45. (a) 3.21×10^{12} molecules (b) 779 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. 510 K and 290 K

57. 0.623

59. (a) Pressure increases as volume decreases
(d) 0.500 atm^{-1}, 0.300 atm^{-1}

61. (a) 0.514 m^3 (b) 2.06 m^3 (c) 2.38×10^3 K
(d) − 480 kJ (e) 2.28 MJ

63. 1.09×10^{-3}; 2.69×10^{-2}; 0.529; 1.00; 0.199; 1.01×10^{-41}; 1.25×10^{-1082}

67. (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	1.00	5.00	300	0.760
B	3.00	5.00	900	2.28
C	1.00	15.0	900	2.28
A	1.00	5.00	300	0.760

(e) Lock the piston in place and put the cylinder into an oven at 900 K. Keep the gas in the oven while gradually letting the gas expand to lift a load on the piston as far as it can. 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
AB	1.52	0	1.52
BC	1.67	− 1.67	0
CD	− 2.53	+ 1.01	− 1.52
$ABCA$	0.656	− 0.656	0

69. 1.60×10^4 K

CHAPTER 22

1. (a) 6.94% (b) 335 J

3. (a) 10.7 kJ (b) 0.533 s

5. (a) 29.4 L/h (b) 185 hp (c) 527 N·m
(d) 1.91×10^5 W

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

9. (a) 2.93 (b) coefficient of performance for a refrigerator
(c) \$300 is twice as large as \$150

11. (a) 67.2% (b) 58.8 kW

13. (a) 741 J (b) 459 J

15. (a) 4.20 W (b) 31.2 g

17. (a) 564 K (b) 212 kW (c) 47.5%

19. (b) $1 - T_c/T_h$ (c) $(T_c + T_h)/2$ (d) $(T_hT_c)^{1/2}$

21. (a) 214 J, 64.3 J
(b) − 35.7 J, − 35.7 J. The net effect is the transport of energy by heat 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 converting energy, taken in by heat, entirely into energy output by work in a cyclic process.
(e) − 0.111 J/K. The entropy of the Universe has decreased.

23. 9.00

27. 72.2 J

29. 1.86

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

33. 146 kW, 70.8 kW

35. − 610 J/K

37. 195 J/K

39. 236 J/K

41. 1.02 kJ/K

43. ~ 10^0 W/K from metabolism; much more if you are using high-power electric appliances or an automobile, or if your taxes are paying for a war.

45. 5.76 J/K; temperature is constant if the gas is ideal

47. 18.4 J/K

49. (a) 1 (b) 6

51. (a)

Result	Number of Ways to Draw
All R	1
2 R, 1 G	3
1R, 2 G	3
All G	1

(b)

Result	Number of Ways to Draw
All R	1
4R, 1G	5
3R, 2G	10
2R, 3G	10
1R, 4G	5
All G	1

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

55. (a) 0.476 J/K (b) 417 J (c) $W_{\text{net}} = T_1 \Delta S_U = 167$ J

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

59. 5.97×10^4 kg/s

61. (a) 3.19 cal/K (b) 98.19°F, 2.59 cal/K

63. (a) 8.48 kW (b) 1.52 kW (c) 1.09×10^4 J/K
(d) COP drops by 20.0%

65. (a) $10.5nRT_i$ (b) $8.50nRT_i$ (c) 0.190 (d) 0.833

67. (a) $nC_P \ln 3$
(b) Both ask for the change in entropy between the same two states of the same system. Entropy is a function of state. The change in entropy does not depend on path, but only on original and final states.

71. (a) 20.0°C (c) $\Delta S = +4.88$ J/K (d) Yes

CHAPTER 23

1. (a) + 160 zC, 1.01 u (b) + 160 zC, 23.0 u
(c) − 160 zC, 35.5 u (d) + 320 zC, 40.1 u
(e) − 480 zC, 14.0 u (f) + 640 zC, 14.0 u
(g) + 1.12 aC, 14.0 u (h) − 160 zC, 18.0 u

3. The force is ~ 10^{26} N.

5. (a) 1.59 nN away from the other
(b) 1.24×10^{36} times larger
(c) 8.61×10^{-11} C/kg

7. 0.872 N at 330°

9. (a) 2.16×10^{-5} N toward the other (b) 8.99×10^{-7} N away from the other

11. (a) 82.2 nN (b) 2.19 Mm/s

13. (a) 55.8 pN/C down (b) 102 nN/C up

15. 1.82 m to the left of the negative charge

17. $-9Q$ and $+27Q$

19. (a) $(-0.599\hat{\mathbf{i}} - 2.70\hat{\mathbf{j}})$ kN/C (b) $(-3.00\hat{\mathbf{i}} - 13.5\hat{\mathbf{j}})$ μN

21. (a) $5.91k_e q/a^2$ at 58.8° (b) $5.91k_e q^2/a^2$ at 58.8°

23. (a) $[k_e Qx/(R^2 + x^2)^{3/2}]\hat{\mathbf{i}}$ (b) As long as the charge is symmetrically placed, the number of charges does not matter. A continuous ring corresponds to n becoming larger without limit.

25. 1.59×10^6 N/C toward the rod

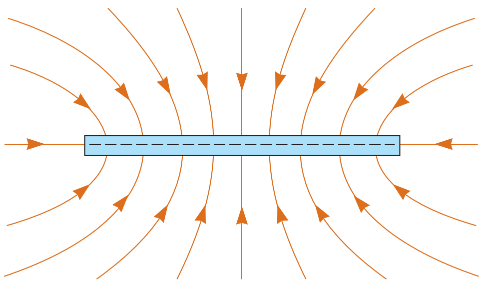
27. (a) $6.64\hat{\mathbf{i}}$ MN/C (b) $24.1\hat{\mathbf{i}}$ MN/C (c) $6.40\hat{\mathbf{i}}$ MN/C (d) $0.664\hat{\mathbf{i}}$ MN/C, taking the axis of the ring as the x axis

31. (a) 93.6 MN/C; the near-field approximation is 104 MN/C, about 11% high (b) 0.516 MN/C; the point-charge approximation is 0.519 MN/C, about 0.6% high

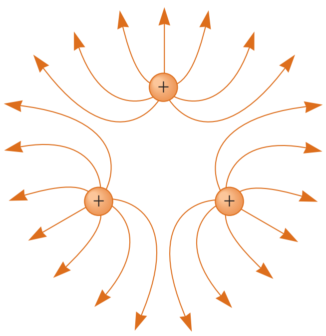
33. $-21.6\hat{\mathbf{i}}$ MN/C

37. (a) 86.4 pC for each
(b) 324 pC, 459 pC, 459 pC, 432 pC
(c) 57.6 pC, 106 pC, 154 pC, 96.0 pC

39.



