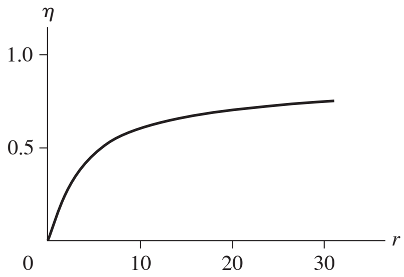
65. b. 1.1×10^{3}°C
67. b. $Q_C = 80$ J
69. 5.3×10^4 J
71. a. 1.19 b. 227 W
73. c.



Chapter 22

Stop to Think Questions

1. **b.** Charged objects are attracted to neutral objects, so an attractive force is inconclusive. Repulsion is the only sure test.
2. $\boldsymbol{q_E(+3e) > q_A(+1e) > q_D(0) > q_B(-1e) > q_C(-2e)}$.
3. **a.** The negative plastic rod will polarize the electroscope by pushing electrons down toward the leaves. This will partially neutralize the positive charge the leaves had acquired from the glass rod.
4. **b.** The two forces are an action/reaction pair, opposite in direction but *equal* in magnitude.
5. **c.** There's an electric field at *all* points, whether an $\vec{E}$ vector is shown or not. The electric field at the dot is to the right. But an electron is a negative charge, so the force of the electric field on the electron is to the left.
6. $\boldsymbol{E_2 > E_1 > E_4 > E_3}$.

Exercises and Problems

1. 4.0×10^{-9} C or 4.0 nC
3. a. Electrons transferred to the sphere b. 5×10^{10}
5. -1.1×10^7 C
7. 5.1×10^{13}
13. a. 9×10^{-3} N b. 0.45 m/s^2
15. a. 230.4 N b. 1.86×10^{-36} c. $\dfrac{F_E}{F_G} = 1.23 \times 10^{-36}$
17. 0 N
19. 1.8×10^{-4} N $(-\hat{\imath})$, downward
21. a. $(1.3 \times 10^{14}$ m/s^2, toward bead$)$
 b. $(2.4 \times 10^{17}$ m/s^2, away from bead$)$
23. $\frac{4}{9}q$, negative, $x = \dfrac{L}{3}$
25. -440 nC
27. a. $(1.4 \times 10^{-3}$ N/C, away from proton$)$
 b. $(1.4 \times 10^{-3}$ N/C, toward electron$)$
29. a. $(6.4\hat{\imath} + 1.6\hat{\jmath}) \times 10^{-17}$ N b. $(6.4\hat{\imath} + 1.6\hat{\jmath}) \times 10^{-17}$ N
 c. 4.0×10^{10} m/s^2 d. 7.3×10^{13} m/s^2
31. $(-2.5$ cm, -2.5 cm$)$
33. $4.3 \times 10^4\hat{\imath}$ N/C, $(-1.5 \times 10^4\,\hat{\imath} + 1.5 \times 10^4\,\hat{\jmath})$ N/C, $(-1.5 \times 10^4\,\hat{\imath} - 1.5 \times 10^4\,\hat{\jmath})$ N/C
35. $-1.0 \times 10^5\hat{\jmath}$ N/C, $(-2.9 \times 10^4\hat{\imath} - 2.2 \times 10^4\hat{\imath})$ N/C, $-5.6 \times 10^4\hat{\imath}$ N/C
37. 82 nC
39. 0.92 N/m
41. 8.4×10^{21}
43. 4.6×10^{-3} N, 81° ccw from $-x$-axis
45. $1.0 \times 10^{-3}\,\hat{\imath}$ N
47. $1.1 \times 10^{-5}\,\hat{\imath}$ N
49. a. -2.4 cm b. Yes
51. 0.68 nC
53. $\left(2 - \sqrt{2}\right)\dfrac{KQq}{L^2}$
55. 6.6×10^{15} rev/s
57. 8.1 nC
59. 7.2×10^{-4} N/s
61. $\tau = Eqs = pE$
63. 4.4°
65. a. $(-1.0$ cm, 2.0 cm$)$ b. (3.0 cm, 3.0 cm) c. $(4.0$ cm, -2.0 cm$)$
67. 0.18 μC
69. 19 mm
71. 0.32 N
73. b. ± 22 nC
75. b. 5.1 nC
77. 7.3 m/s
79. 1.7×10^{-4} N

Chapter 23

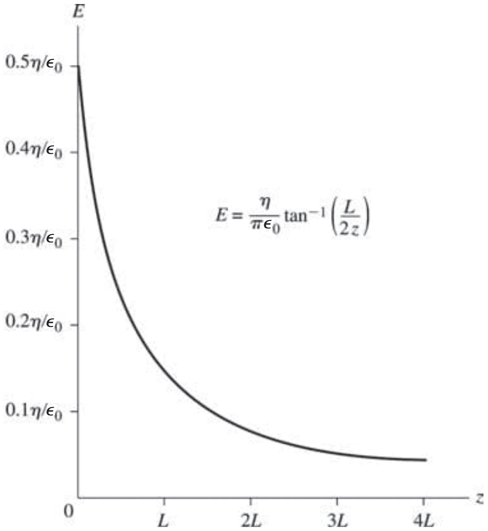
Stop to Think Questions

1. **c.** From symmetry, the fields of the positive charges cancel. The net field is that of the negative charge, which is toward the charge.
2. $\boldsymbol{\eta_C = \eta_B = \eta_A}$. All pieces of a uniformly charged surface have the same surface charge density.
3. **b, e, and h.** b and e both increase the linear charge density λ.
4. $\boldsymbol{E_1 = E_2 = E_3 = E_4 = E_5}$. The field strength of a charged plane is the same at all distances from the plane. An electric field diagram shows the electric field vectors at only a few points; the field exists at all points.
5. $\boldsymbol{E_1 = E_2 = E_3 = E_4 = E_5}$. The electric field strength between the plates of a capacitor is the same at all points.
6. **c.** Parabolic trajectories require *constant* acceleration and thus a *uniform* electric field. The proton has an initial velocity component to the left, but it's being pushed back to the right.

Exercises and Problems

1. 7.6×10^3 N/C vertical, 0° from vertical
3. 5.4×10^2 N/C, 90° cw from horizontal
5. a. 1.1×10^{-11} Cm b. 5.6 nC c. 2.2 nC
7. 2.9×10^{-3} N
9. 2.0×10^4 N/C
11. 2.3×10^5 N/C, 1.67×10^5 N/C, 2.3×10^5 N/C
13. 44 nC
15. a. $(2.6 \times 10^4$ N/C, left$)$ b. $(2.6 \times 10^{-5}$ N, right$)$
17. 54 nC
19. $-\dfrac{\eta_0}{\epsilon_0}\hat{\imath},\ -(2\eta_0/\epsilon_0)\hat{\imath},\ +(\eta_0/\epsilon_0)\hat{\imath}$
21. 0.16 pC
23. 1.2 cm
25. 6.7 nC
27. a. 3.6×10^6 N/C b. 8.3×10^5 m/s
29. 0.18 m
31. a. 0.040 s b. 1.6×10^4 N/C
33. a. $\dfrac{1}{4\pi\epsilon_0}\dfrac{qQs}{r^3}$ b. $\dfrac{1}{4\pi\epsilon_0}\dfrac{qQs}{r^2}$
35. 1.8×10^{-21} N m
37. a. 1.2×10^4 N/C $\hat{\imath} + 2.4 \times 10^5$ N/C $\hat{\jmath}$ b. 2.5×10^5 N/C, 87° ccw from $+x$-axis
39. $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{L^2}\left(\sqrt{2} - 1\right)(\hat{\imath} + \hat{\jmath})$
41. $\dfrac{1}{4\pi\epsilon_0}\dfrac{16\lambda y}{4y^2 + d^2}$
45. $E_z = \dfrac{zQ}{4\pi\epsilon_0(z^2 + R^2)^{3/2}}$
47. a. $\pm\dfrac{R}{\sqrt{2}}$ b. $\dfrac{2}{3\sqrt{3}}\dfrac{Q}{4\pi\epsilon_0 R^2}$
49. a. $(E_i)_x = \dfrac{1}{4\pi\epsilon_0}\left(\dfrac{2Q}{\pi R^2}\right)\Delta\theta\cos\theta_i$, $(E_i)_y = \dfrac{1}{4\pi\epsilon_0}\left(\dfrac{2Q}{\pi R^2}\right)\Delta\theta\sin\theta_i$
 b. $E_x = \dfrac{1}{4\pi\epsilon_0}\left(\dfrac{2Q}{\pi R^2}\right)\displaystyle\int_0^{\pi/2}\cos\theta\,d\theta$, $E_y = \dfrac{1}{4\pi\epsilon_0}\left(\dfrac{2Q}{\pi R^2}\right)\displaystyle\int_0^{\pi/2}\sin\theta\,d\theta$
 c. $\vec{E}_{net} = \dfrac{1}{4\pi\epsilon_0}\dfrac{2Q}{\pi R^2}(\hat{\imath} + \hat{\jmath})$

51. 3.8×10^6 m/s
53. 1.19×10^7 m/s
55. a. Negative b. 3.8×10^4 N/C c. 2.5 mm
57. 4.2×10^{-4} N
59. 6.56×10^{15} Hz
61. a. $\dfrac{C^2 s^2}{kg}$ b. $\vec{F}_{\text{ion on dipole}} = \left(\left(\dfrac{1}{4\pi\epsilon_0}\right)^2 \dfrac{2q^2\alpha}{r^5}\text{, toward ion}\right)$
63. 0.74 GHz
65. b. 14 cm
67. b. 7.4×10^{-11} C
69. c.



71. $\dfrac{\eta}{2\epsilon_0}\left[1 - \dfrac{R}{\sqrt{L^2 + R^2}}\right]$
73. -2.3 nC/m

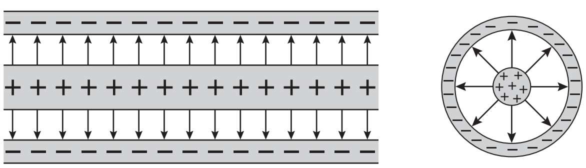
Chapter 24

Stop to Think Questions

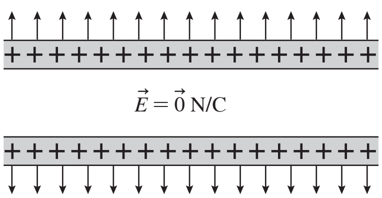
1. **a and d.** Symmetry requires the electric field to be unchanged if front and back are reversed, if left and right are reversed, or if the field is rotated about the wire's axis. Fields a and d both have the proper symmetry. Other factors would now need to be considered to determine the correct field.
2. **e.** The net flux is into the box.
3. **c.** There's no flux through the four sides. The flux is positive 1 N m^2/C through both the top and bottom because $\vec{E}$ and $\vec{A}$ both point outward.
4. $\Phi_B = \Phi_E > \Phi_A = \Phi_C = \Phi_D$**.** The flux through a closed surface depends only on the amount of enclosed charge, not the size or shape of the surface.
5. **d.** A cube doesn't have enough symmetry to use Gauss's law. The electric field of a charged cube is *not* constant over the face of a cubic Gaussian surface, so we can't evaluate the surface integral for the flux.

Exercises and Problems

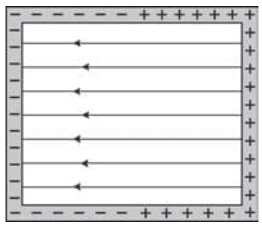
1.



3.

