

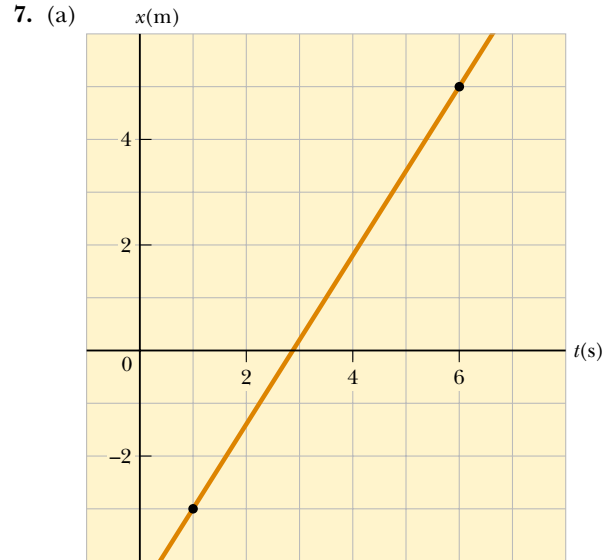
Answers to Odd-Numbered Problems

Chapter 1

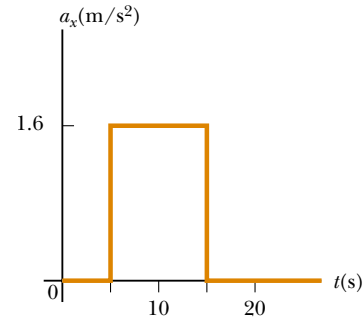
1. $2.15 \times 10^4 \text{ kg/m}^3$
3. 184 g
5. (a) 7.10 cm^3 (b) $1.18 \times 10^{-29} \text{ m}^3$ (c) 0.228 nm
(d) 12.7 cm^3 , $2.11 \times 10^{-29} \text{ m}^3$, 0.277 nm
7. (a) $4.00 \text{ u} = 6.64 \times 10^{-24} \text{ g}$ (b) $55.9 \text{ u} = 9.29 \times 10^{-23} \text{ g}$ (c) $207 \text{ u} = 3.44 \times 10^{-22} \text{ g}$
9. (a) $9.83 \times 10^{-16} \text{ g}$ (b) $1.06 \times 10^7 \text{ atoms}$
11. (a) $4.01 \times 10^{25} \text{ molecules}$ (b) $3.65 \times 10^4 \text{ molecules}$
13. no
15. (b) only
17. $0.579 t \text{ ft}^3/\text{s} + 1.19 \times 10^{-9} t^2 \text{ ft}^3/\text{s}^2$
19. $1.39 \times 10^3 \text{ m}^2$
21. (a) 0.071 4 gal/s (b) $2.70 \times 10^{-4} \text{ m}^3/\text{s}$ (c) 1.03 h
23. $4.05 \times 10^3 \text{ m}^2$
25. $11.4 \times 10^3 \text{ kg/m}^3$
27. $1.19 \times 10^{57} \text{ atoms}$
29. (a) 190 y (b) $2.32 \times 10^4 \text{ times}$
31. 151 μm
33. $1.00 \times 10^{10} \text{ lb}$
35. $3.08 \times 10^4 \text{ m}^3$
37. 5.0 m
39. 2.86 cm
41. $\sim 10^6 \text{ balls}$
43. $\sim 10^7 \text{ or } 10^8 \text{ rev}$
45. $\sim 10^7 \text{ or } 10^8 \text{ blades}$
47. $\sim 10^2 \text{ kg}$; $\sim 10^3 \text{ kg}$
49. $\sim 10^2 \text{ tuners}$
51. (a) $(346 \pm 13) \text{ m}^2$ (b) $(66.0 \pm 1.3) \text{ m}$
53. $(1.61 \pm 0.17) \times 10^3 \text{ kg/m}^3$
55. 115.9 m
57. 316 m
59. 4.50 m^2
61. 3.41 m
63. 0.449%
65. (a) 0.529 cm/s (b) 11.5 cm/s
67. $1 \times 10^{10} \text{ gal/yr}$
69. $\sim 10^{11} \text{ stars}$

Chapter 2

1. (a) 2.30 m/s (b) 16.1 m/s (c) 11.5 m/s
3. (a) 5 m/s (b) 1.2 m/s (c) -2.5 m/s (d) -3.3 m/s
(e) 0
5. (a) 3.75 m/s (b) 0



- (b) 1.60 m/s
9. (a) -2.4 m/s (b) -3.8 m/s (c) 4.0 s
11. (a) 5.0 m/s (b) -2.5 m/s (c) 0 (d) 5.0 m/s
13. $1.34 \times 10^4 \text{ m/s}^2$
15. (a)

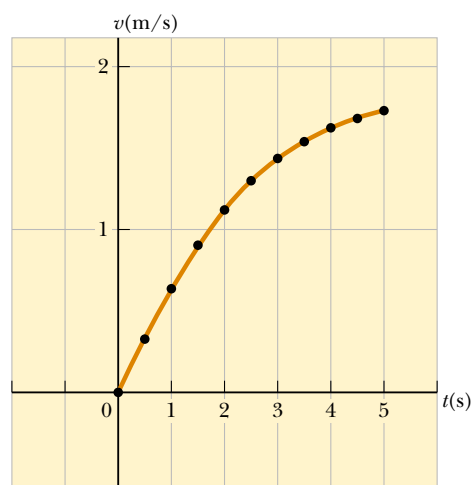


- (b) 1.6 m/s^2 and 0.80 m/s^2
17. (a) 2.00 m (b) -3.00 m/s (c) -2.00 m/s²
19. (a) 1.3 m/s^2 (b) 2.0 m/s^2 at 3 s (c) at $t = 6 \text{ s}$ and for $t > 10 \text{ s}$ (d) -1.5 m/s^2 at 8 s
21. $2.74 \times 10^5 \text{ m/s}^2$, which is $2.79 \times 10^4 g$
23. (a) 6.61 m/s (b) -0.448 m/s²
25. -16.0 cm/s²
27. (a) 2.56 m (b) -3.00 m/s
29. (a) 8.94 s (b) 89.4 m/s
31. (a) 20.0 s (b) no
33. $x_f - x_i = v_{xf} t - a_x t^2/2$; $v_{xf} = 3.10 \text{ m/s}$

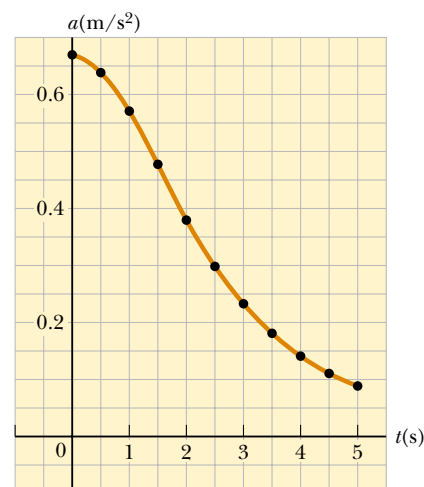
35. (a) 35.0 s (b) 15.7 m/s
 37. (a) -202 m/s^2 (b) 198 m
 39. (a) 3.00 m/s (b) 6.00 s (c) -0.300 m/s^2
 (d) 2.05 m/s
 41. (a) -4.90 m , -19.6 m , -44.1 m (b) -9.80 m/s ,
 -19.6 m/s , -29.4 m/s
 43. (a) 10.0 m/s up (b) 4.68 m/s down
 45. No. In 0.2 s the bill falls out from between David's fin-
 gers.
 47. (a) 29.4 m/s (b) 44.1 m
 49. (a) 7.82 m (b) 0.782 s
 51. (a) 1.53 s (b) 11.5 m (c) -4.60 m/s , -9.80 m/s^2
 53. (a) $a_x = a_{xi} + \int t$, $v_x = v_{xi} + a_{xi}t + \frac{1}{2}\int t^2$,
 $x = x_i + v_{xi}t + \frac{1}{2}a_{xi}t^2 + \frac{1}{6}\int t^3$
 55. 0.222 s
 57. 0.509 s
 59. (a) 41.0 s (b) 1.73 km (c) -184 m/s
 61. $v_{xi}t + at^2/2$, in agreement with Equation 2.11
 63. (a) 5.43 m/s^2 and 3.83 m/s^2 (b) 10.9 m/s and 11.5 m/s
 (c) Maggie by 2.62 m
 65. (a) 45.7 s (b) 574 m (c) 12.6 m/s (d) 765 s
 67. (a) 2.99 s (b) -15.4 m/s (c) 31.3 m/s down and
 34.9 m/s down
 69. (a) 5.46 s (b) 73.0 m (c) $v_{\text{Stan}} = 22.6 \text{ m/s}$, $v_{\text{Kathy}} =$
 26.7 m/s
 71. (a) See top of next column.
 (b) See top of next column.
 73. $0.577v$

Chapter 3

1. $(-2.75, -4.76) \text{ m}$
 3. 1.15; 2.31
 5. (a) 2.24 m (b) 2.24 m at 26.6° from the positive x axis.
 7. (a) 484 m (b) 18.1° north of west
 9. 70.0 m
 11. (a) approximately 6.1 units at 112° (b) approximately
 14.8 units at 22°
 13. (a) 10.0 m (b) 15.7 m (c) 0
 15. (a) 5.2 m at 60° (b) 3.0 m at 330° (c) 3.0 m at 150°
 (d) 5.2 m at 300°
 17. approximately 420 ft at -3°
 19. 5.83 m at 59.0° to the right of his initial direction
 21. 1.31 km north and 2.81 km east
 23. (a) 10.4 cm (b) 35.5°
 25. 47.2 units at 122° from the positive x axis.
 27. $(-25.0\mathbf{i})\text{m} + (43.3\mathbf{j})\text{m}$
 29. 7.21 m at 56.3° from the positive x axis.
 31. (a) $2.00\mathbf{i} - 6.00\mathbf{j}$ (b) $4.00\mathbf{i} + 2.00\mathbf{j}$ (c) 6.32 (d) 4.47
 (e) 288° ; 26.6° from the positive x axis.
 33. (a) $(-11.1\mathbf{i} + 6.40\mathbf{j}) \text{ m}$ (b) $(1.65\mathbf{i} + 2.86\mathbf{j}) \text{ cm}$
 (c) $(-18.0\mathbf{i} - 12.6\mathbf{j}) \text{ in.}$
 35. 9.48 m at 166°
 37. (a) 185 N at 77.8° from the positive x axis
 (b) $(-39.3\mathbf{i} - 181\mathbf{j}) \text{ N}$
 39. $\mathbf{A} + \mathbf{B} = (2.60\mathbf{i} + 4.50\mathbf{j}) \text{ m}$



