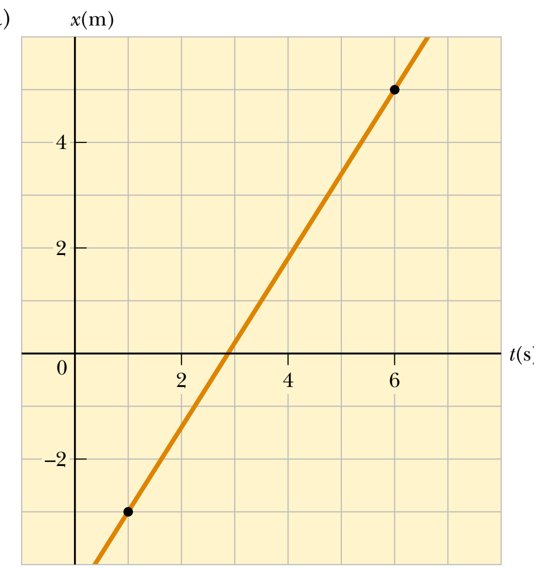
Answers to Odd-Numbered Problems

Chapter 1

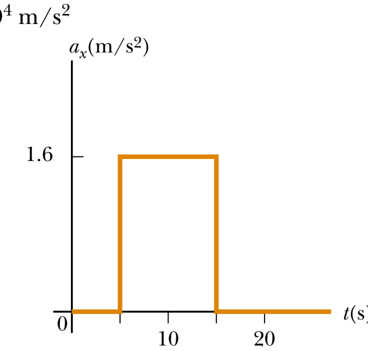
1. 2.15×10^4 kg/m^3
3. 184 g
5. (a) 7.10 cm^3 (b) 1.18×10^{-29} m^3 (c) 0.228 nm (d) 12.7 cm^3, 2.11×10^{-29} m^3, 0.277 nm
7. (a) 4.00 u = 6.64×10^{-24} g (b) 55.9 u = 9.29×10^{-23} g (c) 207 u = 3.44×10^{-22} g
9. (a) 9.83×10^{-16} g (b) 1.06×10^7 atoms
11. (a) 4.01×10^{25} molecules (b) 3.65×10^4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



(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. 1.34×10^4 m/s^2
15. (a)

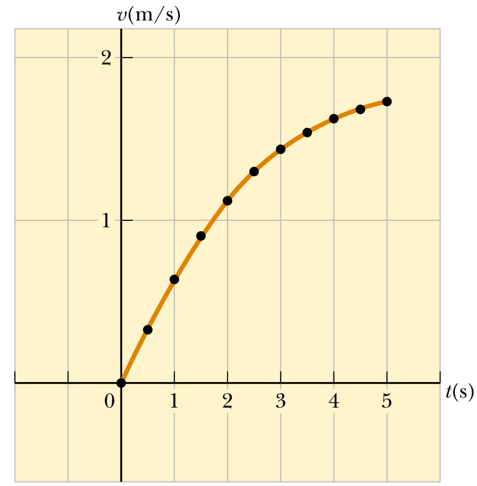


(b) 1.6 m/s^2 and 0.80 m/s^2
17. (a) 2.00 m (b) − 3.00 m/s (c) − 2.00 m/s^2
19. (a) 1.3 m/s^2 (b) 2.0 m/s^2 at 3 s (c) at t = 6 s and for $t > 10$ s (d) − 1.5 m/s^2 at 8 s
21. 2.74×10^5 m/s^2, which is 2.79×10^4 g
23. (a) 6.61 m/s (b) − 0.448 m/s^2
25. − 16.0 cm/s^2
27. (a) 2.56 m (b) − 3.00 m/s
29.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

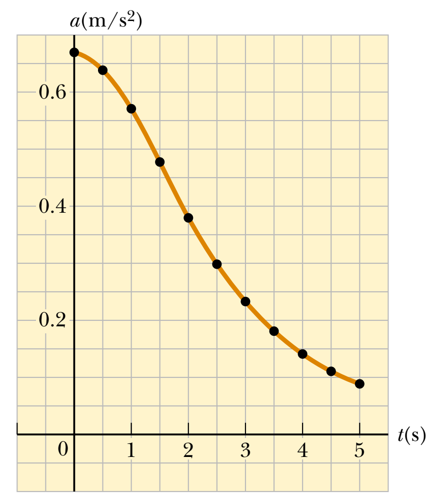
35. (a) 35.0 s (b) 15.7 m/s
37. (a) -202 m/s^2 (b) 198 m
39. (a) 3.00 m/s (b) 6.00 s (c) -0.300 m/s^2 (d) 2.05 m/s
41. (a) -4.90 m, -19.6 m, -44.1 m (b) -9.80 m/s, -19.6 m/s, -29.4 m/s
43. (a) 10.0 m/s up (b) 4.68 m/s down
45. No. In 0.2 s the bill falls out from between David's fingers.
47. (a) 29.4 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) $a_x = a_{xi} + Jt$, $v_x = v_{xi} + a_{xi}t + \frac{1}{2}Jt^2$, $x = x_i + v_{xi}t + \frac{1}{2}a_{xi}t^2 + \frac{1}{6}Jt^3$
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) $v_{\text{Stan}} = 22.6$ 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. $(-2.75, -4.76)$ 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. $(-25.0\mathbf{i})$m + $(43.3\mathbf{j})$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) $(-11.1\mathbf{i} + 6.40\mathbf{j})$ m (b) $(1.65\mathbf{i} + 2.86\mathbf{j})$ cm (c) $(-18.0\mathbf{i} - 12.6\mathbf{j})$ in.
35. 9.48 m at 166°
37. (a) 185 N at 77.8° from the positive x axis (b) $(-39.3\mathbf{i} - 181\mathbf{j})$ N
39. $\mathbf{A} + \mathbf{B} = (2.60\mathbf{i} + 4.50\mathbf{j})$ m



