53. 1.02×10^{20} molecules
55. 2.6×10^{-10} m
57. 6.19×10^{5} Pa

CHAPTER 15

1. 32 miles
3. **(a)** -3700 J
(b) Heat flows out of the gas.
5. **(a)** -261 J
(b) Work is done on the system.
7. **(a)** -7.5×10^{2} J **(b)** $+9.0 \times 10^{2}$ J
9. **(a)** 3100 J **(b)** Negative
11. 0.24 m
13. 1.2×10^{7} Pa
15. The answer is a proof.
17. 4.99×10^{-6}
19. **(a)** -2.1×10^{2} K **(b)** Decrease
21. 3.17
23. 1.81
25. 18.0
27. **(a)** -8.00×10^{4} J
(b) Heat flows out of the gas.
29. **(a)** 327 K **(b)** 0.132 m^3
31. 2400 J
33. **(a)** 1.1×10^{4} J **(b)** 1.8×10^{4} J
35. 5/2
37. **(a)** 60.0% **(b)** 40.0%
39. 2.38×10^{4} J
41. 0.631
43. **(a)** 8600 J **(b)** 3100 J
45. **(a)** 5/9 **(b)** 1/3
47. 3000 J
49. **(a)** 1260 K **(b)** 1.74×10^{4} J
51. 0.015 kg
53. **(a)** 0.360 **(b)** 1.3×10^{13} J
55. 5.7 C°
57. 284 K
59. 5.86×10^{5} J
61. **(a)** 1050 J **(b)** 2.99
63. 1.4
65. **(a)** 2.0×10^{1} **(b)** 1.5×10^{4} J
67. 1.26×10^{3} K
69. 6.0×10^{1} J/K
71. **(a)** Reversible **(b)** -125 J/K
73. **(a)** $+541$ J/K
(b) The entropy of the universe increases.
75. **(a)** 0 J **(b)** -6.1×10^{3} J
(c) 310 K
77. 13 000 J
79. **(a)** $+3.68 \times 10^{3}$ J/K
(b) $+1.82 \times 10^{4}$ J/K
(c) The vaporization process creates more disorder.
81. 9.03
83. 3.0×10^{5} Pa
85. 279 s
87. 8.49×10^{5} Pa
89. 75 K
91. $e = e_1 + e_2 - e_1 e_2$

CHAPTER 16

1. 0.083 Hz
3. 0.25 m
5. 0.49 m
7. 78 cm
9. 5.0×10^{1} s
11. **(a)** 1.1 m/s **(b)** 6.55 m
13. 64 N
15. 8.68×10^{-3} kg/m
17. 1.2 m/s^2
19. 153 N
21. 3.26×10^{-3} s
23. $y = (0.37\text{ m}) \sin(2.6\,\pi t + 0.22\,\pi x)$, where x and y are in meters and t is in seconds.
25. **(a)** $+x$ direction **(b)** -0.080 m
27. 2.5 N
29. 1730 m/s
31. 8.19×10^{-2} m
33. **(a)** 431 m/s **(b)** 322 m/s
35. **(a)** steel, water, air
(b) 0.059 s, 0.339 s
37. 28.8 K
39. tungsten
41. 650 m
43. 8.0×10^{2} m/s
45. 57% argon, 43% neon
47. 0.404 m
49. 6.5 W
51. 190 m
53. 1.98%
55. 1.0×10^{4} W/m^2
57. 2.6 s
59. 0.316 W/m^2
61. 1000
63. -6.0 dB
65. 9.5 J
67. 0.84 s
69. 2.39 dB
71. 17 m/s
73. 56 m/s
75. 1350 Hz
77. 615 Hz
79. 209 m
81. 25
83. 2.06
85. 786 Hz
87. 1.3
89. **(a)** 7.87×10^{-3} s
(b) 4.12 wavelengths
91. 860 Hz
93. 120 dB
95. $m_1 = 28.7$ kg, $m_2 = 14.3$ kg
97. 21.2 m/s
99. 76.8 dB
101. 239 m/s