Chapter 2, Problem 71(a)

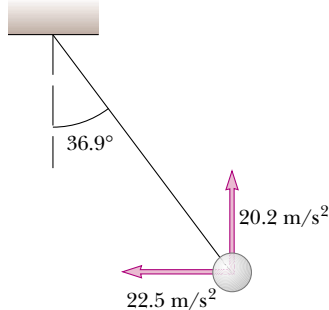


Chapter 2, Problem 71(b)

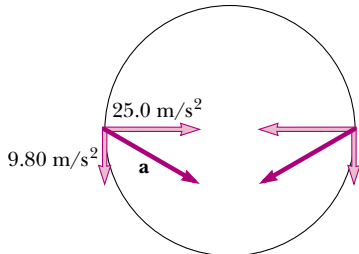
41. 196 cm at -14.7° from the positive x axis.
 43. (a) $8.00\mathbf{i} + 12.0\mathbf{j} - 4.00\mathbf{k}$ (b) $2.00\mathbf{i} + 3.00\mathbf{j} - 1.00\mathbf{k}$
 (c) $-24.0\mathbf{i} - 36.0\mathbf{j} + 12.0\mathbf{k}$
 45. (a) 5.92 m is the magnitude of $(5.00\mathbf{i} - 1.00\mathbf{j} - 3.00\mathbf{k}) \text{ m}$
 (b) 19.0 m is the magnitude of $(4.00\mathbf{i} - 11.0\mathbf{j} + 15.0\mathbf{k}) \text{ m}$
 47. 157 km
 49. (a) $-3.00\mathbf{i} + 2.00\mathbf{j}$ (b) 3.61 at 146° from the positive
 x axis. (c) $3.00\mathbf{i} - 6.00\mathbf{j}$
 51. (a) $49.5\mathbf{i} + 27.1\mathbf{j}$ (b) 56.4 units at 28.7° from the posi-
 tive x axis.
 53. 1.15°
 55. (a) 2.00, 1.00, 3.00 (b) 3.74 (c) $\theta_x = 57.7^\circ$, $\theta_y = 74.5^\circ$,
 $\theta_z = 36.7^\circ$
 57. 240 m at 237°
 59. 390 mi/h at 7.37° north of east
 61. $\mathbf{R}_1 = a\mathbf{i} + b\mathbf{j}$; $R_1 = \sqrt{a^2 + b^2}$ (b) $\mathbf{R}_2 = a\mathbf{i} + b\mathbf{j} + c\mathbf{k}$

Chapter 4

1. (a) 4.87 km at 209° from east (b) 23.3 m/s
(c) 13.5 m/s at 209°
3. (a) $(18.0t)\mathbf{i} + (4.00t - 4.90t^2)\mathbf{j}$
(b) $18.0\mathbf{i} + (4.00 - 9.80t)\mathbf{j}$ (c) $-9.80\mathbf{j}$
(d) $(54.0\mathbf{i} - 32.1\mathbf{j})$ m
(e) $(18.0\mathbf{i} - 25.4\mathbf{j})$ m/s (f) $(-9.80\mathbf{j})$ m/s²
5. (a) $(2.00\mathbf{i} + 3.00\mathbf{j})$ m/s²
(b) $(3.00t + t^2)\mathbf{i}$ m, $(1.50t^2 - 2.00t)\mathbf{j}$ m
7. (a) $(0.800\mathbf{i} - 0.300\mathbf{j})$ m/s² (b) 339°
(c) $(360\mathbf{i} - 72.7\mathbf{j})$ m, -15.2°
9. (a) $(3.34\mathbf{i})$ m/s (b) -50.9°
11. (a) 20.0° (b) 3.05 s
13. $x = 7.23$ km $y = 1.68$ km
15. 53.1°
17. 22.4° or 89.4°
19. (a) The ball clears by 0.889 m (b) while descending
21. $d \tan \theta_i - gd^2/(2v_i^2 \cos^2 \theta_i)$
23. (a) 0.852 s (b) 3.29 m/s (c) 4.03 m/s (d) 50.8°
(e) 1.12 s
25. 377 m/s²
27. 10.5 m/s, 219 m/s²
29. (a) 6.00 rev/s (b) 1.52 km/s² (c) 1.28 km/s²
31. 1.48 m/s² inward at 29.9° behind the radius
33. (a) 13.0 m/s² (b) 5.70 m/s (c) 7.50 m/s²
35. (a)



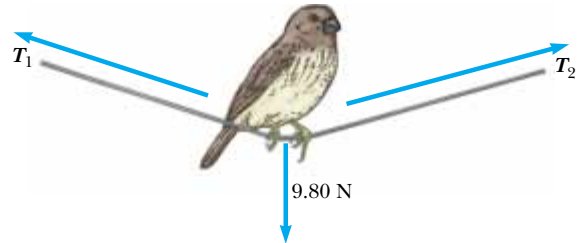
- (b) 29.7 m/s² (c) 6.67 m/s at 36.9° above the horizontal
37. 2.02×10^3 s; 21.0% longer
39. 153 km/h at 11.3° north of west
41. (a) 36.9° (b) 41.6° (c) 3.00 min
43. 15.3 m
45. $2v_i t \cos \theta_i$
47. (b) $45^\circ + \phi/2$; $v_i^2(1 - \sin \phi)/g \cos^2 \phi$
49. (a) 41.7 m/s (b) 3.81 s (c) $(34.1\mathbf{i} - 13.4\mathbf{j})$ m/s; 36.6 m/s
51. (a) 25.0 m/s² (radial); 9.80 m/s² (tangential)
(b)



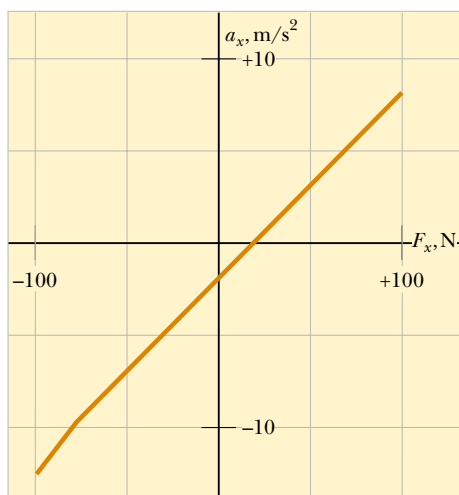
- (c) 26.8 m/s² inward at 21.4° below the horizontal
53. 8.94 m/s at -63.4° relative to the positive x axis.
55. 20.0 m
57. (a) 0.600 m (b) 0.402 m (c) 1.87 m/s² toward center
(d) 9.80 m/s² down
59. (a) 6.80 km (b) 3.00 km vertically above the impact point (c) 66.2°
61. (a) 46.5 m/s (b) -77.6° (c) 6.34 s
63. (a) 1.53 km (b) 36.2 s (c) 4.04 km
65. (a) 20.0 m/s, 5.00 s (b) $(16.0\mathbf{i} - 27.1\mathbf{j})$ m/s (c) 6.54 s
(d) $(24.6\mathbf{i})$ m
67. (a) 43.2 m (b) $(9.66\mathbf{i} - 25.5\mathbf{j})$ m/s
69. Imagine you are shaking down the mercury in a fever thermometer. Starting with your hand at the level of your shoulder, move your hand down as fast as you can and snap it around an arc at the bottom. ~ 100 m/s² $\approx 10g$

Chapter 5

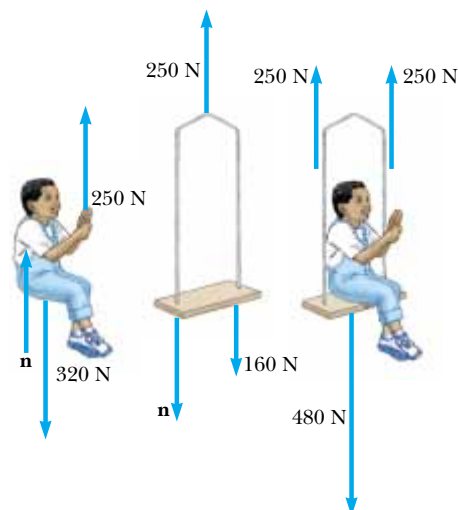
1. (a) 1/3 (b) 0.750 m/s²
3. $(6.00\mathbf{i} + 15.0\mathbf{j})$ N; 16.2 N
5. 312 N
7. (a) $x = vt/2$ (b) $F_g v \mathbf{i} / gt + F_g \mathbf{j}$
9. (a) $(2.50\mathbf{i} + 5.00\mathbf{j})$ N (b) 5.59 N
11. (a) 3.64×10^{-18} N (b) 8.93×10^{-30} N is 408 billion times smaller.
13. 2.38 kN
15. (a) 5.00 m/s² at 36.9° (b) 6.08 m/s² at 25.3°
17. (a) $\sim 10^{-22}$ m/s² (b) $\sim 10^{-23}$ m
19. (a) 0.200 m/s² forward (b) 10.0 m (c) 2.00 m/s
21. (a) 15.0 lb up (b) 5.00 lb up (c) 0
23. 613 N



27. (a) 49.0 N (b) 98.0 N (c) 24.5 N
29. 8.66 N east
31. 100 N and 204 N
33. 3.73 m
35. $a = F/(m_1 + m_2)$; $T = Fm_1/(m_1 + m_2)$
37. (a) $F_x > 19.6$ N (b) $F_x \leq -78.4$ N
(c) See top of next page.
39. (a) 706 N (b) 814 N (c) 706 N (d) 648 N
41. $\mu_s = 0.306$; $\mu_k = 0.245$
43. (a) 256 m (b) 42.7 m
45. (a) 1.78 m/s² (b) 0.368 (c) 9.37 N (d) 2.67 m/s
47. (a) 0.161 (b) 1.01 m/s²
49. 37.8 N

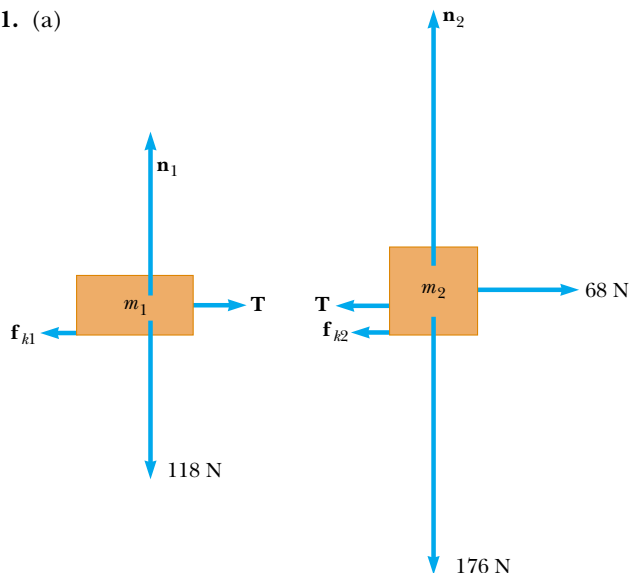


Chapter 5, Problem 37(c)



Chapter 5, Problem 55(a)

51. (a)

(b) 27.2 N, 1.29 m/s²

53. Any value between 31.7 N and 48.6 N

55. (a) See top of next column.