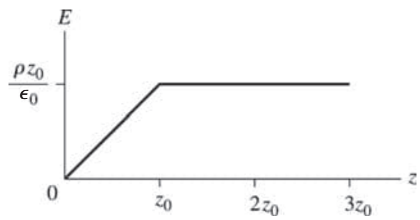


5. Negative
7. Inward, $|E| > 10$ N/C
9. -2.0 N m^2/C
11. a. 1.0 N/C b. 1.0 N/C
13. -1.3 N m^2/C
15. 5×10^{-4} N m^2/C
19. $+2q, +q, -3q$
21. 0.11 kN m^2/C
23. 21 nC
25. a. 2.5×10^4 N/C, downward b. 0 N/C c. 2.5×10^4 N/C, upward
27. 0.90 kN/C, 0, 0
29. $\Phi_1 = -3.2$ kN m^2/C, $\Phi_2 = \Phi_3 = \Phi_5 = 0.0$ N m^2/C, $\Phi_4 = 3.2$ kN m^2/C
31. 9.4 $\times 10^5$ Nm 2/C
33. a. -100 nC b. ± 50 nC
35. a. $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r^2}\hat{r}$, 0.0 N/C, $\dfrac{1}{4\pi\epsilon_0}\left(\dfrac{3Q}{r^2}\right)\hat{r}$ b. $-Q, +3Q$
37. a. -1×10^{-8} C b. $+1 \times 10^{-8}$ C c. 4.8×10^{-8} C
39.



41. 700 nC/m^2
43. 0 N/C, $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r^2}\hat{r}$
45. a. $\vec{E}(|z| \le z_0) = \dfrac{\rho z}{\epsilon_0}\hat{k}$ b. $\vec{E}(z \ge z_0) = \dfrac{\rho z_0}{\epsilon_0}\hat{k}$

c.



47. a. $3Q/(2\epsilon_0 A)$, 0, $Q/(2\epsilon_0 A)$, 0, $3Q/(2\epsilon_0 A)$
b. $+\dfrac{3Q}{2A}$, $-\dfrac{1Q}{2A}$, $+Q/(2A)$, $+3Q/(2A)$
49. a. $\left(\dfrac{\lambda}{2\pi\epsilon_0}\dfrac{1}{r}\right)\hat{r}$ b. $\dfrac{1}{2\pi\epsilon_0}\dfrac{\lambda r}{R^2}\hat{r}$
51. 6.2×10^{-11} C^2/N m^2
53. $\dfrac{\rho}{6\epsilon_0}r$
55. b. 0, because this is a neutral atom c. 4.6×10^{13} N/C
57. a. $\dfrac{\lambda L^2 dy}{4\pi\epsilon_0[y^2 + (L/2)^2]}$ b. $\lambda L/(4\epsilon_0)Q_{\text{in}}/\epsilon_0$
59. a. $C = \dfrac{Q}{4\pi R}$ b. $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{Rr}\hat{r}$ c. Yes
61. a. $\dfrac{Q}{4\pi\epsilon_0 R^2}$ b. $\dfrac{3Qr^3}{2\pi R^6}$

Chapter 25

Stop to Think Questions

1. **Zero.** The motion is always perpendicular to the electric force.
2. $U_B = U_D > U_A = U_C$**.** The potential energy depends inversely on *r*. The effects of doubling the charge and doubling the distance cancel each other.
3. The proton gains speed by losing potential energy. It loses potential energy by moving in the direction of decreasing electric potential.
4. $V_1 = V_2 > V_3 > V_4 = V_5$**.**
5. $\Delta V_{13} = \Delta V_{23} > \Delta V_{12}$**.** The potential depends only on the distance from the charge, not the direction. $\Delta V_{12} = 0$ because these points are at the same distance.

Exercises and Problems

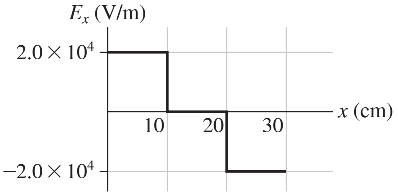
1. 9.8×10^4 m/s
3. 1.7×10^6 m/s
5. 0 J
7 1.5×10^{-3} N
9. 1.4×10^9 N/C
11. 2.1×10^6 m/s
13. 33 V
15. a. Higher potential b. 0.21 kV
17. 10 nC
19. 1.5×10^5 m/s
23. a. 200 V b. 400 V
25. 1.4×10^3 V
27. a. 1800 V, 1800 V, 900 V b. 0 V, 900 V
29. a. 27 V b. -4.3×10^{-18} J
31. 8.7×10^2 V
33. 1.1×10^6 m/s
35. 0 V
37. −10 nC, 40 nC
39. 3.0 cm, 6.0 cm
41. $y = \pm 12$ cm
43. 1.0×10^5 m/s
45. 2.5 cm/s
47. a. 9.8×10^5 m/s b. 1.4×10^6 m/s
49. 1.5 kV
51. 8.0×10^7 m/s
53. -5.1×10^{-19} J
55. 4.2×10^{-10} C
57. 4.1×10^7 m/s
59. 3.3×10^5 m/s
61. a. 15 V, 3.0 kV/m, 2.1×10^{-10} C b. 15 V, 1.5 kV/m, 1.0×10^{-10} C c. 15 V, 3.0 kV/m, 8.3×10^{-10} C
63. 1.8×10^2 N/C
65. 0.47 kV
67. 5447 V, point 2
69. $V_{net} = \dfrac{1}{4\pi\epsilon_0}\dfrac{(2qs^2)}{y^3} = \dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{y^3}$
71. $V = \dfrac{Q}{2\pi\epsilon_0 L}\ln\left[\left(\dfrac{L}{2z}\right) + \sqrt{1 + \left(\dfrac{L}{2z}\right)^2}\right]$
73. $V = \dfrac{Q}{2\pi\epsilon_0 R_{out}^2}\left[\sqrt{R_{out}^2 + z^2} - z\right]$
75. b. 10 nC, 30 nC
77. b. 6.0 cm
79. 1.9×10^{-14} m
81. −9.8 cm/s, 4.9 cm/s
83. $\dfrac{2Q/L}{4\pi\epsilon_0}\left[\ln\left(z + \sqrt{R^2 + z^2}\right)\right]_0^{L/2}$

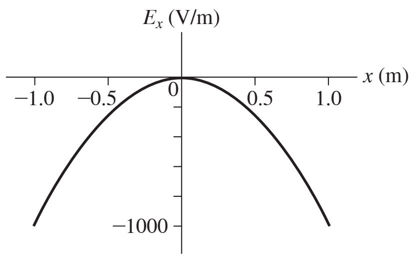
Chapter 26

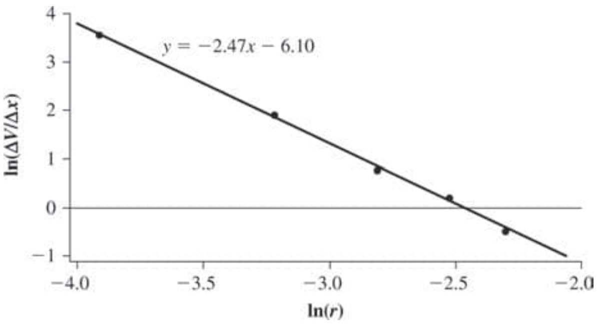
Stop to Think Questions

1. E_y is the negative of the slope of the V-versus-y graph. E_y is positive because $\vec{E}$ points up, so the graph has a negative slope. E_y has constant magnitude, so the slope has a constant value.
2. **b.** $\vec{E}$ points "downhill," so the potential must decrease from right to left. The field is everywhere perpendicular to equipotential surfaces, which rules out d. The field is stronger at the ends, where the field lines are closer together, so the contour lines at the ends must be closer together than in the middle.
3. **b.** Because of the connecting wire, the three spheres form a single conductor in electrostatic equilibrium. Thus all points are at the same potential. The electric field of a sphere is related to the sphere's potential by $E = V/R$, so a smaller-radius sphere has a larger E.
4. **5.0 V.** The potentials add, but $\Delta V = -1.0$ V because the charge escalator goes *down* by 1.0 V.
5. $\mathbf{(C_{eq})_B > (C_{eq})_A = (C_{eq})_D > (C_{eq})_C}$. $(C_{eq})_B = 3\ \mu F + 3\ \mu F = 6\ \mu F$. The equivalent capacitance of series capacitors is less than any capacitor in the group, so $(C_{eq})_C < 3\ \mu F$. Only d requires any real calculation. The two 4 μF capacitors are in series and are equivalent to a single 2 μF capacitor. The 2 μF equivalent capacitor is in parallel with 3 μF, so $(C_{eq})_D = 5\ \mu F$

Exercises and Problems

1. 380 V
3. −400 V
5. $E_1 > E_2$
7. 2.0×10^4 V/m 45° ccw from the $-x$-axis
9. (3750 V/m, down), (7500 V/m, up)
11. 

13. 3.3 kV/m
15. a. −70 V/m b. −1.10 kV/m
17. 3.0 C
19. 1.5 V
21. a. 7.4 pF b. 0.89 nC
23. 4.8 cm
25. 3.0 μF
27. 1.5 μF
29. 150 μF, in series
31. 1.4 kV
33. 4.75 kV/m
35. a. 0.15 nF b. 12 kV
37. 89 pF
39. a. 

b. 12V
41. a. $-(1.4 \times 10^7 \hat{\imath})$ V/m, 7×10^4 V b. 0.0 V/m, 1.4×10^5 V c. $1.4 \times 10^7 \hat{\imath}$ V/m, 7×10^4 V
43. $\dfrac{Q}{4\pi\epsilon_0 z^2}$
45. 1000 V/m, 127° ccw from $+x$-axis
47. 

49. a. $V = \dfrac{2kq}{\sqrt{a^2 + x^2}}$ b. $\dfrac{2kq}{a}\left(1 - \dfrac{x^2}{2a^2}\right)$ c. $\dfrac{2kqx}{a^3}$
d. $F_x = -\dfrac{2kqex}{a^3}$ e. 8.9 GHz
51. $Q_{1f} = 2$ nC, $Q_{2f} = 4$ nC
53. 5.0 cm
55. a. ± 32 pC b. ± 16.0 pC
57. $V_1 = 12$ V, $V_2 = 7.2$ V, $V_3 = 4.8$ V; $Q_1 = 190\ \mu$C, $Q_2 = 290\ \mu$C, $Q_3 = 290\ \mu$C
59. a. $\frac{3}{2}$ pC b. 0
61. 12 V
63. $Q_1' = 33\ \mu$C, $Q_2' = 67\ \mu$C, $\Delta V_1' = \Delta V_2' = 3.3$ V
65. 11 μF
67. 5.0 μF
69. a. 8.0 kV b. 4.3×10^7 V/m
71. $C_0 \dfrac{2\kappa}{1 + \kappa}$
73. 6.1×10^7 ions
75. b. $(10 - az^2)$ V, with z in m
77. b. 2 μF
79. $\dfrac{\rho R^2}{2\epsilon_0}$
81. a. $C = \dfrac{Q}{\Delta V_C} 4\pi\epsilon_0 \left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)^{-1}$ b. 5.9 cm, 6.1 cm
83. 2 C

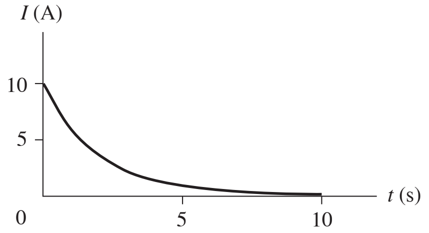
Chapter 27

Stop to Think Questions

1. **$i_C > i_B > i_A > i_D$.** The electron current is proportional to $r^2 v_D$ Changing r by a factor of 2 has more influence than changing v_D by a factor of 2.
2. **The electrons don't have to move from the switch to the bulb, which could take hours.** Because the wire between the switch and the bulb is already full of electrons, a flow of electrons from the switch into the wire immediately causes electrons to flow from the other end of the wire into the lightbulb.
3. **$E_D > E_B > E_E > E_A = E_C$.** The electric field strength depends on the *difference* in the charge on the two wires. The electric fields of the rings in A and C are opposed to each other, so the net field is zero. The rings in D have the largest charge *difference*.
4. **1 A into the junction.** The total current entering the junction must equal the total current leaving the junction.
5. **$J_B > J_A = J_D > J_C$.** The current density $J = I/\pi r^2$ is independent of the conductivity σ, so A and D are the same. Changing r by a factor of 2 has more influence than changing I by a factor of 2.
6. **$I_1 = I_2 = I_3 = I_4$.** Conservation of charge requires $I_1 = I_2$. The current in each wire is $I = \Delta V_{wire}/R$. All the wires have the same resistance because they are identical, and they all have the same potential difference because each is connected directly to the battery, which is a *source of potential*.