41. (a)



The field is zero at the center of the triangle.
(b) $1.73k_e q\hat{\mathbf{j}}/a^2$

43. (a) 61.3 Gm/s^2 (b) 19.5 μs (c) 11.7 m (d) 1.20 fJ

45. K/ed in the direction of motion

47. (a) 111 ns (b) 5.68 mm (c) $(450\hat{\mathbf{i}} + 102\hat{\mathbf{j}})$ km/s

49. (a) 36.9°, 53.1° (b) 167 ns, 221 ns

51. (a) 21.8 μm (b) 2.43 cm

53. (a) mv^2/qR (b) $mv^2/2^{1/2}qR$ oriented at 135° to the x axis

55. (a) 10.9 nC (b) 5.44 mN

57. 40.9 N at 263°

59. $Q = 2L\sqrt{\dfrac{k(L - L_i)}{k_e}}$

63. $-707\hat{\mathbf{j}}$ mN

65. (a) $\theta_1 = \theta_2$

67. (a) 0.307 s (b) Yes. Ignoring gravity makes a difference of 2.28%.

69. (a) $\mathbf{F} = 1.90(k_e q^2/s^2)(\hat{\mathbf{i}} + \hat{\mathbf{j}} + \hat{\mathbf{k}})$ (b) $\mathbf{F} = 3.29(k_e q^2/s^2)$ in the direction away from the diagonally opposite vertex

CHAPTER 24

1. (a) 858 N·m^2/C (b) 0 (c) 657 N·m^2/C

3. 4.14 MN/C

5. (a) aA (b) bA (c) 0

7. 1.87 kN·m^2/C

9. (a) -6.89 MN·m^2/C (b) The number of lines entering exceeds the number leaving by 2.91 times or more.

11. $-Q/\epsilon_0$ for S_1; 0 for S_2; $-2Q/\epsilon_0$ for S_3; 0 for S_4

13. $E_0\pi r^2$

15. (a) $+Q/2\epsilon_0$ (b) $-Q/2\epsilon_0$

17. -18.8 kN·m^2/C

19. 0 if $R \le d$; $\dfrac{2\lambda}{\epsilon_0}\sqrt{R^2 - d^2}$ if $R > d$

21. (a) 3.20 MN·m^2/C (b) 19.2 MN·m^2/C (c) The answer to (a) could change, but the answer to (b) would stay the same.

23. 2.33×10^{21} N/C

25. -2.48 μC/m^2

27. 5.94×10^5 m/s

29. $\mathbf{E} = \rho r/2\epsilon_0$ away from the axis

31. (a) 0 (b) 7.19 MN/C away from the center

33. (a) ~1 mN (b) ~100 nC (c) ~10 kN/C
(d) ~10 kN·m^2/C

35. (a) 51.4 kN/C outward (b) 646 N·m^2/C

37. 508 kN/C up

39. (a) 0 (b) 5 400 N/C outward (c) 540 N/C outward

41. $\mathbf{E} = Q/2\epsilon_0 A$ vertically upward in each case if $Q > 0$

43. (a) $+708$ nC/m^2 and -708 nC/m^2 (b) $+177$ nC and -177 nC

45. 2.00 N

47. (a) $-\lambda$, $+3\lambda$ (b) $3\lambda/2\pi\epsilon_0 r$ radially outward

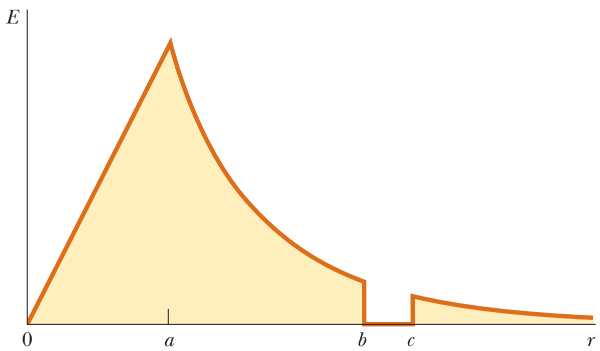
49. (a) 80.0 nC/m^2 on each face (b) $9.04\hat{\mathbf{k}}$ kN/C
(c) $-9.04\hat{\mathbf{k}}$ kN/C

51. $\mathbf{E} = 0$ inside the sphere and within the material of the shell. $\mathbf{E} = k_e Q/r^2$ radially inward between the sphere and the shell. $\mathbf{E} = 2k_e Q/r^2$ radially outward outside the shell. Charge $-Q$ resides on the outer surface of the sphere.

$+Q$ is on the inner surface of the shell. $+2Q$ is on the outer surface of the shell.

53. (b) $Q/2\epsilon_0$ (c) Q/ϵ_0

55. (a) $+2Q$ (b) radially outward (c) $2k_eQ/r^2$ (d) 0 (e) 0 (f) $3Q$ (g) $3k_eQ/r^2$ radially outward (h) $3Qr^3/a^3$ (i) $3k_eQr/a^3$ radially outward (j) $-3Q$ (k) $+2Q$ (l) See below.



57. (a) $\rho r/3\epsilon_0$; $Q/4\pi\epsilon_0 r^2$; 0; $Q/4\pi\epsilon_0 r^2$, all radially outward (b) $-Q/4\pi b^2$ and $+Q/4\pi c^2$

59. $\theta = \tan^{-1}[qQ/(2\pi\epsilon_0 dmv^2)]$

61. For $r < a$, $\mathbf{E} = \lambda/2\pi\epsilon_0 r$ radially outward. For $a < r < b$, $\mathbf{E} = [\lambda + \rho\pi(r^2 - a^2)]/2\pi\epsilon_0 r$ radially outward. For $r > b$, $\mathbf{E} = [\lambda + \rho\pi(b^2 - a^2)]/2\pi\epsilon_0 r$ radially outward.