(b) 0.408 m/s² (c) 83.3 N

57. 1.18 kN

59. (a) $Mg/2$, $Mg/2$, $Mg/2$, $3Mg/2$, Mg (b) $Mg/2$

61. (b)

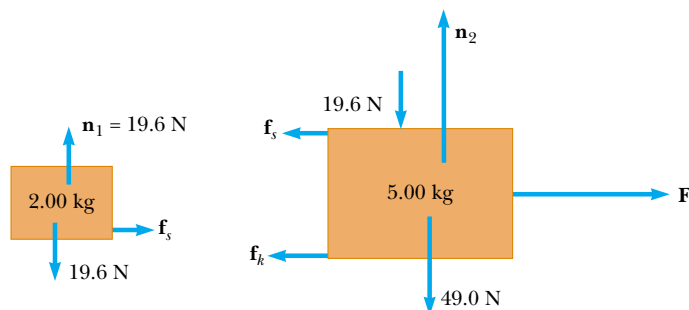
θ	0	15.0°	30.0°	45.0°	60.0°
$P(N)$	40.0	46.4	60.1	94.3	260

63. (a) 19.3° (b) 4.21 N

65. (a) 2.13 s (b) 1.67 m

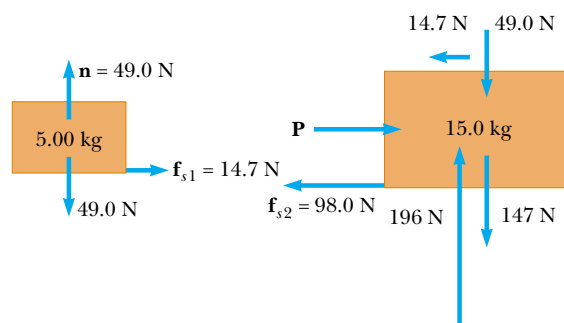
67. (a) See next column.

Static friction between the two blocks accelerates the upper block. (b) 34.7 N (c) 0.306

69. $(M + m_1 + m_2)(m_2 g / m_1)$ 

Chapter 5, Problem 67(a)

71. (a)

(b) 113 N (c) 0.980 m/s² and 1.96 m/s²

73. (a) 0.087 1 (b) 27.4 N

75. (a) 30.7° (b) 0.843 N

77. (a) 3.34 (b) Either the car would flip over backwards, or the wheels would skid, spinning in place, and the time would increase.

Chapter 6

1. (a) 8.00 m/s (b) 3.02 N

3. Any speed up to 8.08 m/s

5. $6.22 \times 10^{-12} \text{ N}$
 7. (a) 1.52 m/s^2 (b) 1.66 km/s (c) $6\,820 \text{ s}$
 9. (a) static friction (b) $0.085\,0$
 11. $v \leq 14.3 \text{ m/s}$
 13. (a) 68.6 N toward the center of the circle and 784 N up
 (b) 0.857 m/s^2
 15. No. The jungle lord needs a vine of tensile strength
 1.38 kN .
 17. (a) 4.81 m/s (b) 700 N up
 19. 3.13 m/s
 21. (a) $2.49 \times 10^4 \text{ N}$ up (b) 12.1 m/s
 23. (a) 0.822 m/s^2 (b) 37.0 N (c) 0.0839
 25. (a) 17.0° (b) 5.12 N
 27. (a) 491 N (b) 50.1 kg (c) 2.00 m/s^2
 29. 0.0927°
 31. (a) 32.7 s^{-1} (b) 9.80 m/s^2 (c) 4.90 m/s^2
 33. 3.01 N
 35. (a) $1.47 \text{ N}\cdot\text{s/m}$ (b) $2.04 \times 10^{-3} \text{ s}$ (c) $2.94 \times 10^{-2} \text{ N}$
 37. (a) 0.0347 s^{-1} (b) 2.50 m/s (c) $a = -cv$
 39. $\sim 10^1 \text{ N}$
 41. (a) 13.7 m/s down

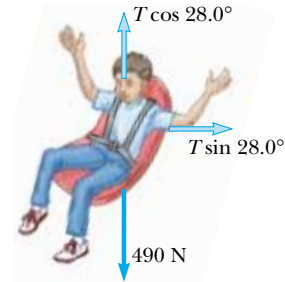
(b)	$t \text{ (s)}$	$x \text{ (m)}$	$v \text{ (m/s)}$
	0	0	0
	0.2	0	-1.96
	0.4	-0.392	-3.88
	...	...	...
	1.0	-3.77	-8.71
	...	...	...
	2.0	-14.4	-12.56
	...	...	...
	4.0	-41.0	-13.67

43. (a) 49.5 m/s and 4.95 m/s

(b)	$t \text{ (s)}$	$y \text{ (m)}$	$v \text{ (m/s)}$
	0	1 000	0
	...	...	...
	1	995	-9.7
	...	...	...
	2	980	-18.6
	...	...	...
	10	674	-47.7
	...	...	...
	10.1	671	-16.7
	...	...	...
	12	659	-4.95
	...	...	...
	145	0	-4.95

45. (a) $2.33 \times 10^{-4} \text{ kg/m}$ (b) 53 m/s (c) 42 m/s . The second trajectory is higher and shorter. In both, the ball attains maximum height when it has covered about 57% of its horizontal range, and it attains minimum speed somewhat later. The impact speeds also are both about 30 m/s .
 47. (a) $mg - mv^2/R$ (b) $\sqrt{gR}$
 49. (a) 2.63 m/s^2 (b) 201 m (c) 17.7 m/s
 51. (a) 9.80 N (b) 9.80 N (c) 6.26 m/s
 53. (b) 732 N down at the equator and 735 N down at the poles
 59. (a) 1.58 m/s^2 (b) 455 N (c) 329 N (d) 397 N upward and 9.15° inward

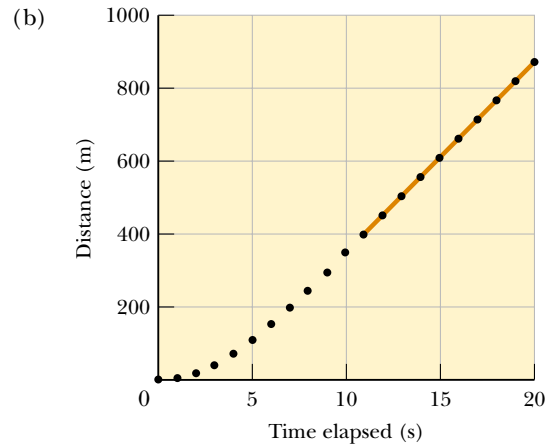
61. (a) 5.19 m/s (b) Child + seat:



$$T = 555 \text{ N}$$

63. (b) 2.54 s ; 23.6 rev/min
 65. 215 N horizontally inward
 67. (a) either 70.4° or 0° (b) 0°
 69. 12.8 N

(a)	$t \text{ (s)}$	$d \text{ (m)}$
	0	0
	1	4.9
	2	18.9
	...	...
	5	112.6
	...	...
	10	347.0
	11	399.1
	...	...
	15	611.3
	...	...
	20	876.5



- (c) The graph is straight for $11 \text{ s} < t < 20 \text{ s}$, with slope 53.0 m/s .

Chapter 7

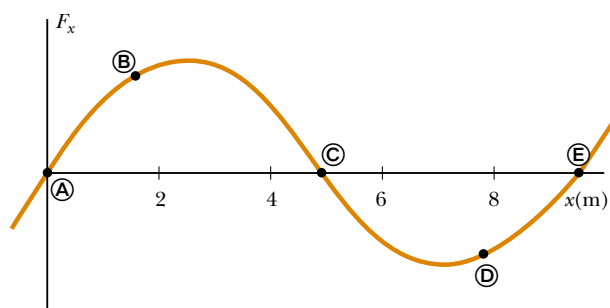
1. 15.0 MJ
 3. (a) 32.8 mJ (b) -32.8 mJ
 5. (a) 31.9 J (b) 0 (c) 0 (d) 31.9 J
 7. 4.70 kJ
 9. 14.0
 11. (a) 16.0 J (b) 36.9°
 13. (a) 11.3° (b) 156° (c) 82.3°

