frac{3Mgh}{2m}}$;
(e) $\sqrt{\frac{3Mg}{8mh}}$; (f) $\sqrt{\frac{2mh}{3Mg}}$; (g) $h$;
(h) $(2.00\times 10^{-2})\sqrt{\frac{3Mg}{8mh}}$

**P18.66** (a) 45.0 Hz or 55.0 Hz; (b) 162 N or 242 N

**P18.68** see the solution

**P18.70** 262 kHz

# Chapter Nineteen

**P19.2** (a) $1.06\text{ atm}$; (b) $-124°\text{C}$

**P19.4** (a) $37.0°\text{C} = 310\text{ K}$; (b) $-20.6°\text{C} = 253\text{ K}$

**P19.6** $T_C = (1.33\text{ C°/S°})T_S + 20.0°\text{C}$

**P19.8** 0.313 m

**P19.10** 1.20 cm

**P19.12** $15.8\mu\text{ m}$

**P19.14** 0.663 mm to the right at $78.2°$ below the horizontal

**P19.16** (a) $0.109\text{ cm}^2$; (b) increase

**P19.18** (a) $437°\text{C}$; (b) $3\,000°\text{C}$; no

**P19.20** (a) $2.52\times10^6\text{ N/m}^2$; (b) no

**P19.22** $0.812\text{ cm}^3$

**P19.24** (a) 396 N; (b) $-101°\text{C}$; (c) no change

**P19.26** (a) $2.99\text{ mol}$; (b) $1.80\times10^{24}$ molecules

**P19.28** 884 balloons

**P19.30** (a) $1.06\times10^{21}\text{ kg}$; (b) $56.9\text{ K}$

**P19.32** (a) 900 K; (b) 1 200 K

**P19.34** see the solution

**P19.36** $3.96\times10^{-2}\text{ mol}$

**P19.38** $3.67\text{ cm}^3$

**P19.40** between $10^1\text{ kg}$ and $10^2\text{ kg}$

**P19.42** $2.41\times10^{11}$ molecules

**P19.44** (a) 2.24 m; (b) $9.28\times10^5\text{ Pa}$

**P19.46** 0.523 kg

**P19.48** (a) see the solution; (b) $\alpha << \beta$

**P19.50** (a) 0.169 m; (b) $1.35\times10^5$ Pa

**P19.52** 6.57 MPa

**P19.54** (a) $\theta = \frac{(\alpha_2-\alpha_1)L_i\Delta T}{\Delta r}$; (b) see the solution; (c) it bends the other way; (d) $0.830°$

**P19.56** (a) increase by $95.0\ \mu\text{s}$; (b) loses 57.5 s

**P19.58** (a) $B = \rho g P_0 V_i (P_0 + \rho g d)^{-1}$ up; (b) decrease; (c) 10.3 m

**P19.60** (a) yes; see the solution; (b) $25.7\text{ rad/s}$

**P19.62** $y \approx L(2\alpha\Delta T)^{1/2}$

**P19.64** (a) see the solution; (b) $3.66\times10^{-3}\text{ K}^{-1}$, within 0.06% and 0.2% of the experimental values

**P19.66** (a) 79.1 kPa for $N_2$; 21.2 kPa for $O_2$; 940 Pa for Ar; 33.3 Pa for $CO_2$; (b) 81.7 L; $1.22\text{ kg/m}^3$; (c) $29.0\text{ g/mol}$

**P19.68** (a) 7.06 mm; (b) 297 K

**P19.70** $125\text{ N}$; $-42.0\mu\text{m}$

**P19.72** 1.12 atm

**P19.74** (a), (b), (c) see the solution; (d) $0.275\text{ mm}$;

## Chapter Twenty

**P20.2** 0.105°C

**P20.4** 87.0°C

**P20.6** The energy input to the water is 6.70 times larger than the laser output of 40.0 kJ.

**P20.8** 88.2 W

**P20.10** (a) 25.8°C ; (b) no

**P20.12** $T_f = \dfrac{(m_{\text{Al}}c_{\text{Al}} + m_c c_w)T_c + m_h c_w T_h}{m_{\text{Al}}c_{\text{Al}} + m_c c_w + m_h c_w}$