Chapter 2, Problem 71(a)

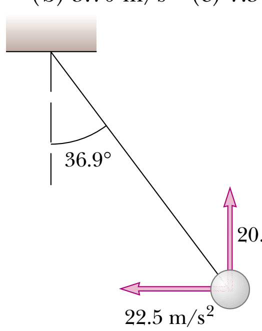


Chapter 2, Problem 71(b)

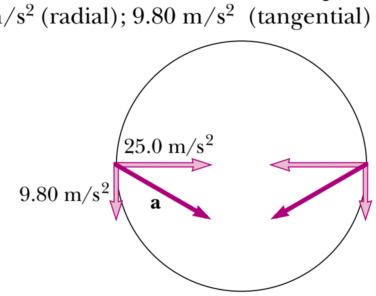
41. 196 cm at $-14.7°$ from the positive x axis.
43. (a) $8.00\mathbf{i} + 12.0\mathbf{j} - 4.00\mathbf{k}$ (b) $2.00\mathbf{i} + 3.00\mathbf{j} - 1.00\mathbf{k}$ (c) $-24.0\mathbf{i} - 36.0\mathbf{j} + 12.0\mathbf{k}$
45. (a) 5.92 m is the magnitude of $(5.00\mathbf{i} - 1.00\mathbf{j} - 3.00\mathbf{k})$ m (b) 19.0 m is the magnitude of $(4.00\mathbf{i} - 11.0\mathbf{j} + 15.0\mathbf{k})$ 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 positive x axis.
53. 1.15°
55. (a) 2.00, 1.00, 3.00 (b) 3.74 (c) $\theta_x = 57.7°$, $\theta_y = 74.5°$, $\theta_z = 36.7°$
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/s^2
5. (a) $(2.00\mathbf{i} + 3.00\mathbf{j})$ m/s^2 (b) $(3.00t + t^2)\mathbf{i}$ m, $(1.50\,t^2 - 2.00t)\mathbf{j}$ m
7. (a) $(0.800\mathbf{i} - 0.300\mathbf{j})$ m/s^2 (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/s^2
27. 10.5 m/s, 219 m/s^2
29. (a) 6.00 rev/s (b) 1.52 km/s^2 (c) 1.28 km/s^2
31. 1.48 m/s^2 inward at 29.9° behind the radius
33. (a) 13.0 m/s^2 (b) 5.70 m/s (c) 7.50 m/s^2
35. (a)



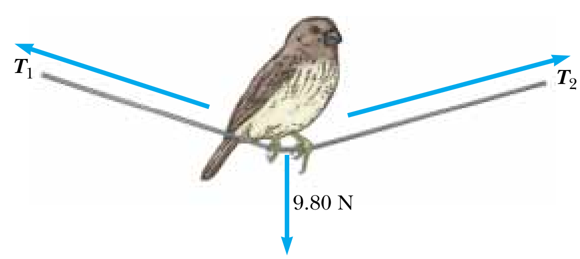
(b) 29.7 m/s^2 (c) 6.67 m/s at 36.9° above the horizontal
37. 2.02×10^3 s; 21.0% longer
39. 153 km/h at 11.3° north of west
41. (a) 36.9° (b) 41.6° (c) 3.00 min
43. 15.3 m
45. $2\,v_i t\cos\theta_i$
47. (b) $45° + \phi/2$; $v_i^2(1 - \sin\phi)/g\cos^2\phi$
49. (a) 41.7 m/s (b) 3.81 s (c) $(34.1\mathbf{i}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