15. (a) 24.0 J (b) -3.00 J (c) 21.0 J
 17. (a) 7.50 J (b) 15.0 J (c) 7.50 J (d) 30.0 J
 19. (a) 0.938 cm (b) 1.25 J
 21. 0.299 m/s
 23. 12.0 J
 25. (b) mgR
 27. (a) 1.20 J (b) 5.00 m/s (c) 6.30 J
 29. (a) 60.0 J (b) 60.0 J
 31. (a) $\sqrt{2W/m}$ (b) W/d
 33. (a) 650 J (b) -588 J (c) 0 (d) 0 (e) 62.0 J
 (f) 1.76 m/s
 35. (a) -168 J (b) -184 J (c) 500 J (d) 148 J
 (e) 5.64 m/s
 37. 2.04 m
 39. (a) 22 500 N (b) 1.33×10^{-4} s
 41. (a) 0.791 m/s (b) 0.531 m/s
 43. 875 W
 45. 830 N
 47. (a) 5 910 W (b) It is 53.0% of 11 100 W
 49. (a) 0.013 5 gal (b) 73.8 (c) 8.08 kW
 51. 5.90 km/L
 53. (a) 5.37×10^{-11} J (b) 1.33×10^{-9} J
 55. 90.0 J
 59. (a) $(2 + 24t^2 + 72t^4)$ J (b) $12t$ m/s²; $48t$ N
 (c) $(48t + 288t^3)$ W (d) 1 250 J
 61. -0.047 5 J
 63. 878 kN
 65. (b) 240 W
 67. (a) $\mathbf{F}_1 = (20.5\mathbf{i} + 14.3\mathbf{j})$ N; $\mathbf{F}_2 = (-36.4\mathbf{i} + 21.0\mathbf{j})$ N
 (b) $(-15.9\mathbf{i} + 35.3\mathbf{j})$ N (c) $(-3.18\mathbf{i} + 7.07\mathbf{j})$ m/s²
 (d) $(-5.54\mathbf{i} + 23.7\mathbf{j})$ m/s (e) $(-2.30\mathbf{i} + 39.3\mathbf{j})$ m
 (f) 1 480 J (g) 1 480 J
 69. (a) 4.12 m (b) 3.35 m
 71. 1.68 m/s
 73. (a) 14.5 m/s (b) 1.75 kg (c) 0.350 kg
 75. 0.799 J

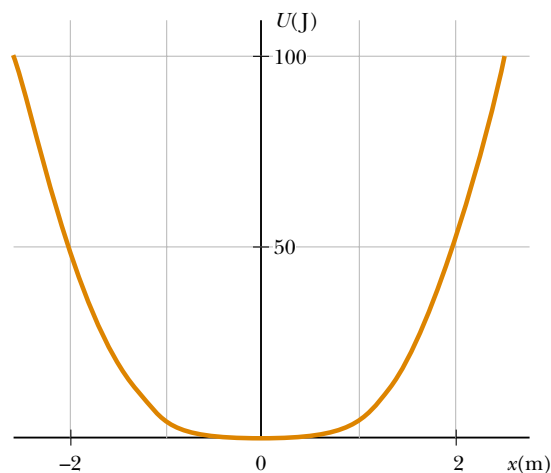
Chapter 8

1. (a) 259 kJ, 0, -259 kJ (b) 0, -259 kJ, -259 kJ
 3. (a) -196 J (b) -196 J (c) -196 J. The force is conservative.
 5. (a) 125 J (b) 50.0 J (c) 66.7 J (d) Nonconservative. The results differ.
 7. (a) 40.0 J (b) -40.0 J (c) 62.5 J
 9. (a) $Ax^2/2 - Bx^3/3$ (b) $\Delta U = 5A/2 - 19B/3$;
 $\Delta K = -5A/2 + 19B/3$
 11. 0.344 m
 13. (a) $v_B = 5.94$ m/s; $v_C = 7.67$ m/s (b) 147 J
 15. $v = (3gR)^{1/2}$, 0.098 0 N down
 17. 10.2 m
 19. (a) 19.8 m/s (b) 78.4 J (c) 1.00
 21. (a) 4.43 m/s (b) 5.00 m
 23. (a) 18.5 km, 51.0 km (b) 10.0 MJ
 25. (b) 60.0°
 27. 5.49 m/s

29. 2.00 m/s, 2.79 m/s, 3.19 m/s
 31. 3.74 m/s
 33. (a) -160 J (b) 73.5 J (c) 28.8 N (d) 0.679
 35. 489 kJ
 37. (a) 1.40 m/s (b) 4.60 cm after release (c) 1.79 m/s
 39. 1.96 m
 41. (A/r^2) away from the other particle
 43. (a) $r = 1.5$ mm, stable; 2.3 mm, unstable; 3.2 mm, stable;
 $r \rightarrow \infty$ neutral (b) $-5.6 \text{ J} < E < 1 \text{ J}$
 (c) $0.6 \text{ mm} < r < 3.6 \text{ mm}$ (d) 2.6 J (e) 1.5 mm
 (f) 4 J
 45. (a) + at Ⓑ, - at Ⓓ, 0 at Ⓐ, Ⓒ, and Ⓔ (b) Ⓒ stable;
 Ⓐ and Ⓔ unstable
 (c)



47. (b)



- Equilibrium at $x = 0$ (c) $v = \sqrt{0.800 \text{ J/m}}$
 49. (a) 1.50×10^{-10} J (b) 1.07×10^{-9} J (c) 9.15×10^{-10} J
 51. 48.2° Note that the answer is independent of the pumpkin's mass and of the radius of the dome.
 53. (a) 0.225 J (b) $\Delta E_f = -0.363 \text{ J}$ (c) No; the normal force changes in a complicated way.
 55. $\sim 10^2$ W sustainable power
 57. 0.327
 59. (a) 23.6 cm (b) 5.90 m/s² up the incline; no.
 (c) Gravitational potential energy turns into kinetic energy plus elastic potential energy and then entirely into elastic potential energy.
 61. 1.25 m/s

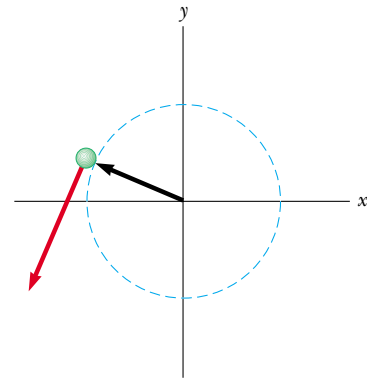
63. (a) 0.400 m (b) 4.10 m/s (c) The block stays on the track.
 65. (b) 2.06 m/s
 67. (b) 1.44 m (c) 0.400 m (d) No. A very strong wind pulls the string out horizontally (parallel to the ground). The largest possible equilibrium height is equal to L .
 71. (a) 6.15 m/s (b) 9.87 m/s
 73. 0.923 m/s

Chapter 9

1. (a) $(9.00\mathbf{i} - 12.0\mathbf{j}) \text{ kg}\cdot\text{m/s}$ (b) $15.0 \text{ kg}\cdot\text{m/s}$ at 307°
 3. 6.25 cm/s west
 5. $\sim 10^{-23} \text{ m/s}$
 7. (b) $p = \sqrt{2mK}$
 9. (a) 13.5 N·s (b) 9.00 kN (c) 18.0 kN
 11. 260 N normal to the wall
 13. 15.0 N in the direction of the initial velocity of the exiting water stream
 15. 65.2 m/s
 17. 301 m/s
 19. (a) $v_{gx} = 1.15 \text{ m/s}$ (b) $v_{px} = -0.346 \text{ m/s}$
 21. (a) 20.9 m/s east (b) 8.68 kJ into internal energy
 23. (a) 2.50 m/s (b) 37.5 kJ (c) Each process is the time-reversal of the other. The same momentum conservation equation describes both.
 25. (a) 0.284 (b) 115 fJ and 45.4 fJ
 27. 91.2 m/s
 29. (a) 2.88 m/s at 32.3° north of east (b) 783 J into internal energy
 31. No; his speed was 41.5 mi/h.
 33. 2.50 m/s at -60.0°
 35. $(3.00\mathbf{i} - 1.20\mathbf{j}) \text{ m/s}$
 37. Orange: $v_i \cos \theta$; yellow: $v_i \sin \theta$
 39. (a) $(-9.33\mathbf{i} - 8.33\mathbf{j}) \text{ Mm/s}$ (b) 439 fJ
 41. $\mathbf{r}_{\text{CM}} = (11.7\mathbf{i} + 13.3\mathbf{j}) \text{ cm}$
 43. 0.006 73 nm from the oxygen nucleus along the bisector of the angle
 45. (a) 15.9 g (b) 0.153 m
 47. 0.700 m
 49. (a) $(1.40\mathbf{i} + 2.40\mathbf{j}) \text{ m/s}$ (b) $(7.00\mathbf{i} + 12.0\mathbf{j}) \text{ kg}\cdot\text{m/s}$
 51. (a) 39.0 MN up (b) 3.20 m/s^2 up
 53. (a) 442 metric tons (b) 19.2 metric tons
 55. (a) $(1.33\mathbf{i}) \text{ m/s}$ (b) $(-235\mathbf{i}) \text{ N}$ (c) 0.680 s
 (d) $(-160\mathbf{i}) \text{ N}\cdot\text{s}$ and $(+160\mathbf{i}) \text{ N}\cdot\text{s}$ (e) 1.81 m
 (f) 0.454 m (g) -427 J (h) $+107 \text{ J}$
 (i) Equal friction forces act through different distances on person and cart to do different amounts of work on them. The total work on both together, -320 J , becomes $+320 \text{ J}$ of internal energy in this perfectly inelastic collision.
 57. 1.39 km/s
 59. 240 s
 61. 0.980 m
 63. (a) 6.81 m/s (b) 1.00 m
 65. $(3Mgx/L)\mathbf{j}$
 67. (a) $3.75 \text{ kg}\cdot\text{m/s}^2$ (b) 3.75 N (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 internal energy.
 69. (a) As the child walks to the right, the boat moves to the left and the center of mass remains fixed. (b) 5.55 m from the pier (c) No, since 6.55 m is less than 7.00 m.
 71. (a) 100 m/s (b) 374 J
 73. (a) $\sqrt{2} v_i$ for m and $\sqrt{2/3} v_i$ for $3m$ (b) 35.3°
 75. (a) 3.73 km/s (b) 153 km