**P20.14** (a) 380 K; (b) 206 kPa

**P20.16** 12.9 g

**P20.18** (a) all the ice melts; 40.4°C ;
(b) 8.04 g melts; 0°C

**P20.20** 34.0 km

**P20.22** liquid lead at 805°C

**P20.24** (a) −12.0 MJ ; (b) +12.0 MJ

**P20.26** $-nR(T_2 - T_1)$

**P20.28** (a) 567 J ; (b) 167 J

**P20.30** (a) 12.0 kJ ; (b) −12.0 kJ

**P20.32** 42.9 kJ

**P20.34** (a) 7.65 L; (b) 305 K

**P20.36** (a) −48.6 mJ ; (b) 16.2 kJ ; (c) 16.2 kJ

**P20.38** (a) $-4P_iV_i$ ; (b) $+4P_iV_i$ ; (c) −9.08 kJ

**P20.40** (a) 1 300 J ; (b) 100 J ; (c) −900 J ; (d) −1 400 J

**P20.42** 10.0 kW

**P20.44** 1.34 kW

**P20.46** (a) $0.890\ \text{ft}^2 \cdot °\text{F} \cdot \text{h/Btu}$; (b) $1.85 \dfrac{\text{ft}^2 \cdot °\text{F} \cdot \text{h}}{\text{Btu}}$;
(c) 2.08

**P20.48** (a) $\sim 10^3$ W ; (b) $\sim -10^{-1}$ K/s

**P20.50** 364 K

**P20.52** 47.7 g

**P20.54** (a) 13.0°C ; (b) −0.532 °C/s

**P20.56** (a) 64.1°C ; (b) 113°C

**P20.58** see the solution (a) $\frac{1}{2}P_iV_i$; (b) $1.39P_iV_i$; (c) 0

**P20.60** (a) $9.31 \times 10^{10}$ J; (b) $-8.47 \times 10^{12}$ J ;
(c) $8.38 \times 10^{12}$ J

**P20.62** (a) 2 000 W ; (b) 4.47°C

**P20.64** 3.76 m/s

**P20.66** (a) 15.0 mg ; block: $Q = 0$; $W = -5.00$ J ;
$\Delta E_{\text{int}} = 0$ ; $\Delta K = -5.00$ J ;
ice: $Q = 0$; $W = 5.00$ J ; $\Delta E_{\text{int}} = 5.00$ J ; $\Delta K = 0$
(b) 15.0 mg ; block: $Q = 0$; $W = 0$;
$\Delta E_{\text{int}} = 5.00$ J ; $\Delta K = -5.00$ J ;
metal: $Q = 0$; $W = 0$; $\Delta E_{\text{int}} = 0$ ; $\Delta K = 0$
(c) 0.004 04°C ; moving block: $Q = 0$;
$W = -2.50$ J ; $\Delta E_{\text{int}} = 2.50$ J ; $\Delta K = -5.00$ J ;
stationary block: $Q = 0$; $W = 2.50$ J ;
$\Delta E_{\text{int}} = 2.50$ J ; $\Delta K = 0$