CHAPTER 17

1. The answer is a series of drawings.
3. **(a)** 2 cm **(b)** 1 cm
5. 5.06 m
7. 3.89 m
9. 3.90 m, 1.55 m, 6.25 m
11. **(a)** 44° **(b)** 0.10 m
13. 1.5×10^{4} Hz
15. 8.9 m
17. **(a)** 50 kHz
(b) 90 kHz
19. 8 Hz
21. 8 Hz
23. 1.10×10^{2} Hz
25. 0.46 m
27. 3.93×10^{-3} kg/m
29. **(a)** 1.00 m **(b)** 85.0 m/s
(c) 17.0 Hz
31. 0.077 m
33. 20.8° and 53.1°
35. 0.445
37. 0.50 m
39. 602 Hz
41. 1.2 m/s
43. 1.68×10^{5} Pa
45. 88 m/s
47. 107 Hz
49. 0.30 m
51. 171 N
53. $f_n = n\left(\frac{v}{2L}\right)$, where $n = 1, 2, 3, \ldots$
55. 12 Hz

CHAPTER 18

1. 1.5×10^{13} electrons
3. $-1.6\ \mu$C
5. **(a)** $+1.5\,q$ **(b)** $+4\,q$
(c) $+4\,q$
7. **(a)** 0.83 N
(b) Attractive, because the spheres carry charges of opposite sign.
9. 0.14 N
11. 0.38 N, 49° below the $-x$ axis.
13. 6.8 N
15. **(a)** 4.56×10^{-8} C
(b) 3.25×10^{-6} kg
17. 2.6×10^{12} electrons
19. 92.0 N/m
21. 3.5×10^{-5} C
23. **(a)** 15.4° **(b)** 0.813 N

25. 1.8 N, due east
27. 0.45 N, due east
29. (a) 3.0 m (b) 0 N
31. 1.3 m
33. $7.1 \times 10^{-2}\ \text{m}^2$
35. (a) Positive, so that the electrostatic force points upward
(b) 2.53×10^7 protons
37. 35 N/C
39. $q_1 = 0.716\,q$, $q_2 = 0.0895\,q$
41. 0.364
43. 61°
45. 3.25×10^{-8} C
47. (a) 350 N·m²/C (b) 460 N·m²/C
49. (a) 2.3×10^5 N·m²/C
(b) 2.3×10^5 N·m²/C
(c) 2.3×10^5 N·m²/C
51. (a) The flux through the face in the x, z plane at $y = 0$ m is -6.0×10^1 N·m²/C. The flux through the face parallel to the x, z plane at $y = 0.20$ m is $+6.0 \times 10^1$ N·m²/C. The flux through each of the remaining four faces is zero.
(b) 0 N·m²/C
53. The answer is a proof.
55. 120 N
57. $x = +0.71$ m
59. 6.5×10^3 N/C, downward
61. (a) both positive or both negative
(b) 1.7×10^{-16} C
63. 2.8×10^5 N/C, $-x$ direction
65. -3.3×10^{-6} C
67. 0.37 N

CHAPTER 19

1. 1.1×10^{-20} J
3. 4.7×10^7
5. 9.4×10^7 m/s
7. 7.0×10^1 hp
9. 339 V
11. $+3.6 \times 10^{-9}$ C
13. -4.35×10^{-18} J
15. -4.7×10^{-2} J
17. $-q/\sqrt{2}$
19. 0.0342 m
21. 6.1×10^{-14} m
23. −0.746 J
25. (a) $-2q/3$ (b) $-2q$
27. 18 000 V
29. 3.5×10^4 V
31. 4.2×10^3 V/m, directed from A to B
33. (a) 159 V (b) 125 V
(c) 135 V
35. 0.213 J
37. 1.1×10^3 V
39. (a) 1.3×10^{-12} C (b) 8.1×10^6
41. (a) 41 J (b) 8200 W
43. 52 V
45. 1.1×10^{-2} m
47. 2.77×10^6 m/s
49. 41 V
51. 5.3
53. 2×10^{-8} F
55. $+9.0 \times 10^3$ V
57. 1.0×10^{-4} C
59. The answer is a proof.