Exercises and Problems

1. 3.0 d
3. 2.2×10^{25} electrons
5. a. 4.6×10^{21} electrons b. 4.3×10^{-12} m
7. 66 mV/m
9. a. 1.7×10^7 A/m^2 b. 5.3×10^{18} s^{-1}
11. 0.161 C
13. 1.8 μA
15. 5.1×10^6 A/m^2
17. 5.7 A
19. 0.16 V/M
21. $5.0 \times 10^{-8}\ \Omega$ m
23. 1.7×10^{-5} V/m
25. a. 1 b. 0.33 Ω
27. Silver
29. 1.5 mV
31. 2.3 mA
33. 0.87 V
35. 50 Ω
37. 380
39. 6.2×10^6
41. a. 3.1×10^{14} b. 4.0×10^2 A/m^2 c. 9.1×10^5 V/m d. 0.23 W
43. a. 75 nA b. 130 s
45. Yes, $2.2 \times 10^5\ \Omega^{-1}$m^{-1}
47. $6.1 \times 10^{10}\ \Omega^{-1}$m^{-1}, 1000 times greater
49. 71°C
51. 100 V
53. a. $\Delta V = IR \Rightarrow \Delta V = I/G$ b. 5.9 Ω^{-1} c. 0.25 V
55. 0.60 kA
57. a. $\dfrac{(\Delta V)A[1 - \alpha(T - T_0)]}{\rho_0 L}$ b. 4.4 A c. -0.017 A/°C
59. a. $\dfrac{1}{4\pi\sigma r^2}$ b. $E_{inner} = 3.3 \times 10^{-4}$ V/m, $E_{outer} = 5.3 \times 10^{-5}$ V/m
c.



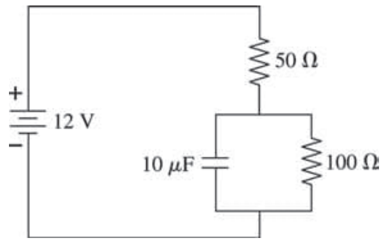
61. 1.01×10^{23}
63. a. 2.0 A b. 5.0×10^{-5} m/s
65. a. 2.5 C b. 1.8 cm
67. 36 A
69. 1.80×10^3 C
71. 4R
73. $\dfrac{3}{2}\dfrac{I}{\pi R^3}$
75. 1.0 s

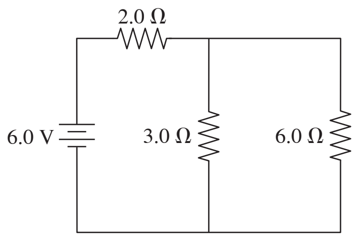
Chapter 28

Stop to Think Questions

1. **a, b, and d.** These three are the same circuit because the logic of the connections is the same. In c, the functioning of the circuit is changed by the extra wire connecting the two sides of the capacitor.
2. **ΔV increases by 2 V in the direction of I.** Kirchhoff's loop law, starting on the left side of the battery, is then $+12$ V $+ 2$ V $- 8$ V $- 6$ V $= 0$.
3. **$P_B > P_D > P_A > P_C$.** The power dissipated by a resistor is $P_R = (\Delta V_R)^2/R$. Increasing R decreases P_R; increasing ΔV increases P_R. But the potential has a larger effect because P_R depends on the square of ΔV_R.
4. **$I = 2$ A for all. $V_1 = 20$ V, $V_2 = 16$ V, $V_3 = 10$ V, $V_4 = 8$ V, $V_5 = 0$ V.** The potential is 0 V on the right and increases by IR for each resistor going to the left.
5. **A > B > C = D.** All the current from the battery goes through A, so it is brightest. The current divides at the junction, but not equally. Because B is in parallel with C + D but has half the resistance, twice as much current travels through B as through C + D. So B is dimmer than A but brighter than C and D. C and D are equal because current is the same through bulbs in series.
6. **b.** The two 2 Ω resistors are in series and equivalent to a 4 Ω resistor. Thus $\tau = RC = 4$ s.

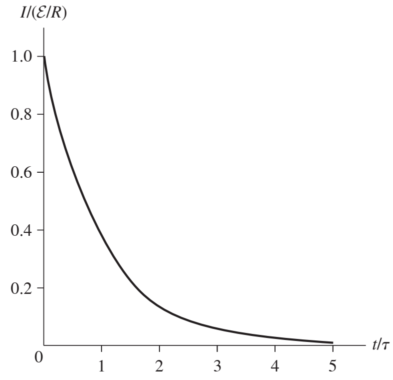
Exercises and Problems

1. 

3. 2A, to the left
5. 13 V, 27 V
7. 3,600,000 J
9. a. 60 W b. 23 W, 14 W
11. P > S = T > Q = R
13. 12 μm
15. $2800
17. 0.9 Ω
19. 2.0 A
21. 9.0 V, 0.50 Ω
23. 240 Ω
25. 183 Ω
27. 24 Ω
29. 20 W, 45 W
31. Point 1
33. 2.0 ms
35. 6.9 ms
37. 14 μF
39. Incandescent: $140, LED: $28
41. 19 W
43. 

45. a. Points 2, 3 b. 9.3 W
47. a. 0.84 kW b. 6.6 s
49. 9.5
51. a. $R = r$ b. 20 W
53. $I_1 = 5.0$ A, $I_2 = 8.0$ A, $\mathcal{E} = 14$ V
55. a. 8 V b. 0 V
57.

R **(Ohms)**	***I*** **(A)**	***V*** **(V)**
4	2.4	9.6
5	1.6	8
6	2.4	14.4
10	1.6	16

59. 2.0 A
61. 0.12 A, left to right
63. 150 V, bottom
65. 0.3 W
67. a. 35 ms b. 17 ms
69. 79 Ω
71. 48 μJ
73. a. $\mathcal{E}$ b. $C\mathcal{E}$ c. $I = +dQ/dt$ d. $I = \dfrac{\mathcal{E}}{R}e^{-t/\tau}$
e. 

75. a. 1.2 ms b. 4.2 kW c. 2.9 J
77. 0.69 ms
79. 2.0 m, 0.49 mm
81. a. 80 μC b. 0.23 ms
83. 5.1 kΩ

Chapter 29

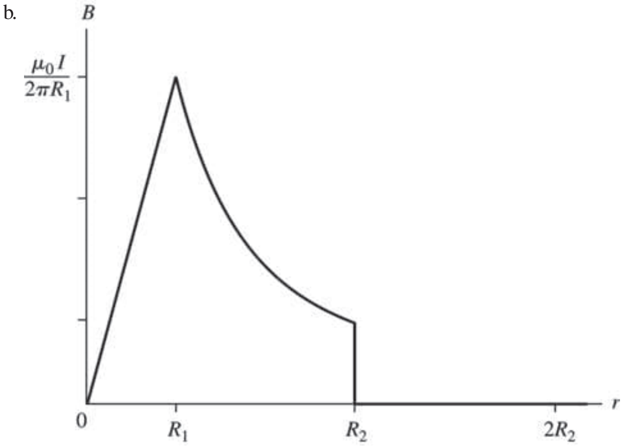
Stop to Think Questions

1. **Not at all.** The charge exerts weak, attractive polarization forces on both ends of the compass needle, but in this configuration the forces will balance and have no net effect.
2. **d.** Point your right thumb in the direction of the current and curl your fingers around the wire.
3. **b.** Point your right thumb out of the page, in the direction of $\vec{v}$ .Your fingers are pointing down as they curl around the left side.
4. **b.** The right-hand rule gives a downward $\vec{B}$ for a clockwise current. The north pole is on the side from which the field emerges.
5. **c.** For a field pointing into the figure, $\vec{v} \times \vec{B}$ is to the right. But the electron is negative, so the force is in the direction of $-(\vec{v} \times \vec{B})$.
6. **b.** Repulsion indicates that the south pole of the loop is on the right, facing the bar magnet; the north pole is on the left. Then the right-hand rule gives the current direction.
7. **a or c.** Any magnetic field to the right, whether leaving a north pole or entering a south pole, will align the magnetic domains as shown.

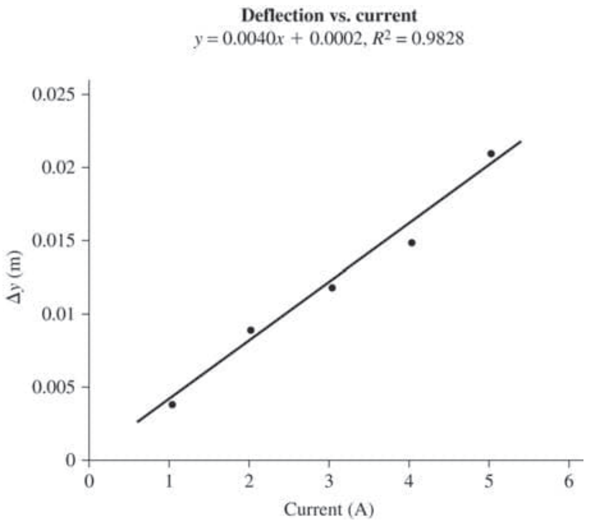
Exercises and Problems

1. $B_2 = 40$ mT, $B_3 = 0$ T, $B_4 = 40$ mT
3. a. 0 T b. $0.8 \times 10^{-15}\hat{k}$ T c. $-3.2 \times 10^{-15}\hat{k}$ T
5. $(-2.8 \times 10^{-16}$ T$)\,\hat{k}$
7. 2.5 A, 250 A, 5000 A to 50,000 A, 500,000 A
9. 0.06 μA
11. a. 23 A b. 2.4×10^{-3} m
13. $\vec{B}_a = 2.0 \times 10^{-4}\hat{\imath}$ T, $\vec{B}_b = 4.0 \times 10^{-4}\hat{\imath}$ T, $\vec{B}_c = 2.0 \times 10^{-4}\hat{\imath}$ T
15. 11 A
17. a. 1.7 A m^2 b. 3.4×10^{-4} T
19. 0
21. 23.0 A, into the page
23. 1.26×10^{-6} T m
25. 2.4 kA
27. a. 8.0×10^{-13} N in $-\hat{\jmath}$ b. 5.7×10^{-13} N in $\hat{\jmath}$
29. a. 1.4442 MHz b. 1.6450 MHz c. 1.6457 MHz
31. a. 86 mT b. 1.62×10^{-14} J

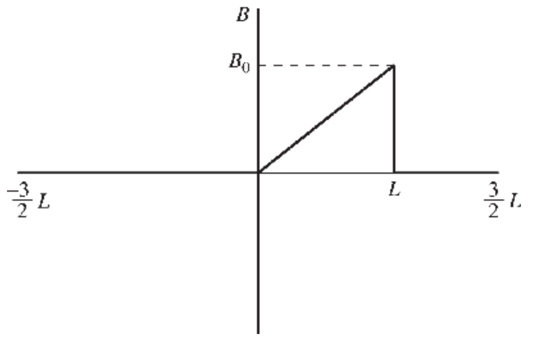
33. 3.0 Ω
35. $\vec{F}_{\text{on }1} = (2.5 \times 10^{-4}\,\text{N, up})$, $\vec{F}_{\text{on }2} = 0\,\text{N}$, $\vec{F}_{\text{on }3} = (2.5 \times 10^{-4}\,\text{N, down})$
37. 240 A
39. a. 1.26×10^{-11} N m b. 0° or 180°
41. a. $x = 0.50$ cm b. $x = 8.0$ cm
43. 4.1×10^{-4} T, into the page
45. $\dfrac{\mu_0 I \theta}{4\pi R}$
47. 5.0×10^{-3} T
49. Wire 1, $I = 4.8$ A
51. 1.1 μA
53. $\dfrac{\mu_0 I}{4R}$
55. a. $I_{\text{through}} = \dfrac{Ir^2}{R_1^{\,2}}$; $I_{\text{through}} = I$, $I_{\text{through}} = 0$ A
b.