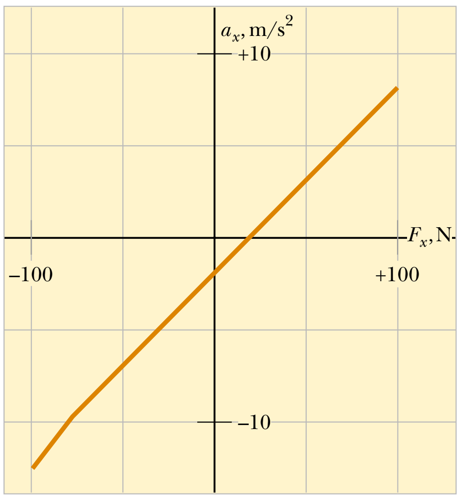
(c) 26.8 m/s^2 inward at 21.4° below the horizontal
53. 8.94 m/s at −63.4° relative to the positive x axis.
55. 20.0 m
57. (a) 0.600 m (b) 0.402 m (c) 1.87 m/s^2 toward center (d) 9.80 m/s^2 down
59. (a) 6.80 km (b) 3.00 km vertically above the impact point (c) 66.2°
61. (a) 46.5 m/s (b) −77.6° (c) 6.34 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/s$^2 \approx 10\,g$

Chapter 5

1. (a) 1/3 (b) 0.750 m/s^2
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/s^2 at 36.9° (b) 6.08 m/s^2 at 25.3°
17. (a) $\sim 10^{-22}$ m/s^2 (b) $\sim 10^{-23}$ m
19. (a) 0.200 m/s^2 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

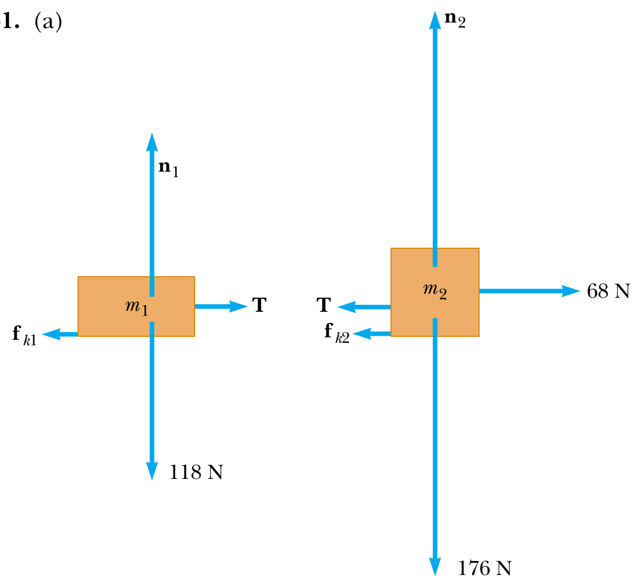


27. (a) 49.0 N (b) 98.0 N (c) 24.5 N
29. 8.66 N east
31. 100 N and 204 N
33. 3.73 m
35. $a = F/(m_1 + m_2)$; $T = F\,m_1/(m_1 + m_2)$
37. (a) $F_x > 19.6$ N (b) $F_x \le -78.4$ N (c) See top of next page.
39. (a) 706 N (b) 814 N (c) 706 N (d) 648 N
41. $\mu_s = 0.306$; $\mu_k = 0.245$
43. (a) 256 m (b) 42.7 m
45. (a) 1.78 m/s^2 (b) 0.368 (c) 9.37 N (d) 2.67 m/s
47. (a) 0.161 (b) 1.01 m/s^2
49. 37.8 N



Chapter 5, Problem 37(c)

51. (a)



(b) 27.2 N, 1.29 m/s^2

53. Any value between 31.7 N and 48.6 N

55. (a) See top of next column.
(b) 0.408 m/s^2 (c) 83.3 N

57. 1.18 kN

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

61. (b)

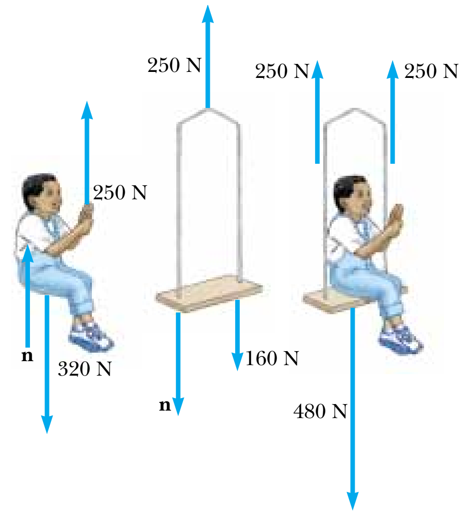
θ	0	15.0°	30.0°	45.0°	60.0°
P(N)	40.0	46.4	60.1	94.3	260