63. (a) σ/ϵ_0 away from both plates (b) 0 (c) σ/ϵ_0 away from both plates

65. $\sigma/2\epsilon_0$ radially outward

69. $\mathbf{E} = a/2\epsilon_0$ radially outward

73. (b) $\mathbf{g} = GM_E r/R_E{}^3$ radially inward

CHAPTER 25

1. 1.35 MJ

3. (a) 152 km/s (b) 6.49 Mm/s

5. (a) $-600\ \mu$J (b) -50.0 V

7. 38.9 V; the origin

9. $+260$ V

11. (a) $2QE/k$ (b) QE/k (c) $2\pi\sqrt{m/k}$ (d) $2(QE - \mu_k mg)/k$

13. (a) 0.400 m/s (b) the same

15. (a) 1.44×10^{-7} V (b) -7.19×10^{-8} V (c) -1.44×10^{-7} V, $+7.19 \times 10^{-8}$ V

17. (a) 6.00 m (b) $-2.00\ \mu$C

19. -11.0 MV

21. 8.95 J

25. (a) no point at a finite distance from the charges (b) $2k_eq/a$

27. (a) $v_1 = \sqrt{\dfrac{2m_2k_eq_1q_2}{m_1(m_1+m_2)}\left(\dfrac{1}{r_1+r_2} - \dfrac{1}{d}\right)}$

$$v_2 = \sqrt{\frac{2m_1k_eq_1q_2}{m_2(m_1+m_2)}\left(\frac{1}{r_1+r_2} - \frac{1}{d}\right)}$$

(b) faster than calculated in (a)

29. $5k_eq^2/9d$

31. 0.720 m, 1.44 m, 2.88 m. No. The radii of the equipotentials are inversely proportional to the potential.

33. 7.26 Mm/s

35. $\left[\left(1 + \sqrt{\dfrac{1}{8}}\right)\dfrac{k_eq^2}{mL}\right]^{1/2}$

37. (a) 10.0 V, -11.0 V, -32.0 V (b) 7.00 N/C in the $+x$ direction

39. $\mathbf{E} = (-5 + 6xy)\hat{\mathbf{i}} + (3x^2 - 2z^2)\hat{\mathbf{j}} - 4yz\hat{\mathbf{k}}$; 7.07 N/C

41. $E_y = \dfrac{k_eQ}{y\sqrt{\ell^2 + y^2}}$

43. (a) C/m^2 (b) $k_e\alpha[L - d\ln(1 + L/d)]$

45. -1.51 MV

47. $k_e\lambda(\pi + 2\ln 3)$

49. (a) 0, 1.67 MV (b) 5.84 MN/C away, 1.17 MV (c) 11.9 MN/C away, 1.67 MV

51. (a) 450 kV (b) 7.51 μC

53. 253 MeV

55. (a) -27.2 eV (b) -6.80 eV (c) 0

59. $k_eQ^2/2R$

63. $V_2 - V_1 = (-\lambda/2\pi\epsilon_0)\ln(r_2/r_1)$

69. (b) $E_r = (2k_ep\cos\theta)/r^3$; $E_\theta = (k_ep\sin\theta)/r^3$; yes; no (c) $V = k_epy(x^2 + y^2)^{-3/2}$; $\mathbf{E} = 3k_epxy(x^2 + y^2)^{-5/2}\hat{\mathbf{i}} + k_ep(2y^2 - x^2)(x^2 + y^2)^{-5/2}\hat{\mathbf{j}}$

71. $V = \pi k_eC\left[R\sqrt{x^2 + R^2} + x^2\ln\left(\dfrac{x}{R + \sqrt{x^2 + R^2}}\right)\right]$

73. (a) 8 876 V (b) 112 V

CHAPTER 26

1. (a) 48.0 μC (b) 6.00 μC

3. (a) 1.33 μC/m^2 (b) 13.3 pF

5. (a) 5.00 μC on the larger and 2.00 μC on the smaller sphere (b) 89.9 kV

7. (a) 11.1 kV/m toward the negative plate. (b) 98.3 nC/m^2 (c) 3.74 pF (d) 74.7 pC

9. 4.42 μm

11. (a) 2.68 nF (b) 3.02 kV

13. (a) 15.6 pF (b) 256 kV

15. 708 μF

17. (a) 3.53 μF (b) 6.35 V and 2.65 V (c) 31.8 μC on each

19. 6.00 pF and 3.00 pF

21. (a) 5.96 μF (b) 89.5 μC on 20 μF, 63.2 μC on 6 μF, 26.3 μC on 15 μF and on 3 μF

23. 120 μC; 80.0 μC and 40.0 μC

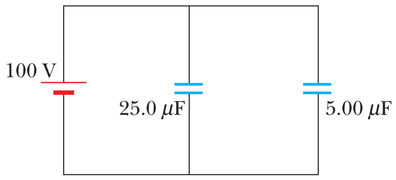
25. 10

27. 6.04 μF

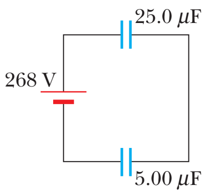
29. 12.9 μF

31. (a) 216 μJ (b) 54.0 μJ

33. (a) Circuit diagram:



Stored energy = 0.150 J
(b) Potential difference = 268 V
Circuit diagram:



35. (a) 1.50 μC (b) 1.83 kV

39. 9.79 kg

43. (a) 81.3 pF (b) 2.40 kV

45. 1.04 m

47. (a) 369 pC (b) 118 pF, 3.12 V (c) -45.5 nJ

49. 22.5 V

51. (b) -8.78×10^6 N/C·m; $-5.53 \times 10^{-2}\,\hat{\mathbf{i}}$ N

55. (a) 11.2 pF (b) 134 pC (c) 16.7 pF (d) 66.9 pC

57. (a) $-2Q/3$ on upper plate, $-Q/3$ on lower plate
(b) $2Qd/3\epsilon_0 A$

59. 0.188 m^2

61. (a) $C = \dfrac{\epsilon_0 A}{d}\left(\dfrac{\kappa_1}{2} + \dfrac{\kappa_2 \kappa_3}{\kappa_2 + \kappa_3}\right)$ (b) 1.76 pF

63. (b) $1/C$ approaches $\dfrac{1}{4\pi\epsilon_0 a} + \dfrac{1}{4\pi\epsilon_0 b}$