57. 0; $\dfrac{\mu_0 I}{2\pi r}\left(\dfrac{r^2 - R_1^2}{R_2^{\,2} - R_1^{\,2}}\right)$; $\dfrac{\mu_0 I}{2\pi r}$
59. 2.0 mT, into the page
61. 2.4×10^{10} m/s^2, up
63. a. 2.7×10^{-16} J b. 1400 rev
65. 0.82 mm, 3.0 mm
67. 0.69 T
69. 2.10 T
71. 2.0 A
73.



75. a. $B = \dfrac{\mu g \tan\theta}{I}$ b. $\vec{B} = (11\,\text{mT, down})$
77. a.



b. $\frac{1}{2} ILB_0\hat{j}$ c. $\frac{1}{3} IL^2B_0$
79. 0.16 T
81. a. $\dfrac{\mu_0 IL}{4\pi d\sqrt{(L/2)^2 + d^2}}$ b. $\dfrac{\sqrt{2}\mu_0 I}{\pi R}$
83. a. Horizontal and to the left above the sheet; horizontal and to the right below the sheet b. $\frac{1}{2}\mu_0 j_s$

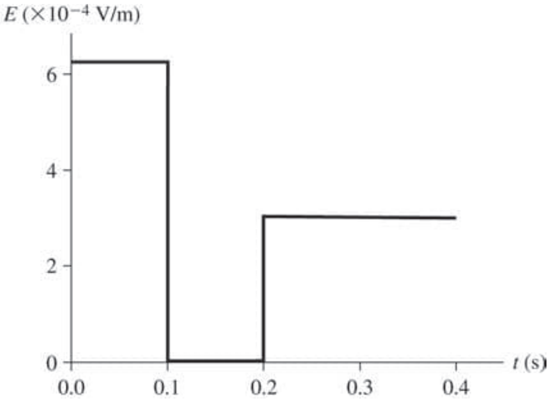
Chapter 30

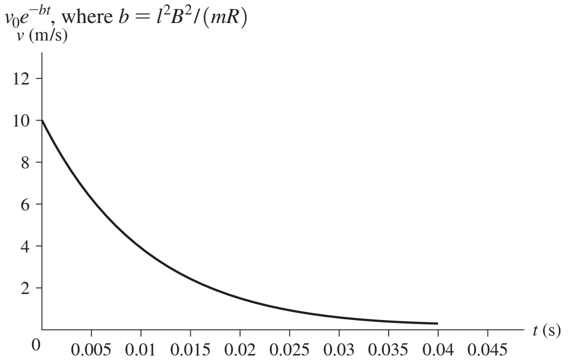
Stop to Think Questions

1. **d.** According to the right-hand rule, the magnetic force on a positive charge carrier is to the right.
2. **No.** The charge carriers in the wire move parallel to $\vec{B}$. There's no magnetic force on a charge moving parallel to a magnetic field.
3. $\boldsymbol{F_2 = F_4 > F_1 = F_3}$**.** $\vec{F}_1$ is zero because there's no field. $\vec{F}_3$ is also zero because there's no current around the loop. The charge carriers in both the right and left edges are pushed to the bottom of the loop, creating a motional emf but no current. The currents at 2 and 4 are in opposite directions, but the forces on the segments in the field are both to the left and of equal magnitude.
4. **Clockwise.** The wire's magnetic field as it passes through the loop is into the page. The flux through the loop decreases into the page as the wire moves away. To oppose this decrease, the induced magnetic field needs to point into the page.
5. **d.** The flux is increasing into the loop. To oppose this increase, the induced magnetic field needs to point out of the figure. This requires a ccw induced current. Using the right-hand rule, the magnetic force on the current in the left edge of the loop is to the right, away from the field. The magnetic forces on the top and bottom segments of the loop are in opposite directions and cancel each other.
6. **b or f.** The potential decreases in the direction of increasing current and increases in the direction of decreasing current.
7. $\boldsymbol{\tau_C > \tau_A > \tau_B}$**.** $\tau = L/R$, so smaller total resistance gives a larger time constant. The parallel resistors have total resistance $R/2$. The series resistors have total resistance $2R$.

Exercises and Problems

1. 2.67×10^4 m/s
3. 0.10 T, into the page
5. 0 T m^2
7. 3.8×10^{-4} T m^2
9. a. Yes, right to left b. No
11. a. 8.7×10^{-4} Wb b. Clockwise
13. a. 20 mA, ccw b. 20 mA, ccw c. 0 A
15. Decreasing, 7.0 T/s
17. a. $\mathcal{E} = (2.5 + 2.0t)$ mV and $I(t) = (8.4 + 6.7t)$ mA
b. 22 mA and 35 mA

19. 

21. 1.3 T
23. 508×10^3 turns
25. 1.5 ms
27. 0.20 J
29. 250 kHz to 360 kHz
31. 3.8×10^{-18} F
33. 30 nF
35. 1.7×10^{-4} s
37. 1.6 A, 0.0 A, −1.6 A
39. 8.7 T/s
41. $\mathcal{E} = 2\beta\pi r_0^2 B e^{-2\beta t}$
43. a. 32 A b. 1.3 m/s
45. 44 μA
47. −15 μA
49. 0.15 T
51. 4.0 nA
53. a. Ccw b. 15 A
55. a. 0.20 A b. 4.0 mN c. 11 K
57. a. $(4.9 \times 10^{-3}) f \sin(2\pi f t)$ A b. 4.1×10^2 Hz, no
59. a. $\dfrac{\mathcal{E}_{bat}}{Bl}$ b. 0.98 m/s
61. 3.9 V
63. $(R^2/2r)(dB/dt)$
65. 3.0 s
67. 0.75 A
69. a. 1.9×10^{-4} T b. 92 Ω
71. a. 6.3×10^{-7} s b. 0.050 mA
73. 2.0 mH, 0.13 μF
75. a. 50 V b. Close S_1 at $t = 0$ s, open S_1 and close S_2 at $t = 0.0625$ s, then open S_2 at $t = 0.1875$ s
77. a. $I_0 = \Delta V_{bat}/R$ b. $I = I_0(1 - e^{-t/(L/R)})$
79. 0.72 mH
81. 1.0 mA
83. a. $v_0 e^{-bt}$, where $b = l^2 B^2/(mR)$
b. 

85. 1.6×10^2 A/s

Chapter 31

Stop to Think Questions

1. **b.** $\vec{v}_{AB}$ is parallel to $\vec{B}_A$ hence $\vec{v}_{AB} \times \vec{B}_A$ is zero. $\vec{E}_B = \vec{E}_A$ and points in the positive z-direction. $\vec{v}_{AB} \times \vec{E}_A$ points down, in the negative y-direction, so $-\vec{v}_{AB} \times \vec{E}_A/c^2$ points in the positive y-direction and causes $\vec{B}_B$ to be angled upward.
2. $\boldsymbol{B_C > B_A > B_D > B_B}$**.** The induced magnetic field strength depends on the *rate* dE/dt at which the electric field is changing. Steeper slopes on the graph correspond to larger magnetic fields.
3. **e.** $\vec{E}$ is perpendicular to $\vec{B}$ and to $\vec{v}$, so it can only be along the z-axis. According to the Ampère-Maxwell law, $d\Phi_e/dt$ has the same sign as the line integral of $\vec{B} \cdot d\vec{s}$ around the closed curve. The integral is positive for a cw integration. Thus, from the right-hand rule, $\vec{E}$ is either into the page (negative z-direction) and increasing, or out of the page (positive z-direction) and decreasing. We can see from the figure that B is decreasing in strength as the wave moves from left to right, so E must also be decreasing. Thus $\vec{E}$ points along the positive z-axis.
4. **a.** The Poynting vector $\vec{S} = (\vec{E} \times \vec{B})/\mu_0$ points in the direction of travel, which is the positive y-direction. $\vec{B}$ must point in the positive x-direction in order for $\vec{E} \times \vec{B}$ to point upward.
5. **b.** The intensity along a line from the antenna decreases inversely with the square of the distance, so the intensity at 20 km is $\frac{1}{4}$ that at 10 km. But the intensity depends on the square of the electric field amplitude, or, conversely, E_0 is proportional to $I^{1/2}$. Thus E_0 at 20 km is $\frac{1}{2}$ that at 10 km.
6. $\boldsymbol{I_D > I_A > I_B = I_C}$**.** The intensity depends on $\cos^2\theta$ where θ is the angle *between* the axes of the two filters. The filters in D have $\theta = 0°$. The two filters in both B and C are crossed $(\theta = 90°)$ and transmit no light at all.

Exercises and Problems

1. a. Along the $-x$-axis b. Along the y-axis (+ or −) c. Along the $+x$-axis
3. $-1.11 \times 10^{-5}\,\hat{j}$ T
5. 11 T, inward
7. 7.5 μA
11. 6.0×10^5 V/m
13. a. 314 nm b. 9.55×10^{14} Hz c. 1200 V/m
15. $-z$-direction
17. 980 V/M, 3.3 T
19. a. 2.2×10^{-6} W/m² b. 0.041 V/m
21. 4.6×10^{-7} T
23. 3.3×10^{-6} T, $(-1.7 \times 10^{-6}\text{ T})\hat{\imath}$
25. 66 mW
27. $(-1.73 \times 10^6\,\hat{\imath} + 2.0 \times 10^6\,\hat{j})$ V/m
29. a. (0.10 T, into page) b. 0 V/m, (0.10 T, into page)
31. $(-3.2 \times 10^{-14}\,\hat{\imath} - 4.8 \times 10^{-14}\,\hat{j})$ N
33. a. 0.94 V/m b. 10.0 T
37. a. 1.0 mT b. 0.160 mT
39. a. 5.4×10^{15} N/C s b. Opposite
41. a. -14.6, 6.8×10^{-2} b. $-260\hat{\imath} + 140\hat{j} - 200\hat{k}$ W/m²
43. a. 3.85×10^{26} W b. 589 W/m²
45. 1.3 m
47. 0.092 V/m
49. 1.8×10^7 V/m
51. 1.3 m
53. 4.9×10^7 W/m²
55. 0.41 m/s
57. 63°
59. a. 7.9×10^4 m/s b. 0.81 m/s² c. 27 h d. 1.2 GW
61. 16°
63. 8.8 h
65. 5.2 μV/m

Chapter 32

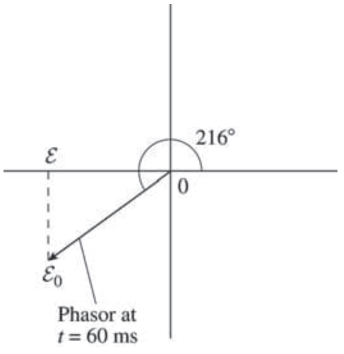
Stop to Think Questions

1. **a.** The instantaneous emf value is the projection down onto the horizontal axis. The emf is negative but increasing in magnitude as the phasor, which rotates ccw, approaches the horizontal axis.
2. **c.** Voltage and current are measured using different scales and units. You can't compare the length of a voltage phasor to the length of a current phasor.
3. **a.** There is "no capacitor" when the separation between the two capacitor plates becomes zero and the plates touch. Capacitance C is inversely proportional to the plate spacing d, hence $C \to \infty$ as $d \to 0$. The capacitive reactance is inversely proportional to C, so $X_C \to 0$ as $C \to \infty$.
4. $(\omega_C)_D > (\omega_C)_C = (\omega_C)_A > (\omega_C)_B$**.** The crossover frequency is $1/RC$.
5. **Above.** $V_L > V_C$ tells us that $X_L > X_C$. This is the condition above resonance, where X_L is increasing with ω while X_C is decreasing.
6. **a, b, and c.** You can always increase power by turning up the voltage. Power is maximum at resonance when the power factor is zero. The current leads the emf, telling us that the resonance frequency is higher than the emf frequency. We need to lower the resonance frequency to match the emf frequency, which can be done by increasing either L or C.