**P20.68** 10.2 h

**P20.70** see the solution

**P20.72** 800 J/kg·°C

## Chapter Twenty-One

**P21.2** 17.6 kPa

**P21.4** $5.05 \times 10^{-21}$ J/molecule

**P21.6** $6.64 \times 10^{-27}$ kg

**P21.8** 477 m/s

**P21.10** (a) 2.28 kJ ; (b) $6.21 \times 10^{-21}$ J

**P21.12** 74.8 J

**P21.14** 7.52 L

**P21.16** (a) 118 kJ ; (b) $6.03 \times 10^{3}$ kg

**P21.18** (a) 719 J/kg · K ; (b) 0.811 kg ; (c) 233 kJ ; (d) 327 kJ

**P21.20** $13.5PV$

**P21.22** (a) $4T_i$ ; (b) $9(1\text{ mol})RT_i$

**P21.24** (a) 0.118 ; (b) 2.35 ; (c) 0; 135 J ; 135 J

**P21.26** (a) $5.15 \times 10^{-5}$ m$^3$ ; (b) 560 K ; (c) 2.24 K

**P21.28** (a) 1.55 ; (b) 0.127 m$^3$

**P21.30** (a) see the solution; (b) $2.19V_i$ ; (c) $3T_i$ ; (d) $T_i$ ; (e) $-0.830P_iV_i$

**P21.32** 25.0 kW

**P21.34** see the solution

**P21.36** (a) No atom, almost all the time; (b) $2.70 \times 10^{20}$

**P21.38** (a) 1.03 ; (b) $^{35}$Cl

**P21.40** 132 m/s

**P21.42** 819°C

**P21.44** (a) see the solution; (b) 8.31 km

**P21.46** (a) $5.63 \times 10^{18}$ m ; $1.00 \times 10^{9}$ yr ; (b) $5.63 \times 10^{12}$ m ; $1.00 \times 10^{3}$ yr

**P21.48** 193 molecular diameters

**P21.50** (a) $7.89 \times 10^{26}$ molecules ; (b) 37.9 kg ; (c) $6.07 \times 10^{-21}$ J/molecule ; (d) 503 m/s ; (e) 7.98 MJ ; (f) 7.98 MJ

**P21.52** (a) $3.65v$ ; (b) $3.99v$ ; (c) $3.00v$ ; (d) $106\left(\frac{mv^2}{V}\right)$ ; (e) $7.98mv^2$

**P21.54** (a) 300 K ; (b) 1.00 atm

**P21.56** $5.74 \times 10^{6}$ Pa

**P21.58** (a) see the solution; (b) $5.1 \times 10^{2}$ m/s ; (c) $v_{\text{av}} = 575$ m/s ; $v_{\text{rms}} = 624$ m/s ; (d) 44%

**P21.60** (a) see the solution; (b) 344 m/s nearly agreeing with the tabulated value; (c) see the solution; somewhat smaller than each

**P21.62** 0.296°C

**P21.64** see the solution

**P21.66** see the solution

**P21.68** (a) $3.34 \times 10^{26}$ molecules ; (b) during the 27th day; (c) $2.53 \times 10^{6}$ molecules

**P21.70** (a) 0.510 m/s ; (b) 20 ms

# Chapter Twenty-Two

**P22.2** (a) 667 J; (b) 467 J

**P22.4** (a) 30.0%; (b) 60.0%

**P22.6** 55.4%

**P22.8** 77.8 W

**P22.10** (a) 869 MJ; (b) 330 MJ

**P22.12** 197 kJ

**P22.14** 546°C

**P22.16** 33.0%

**P22.18** (a) 5.12%; (b) 5.27 TJ/h;
(c) see the solution

**P22.20** 453 K

**P22.22** (a), (b) see the solution;
(c) 23.7%; see the solution

**P22.24** 11.8

**P22.26** 1.17 J

**P22.28** (a) 204 W; (b) 2.43 kW

**P22.30** (a) 2.00; (b) 3.00; (c) 33.3%

**P22.32** (a) 51.2%; (b) 36.2%

**P22.34** (a), (b) see the solution;
(c) $Q_h = 149$ J; $|Q_c| = 65.0$ J; $W_{eng} = 84.3$ J;
(d) 56.5%; (e) $1.42 \times 10^3$ rev/min

**P22.36** 4.88 kJ/kg·K

**P22.38** (a) isobaric; (b) 402 kJ; (c) 1.20 kJ/K

**P22.40** 3.27 J/K

**P22.42** 718 J/K

**P22.44** (a) 39.4 L; (b) −2.50 kJ; (c) −2.50 kJ;
(d) −6.87 J/K; (e) +9.16 J/K

**P22.46** 0.507 J/K

**P22.48** 34.6 J/K

**P22.50** (a) 2 heads and 2 tails;
(b) All heads or all tails;
(c) 2 heads and 2 tails

**P22.52** 8.36 MJ/K

**P22.54** 32.9 kJ

**P22.56** see the solution

**P22.58** (a) $2.62 \times 10^3$ tons/d; (b) \$7.65 million/yr;
(c) $4.06 \times 10^4$ kg/s

**P22.60** $\frac{\mathcal{P} T_c}{(T_h - T_c) c \Delta T}$

**P22.62** (a) 4.11 kJ; (b) 14.2 kJ; (c) 10.1 kJ; (d) 28.9%

**P22.64** see the solution

**P22.66** $nC_P \ln 3$

**P22.68** no; see the solution

**P22.70** (a)

| | $P$, atm | $V$, L |
|---|---|---|
| A | 25.0 | 1.97 |
| B | 4.14 | 11.9 |
| C | 1.00 | 32.8 |
| D | 6.03 | 5.44 |

(b) 2.99 kJ; (c) 33.3%