65. (a) $Q_0{}^2\, d(\ell - x)/(2\ell^3\epsilon_0)$ (b) $Q_0{}^2\, d/(2\ell^3\epsilon_0)$ to the right
(c) $Q_0{}^2/(2\ell^4\epsilon_0)$ (d) $Q_0{}^2/(2\ell^4\epsilon_0)$

67. 4.29 μF

69. (a) The additional energy comes from work done by the electric field in the wires as it forces more charge onto the already-charged plates. (b) $Q/Q_0 = \kappa$

71. 750 μC on C_1 and 250 μC on C_2

73. 19.0 kV

75. $\frac{4}{3}C$

CHAPTER 27

1. 7.50×10^{15} electrons

3. (a) 0.632 $I_0\tau$ (b) 0.999 95 $I_0\tau$ (c) $I_0\tau$

5. $q\omega/2\pi$

7. 0.265 C

9. (a) 2.55 A/m^2 (b) 5.31×10^{10} m^{-3} (c) 1.20×10^{10} s

11. 0.130 mm/s

13. 500 mA

15. 6.43 A

17. (a) 1.82 m (b) 280 μm

19. (a) $\sim 10^{18}\ \Omega$ (b) $\sim 10^{-7}\ \Omega$ (c) $\sim$100 aA, $\sim$1 GA

21. $R/9$

23. $6.00 \times 10^{-15}/\Omega\cdot$m

25. 0.181 V/m

27. 21.2 nm

29. 1.44×10^3°C

31. (a) 31.5 n$\Omega\cdot$m (b) 6.35 MA/m^2 (c) 49.9 mA
(d) 659 μm/s (e) 0.400 V

33. 0.125

35. 67.6°C

37. 7.50 W

39. 28.9 Ω

41. 36.1%

43. (a) 5.97 V/m (b) 74.6 W (c) 66.1 W

45. 0.833 W

47. $0.232

49. 26.9 cents/d

51. (a) 184 W (b) 461°C

53. ~$1

55. (a) $Q/4C$ (b) $Q/4$ and $3Q/4$ (c) $Q^2/32C$ and $3Q^2/32C$ (d) $3Q^2/8C$

59. Experimental resistivity = 1.47 $\mu\Omega\cdot$m $\pm$ 4%, in agreement with 1.50 $\mu\Omega\cdot$m

61. (a) $(8.00\hat{\mathbf{i}})$ V/m (b) 0.637 Ω (c) 6.28 A
(d) $(200\hat{\mathbf{i}})$ MA/m^2

63. 2 020°C

65. (a) 667 A (b) 50.0 km

67.

Material	$\boldsymbol{\alpha' = \alpha/(1 - 20\alpha)}$
Silver	4.1×10^{-3}/°C
Copper	4.2×10^{-3}/°C
Gold	3.6×10^{-3}/°C
Aluminum	4.2×10^{-3}/°C
Tungsten	4.9×10^{-3}/°C
Iron	5.6×10^{-3}/°C
Platinum	4.25×10^{-3}/°C
Lead	4.2×10^{-3}/°C
Nichrome	0.4×10^{-3}/°C
Carbon	-0.5×10^{-3}/°C
Germanium	-24×10^{-3}/°C
Silicon	-30×10^{-3}/°C

69. No. The fuses should pass no more than 3.87 A.

73. (b) 1.79 PΩ

75. (a) $\dfrac{\epsilon_0 \ell}{2d}(\ell + 2x + \kappa\ell - 2\kappa x)$

(b) $\dfrac{\epsilon_0 \ell v\, \Delta V(\kappa - 1)}{d}$ clockwise

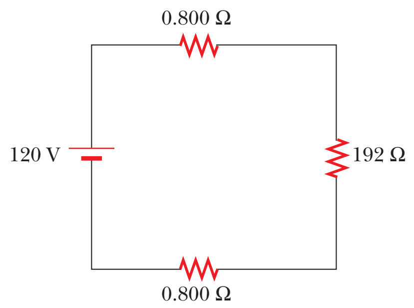
CHAPTER 28

1. (a) 6.73 Ω (b) 1.97 Ω

3. (a) 4.59 Ω (b) 8.16%

5. 12.0 Ω

7. Circuit diagram:



power 73.8 W

9. (a) 227 mA (b) 5.68 V

11. (a) 75.0 V (b) 25.0 W, 6.25 W, and 6.25 W; 37.5 W

13. 1.00 kΩ

15. 14.2 W to 2 Ω, 28.4 W to 4 Ω, 1.33 W to 3 Ω, 4.00 W to 1 Ω

17. (a) $\Delta t_p = 2\Delta t/3$ (b) $\Delta t_s = 3\Delta t$

19. (a) $\Delta V_4 > \Delta V_3 > \Delta V_1 > \Delta V_2$
(b) $\Delta V_1 = \mathcal{E}/3, \Delta V_2 = 2\mathcal{E}/9, \Delta V_3 = 4\mathcal{E}/9, \Delta V_4 = 2\mathcal{E}/3$
(c) $I_1 > I_4 > I_2 = I_3$ (d) $I_1 = I, I_2 = I_3 = I/3, I_4 = 2I/3$
(e) I_4 increases while I_1, I_2, and I_3 decrease
(f) $I_1 = 3I/4, I_2 = I_3 = 0, I_4 = 3I/4$

21. 846 mA down in the 8-Ω resistor; 462 mA down in the middle branch; 1.31 A up in the right-hand branch

23. (a) − 222 J and 1.88 kJ (b) 687 J, 128 J, 25.6 J, 616 J, 205 J (c) 1.66 kJ of chemical energy is transformed into internal energy

25. 50.0 mA from *a* to *e*

27. starter 171 A; battery 0.283 A

29. (a) 909 mA (b) $-1.82\text{ V} = V_b - V_a$

31. (a) 5.00 s (b) 150 μC (c) 4.06 μA

33. $U_0/4$

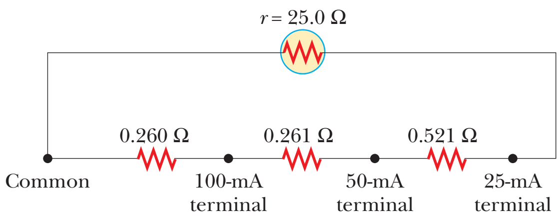
37. (a) 6.00 V (b) 8.29 μs

39. (a) 12.0 s (b) $I(t) = (3.00\ \mu\text{A})e^{-t/12.0\text{ s}}$; $q(t) = (36.0\ \mu\text{C})\ (1 - e^{-t/12.0\text{ s}})$

41. 0.302 Ω

43. 16.6 kΩ

45.