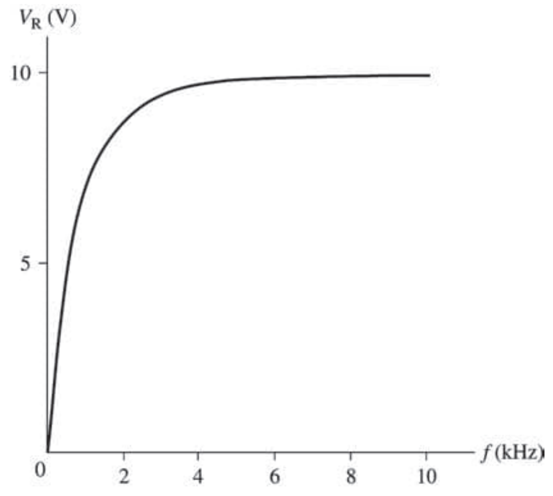
Exercises and Problems

1. a. 2.0×10^3 rad/s b. 71 V

3.



5. a. 50 mA b. 50 mA
7. a. 1.25 mA b. 1.25 A
9. a. 50 Hz b. 4.8 μF
11. a. 80 kHz b. 0 V
13. b.



15. 6.37 μF
17. a. ≈ 8 Hz

b.

f	V_c (V)
$\frac{1}{2}f_c$	8.9
f_c	7.1
$2f_c$	4.5

19. a. 3.0 V, 9.5 V b. 10 V, 3.2 V
21. a. 0.9770 b. 0.9998
23. a. 0.80 A b. 0.80 mA
25. a. 24 μH b. 165 μA
27. a. 200 kHz b. 141 kHz
29. a. $Z = 70\ \Omega, I = 0.072$ A, $\phi = -44°$
 b. $Z = 50\ \Omega, I = 0.10$ A, $\phi = 0.0°$
 c. $Z = 62\ \Omega, I = 0.080$ A, $\phi = 37°$
31. 1.0 Ω
33. a. 5×10^3 Hz b. 10 V, 32 V
35. 30°
37. 44 Ω
39. 0.75
43. a. $\omega = \dfrac{1}{\sqrt{3}RC}$ b. $\dfrac{\sqrt{3}}{2}\mathcal{E}_0$
45. 0.50 mm
47. a. $I_R = \dfrac{\mathcal{E}_0}{R}, I_C = \dfrac{\mathcal{E}_0}{(\omega C)^{-1}}$ b. $\mathcal{E}_0\sqrt{(\omega C)^2 + \dfrac{1}{R^2}}$
49. a. $\mathcal{E}_0/\sqrt{R^2 + \omega^2 L^2}, \mathcal{E}_0 R/\sqrt{R^2 + \omega^2 L^2}, \mathcal{E}_0 \omega L/\sqrt{R^2 + \omega^2 L^2}$
 b. $V_R \to \mathcal{E}_0, V_R \to 0$ c. Low pass d. R/L
51. a. 2.0 A b. −30° c. 150 W
53. 10 μT
55. a. 64 mA b. 48 mA
57. a. 3.6 V b. 3.5 V c. −3.6 V
61. a. 0.49 μH b. 10.3 Ω
63. a. 1.25×10^6 A b. 300 A
65. a. 0.44 kA b. 1.8×10^{-4} F c. 7.4 MW
67. a. 0.83 b. 100 V c. 13 Ω d. 3.2×10^{-4} F
71. b. $I = \mathcal{E}_0/R$ in both cases c. 0

Chapter 33

Stop to Think Questions

1. **b.** The antinodal lines seen in Figure 33.4b are diverging.
2. **Smaller.** Shorter-wavelength light doesn't spread as rapidly as longer-wavelength light. The fringe spacing Δy is directly proportional to the wavelength λ.
3. **d.** Larger wavelengths have larger diffraction angles. Red light has a larger wavelength than violet light, so red light is diffracted farther from the center.
4. **b or c.** The width of the central maximum, which is proportional to λ/a, has increased. This could occur either because the wavelength has increased or because the slit width has decreased.
5. **d.** Moving M_1 in by λ decreases r_1 by 2λ. Moving M_2 out by λ increases r_2 by 2λ. These two actions together change the path length by $\Delta r = 4\lambda$.

Exercises and Problems

1. 378 nm
3. 3.2 cm
5. 1.3 m
7. 0.286°
9. 167 cm
11. 530
13. 43.2°
15. 14.5 cm
17. 500 nm
19. 0.20 mm
21. 4.0 mm
23. 633 nm

25. 2.9°
27. 1.3 m
29. 9
31. 1.6
33. 0.015 rad, 0.87°
35. 78 cm
37. 30,467
39. a. Double slit b. 0.16 mm
41. 0.40 mm
43. 6.0 GHz
45. 667.8 nm
47. 1.3 m
49. 43 cm
51. a. $L\lambda/d$ b. $(L/d)\Delta\lambda$ c. 0.250 nm
53. 16°
55. 1.8 μm
57. $\frac{\sqrt{2}}{2}d$
59. b. 50 μm
61. 0.88 mm
63. a. 550 nm b. 0.40 nm
65. 50 cm
67. a. 3.0 mm b. $\frac{1}{4}T$ c. $\frac{1}{2}\pi$rad d. 0.75 mm toward slit with glass
69. a. Dark b. 1.597
71. 3
73. a. $\Delta y = \frac{\Delta\lambda L}{d}$ b. $\Delta y_{min} = \frac{\lambda}{N}$ c. 3646 lines
75. a. 0.52 mm b. 0.074° c. 1.3 m

Chapter 34

Stop to Think Questions

1. **c.** The light spreads vertically as it goes through the vertical aperture. The light spreads horizontally due to different points on the horizontal lightbulb.
2. **c.** There's one image behind the vertical mirror and a second behind the horizontal mirror. A third image in the corner arises from rays that reflect twice, once off each mirror.
3. **a.** The ray travels closer to the normal in both media 1 and 3 than in medium 2, so n_1 and n_3 are both larger than n_2. The angle is smaller in medium 3 than in medium 1, so $n_3 > n_1$.
4. **e.** The rays from the object are diverging. Without a lens, the rays cannot converge to form any kind of image on the screen.
5. **a, e, or f.** Any of these will increase the angle of refraction θ_2.
6. **Away from.** You need to decrease s' to bring the image plane onto the screen. s' is decreased by increasing s.
7. **c.** A concave mirror forms a real image in front of the mirror. Because the object distance is $s \approx \infty$, the image distance is $s' \approx f$.

Exercises and Problems

1. a. 6.66×10^{-9} s b. 1.5 m, 1.34 m, 0.92 m
3. 3.6 m
5. 30°
7. 9.0 cm
9. 433 cm
11. 1.414
13. 23.3°
15. 76.7°
17. 3.2 cm
19. 1.52
21. Inverted
23. 15 cm in front of lens, upright
25. −68 cm
27. 2.0 m
29. 2.0 cm
31. 30 cm, 0.50 cm
33. b. 40 cm, 2.0 cm, agree
35. a. 47 cm, same side b. 6.3 cm, inverted
37. b. −8.6 cm, 1.1 cm, agree
39. Inverted
41. Upright
43. 6.4 cm
45. 1.7
47. a. $2\cos^{-1}\left(\frac{n}{2n_{air}}\right)$ b. 82.8°
49. a. 87 cm b. 65 cm c. 43 cm
51. 4.7 m
53. 1.46
55. 30°
57. 35°
59. 2.7 m/s
61. 15.1 cm
63. 17 cm
65. 2; 0.50 cm, inverted; 8.0 cm, inverted
67. a. 5.9 cm b. 6.0 cm
69. $4f$
71. 16 cm
73. 20 μm/s away from the lens
75. 13 cm
77. 1.2 m
79. 2.8 cm
81. a. $\frac{n_1}{c}\sqrt{x^2 + a^2} + \frac{n_2}{c}\sqrt{(w-x)^2 + b^2}$
    b. $\frac{dt}{dx} = 0 = \frac{n_1 x}{c\sqrt{x^2 + a^2}} - \frac{n_2(w-x)}{c\sqrt{(w-x)^2 + b^2}}$

Chapter 35

Stop to Think Questions

1. **b.** A diverging lens refracts rays away from the optical axis, so the rays will travel farther down the axis before converging.
2. **a.** Because the shutter speed doesn't change, the f-number must remain unchanged. The f-number is f/D, so increasing f requires increasing D.
3. **a.** A magnifier is a converging lens. Converging lenses are used to correct hyperopia.
4. **b.** The objective forms a real image, but the image of the eyepiece—a magnifier—is a virtual image inside the microscope that the eye can view.
5. $w_A > w_D > w_B = w_C$**.** The spot size is proportional to f/D.

Exercises and Problems

1. b. $s'_2 = \approx 73$ cm, $h'_2 = 6.85$ cm
3. b. $s'_2 = -15$ cm, $h'_2 = 3$ cm
5. 10 cm
7. 3.0 mm
9. 1/250 s
11. a. Myopia b. 100 cm
13. 3.0
15. 5.0 cm
17. 13 μm
19. 6.0 mm
21. 0.4°
23. 1600 nm
25. 102 km
27. 2.0 cm, right; 6.0 cm, right
29. a. $f_2 + f_1$ b. $\frac{f_2}{|f_1|}w_1$
31. 16 cm placed 80 cm from screen
33. 23 cm
35. 3.5 m
37. a. +4.5 D lens b. 1.5 c. 0.56 m
39. a. 0.225 mm b. 480 μm

41. 1.0°
43. 15 km
45. a. 1.0×10^{11} km b. 130
47. b. 1.574
49. b. $\Delta n_2 = \frac{1}{2}\Delta n_1$ c. Crown converging, flint diverging d. 4.18 cm

Chapter 36

Stop to Think Questions

1. **a, c, and f.** These move at constant velocity, or very nearly so. The others are accelerating.
2. **a.** $u' = u - v = -10$ m/s $- 6$ m/s $= -16$ m/s. The *speed* is 16 m/s.
3. **c.** Even the light has a slight travel time. The event is the hammer hitting the nail, not your seeing the hammer hit the nail.
4. **At the same time.** Mark is halfway between the tree and the pole, so the fact that he *sees* the lightning bolts at the same time means they *happened* at the same time. It's true that Nancy *sees* event 1 before event 2, but the events actually occurred before she sees them. Mark and Nancy share a reference frame, because they are at rest relative to each other, and all experimenters in a reference frame, after correcting for any signal delays, *agree* on the spacetime coordinates of an event.
5. **After.** This is the same as the case of Priya and Ryan. In Mark's reference frame, as in Ryan's, the events are simultaneous. Nancy *sees* event 1 first, but the time when an event is seen is not when the event actually happens. Because all experimenters in a reference frame agree on the spacetime coordinates of an event, Nancy's position in her reference frame cannot affect the order of the events. If Nancy had been passing Mark at the instant the lightning strikes occur in Mark's frame, then Nancy would be equivalent to Priya. Event 2, like the firecracker at the front of Priya's railroad car, occurs first in Nancy's reference frame.
6. **c.** Nick measures proper time because Nick's clock is present at both the "nose passes Nick" event and the "tail passes Nick" event. Proper time is the smallest measured time interval between two events.
7. $\boldsymbol{L_A > L_B = L_C}$**.** Anjay measures the pole's proper length because it is at rest in his reference frame. Proper length is the longest measured length. Beth and Charles may *see* the pole differently, but they share the same reference frame and their *measurements* of the length agree.
8. **c.** The rest energy E_0 is an invariant, the same in all inertial reference frames. Thus $m = E_0/c^2$ is independent of speed.