63. (a) 19.3° (b) 4.21 N

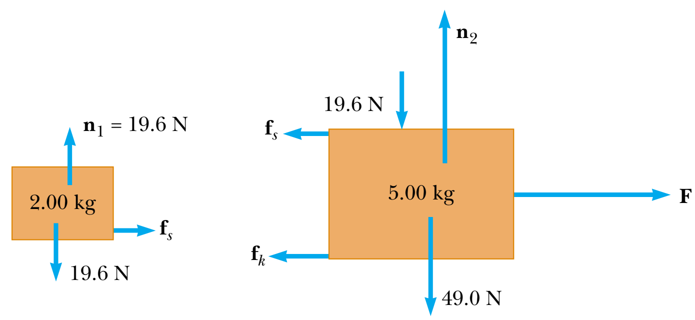
65. (a) 2.13 s (b) 1.67 m

67. (a) See next column.
Static friction between the two blocks accelerates the upper block. (b) 34.7 N (c) 0.306

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

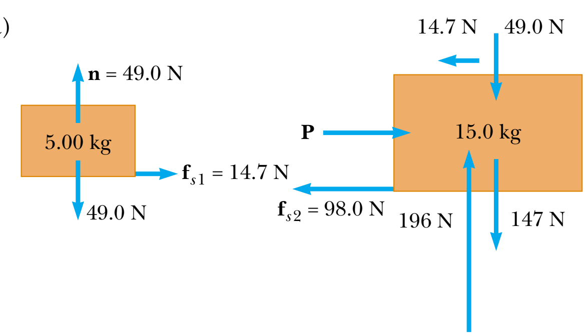


Chapter 5, Problem 55(a)



Chapter 5, Problem 67(a)

71. (a)



(b) 113 N (c) 0.980 m/s^2 and 1.96 m/s^2

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

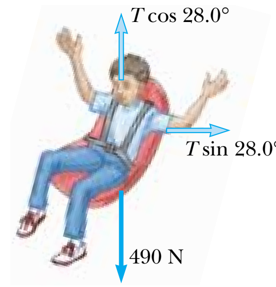
5. 6.22×10^{-12} N
7. (a) 1.52 m/s^2 (b) 1.66 km/s (c) 6 820 s
9. (a) static friction (b) 0.085 0
11. $v \leq 14.3$ m/s
13. (a) 68.6 N toward the center of the circle and 784 N up (b) 0.857 m/s^2
15. No. The jungle lord needs a vine of tensile strength 1.38 kN.
17. (a) 4.81 m/s (b) 700 N up
19. 3.13 m/s
21. (a) 2.49×10^4 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 N·s/m (b) 2.04×10^{-3} s (c) 2.94×10^{-2} N
37. (a) 0.0347 s^{-1} (b) 2.50 m/s (c) $a = -cv$
39. $\sim 10^1$ N
41. (a) 13.7 m/s down
(b)

***t* (s)**	***x* (m)**	***v* (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* (s)**	***y* (m)**	***v* (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

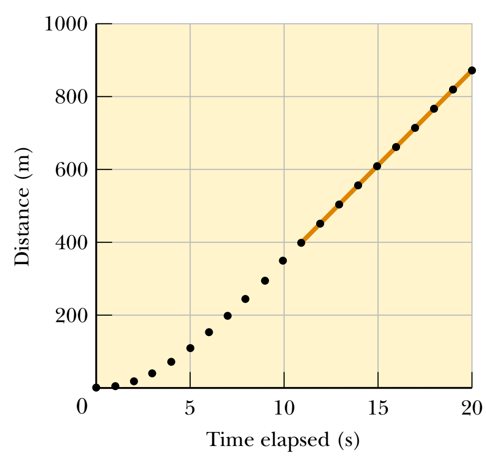
45. (a) 2.33×10^{-4} kg/m (b) 53 m/s (c) 42 m/s. The second trajectory is higher and shorter. In both, the ball attains maximum height when it has covered about 57% of its horizontal range, and it attains minimum speed somewhat later. The impact speeds also are both about 30 m/s.
47. (a) $mg - mv^2/R$ (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:



$T = 555$ 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
71. (a)

***t* (s)**	***d* (m)**
0	0
1	4.9
2	18.9
. . . 5	112.6
. . . 10	347.0
11	399.1
. . . 15	611.3
. . . 20	876.5

(b)