47. 145 Ω, 0.756 mA

49. (a) 12.5 A, 6.25 A, 8.33 A (b) No; together they would require 27.1 A.

51. (a) $\sim 10^{-14}$ A (b) $V_h/2 + (\sim 10^{-10}\text{ V})$ and $V_h/2 - (\sim 10^{-10}\text{ V})$, where V_h is the potential of the live wire, $\sim 10^2$ V

53. (a) either 3.84 Ω or 0.375 Ω (b) impossible

55. (a) $\mathcal{E}^2/3R$ (b) $3\mathcal{E}^2/R$ (c) in the parallel connection

57. (a) $R \to \infty$ (b) $R \to 0$ (c) $R = r$

59. 6.00 Ω; 3.00 Ω

61. (a) 4.40 Ω (b) 32.0 W, 9.60 W, 70.4 W (c) 48.0 W

63. (a) $R \leq 1\,050\ \Omega$ (b) $R \geq 10.0\ \Omega$

65. (a) 9.93 μC (b) 33.7 nA (c) 334 nW (d) 337 nW

67. (a) 40.0 W (b) 80.0 V, 40.0 V, 40.0 V

69. (a) 0.991 (b) 0.648 (c) Insulation should be added to the ceiling.

71. (a) 0 in 3 kΩ and 333 μA in 12 kΩ and 15 kΩ (b) 50.0 μC (c) $(278\ \mu\text{A})\ e^{-t/180\text{ ms}}$ (d) 290 ms

73. (a) $\ln(\mathcal{E}/\Delta V) = (0.011\,8)t + 0.088\,2$ (b) 84.7 s, 8.47 μF

75. $q_1 = (240\ \mu\text{C})(1 - e^{-1\,000t/6})$; $q_2 = (360\ \mu\text{C})(1 - e^{-1\,000t/6})$

CHAPTER 29

1. (a) up (b) out of the plane of the paper (c) no deflection (d) into the plane of the paper

3. negative *z* direction

5. $(-20.9\hat{\mathbf{j}})$ mT

7. 48.9° or 131°

9. 2.34 aN

11. 0.245 T east

13. (a) 4.73 N (b) 5.46 N (c) 4.73 N

15. 1.07 m/s

17. $2\pi rIB \sin\theta$ up

19. 2.98 μN west

21. 18.4 mA · m²

23. 9.98 N · m clockwise as seen looking down from above

27. (a) 118 μN · m (b) $-118\ \mu\text{J} \leq U \leq 118\ \mu\text{J}$

29. (a) 49.6 aN south (b) 1.29 km

31. 115 keV

33. $r_\alpha = r_d = \sqrt{2}r_p$

35. 4.98×10^8 rad/s

37. 7.88 pT

39. $m = 2.99$ u, either ${}^3_1\text{H}^+$ or ${}^3_2\text{He}^+$

41. (a) 8.28 cm (b) 8.23 cm; ratio is independent of both ΔV and B

43. (a) 4.31×10^7 rad/s (b) 51.7 Mm/s

45. (a) 7.66×10^7 rad/s (b) 26.8 Mm/s (c) 3.76 MeV (d) 3.13×10^3 rev (e) 257 μs

47. 70.1 mT

49. $1.28 \times 10^{29}\ \text{m}^{-3}$, 1.52

51. 43.3 μT

53. (a) The electric current experiences a magnetic force.

55. (a) -8.00×10^{-21} kg · m/s (b) 8.90°

57. (a) $(3.52\hat{\mathbf{i}} - 1.60\hat{\mathbf{j}})$ aN (b) 24.4°

59. $(2\pi/d)(2m_e\Delta V/e)^{1/2}$

61. 0.588 T

63. 0.713 A counterclockwise as seen from above

65. 438 kHz

67. 3.70×10^{-24} N·m

69. (a) 0.501 m (b) 45.0°

71. (a) 1.33 m/s (b) Positive ions moving toward you in magnetic field to the right feel upward magnetic force, and migrate upward in the blood vessel. Negative ions moving toward you feel downward magnetic force and accumulate at the bottom of this section of vessel. Thus both species can participate in the generation of the emf.

CHAPTER 30

1. 12.5 T

3. (a) 28.3 μT into the paper (b) 24.7 μT into the paper

5. $\dfrac{\mu_0 I}{4\pi x}$ into the paper

7. 26.2 μT into the paper

9. (a) $2I_1$ out of the page (b) $6I_1$ into the page

11. (a) along the line ($y = -0.420$ m, $z = 0$) (b) $(-34.7\hat{\mathbf{j}})$ mN (c) $(17.3\hat{\mathbf{j}})$ kN/C

13. (a) $4.5\dfrac{\mu_0 I}{\pi L}$ (b) stronger

15. $(-13.0\hat{\mathbf{j}})$ μT

17. $(-27.0\hat{\mathbf{i}})$ μN

19. (a) 12.0 cm to the left of wire 1 (b) 2.40 A, downward

21. 20.0 μT toward the bottom of the page

23. 200 μT toward the top of the page; 133 μT toward the bottom of the page

25. (a) 6.34 mN/m inward (b) greater

27. (a) 0 (b) $\dfrac{\mu_0 I}{2\pi R}$ tangent to the wall in a counterclockwise sense (c) $\dfrac{\mu_0 I^2}{(2\pi R)^2}$ inward

29. (a) $\frac{1}{3}\mu_0 b r_1^{\,2}$ (b) $\dfrac{\mu_0 b R^3}{3r_2}$

31. 31.8 mA

33. 226 μN away from the center of the loop, 0

35. (a) 3.13 mWb (b) 0

37. (a) 11.3 GV·m/s (b) 0.100 A

39. (a) 9.27×10^{-24} A·m^2 (b) down

41. 0.191 T

43. 2.62 MA/m

45. (b) 6.45×10^4 K·A/T·m

47. (a) 8.63×10^{45} electrons (b) 4.01×10^{20} kg

49. $\dfrac{\mu_0 I}{2\pi w}\ln\left(1 + \dfrac{w}{b}\right)\hat{\mathbf{k}}$

51. 12 layers, 120 m

53. 143 pT away along the axis

59. (a) 2.46 N up (b) 107 m/s^2 up

61. (a) 274 μT (b) $(-274\hat{\mathbf{j}})$ μT (c) $(1.15\hat{\mathbf{i}})$ mN (d) $(0.384\hat{\mathbf{i}})$ m/s^2 (e) acceleration is constant (f) $(0.999\hat{\mathbf{i}})$ m/s