Exercises and Problems

1. -5.0 m, 1.0 s; -5.0 m, 5.0 s
3. a. 13 m/s b. 3.0 m/s c. 9.4 m/s
5. 3.0×10^8 m/s
7. 167 ns
9. 2 μs, 1 μs
11. Simultaneously
13. a. 8 y b. 4.8 y c. 14.4 y
15. $0.866c$
17. 46 m/s
19. a. Aged less b. 14 ns
21. $0.55c$
23. 2500 kg/m^3
25. 3.0×10^6 m/s
27. a. 1200 m, -2.0 μs b. 2800 m, 8.7 μs
29. $0.71c$
31. $0.9944c$
33. $0.80c$
35. 240,000,000 m/s
37. a. 1.8×10^{16} J b. 9.0×10^9
39. $0.943c$
41. 2400
43. 11.2 h
45. a. 12.8 μs b. $0.625c$
47. a. $0.80c$ b. 16 y
49. 14 m
51. a. $t'_D = t''_D = t'''_D = 0$ y, $t'_E = 0.42$ y, $t''_E = 0$ y, $t'''_E = -0.56$ y
 b. Yes, spaceship 2 c. Yes, spaceship 3 d. No
53. a. 8.5 ly, 17 y b. 7.4 ly, 15 y c. Both
55. 22 m
57. 3.1×10^6 V
59. a. $0.980c$ b. 8.5×10^{-11} J
63. a. 3.84×10^8 m, 1.29 s, 5.47×10^7 m
 b. 0.00 m, 0.182 s, 5.47×10^7 m
 c. 3.84×10^8 m, 1.28 s, 0.00 m
65. a. 3.5×10^{-18} k/g ms, 1.1×10^{-9} J
 b. 1.6×10^{-18} k/g ms
67. a. 7.6×10^{16} J b. 0.84 kg
69. a. 1.3×10^{17} kg b. 6.7×10^{-12}% c. 15 billion years
71. a. 4.3×10^{-12} J b. 0.72%
73. 1.1 pm
75. $0.85c$

Chapter 37

Stop to Think Questions

1. **a is emission, b is absorption.** All wavelengths in the absorption spectrum are seen in the emission spectrum, but not all wavelengths in the emission spectrum are seen in the absorption spectrum.
2. **b.** This observation says that all electrons are the same.
3. **a.** The alpha particle speeds up because the positive alpha particle is repelled by the positive nucleus.
4. Neutral carbon would have six electrons. C^{++} is missing two.
5. **6 protons and 8 neutrons.** The number of protons is the atomic number, which is 6. That leaves $14 - 6 = 8$ neutrons.

Exercises and Problems

1. 656.9 nm, 486.2 nm, 434.1 nm
3. a. $m = 2$, $n = 3$; $m = 1$, $n = 2$ b. Ultraviolet, visible
5. a. $9.39 \times 10^{3\circ}$C b. 694°C
7. 2.4 μm
9. 5.0×10^{-3} T, out of page
11. a. 2.4×10^{-16} kg b. 1.3×10^{-18} C c. Surplus of 8 electrons
13. 1.33×10^{-19} C
15. a. 1.03×10^7 m/s b. 2.6×10^7 m/s c. Alpha particle
17. a. 10 keV b. 0.14 MeV c. 1.2×10^{19} eV
19. a. 5 electrons, 5 protons, 5 neutrons
 b. 6 electrons, 7 protons, 6 neutrons
 c. 5 electrons, 8 protons, 9 neutrons
21. a. ^{3}H b. $^{18}O^+$
23. a. 82 electrons, 79 protons, 118 neutrons
 b. 2.29×10^{17} kg/m^3
 c. 2.01×10^{13}
25. a. 2.29×10^{17} kg/m^3 b. 13 km
27. a. $0.999998c$ b. $0.99999997c$
29. $0.9999999896c$
31. a. 0.00512 MeV b. 9.39 MeV c. 37.6 MeV
33. 8.4°
35. 9.581×10^7 C/kg, proton
37. 0.1040 nm, 1.34×10^6 m/s
39. 0.000000000058% contains mass, 99.999999999942% empty space
41. 5.5 MeV
43. 1.8×10^7 V
45. a. 3.43×10^7 m/s b. 6.14×10^6 V
47. 2.3×10^7 m/s, 65.1° below $+x$-axis
49. a. mg/E_0 b. mg/b d. 2.4×10^{-18} C e. 15

Chapter 38

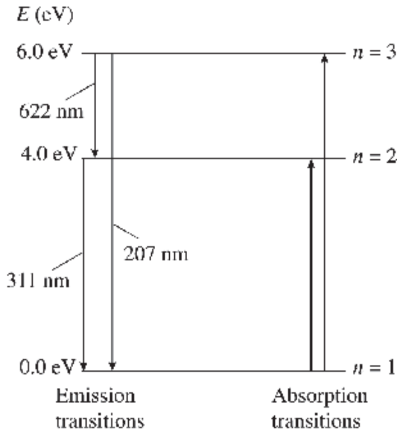
Stop to Think Questions

1. $\boldsymbol{V_A > V_B > V_C}$**.** For a given wavelength of light, electrons are ejected with more kinetic energy for metals with smaller work functions because it takes less energy to remove an electron. Faster electrons need a larger negative voltage to stop them.

2. **d.** Photons always travel at c, and a photon's energy depends only on the light's frequency, not its intensity.
3. **n = 4.** There are four antinodes.
4. **Not in absorption. In emission from the $n = 3$ to $n = 2$ transition.** The photon energy has to match the energy *difference* between two energy levels. Absorption is from the ground state, at $E_1 = 0.00$ eV. There's no energy level at 3.00 eV to which the atom could jump.
5. **n = 3.** Each antinode is half a wavelength, so this standing wave has three full wavelengths in one circumference.

Exercises and Problems

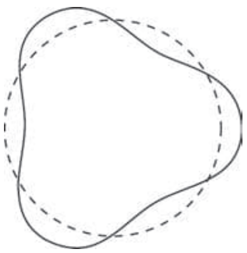
1. a. Sodium, potassium b. All metals except gold
3. 235 nm
5. 1.78 eV
7. a. 2.26 eV b. 0.166 nm
9. a. 1.5×10^{29} photon/s b. Electromagnetic wave
11. 1.44
13. $1. \times 10^{19}$ photon/s
15. 86°
17. 6.0×10^{-6} V
19. a. 1.1×10^{-34} m b. 1.7×10^{-23} m/s
21. 6
23. 2.1 MeV, 8.2 MeV, 19 MeV
25. a. Yes b. 0.50 eV
27. a.



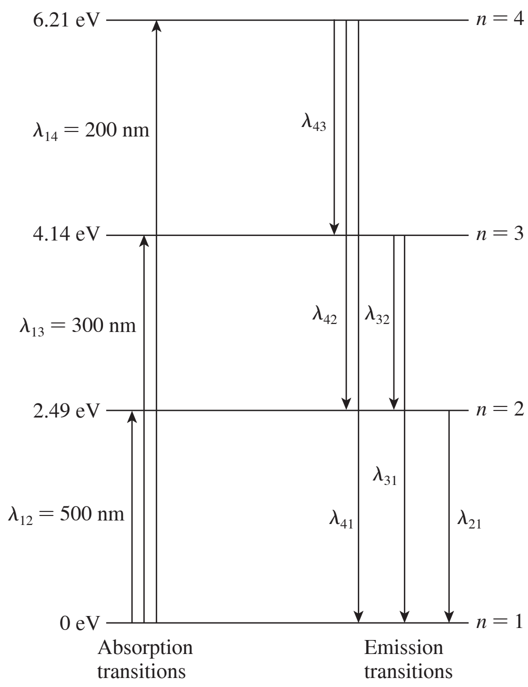
b. 311 nm, 207 nm, 622 nm c. 311 nm, 207 nm

29. a. 0.332 nm, 0.665 nm, 0.997 nm

c.

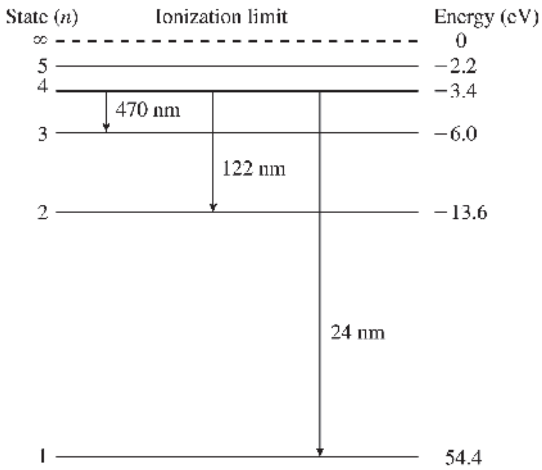


31. a. 31 b. 7.06×10^4 m/s, -0.0142 eV
33. 97.26 nm, 486.3 nm, 4876 nm
35. 97.26 nm
37. 1.24 V
39. 4.3×10^{-10} W
41. a. 5.56×10^{14} Hz, 1.23×10^{15} Hz b. 540 nm, 244 nm c. 10.8×10^5 m/s d. 4.4×10^5 m/s e. 3.35 V, 0.55 V
43. a. Potassium b. 4.24×10^{-15} eVs
45. 71 MeV
47. a. 1.3×10^8 m/s b. 5.5 μm
49. 0.35 nm
51. 18 fm
53. 9.0×10^{-8} eV
55. a.



b. 200 nm, 300 nm, 334 nm, 500 nm, 601 nm, 753 nm

59. 657 nm
61. a. 0.362 m b. 0.000368 nm
63. a.



65. $3 \rightarrow 2$: 10.28 nm, $4 \rightarrow 2$: 7.62 nm, $5 \rightarrow 2$: 6.80 nm; all ultraviolet
67. 44,200 m/s
69. 8.6 mm
71. a. 1.0 m/s b. 3.2° c. 1.1 cm
73. 70 nK

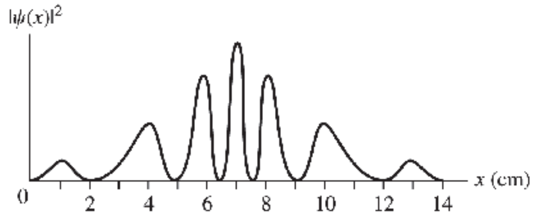
Chapter 39

Stop to Think Questions

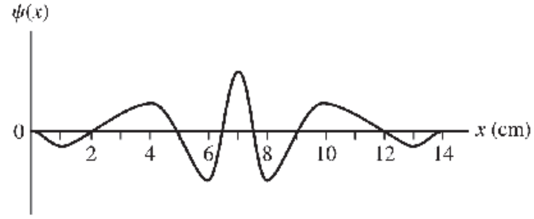
1. **10.** The probability of a 1 is $P_1 = \frac{1}{6}$. Similarly, $P_6 = \frac{1}{6}$. The probability of a 1 *or* a 6 is $P_{1 \text{ or } 6} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3}$. Thus the expected number is $30(\frac{1}{3}) = 10$.
2. **A > B = D > C.** $|A(x)|^2$ is proportional to the density of dots.
3. **x_C.** The probability is largest at the point where the *square* of $\psi(x)$ is largest.
4. **b.** The area $\frac{1}{2}a\,(2 \text{ mm})$ must equal 1.
5. **b.** $\Delta t = 1.0 \times 10^{-7}$ s. The bandwidth is $\Delta f_B = 1/\Delta t = 1.0 \times 10^7$ Hz = 10 MHz.
6. **A.** Wave packet A has a smaller spatial extent Δx. The wavelength isn't relevant.

Exercises and Problems

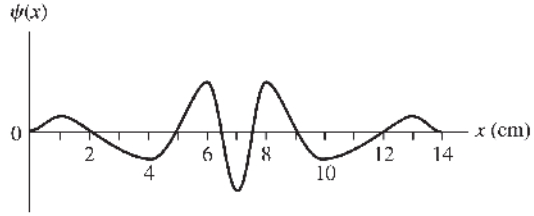
1. $P_C = 20\%$, $P_D = 10\%$
3. a. 7.7% b. 25%
5. a. 1/6 b. 1/6 c. 5/18
7. 70.7 V/m
9. $2.0\ m^{-1}$
11. a.