CHAPTER 20

1. 0.025 A
3. 0.21 A
5. 22 A
7. 6.2×10^4 J
9. (a) 4.7×10^{13} protons (b) 17 C°
11. 1.64
13. 9.9×10^{-3} m
15. 37.8 °C
17. 189 Ω
19. 70
21. 228 W
23. 8.9 h
25. 1.2 A
27. 250 °C
29. 33 °C
31. 1.77 A
33. (a) 9.0×10^2 W (b) 1.8×10^3 W
35. $92
37. 2.0 h
39. (a) 145 Ω (b) 74 V
41. (a) 10.0 V (b) 5.00 V
43. 32 Ω
45. (a) 28.9 V (b) 16.7 W
47. (a) 35 Ω (b) 5.0×10^1 Ω
49. 5.3 Ω
51. (a) 4.57 A (b) 1450 W
53. 240 Ω
55. (a) 3.6 Ω
(b) 33 A, breaker will open
57. 3.58×10^{-8} m²
59. 1.0×10^2 Ω
61. 4.6 Ω
63. 2.2 W
65. (a) 0.750 A (b) 2.11 A
67. 0.12 Ω
69. 30 bulbs
71. 10.9 V
73. (a) 0.38 A (b) 2.0×10^1 V
(c) Point B
75. 33 A
77. 0.75 V, the left end
79. 0.94 V, point D
81. 3.43×10^3 Ω
83. 25 V
85. (a) 30.0 V (b) 28.1 V
87. 2.0 μF
89. 4.69×10^{-4} C
91. The answer is a proof.
93. 11 V
95. 4.1×10^{-7} F
97. 1.2×10^{-2} s
99. 6.9
101. 1.7 μF
103. 82 Ω
105. −34.6 °C
107. 0.450 Ω
109. 6.00 Ω, 0.545 Ω, 3.67 Ω, 2.75 Ω, 2.20 Ω, 1.50 Ω, 1.33 Ω, 0.833 Ω
111. (a) 1.2 Ω (b) 110 V
113. 140 °C
115. C_0

CHAPTER 21

1. 8.1×10^{-5} T
3. (a) 6.50×10^{-2} T
(b) 9.10×10^3 m/s
5. 4.1×10^{-3} m/s
7. 19.7°
9. (a) Due south
(b) 2.55×10^{14} m/s²
11. $+2e$
13. (a) 7.2×10^6 m/s (b) 3.5×10^{-13} N
15. 1.5×10^{-8} s
17. 0.0904 m
19. (a) $\theta = 0^\circ$ (b) 0.29 m
21. 0.13 T
23. 140 V/m, directed toward the bottom of the page
25. 9.6×10^4 m/s
27. 8.1 N
29. 0.96 N (top and bottom sides), 0 N (left and right sides)
31. 57.6°
33. (a) Left-to-right (b) 1.1×10^{-2} m
35. 14 A
37. (a) 24 A·m² (b) 4.8 N·m
39. (a) 13.4 A·m² (b) 24.1 N·m
41. (a) 170 N·m (b) Increase
43. 2.6 N
45. 9.3×10^{-24} A·m²
47. 8.0×10^{-5} T
49. 1.3×10^{-2} T
51. 190 A
53. (a) 4.3×10^{-5} T (b) 5.3×10^{-5} T
55. 6.8 A, opposite to the direction of the current in the inner coil
57. 1.04×10^{-2} T
59. I_3 is directed out of the paper, $I_3/I = 2$
61. (a) 1.1×10^{-5} T (b) 4.4×10^{-6} T