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

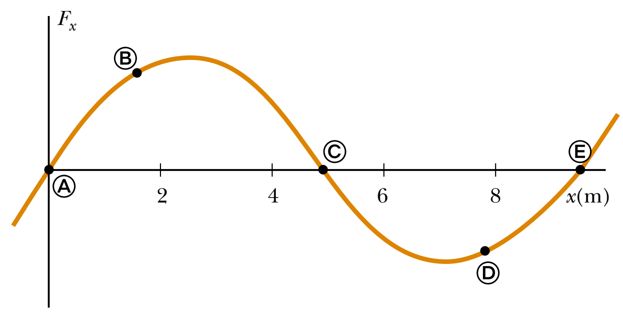
Chapter 7

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°

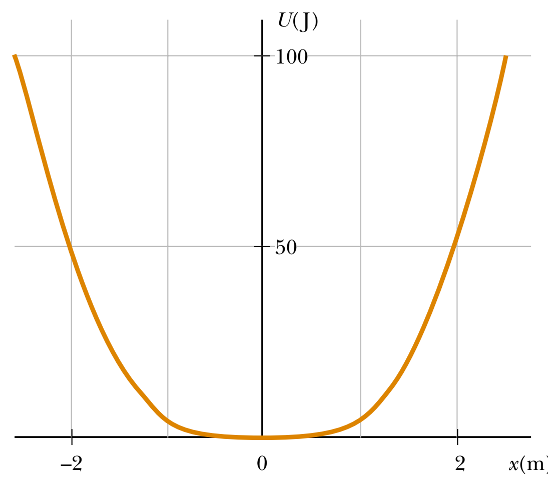
15. (a) 24.0 J (b) − 3.00 J (c) 21.0 J
17. (a) 7.50 J (b) 15.0 J (c) 7.50 J (d) 30.0 J
19. (a) 0.938 cm (b) 1.25 J
21. 0.299 m/s
23. 12.0 J
25. (b) mgR
27. (a) 1.20 J (b) 5.00 m/s (c) 6.30 J
29. (a) 60.0 J (b) 60.0 J
31. (a) $\sqrt{2W/m}$ (b) W/d
33. (a) 650 J (b) − 588 J (c) 0 (d) 0 (e) 62.0 J (f) 1.76 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; $r \to \infty$ 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) $\Delta E_f = -0.363$ 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

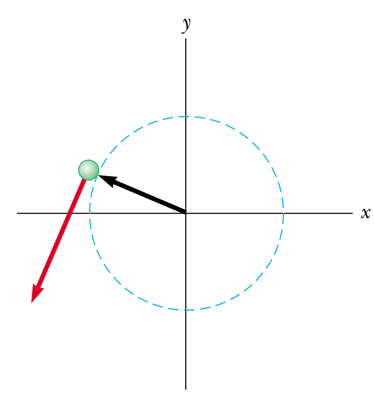
Chapter 9

1. (a) $(9.00\mathbf{i} - 12.0\mathbf{j})$ kg·m/s (b) 15.0 kg·m/s at 307°
3. 6.25 cm/s west
5. $\sim 10^{-23}$ 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) $v_{gx} = 1.15$ m/s (b) $v_{px} = -0.346$ 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. $(3.00\mathbf{i} - 1.20\mathbf{j})$ m/s
37. Orange: $v_i \cos\theta$; yellow: $v_i \sin\theta$
39. (a) $(-9.33\mathbf{i} - 8.33\mathbf{j})$ Mm/s (b) 439 fJ
41. $\mathbf{r}_{CM} = (11.7\mathbf{i} + 13.3\mathbf{j})$ 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) $(1.40\mathbf{i} + 2.40\mathbf{j})$ m/s (b) $(7.00\mathbf{i} + 12.0\mathbf{j})$ kg·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) $(1.33\mathbf{i})$ m/s (b) $(-235\mathbf{i})$ N (c) 0.680 s
(d) $(-160\mathbf{i})$ N·s and $(+160\mathbf{i})$ N·s (e) 1.81 m
(f) 0.454 m (g) -427 J (h) $+107$ 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 $+320$ 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 kg·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. $\sim 10^7$ 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, $a_r = -64.0$ m/s^2, $a_t = 4.00$ 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) $-2.73\mathbf{i}$ m $+ 1.24\mathbf{j}$ m (b) second quadrant, 156°
(c) $-1.85\mathbf{i}$ m/s $- 4.10\mathbf{j}$ m/s
(d) into the third quadrant at 246°



(e) $6.15\mathbf{i}$ m/s^2 $- 2.78\mathbf{j}$ m/s^2
(f) $24.6\mathbf{i}$ N $- 11.1\mathbf{j}$ N
23. (a) 92.0 kg·m^2, 184 J (b) 6.00 m/s, 4.00 m/s, 8.00 m/s, 184 J
25. (a) 143 kg·m^2 (b) 2.57 kJ
29. 1.28 kg·m^2
31. $\sim 10^0 = 1$ kg·m^2
33. -3.55 N·m
35. 882 N·m
37. (a) 24.0 N·m (b) 0.035 6 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