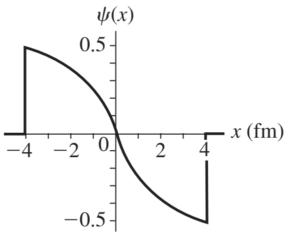
b.



c.

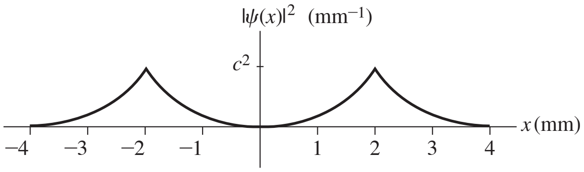


13. a. 5.0×10^{-3} b. 2.5×10^{-3}
    c. 2.5×10^{-3}
15. a. $0.25\ fm^{-1}$
    b.



c. 0.75

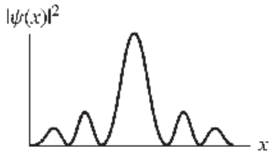
17. a. $\sqrt{\frac{3}{8}}\ mm^{-3/2}$
    b.



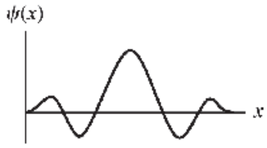
c. 6.3%

19. 1.0×10^5
21. 10.0 kHz
23. -0.65×10^{-36} m/s $\le v_x \le 0.65 \times 10^{-36}$ m/s
25. 4 nm
27. a. 8 cycles b. 0.938 MHz to 1.063 MHz
29. a.

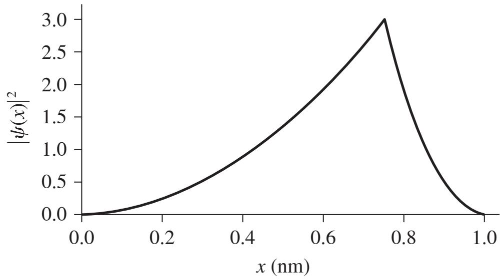
b.



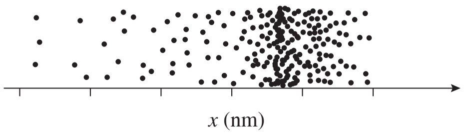
c.



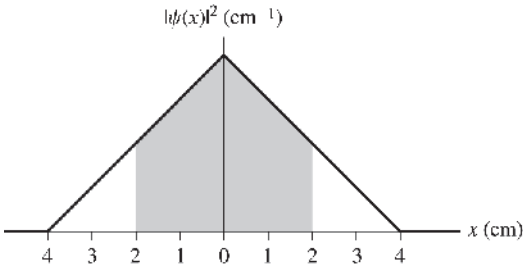
31. a. $\sqrt{3}\ nm^{-\frac{1}{2}}$
    b.



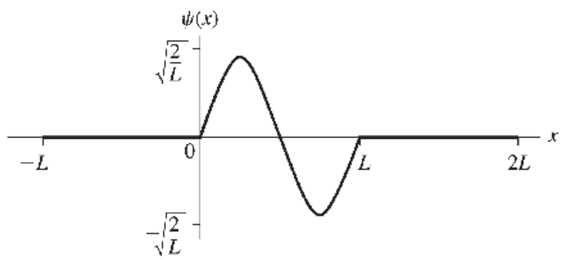
c.



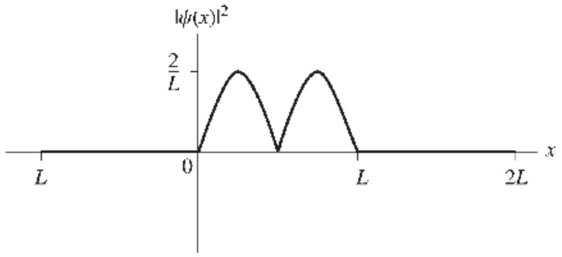
33. a. 4 nm b. 0.0 cm c. $-2.0\ cm \le x \le 2.0\ cm$
    d.



35. a. 0.27% b. 32%
37. a. $\sqrt{\frac{2}{L}}$
    b.



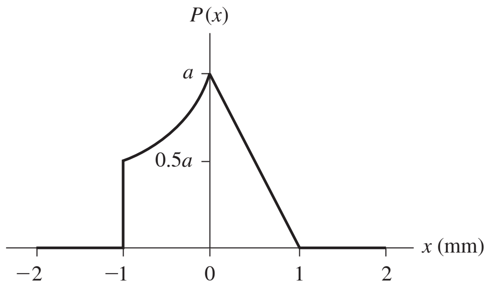
c.



d. 40%

39. a. $a = b$ b. $a = b = 0.84$

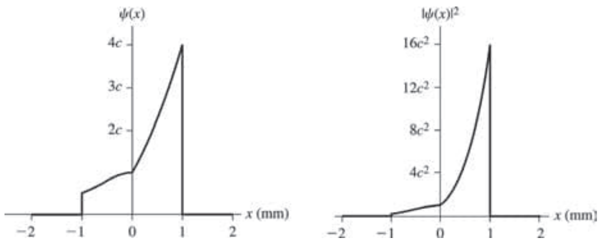
c.



d. 58.1%

41. 18 μm
43. a. 1.7×10^6 m/s b. 1.1×10^{20} reflections/s
45. No, 1.4×10^{-27} m
47. 19%
49. a. $b = c$

b.



c. 91%

51. 200 m

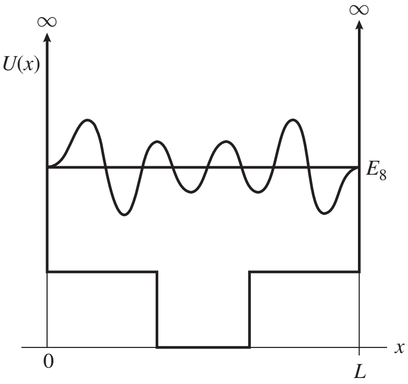
Chapter 40

Stop to Think Questions

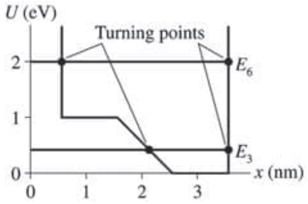
1. $v_A = v_B > v_C$. The de Broglie wavelength is $\lambda = h/mv$, so slower particles have longer wavelengths. The wave amplitude is not relevant.
2. **c.** The $n = 2$ state has a node in the middle of the box. The antinodes are centered in the left and right halves of the box.
3. $n = 5$. There are five antinodes and four nodes (excluding the ends).
4. **d.** The wave function reaches zero abruptly on the right, indicating an infinitely high potential-energy wall. The exponential decay on the left shows that the left wall of the potential energy is *not* infinitely high. The node spacing and the amplitude increase steadily in going from right to left, indicating a *steadily* decreasing kinetic energy and thus a steadily increasing potential energy.
5. **c.** $E = (n - \frac{1}{2})\hbar\omega$, so $\frac{5}{2}\hbar\omega$ is the energy of the $n = 3$ state. An $n = 3$ state has 3 antinodes.
6. **b.** The probability of tunneling through the barrier increases as the difference between E and U_0 decreases. If the tunneling probability increases, the reflection probability must decrease.

Exercises and Problems

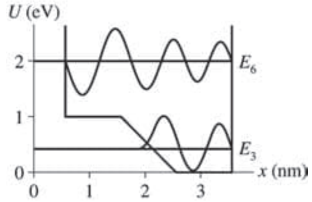
1. a. Infrared b. 1.5 nm
3. 21 eV
5. 17 eV
9. a. 0.159 nm b. 0.195 nm c. 0.275 nm
11. 1.14×10^{-12}m
13.



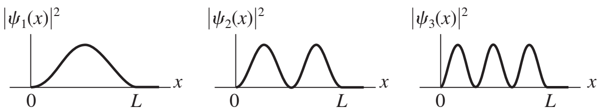
15. a.



b.



17. a. 0.49 eV, 1.5 eV, 2.4 eV b. 640 nm
19. 1.4 N/m
21. 519 nm
25. 0.0006%
27. a. 250,000,000
29. a. 37.7 eV, 151 eV, 339 eV, 603 eV
b. 11.0 nm, 4.12 nm, 6.59 nm, 2.20 nm, 2.75 nm, 4.71 nm
c. Ultraviolet
33.



$n =$	1	2	3
b. Most likely	$\frac{1}{2}L$	$\frac{1}{4}L, \frac{3}{4}L$	$\frac{1}{6}L, \frac{3}{6}L, \frac{5}{6}L$
c. Least likely	$0, L$	$0, \frac{1}{2}L, L$	$0, \frac{1}{3}L, \frac{2}{3}L, L$
d. Prob in left $\frac{1}{3}$ from graph	$< \frac{1}{3}$	$> \frac{1}{3}$	$\frac{1}{3}$
e. Prob in left $\frac{1}{3}$ calculated	0.195	0.402	0.333

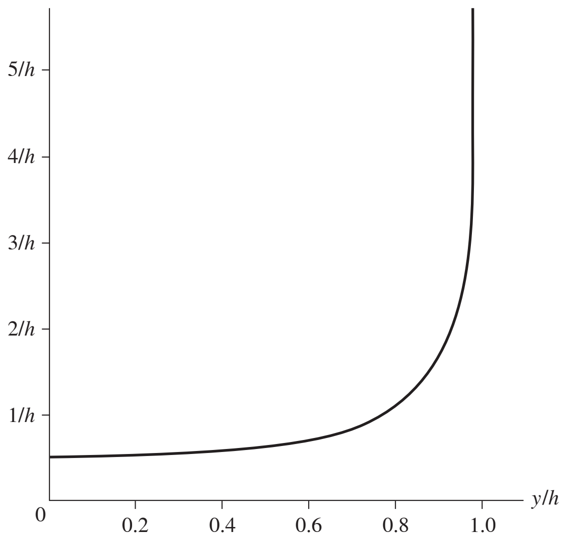
35. 10%
37. a. 0.15 nm b. One atomic diameter

39. a. $A_1 = \dfrac{1}{(\pi b^2)^{1/4}}$

b. $\text{Prob}(x < -b \text{ or } x > b) = \dfrac{2}{\sqrt{\pi b^2}}\displaystyle\int_b^{\infty} e^{-x^2/b^2}dx$ c. 15.7%

41. a. $P_{\text{class}}(y) = \left(\dfrac{1}{2h}\right)\dfrac{1}{\sqrt{1-(y/h)}}$

b.



43. $\frac{1}{4}$ of the radius
45. 0.012
47. 9.7%
49. $10^{-1.17\times 10^{32}}$

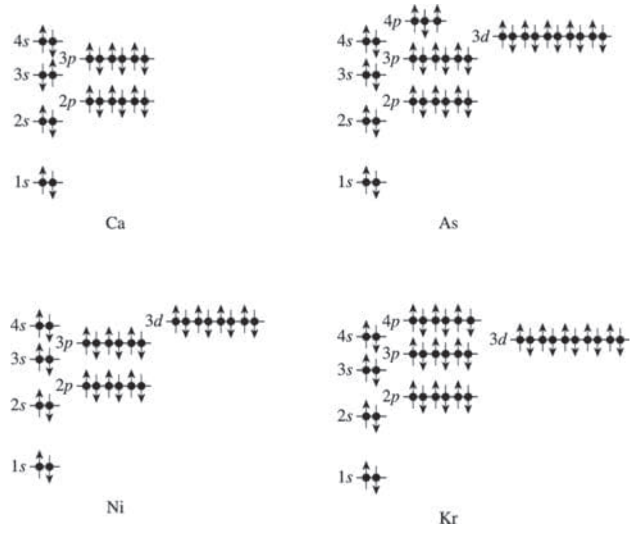
Chapter 41

Stop to Think Questions

1. **$n = 3, l = 1$, or a $3p$ state.**
2. You can see in Figure 41.7 that the ns state has n maxima.
3. **No.** $m_s = \pm\frac{1}{2}$, so the z-component S_z cannot be zero.
4. **b.** The atom would have less energy if the $3s$ electron were in a $2p$ state.
5. **c.** Emission is a quantum jump to a lower-energy state. The $5p \rightarrow 4p$ transition is not allowed because $\Delta l = 0$ violates the selection rule. The lowest-energy allowed transition is $5p \rightarrow 3d$, with $E_{\text{photon}} = \Delta E_{\text{atom}} = 3.0$ eV.
6. **b.** Because $r_B = 2r_A$, the ratio is $e^{-2}/e^{-1} = e^{-1} < \frac{1}{2}$.