Chapter 10

1. (a) 4.00 rad/s^2 (b) 18.0 rad
 3. (a) 1 200 rad/s (b) 25.0 s
 5. (a) 5.24 s (b) 27.4 rad
 7. (a) 5.00 rad, 10.0 rad/s, 4.00 rad/s^2 (b) 53.0 rad, 22.0 rad/s, 4.00 rad/s^2
 9. 13.7 rad/s^2
 11. $\sim 10^7 \text{ rev/y}$
 13. (a) 0.180 rad/s (b) 8.10 m/s^2 toward the center of the track
 15. (a) 8.00 rad/s (b) 8.00 m/s, $a_r = -64.0 \text{ m/s}^2$, $a_t = 4.00 \text{ m/s}^2$ (c) 9.00 rad
 17. (a) 54.3 rev (b) 12.1 rev/s
 19. (a) 126 rad/s (b) 3.78 m/s (c) 1.27 km/s^2 (d) 20.2 m
 21. (a) $-2.73\mathbf{i} \text{ m} + 1.24\mathbf{j} \text{ m}$ (b) second quadrant, 156° (c) $-1.85\mathbf{i} \text{ m/s} - 4.10\mathbf{j} \text{ m/s}$ (d) into the third quadrant at 246°



- (e) $6.15\mathbf{i} \text{ m/s}^2 - 2.78\mathbf{j} \text{ m/s}^2$
 (f) $24.6\mathbf{i} \text{ N} - 11.1\mathbf{j} \text{ N}$
 23. (a) $92.0 \text{ kg}\cdot\text{m}^2$, 184 J (b) 6.00 m/s, 4.00 m/s, 8.00 m/s, 184 J
 25. (a) $143 \text{ kg}\cdot\text{m}^2$ (b) 2.57 kJ
 29. $1.28 \text{ kg}\cdot\text{m}^2$
 31. $\sim 10^0 = 1 \text{ kg}\cdot\text{m}^2$
 33. $-3.55 \text{ N}\cdot\text{m}$
 35. 882 N·m
 37. (a) $24.0 \text{ N}\cdot\text{m}$ (b) 0.0356 rad/s^2 (c) 1.07 m/s^2
 39. (a) 0.309 m/s^2 (b) 7.67 N and 9.22 N
 41. (a) 872 N (b) 1.40 kN

43. 2.36 m/s
 45. (a) 11.4 N, 7.57 m/s², 9.53 m/s down (b) 9.53 m/s
 49. (a) $2(Rg/3)^{1/2}$ (b) $4(Rg/3)^{1/2}$ (c) $(Rg)^{1/2}$
 51. $\frac{1}{3}\ell$
 53. (a) 1.03 s (b) 10.3 rev
 55. (a) 4.00 J (b) 1.60 s (c) yes
 57. (a) 12.5 rad/s (b) 128 rad
 59. (a) $(3g/L)^{1/2}$ (b) $3g/2L$ (c) $-\frac{3}{2}g\mathbf{i} - \frac{3}{4}g\mathbf{j}$
 (d) $-\frac{3}{2}Mg\mathbf{i} + \frac{1}{4}Mg\mathbf{j}$
 61. $\alpha = g(h_2 - h_1)/2\pi R^2$
 63. (b) $2gM(\sin\theta - \mu\cos\theta)(m + 2M)^{-1}$
 65. 139 m/s
 67. 5.80 kg·m²; the height makes no difference.
 69. (a) 2 160 N·m (b) 439 W
 71. (a) 118 N and 156 N (b) 1.19 kg·m²
 73. (a) $\alpha = -0.176 \text{ rad/s}^2$ (b) 1.29 rev (c) 9.26 rev

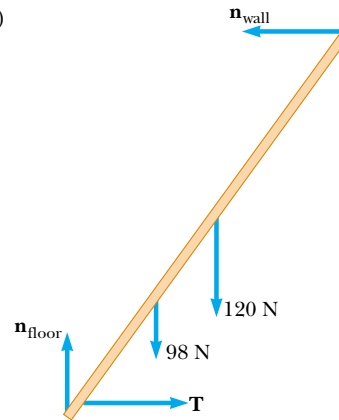
Chapter 11

1. (a) 500 J (b) 250 J (c) 750 J
 3. $\frac{7}{10}Mv^2$
 5. (a) $\frac{2}{3}g \sin\theta$ for the disk, larger than $\frac{1}{2}g \sin\theta$ for the hoop
 (b) $\frac{1}{3} \tan\theta$
 7. $1.21 \times 10^{-4} \text{ kg} \cdot \text{m}^2$. The height is unnecessary.
 9. $-7.00\mathbf{i} + 16.0\mathbf{j} - 10.0\mathbf{k}$
 11. (a) $-17.0\mathbf{k}$ (b) 70.5°
 13. (a) 2.00 N·m (b) $\mathbf{k}$
 15. (a) negative z direction (b) positive z direction
 17. 45.0°
 19. $(17.5\mathbf{k}) \text{ kg} \cdot \text{m}^2/\text{s}$
 21. $(60.0\mathbf{k}) \text{ kg} \cdot \text{m}^2/\text{s}$
 23. $mvR[\cos(vt/R) + 1]\mathbf{k}$
 25. (a) zero (b) $(-mv_i^3 \sin^2\theta \cos\theta/2g)\mathbf{k}$
 (c) $(-2mv_i^3 \sin^2\theta \cos\theta/g)\mathbf{k}$ (d) The downward force of gravity exerts a torque in the $-z$ direction.
 27. $-m\ell g \cos\theta \mathbf{k}$
 29. 4.50 kg·m²/s up
 31. (a) 0.433 kg·m²/s (b) 1.73 kg·m²/s
 33. (a) $\omega_f = \omega_i I_1/(I_1 + I_2)$ (b) $I_1/(I_1 + I_2)$
 35. (a) 1.91 rad/s (b) 2.53 J, 6.44 J
 37. (a) 0.360 rad/s counterclockwise (b) 99.9 J
 39. (a) $mv\ell$ down (b) $M/(M + m)$
 41. (a) $\omega = 2mv_i d/(M + 2m)R^2$ (b) No; some mechanical energy changes into internal energy.
 43. (a) $2.19 \times 10^6 \text{ m/s}$ (b) $2.18 \times 10^{-18} \text{ J}$
 (c) $4.13 \times 10^{16} \text{ rad/s}$
 45. $[10Rg(1 - \cos\theta)/7r^2]^{1/2}$
 51. (a) 2.70R (b) $F_x = -\frac{20}{7}mg$, $F_y = -mg$
 53. 0.632
 55. (a) $v_i r_i/r$ (b) $T = (mv_i^2 r_i^2)r^{-3}$ (c) $\frac{1}{2}mv_i^2(r_i^2/r^2 - 1)$
 (d) 4.50 m/s, 10.1 N, 0.450 J
 57. 54.0°
 59. (a) 3 750 kg·m²/s (b) 1.88 kJ (c) 3 750 kg·m²/s
 (d) 10.0 m/s (e) 7.50 kJ (f) 5.62 kJ
 61. $(M/m)[3ga(\sqrt{2} - 1)]^{1/2}$
 63. (c) $(8Fd/3M)^{1/2}$

67. (a) 0.800 m/s², 0.400 m/s² (b) 0.600 N backward on the plank and forward on the roller, at the top of each roller; 0.200 N forward on each roller and backward on the floor, at the bottom of each roller.

Chapter 12

1. 10.0 N up; 6.00 N·m counterclockwise
 3. $[(m_1 + m_b)d + m_1\ell/2]/m_2$
 5. -0.429 m
 7. (3.85 cm, 6.85 cm)
 9. $(-1.50 \text{ m}, -1.50 \text{ m})$
 11. (a) 859 N (b) 1 040 N left and upward at 36.9°
 13. (a) $f_s = 268 \text{ N}$, $n = 1\,300 \text{ N}$ (b) 0.324
 15. (a) 1.04 kN at 60.0° (b) $(370\mathbf{i} + 900\mathbf{j}) \text{ N}$
 17. 2.94 kN on each rear wheel and 4.41 kN on each front wheel
 19. (a) 29.9 N (b) 22.2 N
 21. (a) 35.5 kN (b) 11.5 kN (c) -4.19 kN
 23. 88.2 N and 58.8 N
 25. 4.90 mm
 27. 0.023 8 mm
 29. 0.912 mm
 31. $\frac{8m_1m_2gL_i}{\pi d^2 Y(m_1 + m_2)}$
 33. (a) $3.14 \times 10^4 \text{ N}$ (b) $6.28 \times 10^4 \text{ N}$
 35. $1.80 \times 10^8 \text{ N/m}^2$
 37. $n_A = 5.98 \times 10^5 \text{ N}$, $n_B = 4.80 \times 10^5 \text{ N}$
 39. (a) 0.400 mm (b) 40.0 kN (c) 2.00 mm (d) 2.40 mm
 (e) 48.0 kN
 41. (a)

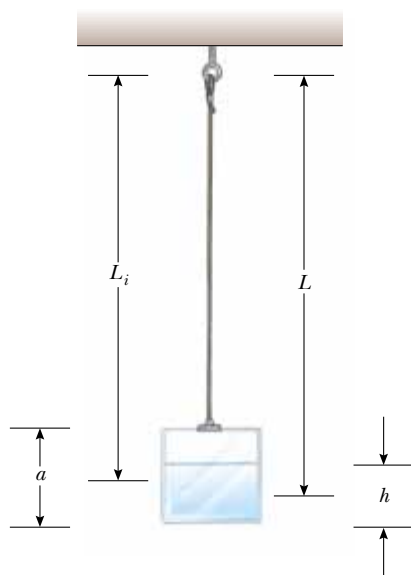


- (b) 69.8 N (c) 0.877L
 43. (a) 160 N right (b) 13.2 N right (c) 292 N up
 (d) 192 N
 45. (a) $T = F_g(L + d)/\sin\theta(2L + d)$
 (b) $R_x = F_g(L + d)\cot\theta/(2L + d)$; $R_y = F_gL/(2L + d)$
 47. 0.789 L
 49. 5.08 kN, $R_x = 4.77 \text{ kN}$, $R_y = 8.26 \text{ kN}$
 51. $T = 2.71 \text{ kN}$, $R_x = 2.65 \text{ kN}$
 53. (a) $\mu_k = 0.571$; the normal force acts 20.1 cm to the left of the front edge of the sliding cabinet. (b) 0.501 m