63. The answer is a proof.
65. 1.9×10^{-4} N·m
67. 8.2×10^{-27} N·m
69. 75.1° and 105°
71. 0.0152 m
73. 8.7×10^{-3} s
75. 1.3×10^{-10} N, directed out of the page
77. 1.2×10^{-5} A·m^2

CHAPTER 22

1. 150 m/s
3. 0.065 V
5. (Rod *A*) emf = 0 V, (Rod *B*) emf = 1.6 V and end 2 is positive, (Rod *C*) emf = 0 V
7. **(a)** 3.3 m/s **(b)** 4.6 N
9. **(a)** 0.23 kg **(b)** −1.8 J **(c)** 1.8 J
11. 70.5°
13. **(a)** 1.2×10^{-4} Wb **(b)** 3.2×10^{-4} Wb **(c)** 2.0×10^{-4} Wb
15. (Two triangular ends) 0 Wb, (Bottom surface) 0 Wb, (1.2 m × 0.30 m surface) 0.090 Wb, (1.2 m × 0.50 m surface) 0.090 Wb
17. **(a)** 0.65 V **(b)** 0.11 A
19. 8.6×10^{-5} T
21. 4.8 s
23. 0.43 V
25. 0.459 T
27. 2100 rad/s
29. (Figure 22.1*b*) right to left, (Figure 22.1*c*) left to right
31. **(a)** clockwise **(b)** clockwise
33. no induced current
35. **(a)** 2.4 Hz **(b)** 15 rad/s **(c)** 0.62 T
37. 0.11 T
39. 0.150 m
41. 102 V
43. **(a)** 9.59 Ω **(b)** 95 V **(c)** 8.9 A
45. 220 turns
47. 1.4 V
49. 1.5×10^{9} J
51. 2.80×10^{-4} H
53. 1.6×10^{-5} A
55. 1/12, step down
57. 7.7 W
59. **(a)** 7.0×10^{5} W **(b)** 7.0×10^{1} W
61. The answer is a proof.
63. 4.0×10^{5} turns
65. **(a)** left to right **(b)** right to left
67. 12 V
69. 0.045 V
71. **(a)** 3.6×10^{-3} V **(b)** 2.0×10^{-3} m^2/s, shrunk
73. **(a)** 0.80 A **(b)** 8.00 A **(c)** 4.40 A

CHAPTER 23

1. 126 Hz
3. 12 Ω
5. **(a)** 2.00 μF **(b)** 0.77 A
7. 3/2
9. 8.0×10^{1} Hz
11. 0.44 A
13. 0.17 V
15. 83.9 V
17. 0.819
19. **(a)** 0.925 A **(b)** 31.8°
21. 270 Hz
23. **(a)** 51.8 V **(b)** −4.21 A
25. 0.651 W
27. **(a)** 352 Hz **(b)** 15.5 A
29. 3.1 kHz
31. **(a)** 1.3×10^{-3} H **(b)** 8.7×10^{-6} F
33. 8
35. **(a)** $4/\sqrt{3}$ **(b)** $1/\sqrt{3}$
37. 5.00×10^{-2} s
39. **(a)** 0.50 A **(b)** 0.34 A **(c)** yes, 0.704 H
41. 176 mH
43. **(a)** 2.94×10^{-3} H **(b)** 4.84 Ω **(c)** 0.163
45. 3.11×10^{3} Hz and 7.50×10^{3} Hz

CHAPTER 24

1. 4.1×10^{16} m
3. 2.19×10^{-11} F
5. The answers are in graphical form.
7. 11.118 m
9. 1.25 m
11. 3.7×10^{4} wavelengths
13. 1.5×10^{10} Hz
15. 1.3×10^{6} m
17. 540 rev/s
19. 8.75×10^{5} times
21. **(a)** 6.81×10^{5} N/C **(b)** 2.27×10^{-3} T
23. 0.07 N/C
25. **(a)** 183 N/C **(b)** 6.10×10^{-7} T
27. 4600 W
29. 920 W
31. **(a)** receding **(b)** 1.8×10^{6} m/s
33. **(a)** 6.175×10^{14} Hz **(b)** 6.159×10^{14} Hz
35. **(a)** 0.82 **(b)** 0.18
37. 62%
39. 20 analyzers
41. 1.4×10^{17} Hz
43. 0.015 m
45. 602 W/m^2
47. 71.6°
49. **(a)** 2.4×10^{9} Hz **(b)** 0.063 m
51. 3.93×10^{26} W
53. **(a)** 5.30 N/C **(b)** 1.77×10^{-8} T