63. 81.7 A

65. $\dfrac{\mu_0 I_1 I_2 L}{\pi R}$ to the right

69. $\dfrac{\mu_0 I}{4\pi}(1 - e^{-2\pi})$ out of the plane of the paper

71. $\frac{1}{3}\rho\mu_0\omega R^2$

73. (a) $\dfrac{\mu_0 I(2r^2 - a^2)}{\pi r(4r^2 - a^2)}$ to the left (b) $\dfrac{\mu_0 I(2r^2 + a^2)}{\pi r(4r^2 + a^2)}$ toward the top of the page

CHAPTER 31

1. 500 mV

3. 9.82 mV

5. 160 A

7. (a) 1.60 A counterclockwise (b) 20.1 μT (c) up

9. (a) $(\mu_0 IL/2\pi)\ln(1 + w/h)$ (b) -4.80 μV; current is counterclockwise

11. 283 μA upward

13. (68.2 mV) $e^{-1.6t}$, tending to produce counterclockwise current

15. 272 m

17. (0.422 V) cos ωt

19. (a) eastward (b) 458 μV

21. (a) 3.00 N to the right (b) 6.00 W

23. 360 T

25. (a) 233 Hz (b) 1.98 mV

27. 2.83 mV

29. (a) $F = N^2B^2w^2v/R$ to the left (b) 0 (c) $F = N^2B^2w^2v/R$ to the left

31. 145 μA

33. 1.80 mN/C upward and to the left, perpendicular to r_1

35. (a) 7.54 kV (b) The plane of the coil is parallel to **B**.

37. (28.6 mV) $\sin(4\pi t)$

39. (a) 110 V (b) 8.53 W (c) 1.22 kW

41. (a) (8.00 mWb) $\cos(377t)$ (b) (3.02 V) $\sin(377t)$ (c) (3.02 A) $\sin(377t)$ (d) (9.10 W) $\sin^2(377t)$ (e) (24.1 mN·m) $\sin^2(377t)$

43. (b) Larger R makes current smaller, so the loop must travel faster to maintain equality of magnetic force and weight. (c) The magnetic force is proportional to the product of field and current, while the current is itself proportional to field. If B becomes two times smaller, the speed must become four times larger to compensate.

45. $(-2.87\hat{\mathbf{j}} + 5.75\hat{\mathbf{k}})$ Gm/s^2

47. (a) Doubling N doubles the amplitude. (b) Doubling ω doubles the amplitude and halves the period. (c) Doubling ω and halving N leaves the amplitude the same and cuts the period in half.

49. 62.3 mA down through 6.00 Ω, 860 mA down through 5.00 Ω, 923 mA up through 3.00 Ω

51. $\sim 10^{-4}$ V, by reversing a 20-turn coil of diameter 3 cm in 0.1 s in a field of 10^{-3} T

53. (a) 254 km/s (b) 215 V

55. 1.20 μC

57. (a) 0.900 A (b) 0.108 N (c) b (d) no

59. (a) $a\pi r^2$ (b) $-b\pi r^2$ (c) $-b\pi r^2/R$ (d) $b^2\pi^2 r^4/R$

61. (a) 36.0 V (b) 600 mWb/s (c) 35.9 V (d) 4.32 N·m

65. 6.00 A

67. (a) (1.19 V) cos(120πt) (b) 88.5 mW

71. (−87.1 mV) cos(200$\pi t + \phi$)

CHAPTER 32

1. 19.5 mV

3. 100 V

5. (18.8 V) cos(377t)

7. −0.421 A/s

9. (a) 188 μT (b) 33.3 nT·m^2 (c) 0.375 mH (d) B and Φ_B are proportional to current; L is independent of current

11. 0.750 m

13. $\mathcal{E}_0/k^2L$

15. (a) 0.139 s (b) 0.461 s

17. (a) 2.00 ms (b) 0.176 A (c) 1.50 A (d) 3.22 ms

19. (a) 0.800 (b) 0

21. (a) 6.67 A/s (b) 0.332 A/s

23. (500 mA)$(1 - e^{-10t/s})$, 1.50 A − (0.25 A) $e^{-10t/s}$

25. 0 for $t < 0$; (10 A)$(1 - e^{-10\,000t})$ for $0 < t < 200$ μs; (63.9 A) $e^{-10\,000t}$ for $t > 200$ μs

27. (a) 5.66 ms (b) 1.22 A (c) 58.1 ms

29. 0.064 8 J

31. 2.44 μJ

33. 44.2 nJ/m^3 for the **E**-field and 995 μJ/m^3 for the **B**-field

35. (a) 0.500 J (b) 17.0 W (c) 11.0 W

37. 2.27 mT

39. 1.73 mH

41. 80.0 mH

43. (a) 18.0 mH (b) 34.3 mH (c) −9.00 mV

45. $(L_1L_2 - M^2)/(L_1 + L_2 - 2M)$

47. 20.0 V

49. 608 pF

51. (a) 135 Hz (b) 119 μC (c) −114 mA

53. (a) 6.03 J (b) 0.529 J (c) 6.56 J

55. (a) 4.47 krad/s (b) 4.36 krad/s (c) 2.53%

57. L = 199 mH; C = 127 nF

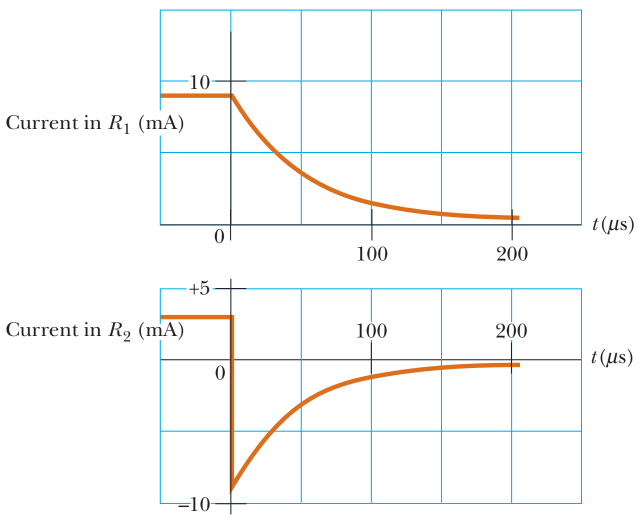
59. (b) $\mu_0 J_s^2/2$ away from the other sheet (c) $\mu_0 J_s$ and zero (d) $\mu_0 J_s^2/2$