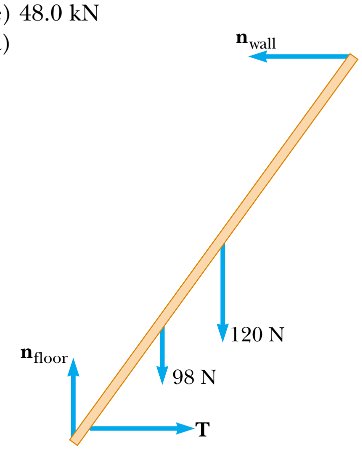
43. 2.36 m/s
45. (a) 11.4 N, 7.57 m/s^2, 9.53 m/s down (b) 9.53 m/s
49. (a) $2(Rg/3)^{1/2}$ (b) $4(Rg/3)^{1/2}$ (c) $(Rg)^{1/2}$
51. $\frac{1}{3}\ell$
53. (a) 1.03 s (b) 10.3 rev
55. (a) 4.00 J (b) 1.60 s (c) yes
57. (a) 12.5 rad/s (b) 128 rad
59. (a) $(3g/L)^{1/2}$ (b) $3g/2L$ (c) $-\frac{3}{2}g\mathbf{i} - \frac{3}{4}g\mathbf{j}$
(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·m^2; 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·m^2
73. (a) $\alpha = -0.176$ 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. 1.21×10^{-4} kg·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. $(17.5\mathbf{k})$ kg·m^2/s
21. $(60.0\mathbf{k})$ kg·m^2/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. $-m\ell gt\cos\theta\,\mathbf{k}$
29. 4.50 kg·m^2/s up
31. (a) 0.433 kg·m^2/s (b) 1.73 kg·m^2/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) $\omega = 2mv_id/(M + 2m)R^2$ (b) No; some mechanical energy changes into internal energy.
43. (a) 2.19×10^6 m/s (b) 2.18×10^{-18} J
(c) 4.13×10^{16} 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_ir_i/r (b) $T = (mv_i^2r_i^2)r^{-3}$ (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·m^2/s (b) 1.88 kJ (c) 3 750 kg·m^2/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/s^2, 0.400 m/s^2 (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 m, -1.50 m)
11. (a) 859 N (b) 1 040 N left and upward at 36.9°
13. (a) $f_s = 268$ N, $n = 1\,300$ N (b) 0.324
15. (a) 1.04 kN at 60.0° (b) $(370\mathbf{i} + 900\mathbf{j})$ 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. $\dfrac{8m_1m_2gL_i}{\pi d^2Y(m_1 + m_2)}$
33. (a) 3.14×10^4 N (b) 6.28×10^4 N
35. 1.80×10^8 N/m^2
37. $n_A = 5.98 \times 10^5$ N, $n_B = 4.80 \times 10^5$ N
39. (a) 0.400 mm (b) 40.0 kN (c) 2.00 mm (d) 2.40 mm
(e) 48.0 kN
41. (a)

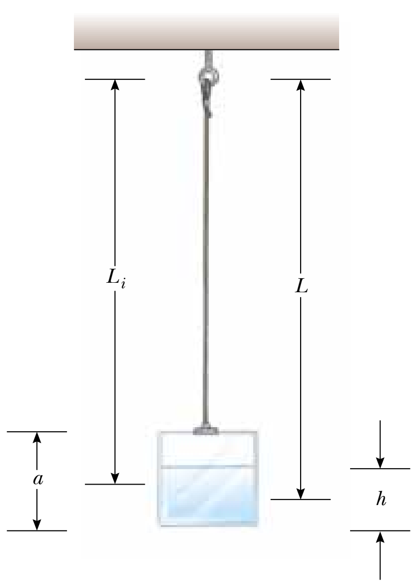


(b) 69.8 N (c) $0.877L$
43. (a) 160 N right (b) 13.2 N right (c) 292 N up
(d) 192 N
45. (a) $T = F_g(L + d)/\sin\theta(2L + d)$
(b) $R_x = F_g(L + d)\cot\theta/(2L + d)$; $R_y = F_gL/(2L + d)$
47. $0.789\,L$
49. 5.08 kN, $R_x = 4.77$ kN, $R_y = 8.26$ kN
51. $T = 2.71$ kN, $R_x = 2.65$ kN
53. (a) $\mu_k = 0.571$; 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/m^2 (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/s^2 at the maximum displacement from equilibrium
5. (b) 18.8 cm/s, 0.333 s (c) 178 cm/s^2, 0.500 s
(d) 12.0 cm
7. 0.627 s
9. (a) 40.0 cm/s, 160 cm/s^2 (b) 32.0 cm/s, -96.0 cm/s^2
(c) 0.232 s
11. 40.9 N/m
13. (a) 0.750 m (b) $x = -(0.750 \text{ m}) \sin(2.00t/\text{s})$
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

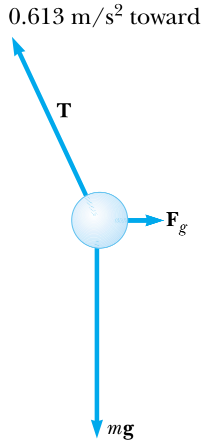


Chapter 13, Problem 57(a)

27. $\sim 10^0$ s
29. (a) 0.817 m/s (b) 2.54 rad/s^2 (c) 0.634 N
33. 0.944 kg·m^2
37. (a) 5.00×10^{-7} kg·m^2 (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) $\dfrac{dT}{dt} = \dfrac{\pi(dM/dt)}{2\rho a^2 g^{1/2}[L_i + (dM/dt)t/2\rho a^2]^{1/2}}$
(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/s^2 toward the Earth
11.