Exercises and Problems

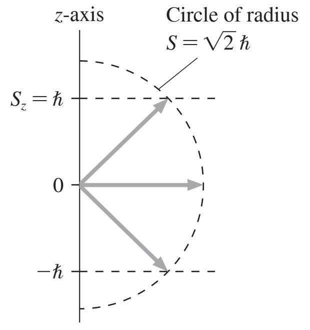
1. a. (3, 1, 1), (3, 1, 0), (3, 1, −1)
   b. (3, 2, 2), (3, 2, 1), (3, 2, 0), (3, 2,−1), (3, 2, −2)
3. $\sqrt{20}\hbar$
5. a. f b. −0.850 eV
7. For $n = 1$, 2 states: $\left(1, 0, 0, \pm\frac{1}{2}\right)$;
   for $n = 2$, 8 states: $\left(2, 0, 0, \pm\frac{1}{2}\right)$,
   $\left(2, 1, -1, \pm\frac{1}{2}\right)$, $\left(2, 1, 0, \pm\frac{1}{2}\right)$, $\left(2, 1, 1, \pm\frac{1}{2}\right)$;
   for $n = 3$, 18 states: $\left(3, 0, 0, \pm\frac{1}{2}\right)$, $\left(3, 1, -1, \pm\frac{1}{2}\right)$,
   $\left(3, 1, 0, \pm\frac{1}{2}\right)$, $\left(3, 1, 1, \pm\frac{1}{2}\right)$, $\left(3, 2, 2, \pm\frac{1}{2}\right)$,
   $\left(3, 2, 1, \pm\frac{1}{2}\right)$, $\left(3, 2, 0, \pm\frac{1}{2}\right)$, $\left(3, 2, -1, \pm\frac{1}{2}\right)$, $\left(3, 2, -2, \pm\frac{1}{2}\right)$
9. $1s^22s^22p^63s^23p$, $1s^22s^22p^63s^23p^64s^23d^{10}4p$, $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p$
11. a. Excited state of Ne b. Ground state of Ti
13.



15. $1s^23s$
17.

Transition	E_{photon} (eV)	λ (nm)
3 → 2	1.89	656
3 → 1	12.09	102
2 → 1	10.20	122

19. 2.0%
21. 32 ns
23. a. 953 nm b. 4.16 W
25. a. 190 nm b. 50 kW
27. a. $\sqrt{2}\hbar$ b. −1, 0, or 1
    c.



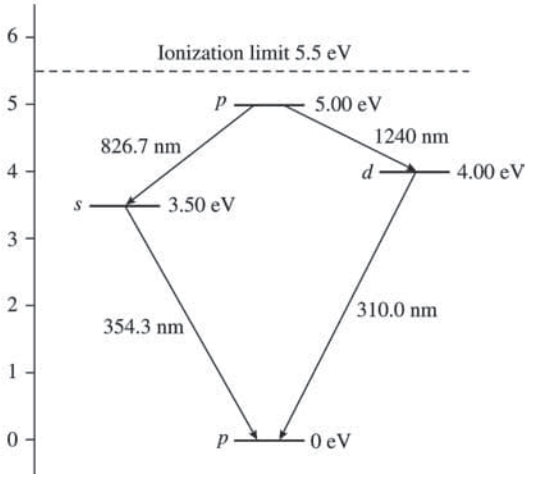
29. $\sqrt{6}\hbar$
31. a. 3.7×10^{-3} b. 5.4×10^{-3} c. 2.9×10^{-3}
37. a.

L_z	S_z	J_z	m_j
$\hbar$	$+\frac{1}{2}\hbar$	$\frac{3}{2}\hbar$	$\frac{3}{2}$
$\hbar$	$-\frac{1}{2}\hbar$	$\frac{1}{2}\hbar$	$\frac{1}{2}$
0	$+\frac{1}{2}\hbar$	$\frac{1}{2}\hbar$	$\frac{1}{2}$
0	$-\frac{1}{2}\hbar$	$-\frac{1}{2}\hbar$	$-\frac{1}{2}$
$-\hbar$	$+\frac{1}{2}\hbar$	$-\frac{1}{2}\hbar$	$-\frac{1}{2}$
$-\hbar$	$-\frac{1}{2}\hbar$	$-\frac{3}{2}\hbar$	$-\frac{3}{2}$

b. $j = \frac{1}{2}$: $(\frac{1}{2}\hbar, -\frac{1}{2}\hbar)$, $j = \frac{3}{2}$: $(\frac{3}{2}\hbar, \frac{1}{2}\hbar, -\frac{1}{2}\hbar, -\frac{3}{2}\hbar)$

39. 4.59 eV

41.

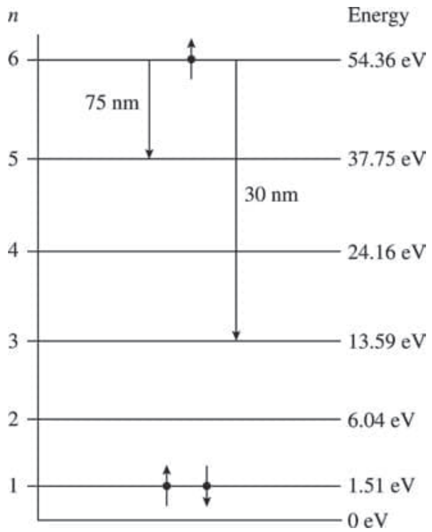


43. a.

Transition	ΔE (eV)	λ (nm)
$6p \rightarrow 6s$	6.70	185
$6d \rightarrow 6p$	2.14	579
$7s \rightarrow 6p$	1.22	1016
$7p \rightarrow 6s$	8.84	140
$7p \rightarrow 7s$	0.92	1350
$8s \rightarrow 6p$	2.52	492
$8s \rightarrow 7p$	0.38	3260
$8p \rightarrow 6s$	9.53	130
$8p \rightarrow 7s$	1.61	770
$8p \rightarrow 8s$	0.31	4000
$8p \rightarrow 6d$	0.69	1800

b. 1.80×10^6 m/s

45. a.



b. 28.7 eV

47. a. 6.3×10^8 s^{-1} b. 0.17 ns
49. 3.5×10^{18} atoms
51. a. $p_{\text{atom}} = 7.0 \times 10^{-23}$ kg m/s; $p_{\text{photon}} = -8.50 \times 10^{-28}$ kg m/s
b. 82×10^3 photons c. 1.2 ms
d. -5.7×10^{-20} N, $-4/0 \times 10^5$ m/s^2 e. 31 cm
53. b. 0.021 nm
57. 5.7 ns

Chapter 42

Stop to Think Questions

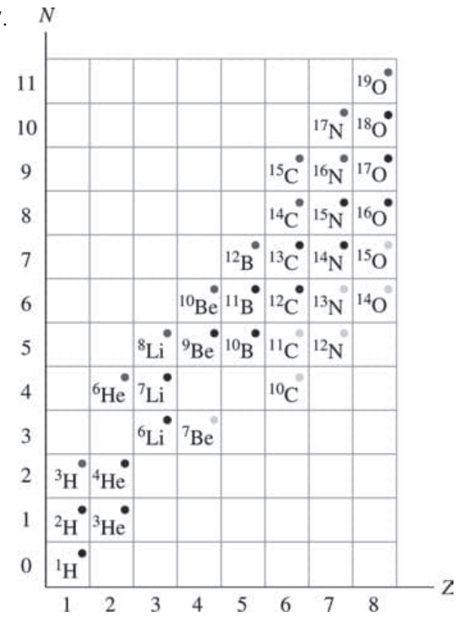
1. **3.** Different isotopes of an element have different numbers of neutrons but the same number of protons. The number of electrons in a neutral atom matches the number of protons.
2. **c.** To keep A constant, increasing N by 1 (going up) requires decreasing Z by 1 (going left).
3. **No.** A Geiger counter responds only to ionizing radiation. Visible light is not ionizing radiation.
4. **c.** One-quarter of the atoms are left. This is one-half of one-half, or $(1/2)^2$.
5. **b.** An increase of Z with no change in A occurs when a neutron changes to a proton and an electron, ejecting the electron.

Exercises and Problems

1.

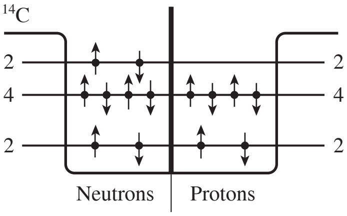
		Protons	Neutrons
a.	^{6}Li	3	3
b.	^{54}Cr	24	30
c.	^{54}Fe	26	28
d.	^{220}Rn	86	134

3. a. 3.8 fm b. 9.2 fm c. 14.9 fm
5. Silicon
7.

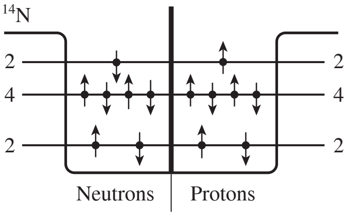


9. ^{2}H: 2.224 MeV, 1.11 MeV; ^{4}He: 28.29 MeV, 7.07 MeV
11. ^{2}He: 2.224 MeV, 1.11 MeV; ^{3}He: 8.48 MeV, 2.83 MeV
13. 8000 N
15. 2.3×10^{-38}

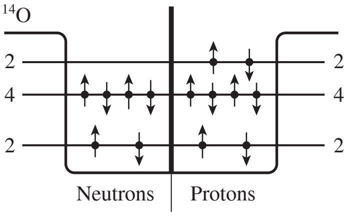
17. a. ^{14}C



^{14}N



^{14}O



b. ^{14}N: stable, ^{14}C: beta-minus decay, ^{14}O: beta-plus decay

19. a. 10 h b. 38 h
21. 4.6×10^9
23. 80 d
25. 9.9 mm
27. a. ^{226}Ra b. ^{35}Cl c. ^{40}Ca d. ^{24}Mg
29. a. ^{19}O, ^{19}F, ^{19}Ne b. ^{17}O
    c. ^{19}O decays by β^- to ^{19}F; ^{19}Ne decays by β^+ to ^{19}F
31. 4.91 MeV
33. 0.0186 MeV
35. 2.0 Gy
37. 6.0 Gy
39. a. 3.5×10^7 m/s b. 26 MeV
41. a. 12.7 km b. 780 μs
43. a. 1.46×10^{-8} u, 1.45×10^{-6}% b. 0.0304 u, 76%
45. 170 MeV
47. 0.93 MeV
49. 17,100 y
51. a. 6.12×10^{-6} kg b. 130 y
53. a. $m(^A X_Z) > m(^A Y_{Z-1}) + 2m_e$ b. 120 MeV
55. a. 3.32 b. 6.64
57. $\dfrac{(N_U)_0}{N_U} = 86$
59. 2.3×10^{12}
61. a. 24 mBq b. 7.5×10^5
63. 6 billion years
65. a. $K_{in} = 65.0$ MeV; $K_{out} = 5.0$ MeV b. 3.7×10^{21} collisions/s
    c. 6.6×10^{-39} d. 650 million years