CHAPTER 25

1. 55°
3. 14°
5. 10°
7. **(a)** 30° **(b)** 30°
9. 1.73
11. **(a)** Image distance is 3.0×10^{1} cm behind the mirror. **(b)** Image height is 5.0 cm.
13. **(a)** Image distance is 16.7 cm behind the mirror. **(b)** Image height is 6.67 cm.
15. 10.9 cm
17. +74 cm
19. **(a)** 2.0×10^{2} cm **(b)** −6.3 cm **(c)** Upside down
21. **(a)** +62 cm **(b)** +0.35 **(c)** Upright **(d)** Smaller
23. **(a)** *R* **(b)** −1 **(c)** Inverted
25. −2
27. 80.0 cm, toward the mirror
29. **(a)** The answer is a proof. **(b)** The answer is a proof.
31. **(a)** Convex **(b)** 24.0 cm
33. $d_i = +31$ cm
35. $d_o = +22$ cm
37. 0.533 m
39. +42.0 cm
41. 33.7°

CHAPTER 26

1. 2.00×10^{8} m/s
3. 1.198
5. 2.0×10^{-11} s
7. 1.40
9. 2.46×10^{8} m/s
11. 1.92×10^{8} m/s
13. 1.64
15. 1.19 mm
17. The answer is a derivation.
19. 2.1 cm
21. 3.23 cm
23. 1.54
25. **(a)** 1.50 **(b)** 1.27
27. 5.1 m
29. 1.35
31. 1.52

33. (a) 53.12° (b) 52.62°
35. 25.0°
37. The answer is a proof.
39. 0.35°
41. (Red) 44.6°, (Violet) 45.9°
43. (Red) 52.7°, (Violet) 56.2°
45. 61.1 mm
47. (a) −15 cm (b) virtual
49. (a) $d_i = -75$ cm, $m = 2.5$
(b) $d_i = -75.0$ cm, $m = 2.50$
51. (a) -7.90×10^{-3} m
(b) -3.44×10^{-2} m
53. 48 cm
55. (a) 4.52×10^{-4} m
(b) 6.12×10^{-2} m
57. +35 cm and +90.5 cm
59. (a) 4.00 cm to the left of the diverging lens
(b) −0.167 (c) virtual
(d) inverted (e) smaller
61. 0.13 m to the right of the second lens
63. (a) 19.6 cm (b) 0.87 cm
65. (a) 18.1 cm (b) real
(c) inverted
67. (a) 46.0 cm (b) 43.0 cm
69. (Right eye) −0.20 diopters,
(Left eye) −0.15 diopters
71. −9.2 cm
73. 26.9 cm
75. (a) −4.5 m (b) 0.50 m
77. 3.7
79. 0.13 m
81. 6.3 cm
83. 4.8×10^{-3} rad
85. 0.81 cm
87. 0.435 cm
89. 0.261 cm
91. 1.1 m
93. (a) the 1.3-diopter lens
(b) 0.86 m
(c) −8.5
95. (a) −194
(b) -7.8×10^{-5} m
(c) 1.94×10^{6} m
97. $d_i = 18$ cm
99. 1.45
101. −220 cm
103. 2.8
105. (a) 43° (b) 31°
107. (a) converging (b) farsighted
(c) 96.3 cm from the eyes
109. (a) 6.74×10^{-7} m^2
(b) 7.86×10^{5} W/m^2
111. (a) converging (b) $d_o = 2f$
(c) $d_i = 2f$
113. (a) 11.8 cm (b) 47.8 cm
115. −181
117. (a) 31.3 cm (b) 2.43 m