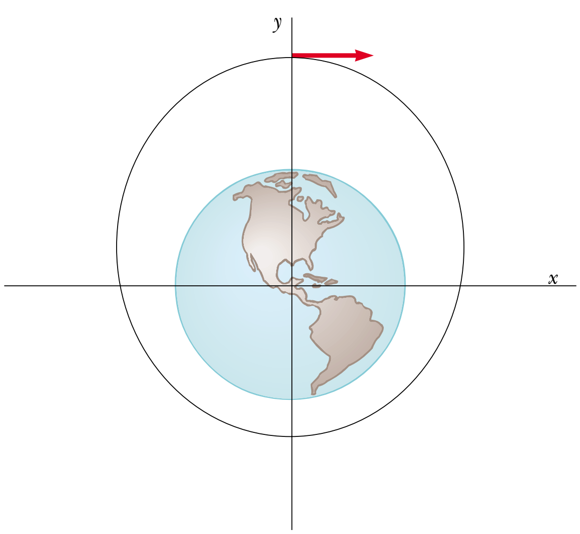


Either (1.000 m − 61.3 nm) or, if the objects have very high density, 247 mm.
15. 12.6×10^{31} kg
17. 1.27
19. 1.90×10^{27} kg
21. 8.92×10^7 m
25. $g = 2MGr(r^2 + a^2)^{-3/2}$ toward the center of mass
27. (a) -4.77×10^9 J (b) 569 N (c) 569 N up
29. (a) 1.84×10^9 kg/m^3 (b) 3.27×10^6 m/s^2
(c) -2.08×10^{13} 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. 1.66×10^4 m/s
41. 15.6 km/s
43. $GM_E m/12R_E$
45. $2GmM/\pi R^2$ straight up in the picture
47. (a) 7.41×10^{-10} N (b) 1.04×10^{-8} N (c) 5.21×10^{-9} N
49. 2.26×10^{-7}
51. (b) 1.10×10^{32} kg
53. (b) $GMm/2R$
55. 7.79×10^{14} kg
57. 7.41×10^{-10} N
59. $v_{esc} = (8\pi G\rho/3)^{1/2} R$
61. (a) $v_1 = m_2(2G/d)^{1/2}(m_1 + m_2)^{-1/2}$
$v_2 = m_1(2G/d)^{1/2}(m_1 + m_2)^{-1/2}$
$v_{rel} = (2G/d)^{1/2}(m_1 + m_2)^{1/2}$
(b) $K_1 = 1.07 \times 10^{32}$ J, $K_2 = 2.67 \times 10^{31}$ 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) 9.24×10^{10} kg·m²/s (c) 5.58 km/s, 10.4 Mm (d) 8.69 Mm (e) 134 min
71.

t (s)	x (m)	y (m)	v_x (m/s)	v_y (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 1.09×10^4 s. A circular orbit would require speed 5.60 km/s.

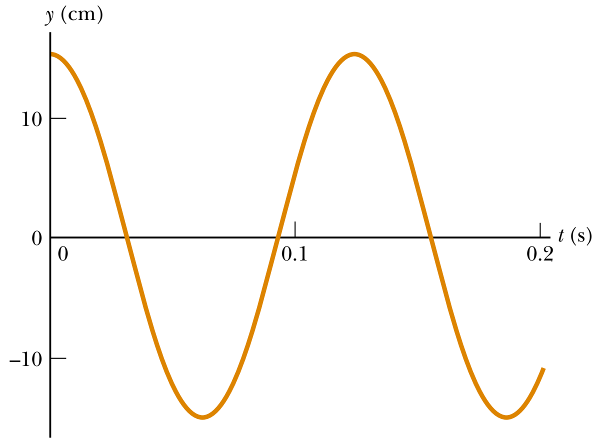


Chapter 15

1. 0.111 kg
3. 6.24 MPa
5. 5.27×10^{18} kg
7. 1.62 m
9. 7.74×10^{-3} m²
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 m²
23. (a) 9.80 N (b) 6.17 N
25. (a) 7.00 cm (b) 2.80 kg
27. $\rho_{oil} = 1\,250$ kg/m³; $\rho_{sphere} = 500$ kg/m³
29. 1 430 m³
31. 2.67×10^3 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/m³
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) 2.31×10^4 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 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/s²
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 m) sin(− 3.14t/s)
(e) (0.100 m) sin(4.71 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 **i**, **j**, and **k**. (c) By inspection, $A = 0$, $B = 7.00$ mm, $C = 3.00$/m, $D = 4.00$/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. ~1 min
51. (a) 3.33**i** 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 μm (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/m^2 (b) 0.600 W/m^2
21. (a) 1.32×10^{-4} 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) 9.49×10^5 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) 8.41×10^{-8} 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. 1.34×10^4 N
67. 95.5 s
69. (b) 531 Hz
71. (a) 6.45 (b) 0
73. ~10^{11} 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 Hz) for $n = 1$ to 9, and n(84.5 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°C = 310 K (b) −20.6°C = 253 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 μm (c) 0.093 0 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) 5×10^{-5} $(°C)^{-1}$
51. (a) $h = nRT/(mg + P_0A)$ (b) 0.661 m
53. $\alpha\,\Delta T$ is much less than 1.
55. (a) 9.49×10^{-5} 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. $L_c = 9.17$ cm, $L_s = 14.2$ cm
67. (a) $L_f = L_i e^{\alpha \Delta T}$ (b) 2.00×10^{-4}%; 59.4%
69. (a) 6.17×10^{-3} kg/m (b) 632 N (c) 580 N; 192 Hz