55. (b) 60.0°
 57. (a) $M = (m/2)(2\mu_s \sin \theta - \cos \theta)(\cos \theta - \mu_s \sin \theta)^{-1}$
 (b) $R = (m + M)g(1 + \mu_s^2)^{1/2}$,
 $F = g[M^2 + \mu_s^2(m + M)^2]^{1/2}$
 59. (a) 133 N (b) $n_A = 429$ N and $n_B = 257$ N
 (c) $R_x = 133$ N and $R_y = -257$ N
 61. 66.7 N
 65. 1.09 m
 67. (a) 4 500 N (b) 4.50×10^6 N/m² (c) yes.
 69. (a) $P_y = (F_g/L)(d - ah/g)$ (b) 0.306 m
 (c) $\mathbf{P} = (-306\mathbf{i} + 553\mathbf{j})$ N
 71. $n_A = n_E = 6.66$ kN; $F_{AB} = 10.4$ kN = $F_{BC} = F_{DC} = F_{DE}$;
 $F_{AC} = 7.94$ kN = F_{CE} ; $F_{BD} = 15.9$ kN

Chapter 13

1. (a) 1.50 Hz, 0.667 s (b) 4.00 m (c) π rad (d) 2.83 m
 3. (a) 20.0 cm (b) 94.2 cm/s as the particle passes through equilibrium (c) 17.8 m/s² at the maximum displacement from equilibrium
 5. (b) 18.8 cm/s, 0.333 s (c) 178 cm/s², 0.500 s
 (d) 12.0 cm
 7. 0.627 s
 9. (a) 40.0 cm/s, 160 cm/s² (b) 32.0 cm/s, -96.0 cm/s²
 (c) 0.232 s
 11. 40.9 N/m
 13. (a) 0.750 m (b) $x = -(0.750 \text{ m}) \sin(2.00 t/s)$
 15. 0.628 m/s
 17. 2.23 m/s
 19. (a) 28.0 mJ (b) 1.02 m/s (c) 12.2 mJ (d) 15.8 mJ
 21. (a) 2.61 m/s (b) 2.38 m/s
 23. 2.60 cm and -2.60 cm
 25. (a) 35.7 m (b) 29.1 s

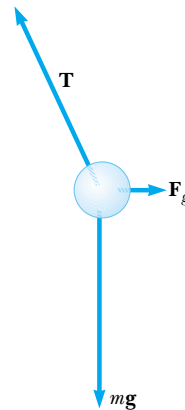


Chapter 13, Problem 57(a)

27. $\sim 10^0$ s
 29. (a) 0.817 m/s (b) 2.54 rad/s² (c) 0.634 N
 33. 0.944 kg·m²
 37. (a) 5.00×10^{-7} kg·m² (b) 3.16×10^{-4} N·m/rad
 39. The x coordinate of the crank pin is $A \cos \omega t$.
 41. 1.00×10^{-3} s⁻¹
 43. (a) 2.95 Hz (b) 2.85 cm
 47. Either 1.31 Hz or 0.641 Hz
 49. 6.58 kN/m
 51. (a) $2Mg$; $Mg(1 + y/L)$ (b) $T = (4\pi/3)(2L/g)^{1/2}$; 2.68 s
 53. 6.62 cm
 55. 9.19×10^{13} Hz
 57. (a) See bottom of preceding column.
 (b) $\frac{dT}{dt} = \frac{\pi(dM/dt)}{2\rho a^2 g^{1/2} [L_i + (dM/dt)t/2\rho a^2]^{1/2}}$
 (c) $T = 2\pi g^{-1/2} [L_i + (dM/dt)t/2\rho a^2]^{1/2}$
 59. $f = (2\pi L)^{-1} (gL + kh^2/M)^{1/2}$
 61. (a) 3.56 Hz (b) 2.79 Hz (c) 2.10 Hz
 63. (a) 3.00 s (b) 14.3 J (c) 25.5°
 65. 0.224 rad/s

Chapter 14

1. $\sim 10^{-7}$ N toward you
 3. $\mathbf{g} = (Gm/\ell^2)(\frac{1}{2} + \sqrt{2})$ toward the opposite corner
 5. $(-100\mathbf{i} + 59.3\mathbf{j})$ pN
 7. (a) 4.39×10^{20} N (b) 1.99×10^{20} N (c) 3.55×10^{22} N
 9. 0.613 m/s² toward the Earth
 11.



Either $(1.000 \text{ m} - 61.3 \text{ nm})$ or, if the objects have very high density, 247 mm.

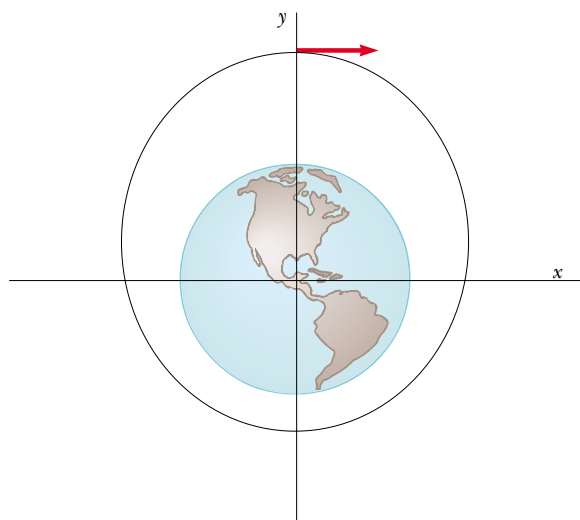
15. 12.6×10^{31} kg
 17. 1.27
 19. 1.90×10^{27} kg
 21. 8.92×10^7 m
 25. $g = 2MGr(r^2 + a^2)^{-3/2}$ toward the center of mass
 27. (a) -4.77×10^9 J (b) 569 N (c) 569 N up
 29. (a) 1.84×10^9 kg/m³ (b) 3.27×10^6 m/s²
 (c) -2.08×10^{13} J
 31. (a) -1.67×10^{-14} J (b) At the center
 33. 1.58×10^{10} J
 35. (a) 1.48 h (b) 7.79 km/s (c) 6.43×10^9 J

37. $1.66 \times 10^4 \text{ m/s}$
 41. 15.6 km/s
 43. $GM_E m/12R_E$
 45. $2GM/\pi R^2$ straight up in the picture
 47. (a) $7.41 \times 10^{-10} \text{ N}$ (b) $1.04 \times 10^{-8} \text{ N}$
 (c) $5.21 \times 10^{-9} \text{ N}$
 49. 2.26×10^{-7}
 51. (b) $1.10 \times 10^{32} \text{ kg}$
 53. (b) $GMm/2R$
 55. $7.79 \times 10^{14} \text{ kg}$
 57. $7.41 \times 10^{-10} \text{ N}$
 59. $v_{\text{esc}} = (8\pi G\rho/3)^{1/2} R$
 61. (a) $v_1 = m_2(2G/d)^{1/2}(m_1 + m_2)^{-1/2}$
 $v_2 = m_1(2G/d)^{1/2}(m_1 + m_2)^{-1/2}$
 $v_{\text{rel}} = (2G/d)^{1/2}(m_1 + m_2)^{1/2}$
 (b) $K_1 = 1.07 \times 10^{32} \text{ J}$, $K_2 = 2.67 \times 10^{31} \text{ J}$
 63. (a) $A = M/\pi R^4$ (b) $F = GmM/r^2$ toward the center
 (c) $F = GmMr^2/R^4$ toward the center
 65. 119 km
 67. (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

71.

$t \text{ (s)}$	$x \text{ (m)}$	$y \text{ (m)}$	$v_x \text{ (m/s)}$	$v_y \text{ (m/s)}$
0	0	12 740 000	5 000	0
10	50 000	12 740 000	4 999.9	-24.6
20	99 999	12 739 754	4 999.7	-49.1
30	149 996	12 739 263	4 999.4	-73.7 . . .

The object does not hit the Earth; its minimum radius is $1.33R_E$. Its period is $1.09 \times 10^4 \text{ s}$. A circular orbit would require speed 5.60 km/s .



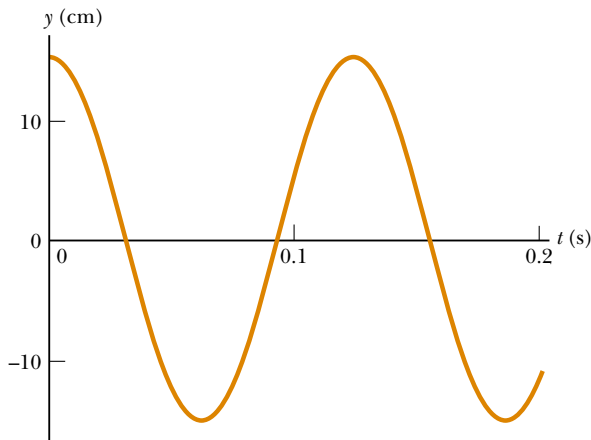
Chapter 15

1. 0.111 kg
 3. 6.24 MPa

5. $5.27 \times 10^{18} \text{ kg}$
 7. 1.62 m
 9. $7.74 \times 10^{-3} \text{ m}^2$
 11. 271 kN horizontally backward
 13. $P_0 + (\rho d/2)(g^2 + a^2)^{1/2}$
 15. 0.722 mm
 17. 10.5 m ; no, some alcohol and water evaporate.
 19. 12.6 cm
 21. 1.07 m^2
 23. (a) 9.80 N (b) 6.17 N
 25. (a) 7.00 cm (b) 2.80 g
 27. $\rho_{\text{oil}} = 1\,250 \text{ kg/m}^3$; $\rho_{\text{sphere}} = 500 \text{ kg/m}^3$
 29. $1\,430 \text{ m}^3$
 31. $2.67 \times 10^3 \text{ kg}$
 33. (a) 1.06 m/s (b) 4.24 m/s
 35. (a) 17.7 m/s (b) 1.73 mm
 37. 31.6 m/s
 39. 68.0 kPa
 41. 103 m/s
 43. (a) 4.43 m/s (b) The siphon can be no higher than 10.3 m .
 45. $2\sqrt{h(h_0 - h)}$
 47. 0.258 N
 49. 1.91 m
 53. 709 kg/m^3
 55. top scale 17.3 N ; bottom scale 31.7 N
 59. 90.04%
 61. 4.43 m/s
 63. (a) 10.3 m (b) 0
 65. (a) 18.3 mm (b) 14.3 mm (c) 8.56 mm
 67. (a) 2.65 m/s (b) $2.31 \times 10^4 \text{ Pa}$
 69. (a) 1.25 cm (b) 13.8 m/s