CHAPTER 27

1. Constructive
3. 16
5. 660 nm
7. 0.0309 m
9. 487 nm
11. 102 nm
13. 198
15. 115 nm
17. 440 nm
19. (a) 0.21° (b) 22°
21. (a) 24° (b) 39°
23. 490 nm
25. 0.447
27. 0.013
29. (a) 220 m (b) No
31. 0.0254 m
33. (a) 5.6 m (b) 56 m
35. 3.2×10^{3} m
37. (a) 37° (b) 22°
39. 5.90×10^{-7} m
41. 4.0×10^{-6} m
43. (a) 7.9° (violet), 13° (red)
(b) 16° (violet), 26° (red)
(c) 24° (violet), 41° (red)
(d) The second and third orders overlap.
45. (a) 2
(b) $m_B = 4$ and $m_A = 2$; $m_B = 6$ and $m_A = 3$
47. 6.0×10^{-5} m
49. 207 nm
51. 1.0×10^{4} m
53. (a) 1.22λ (b) Shorter
55. 3/4
57. 1.95 m

CHAPTER 28

1. 2.4×10^{8} m/s
3. 0.15 rad/s
5. 5.57 s
7. 16
9. 530 m
11. 1.3
13. 6.0 light years
15. 3.0 m × 1.3 m
17. 2.83×10^{8} m/s
19. 1.80×10^{8} m/s
21. −2.0 m/s
23. 5.0×10^{-13} J
25. 1.1 kg
27. (a) 1.0 (b) 6.6
29. The answer is a proof.
31. $0.31c$
33. 42 m
35. (a) $0.940c$
(b) 1.8×10^{-16} kg·m/s
37. 2.60×10^{8} m/s
39. (a) 5.1×10^{15} kg·m/s
(b) 9.7×10^{15} kg·m/s
41. $-0.406c$
43. 8.59

CHAPTER 29

1. 310 nm
3. 7.7×10^{29} photons/s
5. 6.3 eV
7. 138
9. 73 photons/s
11. (a) 2.1×10^{24} photons
(b) 32 molecules/photon
13. 5.1×10^{-33} kg·m/s
15. (a) 2.124×10^{-24} kg·m/s
(b) 2.096×10^{-24} kg·m/s
17. 4.692×10^{-24} kg·m/s
19. 9.50×10^{-17} m
21. 6.6×10^{-27} kg
23. (a) 4.50×10^{-36} m/s
(b) 7.05×10^{27} years
25. 7.38×10^{-11} m
27. 1.2×10^{-36} m
29. 1.5×10^{4} V
31. 8.0×10^{-6} m/s
33. 1.9×10^{-20} kg·m/s
35. $-0.0289° \leq \theta \leq +0.0289°$
37. 2.6×10^{-28} m
39. 7.77×10^{-13} J
41. 1.9
43. 1.10×10^{3} m/s
45. (a) 1.0×10^{-8} N (b) 5.0×10^{-9} N

CHAPTER 30

1. (a) 6.2×10^{-31} m^3
(b) 4×10^{-45} m^3
(c) 7×10^{-13} %
3. 1.5×10^{14}
5. -8.7×10^{6} eV
7. 4.41×10^{-10} m
9. (a) 7458 nm (b) 2279 nm
(c) infrared region
11. 1.98×10^{-19} J
13. −13.6 eV, −3.40 eV, −1.51 eV
15. The answer is a proof.
17. $6 \leq n_i \leq 19$
19. 2180 lines/cm
21. −0.378 eV
23. 2, 3, 4, 5
25. $\pm 3.16 \times 10^{-34}$ J·s,
$\pm 2.11 \times 10^{-34}$ J·s,
$\pm 1.05 \times 10^{-34}$ J·s, 0 J·s