61. (a) −20.0 mV (b) −(10.0 MV/s^2)t^2 (c) 63.2 μs

63. $(Q/2N)(3L/C)^{1/2}$

65. (a) $L \approx (\pi/2)N^2\mu_0 R$ (b) ~100 nH (c) ~1 ns

71. (a) 72.0 V; b
(b)



(b)

(c) 75.2 μs

73. 300 Ω

75. (a) It creates a magnetic field. (b) The long narrow rectangular area between the conductors encloses all of the magnetic flux.

77. (a) 62.5 GJ (b) 2 000 N

79. (a) 2.93 mT up (b) 3.42 Pa (c) clockwise as seen from above (d) up (e) 1.30 mN

CHAPTER 33

1. $\Delta v(t)$ = (283 V) sin(628t)

3. 2.95 A, 70.7 V

5. 14.6 Hz

7. 3.38 W

9. (a) 42.4 mH (b) 942 rad/s

11. 5.60 A

13. 0.450 Wb

15. (a) 141 mA (b) 235 mA

17. 100 mA

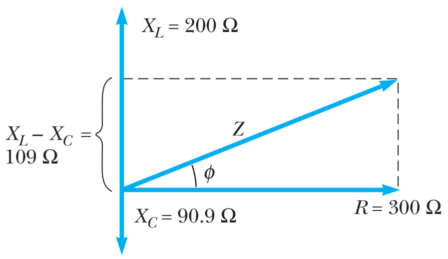
19. (a) 194 V (b) current leads by 49.9°

21. (a) 78.5 Ω (b) 1.59 kΩ (c) 1.52 kΩ (d) 138 mA (e) −84.3°

23. (a) 17.4° (b) voltage leads the current

25. 1.88 V

27.



29. (a) either 123 nF or 124 nF (b) 51.5 kV

31. 8.00 W

33. (a) 16.0 Ω (b) $-12.0\ \Omega$

35. $\sqrt{\dfrac{800\,\rho\mathcal{P}d}{\pi(\Delta V)^2}}$

37. 1.82 pF

39. (a) 633 fF (b) 8.46 mm (c) 25.1 Ω

41. 242 mJ

43. 0.591 and 0.987; the circuit in Problem 23

45. 687 V

47. 87.5 Ω

49. (a) 29.0 kW (b) 5.80×10^{-3} (c) If the generator were limited to 4 500 V, no more than 17.5 kW could be delivered to the load, never 5 000 kW.

51. (b) 0; 1 (c) $f_h = (10.88RC)^{-1}$

53. (a) 613 μF (b) 0.756

55. (a) 580 μH and 54.6 μF (b) 1 (c) 894 Hz (d) ΔV_{out} leads ΔV_{in} by 60.0° at 200 Hz. ΔV_{out} and ΔV_{in} are in phase at 894 Hz. ΔV_{out} lags ΔV_{in} by 60.0° at 4 000 Hz. (e) 1.56 W, 6.25 W, 1.56 W (f) 0.408

57. 56.7 W

59. 99.6 mH

61. (a) 225 mA (b) 450 mA

63. (a) 1.25 A (b) Current lags voltage by 46.7°.

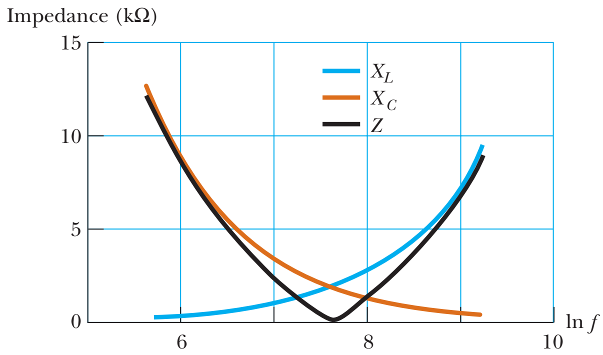
65. (a) 200 mA; voltage leads by 36.8° (b) 40.0 V; $\phi = 0°$ (c) 20.0 V; $\phi = -90.0°$ (d) 50.0 V; $\phi = +90.0°$

67. (b) 31.6

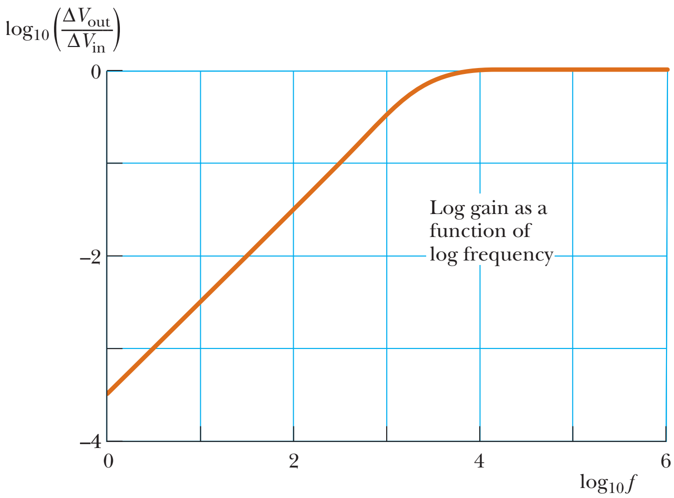
71.

f (Hz)	X_L (Ω)	X_C (Ω)	Z (Ω)
300	283	12 600	12 300
600	565	6 280	5 720
800	754	4 710	3 960
1 000	942	3 770	2 830
1 500	1 410	2 510	1 100
2 000	1 880	1 880	40.0
3 000	2 830	1 260	1 570
4 000	3 770	942	2 830
6 000	5 650	628	5 020
10 000	9 420	377	9 040

(b)



73. (a) 1.84 kHz
(b)



CHAPTER 34

1. (a) $(3.15\hat{\mathbf{j}})$ kN/C (b) $(525\hat{\mathbf{k}})$ nT (c) $(-483\hat{\mathbf{j}})$ aN