Chapter 16

1. $y = 6[(x - 4.5t)^2 + 3]^{-1}$
 3. (a) left (b) 5.00 m/s
 5. (a) longitudinal (b) 665 s
 7. (a) 156° (b) $0.058\,4 \text{ cm}$
 9. (a) y_1 in $+x$ direction, y_2 in $-x$ direction (b) 0.750 s
 (c) 1.00 m
 11. 30.0 N
 13. 1.64 m/s^2
 15. 13.5 N
 17. 586 m/s
 19. 32.9 ms
 21. 0.329 s
 23. (a) See top of next page (b) 0.125 s
 25. 0.319 m
 27. 2.40 m/s
 29. (a) 0.250 m (b) 40.0 rad/s (c) 0.300 rad/m
 (d) 20.9 m (e) 133 m/s (f) $+x$
 31. (a) $y = (8.00 \text{ cm}) \sin(7.85x + 6\pi t)$
 (b) $y = (8.00 \text{ cm}) \sin(7.85x + 6\pi t - 0.785)$
 33. (a) 0.500 Hz , 3.14 rad/s (b) 3.14 rad/m
 (c) $(0.100 \text{ m}) \sin(3.14x/\text{m} - 3.14t/\text{s})$



Chapter 16, Problem 23(a)

- (d) $(0.100 \text{ m}) \sin(-3.14t/s)$
 (e) $(0.100 \text{ m}) \sin(4.71 \text{ rad} - 3.14t/s)$ (f) 0.314 m/s
35. 2.00 cm, 2.98 m, 0.576 Hz, 1.72 m/s
 37. (b) 3.18 Hz
 41. 55.1 Hz
 43. (a) 62.5 m/s (b) 7.85 m (c) 7.96 Hz (d) 21.1 W
 45. (a) $A = 40.0$ (b) $A = 7.00$, $B = 0$, $C = 3.00$. One can take the dot product of the given equation with each one of $\mathbf{i}$, $\mathbf{j}$, and $\mathbf{k}$. (c) By inspection, $A = 0$, $B = 7.00 \text{ mm}$, $C = 3.00/\text{m}$, $D = 4.00/\text{s}$, $E = 2.00$. Consider the average value of both sides of the given equation to find A . Then consider the maximum value of both sides to find B . You can evaluate the partial derivative of both sides of the given equation with respect to x and separately with respect to t to obtain equations yielding C and D upon chosen substitutions for x and t . Then substitute $x = 0$ and $t = 0$ to obtain E .
47. It is if $v = (T/\mu)^{1/2}$
 49. $\sim 1 \text{ min}$
 51. (a) $3.33\mathbf{i} \text{ m/s}$ (b) -5.48 cm (c) 0.667 m , 5.00 Hz (d) 11.0 m/s
 53. $(Lm/Mg \sin \theta)^{1/2}$
 55. (a) 39.2 N (b) 0.892 m (c) 83.6 m/s
 57. 14.7 kg
 61. (a) $(0.707)2(L/g)^{1/2}$ (b) $L/4$
 63. 3.86×10^{-4}
 65. (a) $v = (2T_0/\mu_0)^{1/2} = v_0 2^{1/2}$
 $v' = (2T_0/3\mu_0)^{1/2} = v_0 (2/3)^{1/2}$
 (b) $0.966t_0$
 67. 130 m/s, 1.73 km

Chapter 17

1. 5.56 km
 3. 7.82 m
 5. (a) 27.2 s (b) 25.7 s; the interval in (a) is longer
 7. (a) 153 m/s (b) 614 m
 9. (a) amplitude 2.00 μm , wavelength 40.0 cm, speed 54.6 m/s (b) $-0.433 \mu\text{m}$ (c) 1.72 mm/s

11. $\Delta P = (0.2 \text{ Pa}) \sin(62.8x/\text{m} - 2.16 \times 10^4 t/\text{s})$
 13. (a) 6.52 mm (b) 20.5 m/s
 15. 5.81 m
 17. 66.0 dB
 19. (a) 3.75 W/m² (b) 0.600 W/m²
 21. (a) $1.32 \times 10^{-4} \text{ W/m}^2$ (b) 81.2 dB
 23. 65.6 dB
 25. (a) 65.0 dB (b) 67.8 dB (c) 69.6 dB
 27. 1.13 μW
 29. (a) 30.0 m (b) $9.49 \times 10^5 \text{ m}$
 31. (a) 332 J (b) 46.4 dB
 33. (a) 75.7-Hz drop (b) 0.948 m
 35. 26.4 m/s
 37. 19.3 m
 39. (a) 338 Hz (b) 483 Hz
 41. 56.4°
 43. (a) 56.3 s (b) 56.6 km farther along
 45. 400 m; 27.5%
 47. (a) 23.2 cm (b) $8.41 \times 10^{-8} \text{ m}$ (c) 1.38 cm
 49. (a) 0.515/min (b) 0.614/min
 51. 7.94 km
 53. (a) 55.8 m/s (b) 2 500 Hz
 55. Bat is gaining on the insect at the rate of 1.69 m/s.
 57. (a)



- (b) 0.343 m (c) 0.303 m (d) 0.383 m
 (e) 1.03 kHz
 59. (a) 0.691 m (b) 691 km
 61. 1204.2 Hz
 63. (a) 0.948° (b) 4.40°
 65. $1.34 \times 10^4 \text{ N}$
 67. 95.5 s
 69. (b) 531 Hz
 71. (a) 6.45 (b) 0
 73. $\sim 10^{11} \text{ Hz}$
- Chapter 18**
1. (a) 9.24 m (b) 600 Hz
 3. 5.66 cm
 5. 91.3°
 7. (a) 2 (b) 9.28 m and 1.99 m
 9. 15.7 m, 31.8 Hz, 500 m/s
 11. At 0.089 1 m, 0.303 m, 0.518 m, 0.732 m, 0.947 m, and 1.16 m from one speaker
 13. (a) 4.24 cm (b) 6.00 cm (c) 6.00 cm (d) 0.500 cm, 1.50 cm, and 2.50 cm
 17. 0.786 Hz, 1.57 Hz, 2.36 Hz, and 3.14 Hz
 19. (a) 163 N (b) 660 Hz
 21. 19.976 kHz

23. 31.2 cm from the bridge; 3.84%
 25. (a) 350 Hz (b) 400 kg
 27. 0.352 Hz
 29. (a) 3.66 m/s (b) 0.200 Hz
 31. (a) 0.357 m (b) 0.715 m
 33. (a) 531 Hz (b) 42.5 mm
 35. around 3 kHz
 37. $n(206 \text{ Hz})$ for $n = 1$ to 9, and $n(84.5 \text{ Hz})$ for $n = 2$ to 23
 39. 239 s
 41. 0.502 m and 0.837 m
 43. (a) 350 m/s (b) 1.14 m
 45. (a) 19.5 cm (b) 841 Hz
 47. (a) 1.59 kHz (b) odd-numbered harmonics
 (c) 1.11 kHz
 49. 5.64 beats/s
 51. (a) 1.99 beats/s (b) 3.38 m/s
 53. The second harmonic of E is close to the third harmonic of A, and the fourth harmonic of C# is close to the fifth harmonic of A.
 55. (a) 3.33 rad (b) 283 Hz
 57. 3.85 m/s away from the station or 3.77 m/s toward the station
 59. 85.7 Hz
 61. 31.1 N
 63. (a) 59.9 Hz (b) 20.0 cm
 65. (a) $1/2$ (b) $[n/(n+1)]^2 T$ (c) 9/16
 67. 50.0 Hz, 1.70 m
 69. (a) $2A \sin(2\pi x/\lambda) \cos(2\pi vt/\lambda)$
 (b) $2A \sin(\pi x/L) \cos(\pi vt/L)$
 (c) $2A \sin(2\pi x/L) \cos(2\pi vt/L)$
 (d) $2A \sin(n\pi x/L) \cos(n\pi vt/L)$

Chapter 19

1. (a) $37.0^\circ\text{C} = 310 \text{ K}$ (b) $-20.6^\circ\text{C} = 253 \text{ K}$
 3. (a) -274°C (b) 1.27 atm (c) 1.74 atm
 5. (a) -320°F (b) 77.3 K
 7. (a) 810°F (b) 450 K
 9. 3.27 cm
 11. (a) 3.005 8 m (b) 2.998 6 m
 13. 55.0°C
 15. (a) 0.109 cm^2 (b) increase
 17. (a) 0.176 mm (b) $8.78 \mu\text{m}$ (c) $0.093 0 \text{ cm}^3$
 19. (a) 2.52 MN/m^2 (b) It will not break.
 21. 1.14°C
 23. (a) 99.4 cm^3 (b) 0.943 cm
 25. (a) 3.00 mol (b) 1.80×10^{24} molecules
 27. 1.50×10^{29} molecules
 29. 472 K
 31. (a) 41.6 mol (b) 1.20 kg, in agreement with the tabulated density
 33. (a) 400 kPa (b) 449 kPa
 35. 2.27 kg
 37. 3.67 cm^3
 39. 4.39 kg
 43. (a) 94.97 cm (b) 95.03 cm

45. 208°C
 47. 3.55 cm
 49. (a) Expansion makes density drop. (b) $5 \times 10^{-5} (^\circ\text{C})^{-1}$
 51. (a) $h = nRT/(mg + P_0A)$ (b) 0.661 m
 53. $\alpha \Delta T$ is much less than 1.
 55. (a) $9.49 \times 10^{-5} \text{ s}$ (b) 57.4 s lost
 57. (a) $\rho g P_0 V_i (P_0 + \rho g d)^{-1}$ (b) decrease (c) 10.3 m
 61. (a) 5.00 MPa (b) 9.58×10^{-3}
 63. 2.74 m
 65. $L_c = 9.17 \text{ cm}$, $L_s = 14.2 \text{ cm}$
 67. (a) $L_f = L_i e^{\alpha \Delta T}$ (b) $2.00 \times 10^{-4}\%$; 59.4%
 69. (a) $6.17 \times 10^{-3} \text{ kg/m}$ (b) 632 N (c) 580 N; 192 Hz

Chapter 20

1. $(10.0 + 0.117)^\circ\text{C}$
 3. $0.234 \text{ kJ/kg} \cdot ^\circ\text{C}$
 5. 29.6°C
 7. (a) $0.435 \text{ cal/g} \cdot ^\circ\text{C}$ (b) beryllium
 9. (a) 25.8°C (b) No
 11. 50.7 ks
 13. 0.294 g
 15. 0.414 kg
 17. (a) 0°C (b) 114 g
 19. 59.4°C
 21. 1.18 MJ
 23. (a) $4P_i V_i$ (b) $T = (P_i/nRV_i) V^2$
 25. 466 J
 27. 810 J, 506 J, 203 J
 29. $Q = -720 \text{ J}$
 31.