Chapter 20

1. (10.0 + 0.117)°C
3. 0.234 kJ/kg · °C
5. 29.6°C
7. (a) 0.435 cal/g · °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) $4P_iV_i$ (b) $T = (P_i/nRV_i)V^2$
25. 466 J
27. 810 J, 506 J, 203 J
29. $Q = -720$ 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 m^3 (b) −5.48 kJ (c) −5.48 kJ
41. 2.40×10^6 cal/s
43. 10.0 kW
45. 51.2°C
47. (a) 0.89 $ft^2 \cdot °F \cdot h/Btu$ (b) 1.85 $ft^2 \cdot °F \cdot h/Btu$ (c) 2.08
49. (a) $\sim 10^3$ W (b) decreasing at $\sim 10^{-1}$ K/s
51. 364 K
53. 47.7 g
55. (a) 16.8 L (b) 0.351 L/s
57. 2.00 kJ/kg · °C
59. 1.87 kJ
61. (a) $4P_iV_i$ (b) $4P_iV_i$ (c) 9.08 kJ
63. 5.31 h
65. 872 g
67. (a) 15.0 mg. Block: $Q = 0$, $W = +5.00$ J, $\Delta E_{int} = 0$, $\Delta K = -5.00$ J; Ice: $Q = 0$, $W = -5.00$ J, $\Delta E_{int} = 5.00$ J, $\Delta K = 0$.

(b) 15.0 mg. Block: $Q = 0$, $W = 0$, $\Delta E_{int} = 5.00$ J, $\Delta K = -5.00$ J; Metal: $Q = 0$, $W = 0$, $\Delta E_{int} = 0$, $\Delta K = 0$. (c) 0.004 04°C. Moving slab: $Q = 0$, $W = +2.50$ J, $\Delta E_{int} = 2.50$ J, $\Delta K = -5.00$ J; Stationary slab: $Q = 0$, $W = -2.50$ J, $\Delta E_{int} = 2.50$ J, $\Delta K = 0$

69. 10.2 h

71. 9.32 kW

Chapter 21

1. 6.64×10^{-27} kg

3. 0.943 N; 1.57 Pa

5. 17.6 kPa

7. 3.32 mol

9. (a) 3.53×10^{23} atoms (b) 6.07×10^{-21} J (c) 1.35 km/s

11. (a) 8.76×10^{-21} 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) 6.03×10^{3} kg

19. Between 10^{-2}°C and 10^{-3}°C

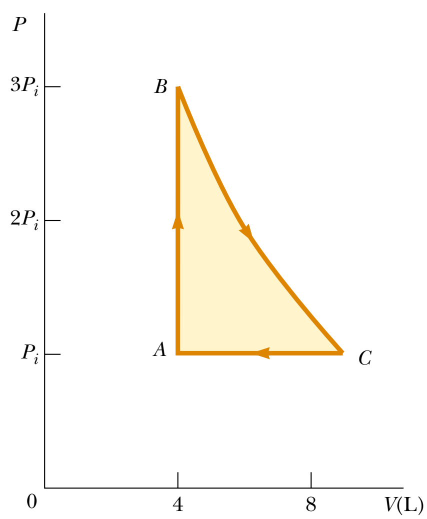
21. (a) 316 K (b) 200 J

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)



(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. 2.33×10^{-21} 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) 6.42×10^{-4} s^{-1}

49. (a) 9.36×10^{-8} m (b) 9.36×10^{-8} 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) $T_B = T_C = 900$ K; $V_C = 15.0$ L

(c, d)	P (atm)	V (L)	T (K)	E_{int} (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 (kJ)	W (kJ)	ΔE_{int} (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, RRGRR, RGRRR, GRRRR	5
3R, 2G	RRRGG, RRGRG, RGRRG, GRRRG, RRGGR, RGRGR, GRRGR, RGGRR, GRGRR, GGRRR	10
2R, 3G	GGGRR, GGRGR, GRGGR, 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. 5.97×10^4 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) 0.833
65. $nC_P \ln 3$
69. (a) 96.9 W = 8.33×10^4 cal/hr
(b) 1.19°C/h = 2.14°F/h