3. 2.25×10^8 m/s

5. (a) 6.00 MHz (b) $(-73.3\hat{\mathbf{k}})$ nT (c) $\mathbf{B} = [(-73.3\hat{\mathbf{k}})\text{ nT}][\cos(0.126x - 3.77 \times 10^7 t)]$

7. (a) 0.333 μT (b) 0.628 μm (c) 477 THz

9. 75.0 MHz

11. 3.33 μJ/m^3

13. 307 μW/m^2

15. 3.33×10^3 m^2

17. (a) 332 kW/m^2 radially inward (b) 1.88 kV/m and 222 μT

19. (a) $\mathbf{E}\cdot\mathbf{B} = 0$ (b) $(11.5\hat{\mathbf{i}} - 28.6\hat{\mathbf{j}})$ W/m^2

21. 29.5 nT

23. (a) 2.33 mT (b) 650 MW/m^2 (c) 510 W

25. (a) 540 V/m (b) 2.58 μJ/m^3 (c) 773 W/m^2 (d) 77.3% of the intensity in Example 34.5

27. 83.3 nPa

29. (a) 1.90 kN/C (b) 50.0 pJ (c) 1.67×10^{-19} kg · m/s

31. (a) 11.3 kJ (b) 1.13×10^{-4} kg · m/s

33. (a) 134 m (b) 46.9 m

35. (a) away along the perpendicular bisector of the line segment joining the antennas (b) along the extensions of the line segment joining the antennas

37. (a) $\mathbf{E} = \frac{1}{2}\mu_0 c J_{\max}[\cos(kx - \omega t)]\hat{\mathbf{j}}$

(b) $\mathbf{S} = \frac{1}{4}\mu_0 c J_{\max}^2[\cos^2(kx - \omega t)]\hat{\mathbf{i}}$

(c) $I = \dfrac{\mu_0 c J_{\max}^2}{8}$ (d) 3.48 A/m

39. 545 THz

41. (a) 6.00 pm (b) 7.50 cm

43. 60.0 km

45. 1.00 Mm = 621 mi; not very practical

47. (a) 3.77×10^{26} W (b) 1.01 kV/m and 3.35 μT

49. (a) $2\pi^2 r^2 f B_{\max} \cos\theta$, where θ is the angle between the magnetic field and the normal to the loop (b) The loop should be in the vertical plane containing the line of sight to the transmitter.

51. (a) 6.67×10^{-16} T (b) 5.31×10^{-17} W/m^2 (c) 1.67×10^{-14} W (d) 5.56×10^{-23} N

53. 95.1 mV/m

55. (a) $B_{\max}$ = 583 nT, k = 419 rad/m, ω = 126 Grad/s; **B** vibrates in xz plane (b) $\mathbf{S}_{av} = (40.6\hat{\mathbf{i}})$ W/m^2 (c) 271 nPa (d) $(406\hat{\mathbf{i}})$ nm/s^2

57. (a) 22.6 h (b) 30.6 s

59. (a) 8.32×10^7 W/m^2 (b) 1.05 kW

61. (a) 1.50 cm (b) 25.0 μJ (c) 7.37 mJ/m^3 (d) 40.8 kV/m, 136 μT (e) 83.3 μN

63. 637 nPa

65. $\epsilon_0 E^2 A/2m$

67. (a) 16.1 cm (b) 0.163 m^2 (c) 470 W/m^2 (d) 76.8 W (e) 595 N/C (f) 1.98 μT (g) The cats are nonmagnetic and carry no macroscopic charge or current. Oscillating charges within molecules make them emit infrared radiation. (h) 119 W

69. 4.77 Gm

CHAPTER 35

1. 299.5 Mm/s

3. 114 rad/s

5. (c) 0.055 7 °

9. 23.3°

11. 15.4°; 2.56 m

13. 19.5° above the horizon

15. (a) 1.52 (b) 417 nm (c) 474 THz (d) 198 Mm/s

17. 158 Mm/s

19. 30.0° and 19.5° at entry; 19.5° and 30.0° at exit

21. 3.88 mm

23. 30.4° and 22.3°

25. ~10^{-11} s; between 10^3 and 10^4 wavelengths

29. 0.171°

31. 86.8°

33. 27.9°

35. 4.61°

37. (a) 33.4° (b) 53.4° (c) There is no critical angle.

39. 1.000 08

41. 1.08 cm < d < 1.17 cm

43. Skylight incident from above travels down the plastic. If the index of refraction of the plastic is greater than 1.41, the rays close in direction to the vertical are totally reflected from the side walls of the slab and from both facets at the bottom of the plastic, where it is not immersed in gasoline. This light returns up inside the plastic and makes it look bright. Where the plastic is immersed in gasoline, total internal reflection is frustrated and the downward-propagating light passes from the plastic out into the gasoline. Little light is reflected up, and the gauge looks dark.

45. Scattered light leaving the photograph in all forward horizontal directions in air is gathered by refraction into a fan in the water of half-angle 48.6°. At larger angles you see things on the other side of the globe, reflected by total internal reflection at the back surface of the cylinder.

47. 77.5°

49. 2.27 m

51. (a) 0.172 mm/s (b) 0.345 mm/s (c) northward at 50.0° below the horizontal (d) northward at 50.0° below the horizontal

53. 62.2%

55. 82 reflections

57. (b) 68.5%

59. 27.5°

61. (a) It always happens. (b) 30.3° (c) It cannot happen.

63. 2.37 cm

67. 1.93

69. (a) $n = [1 + (4t/d)^2]^{1/2}$ (b) 2.10 cm (c) violet

71. (a) 1.20 (b) 3.40 ns

CHAPTER 36

1. ~10^{-9} s younger

3. 35.0 in.

5. 10.0 ft, 30.0 ft, 40.0 ft

7. (a) 13.3 cm, − 0.333, real and inverted (b) 20.0 cm, − 1.00, real and inverted (c) no image is formed

9. (a) − 12.0 cm; 0.400 (b) − 15.0 cm; 0.250 (c) upright

11. (a) q = 45.0 cm; M = − 0.500 (b) q = − 60.0 cm; M = 3.00 (c) Image (a) is real, inverted, and diminished. Image (b) is virtual, upright, and enlarged. The ray diagrams are like Figures 36.15a and 36.15b, respectively.