	Q	W	ΔE_{int}
BC	—	0	—
CA	—	—	—
AB	+	+	+

33. (a) 7.50 kJ (b) 900 K
 35. 3.10 kJ; 37.6 kJ
 37. (a) $0.041 0 \text{ m}^3$ (b) -5.48 kJ (c) -5.48 kJ
 41. $2.40 \times 10^6 \text{ cal/s}$
 43. 10.0 kW
 45. 51.2°C
 47. (a) $0.89 \text{ ft}^2 \cdot ^\circ\text{F} \cdot \text{h/Btu}$ (b) $1.85 \text{ ft}^2 \cdot ^\circ\text{F} \cdot \text{h/Btu}$ (c) 2.08
 49. (a) $\sim 10^3 \text{ W}$ (b) decreasing at $\sim 10^{-1} \text{ K/s}$
 51. 364 K
 53. 47.7 g
 55. (a) 16.8 L (b) 0.351 L/s
 57. $2.00 \text{ kJ/kg} \cdot ^\circ\text{C}$
 59. 1.87 kJ
 61. (a) $4P_i V_i$ (b) $4P_i V_i$ (c) 9.08 kJ
 63. 5.31 h
 65. 872 g
 67. (a) 15.0 mg. Block: $Q = 0$, $W = +5.00 \text{ J}$, $\Delta E_{\text{int}} = 0$,
 $\Delta K = -5.00 \text{ J}$; Ice: $Q = 0$, $W = -5.00 \text{ J}$, $\Delta E_{\text{int}} = 5.00 \text{ J}$,
 $\Delta K = 0$.

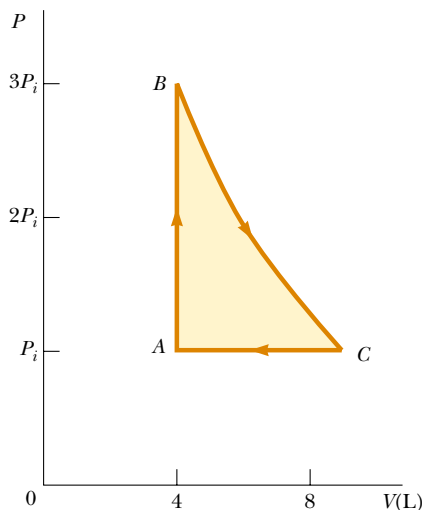
- (b) 15.0 mg. Block: $Q = 0$, $W = 0$, $\Delta E_{\text{int}} = 5.00 \text{ J}$, $\Delta K = -5.00 \text{ J}$; Metal: $Q = 0$, $W = 0$, $\Delta E_{\text{int}} = 0$, $\Delta K = 0$.
 (c) 0.00404°C . Moving slab: $Q = 0$, $W = +2.50 \text{ J}$, $\Delta E_{\text{int}} = 2.50 \text{ J}$, $\Delta K = -5.00 \text{ J}$; Stationary slab: $Q = 0$, $W = -2.50 \text{ J}$, $\Delta E_{\text{int}} = 2.50 \text{ J}$, $\Delta K = 0$

69. 10.2 h

71. 9.32 kW

Chapter 21

1. $6.64 \times 10^{-27} \text{ kg}$
 3. 0.943 N; 1.57 Pa
 5. 17.6 kPa
 7. 3.32 mol
 9. (a) 3.53×10^{23} atoms (b) $6.07 \times 10^{-21} \text{ J}$
 (c) 1.35 km/s
 11. (a) $8.76 \times 10^{-21} \text{ J}$ for both (b) 1.62 km/s for helium;
 514 m/s for argon
 13. 75.0 J
 15. (a) 3.46 kJ (b) 2.45 kJ (c) 1.01 kJ
 17. (a) 118 kJ (b) $6.03 \times 10^3 \text{ kg}$
 19. Between 10^{-2°C and 10^{-3°C
 21. (a) 316 K (b) 200 J
 23. $9 P_i V_i$
 25. (a) 1.39 atm (b) 366 K, 253 K (c) 0, 4.66 kJ, -4.66 kJ
 27. 227 K
 29. (a) P



- (b) 8.79 L (c) 900 K (d) 300 K (e) 336 J

31. 25.0 kW
 33. (a) 9.95 cal/K, 13.9 cal/K (b) 13.9 cal/K, 17.9 cal/K
 35. $2.33 \times 10^{-21} \text{ J}$
 37. The ratio of oxygen to nitrogen molecules decreases to 85.5% of its sea-level value.
 39. (a) 6.80 m/s (b) 7.41 m/s (c) 7.00 m/s
 43. 819°C
 45. (a) 3.21×10^{12} molecules (b) 778 km
 (c) $6.42 \times 10^{-4} \text{ s}^{-1}$
 49. (a) $9.36 \times 10^{-8} \text{ m}$ (b) $9.36 \times 10^{-8} \text{ atm}$ (c) 302 atm
 51. (a) 100 kPa, 66.5 L, 400 K, 5.82 kJ, 7.48 kJ, 1.66 kJ

- (b) 133 kPa, 49.9 L, 400 K, 5.82 kJ, 5.82 kJ, 0
 (c) 120 kPa, 41.6 L, 300 K, 0, -910 J, -910 J
 (d) 120 kPa, 43.3 L, 312 K, 722 J, 0, -722 J

55. 0.625

57. (a) Pressure increases as volume decreases.

(d) 0.500 atm^{-1} , 0.300 atm^{-1} 59. 1.09×10^{-3} ; 2.69×10^{-2} ; 0.529; 1.00; 0.199;
 1.01×10^{-41} ; 1.25×10^{-1082}

61. (a) Larger-mass molecules settle to the outside.

63. (a) 0.203 mol (b) $T_B = T_C = 900 \text{ K}$; $V_C = 15.0 \text{ L}$

(c, d)	$P \text{ (atm)}$	$V \text{ (L)}$	$T \text{ (K)}$	$E_{\text{int}} \text{ (kJ)}$
A	1	5	300	0.760
B	3	5	900	2.28
C	1	15	900	2.28

(e) For $A \rightarrow B$, lock the piston in place and put the cylinder into an oven at 900 K. For $B \rightarrow C$, keep the gas in the oven while gradually letting the gas expand to lift a load on the piston as far as it can. For $C \rightarrow A$, move the cylinder from the oven back to the 300-K room and let the gas cool and contract.

(f, g)	$Q \text{ (kJ)}$	$W \text{ (kJ)}$	$\Delta E_{\text{int}} \text{ (kJ)}$
$A \rightarrow B$	1.52	0	1.52
$B \rightarrow C$	1.67	1.67	0
$C \rightarrow A$	-2.53	-1.01	-1.52
ABCA	0.656	0.656	0

65. (a) 3.34×10^{26} molecules (b) during the 27th day(c) 2.53×10^6

67. (a) 0.510 m/s (b) 20 ms

Chapter 22

1. (a) 6.94% (b) 335 J
 3. (a) 10.7 kJ (b) 0.533 s
 5. (a) 1.00 kJ (b) 0
 7. (a) 67.2% (b) 58.8 kW
 9. (a) 869 MJ (b) 330 MJ
 11. (a) 741 J (b) 459 J
 13. 0.330 or 33.0%
 15. (a) 5.12% (b) 5.27 TJ/h (c) As conventional energy sources become more expensive, or as their true costs are recognized, alternative sources become economically viable.
 17. (a) 214 J, 64.3 J
 (b) -35.7 J, -35.7 J. The net effect is the transport of energy from the cold to the hot reservoir without expenditure of external work.
 (c) 333 J, 233 J
 (d) 83.3 J, 83.3 J, 0. The net effect is the expulsion of the energy entering the system by heat, entirely by work, in a cyclic process.
 (e) -0.111 J/K. The entropy of the Universe has decreased.

19. (a) 244 kPa (b) 192 J

21. 146 kW, 70.8 kW

23. 9.00

27. 72.2 J

29. (a) 24.0 J (b) 144 J

31. -610 J/K 33. 195 J/K 35. 3.27 J/K 37. 1.02 kJ/K 39. 5.76 J/K . Temperature is constant if the gas is ideal.41. 0.507 J/K 43. 18.4 J/K

45. (a) 1 (b) 6

47. (a)

Macrostate	Possible Microstates	Total Number of Microstates
All R	RRR	1
2R, 1G	RRG, RGR, GRR	3
1R, 2G	GRR, GRG, RGG	3
All G	GGG	1

(b)

Macrostate	Possible Microstates	Total Number of Microstates
All R	RRRRR	1
4R, 1G	RRRRG, RRRGR, RRGR, RGRRR, GRRRR	5
3R, 2G	RRRGG, RRGRG, RGRRG, GRRRG, RRGG, RGRGR, GRRGR, RGGR, GRGR, GGRRR	10
2R, 3G	GGGRR, GGRGR, GRGG, RGGGR, GGRRG, GRGRG, RGGRG, GRRGG, RGRGG, RRGGG	10
1R, 4G	GGGGR, GGGRG, GGRGG, GRGGG, RGGGG	5
All G	GGGGG	1

49. 1.86

51. (a) 5.00 kW (b) 763 W

53. (a) $2nRT_i \ln 2$ (b) 0.273

55. 23.1 mW

57. $5.97 \times 10^4 \text{ kg/s}$ 59. (a) 3.19 cal/K (b) 98.19°F , 2.59 cal/K 61. 1.18 J/K 63. (a) $10.5nRT_i$ (b) $8.50nRT_i$ (c) 0.190 (d) 0.83365. $nC_p \ln 3$ 69. (a) $96.9 \text{ W} = 8.33 \times 10^4 \text{ cal/hr}$ (b) $1.19^\circ\text{C/h} = 2.14^\circ\text{F/h}$