53. (a) 26 J (b) 9.0×10^5 J (c) 9.0×10^5 J
55. (a) 2.49 kJ (b) 1.50 kJ (c) −990 J
57. (a) 0.554 (or 55.4%) (b) The Carnot efficiency is 0.749 (or 74.9%)
59. (a) 2.6×10^3 metric tons/day (b) \$$7.7 \times 10^6$/yr (c) 4.1×10^4 kg/s
61. (a) 10 J (b) No work is done; $\Delta U = 42$ J
63. 0.146; 486 kcal

Chapter 13

QUICK QUIZZES

1. (d)
2. (c)
3. (b)
4. (a)
5. (c)
6. (d)
7. (c), (b)
8. (a)
9. (b)

CONCEPTUAL QUESTIONS

1. It will increase. The speed of the wave varies inversely with the mass per unit length of the rope, so it is higher in the lighter rope. The frequency is unchanged as the wave passes from one rope to the other one. The wavelength is $\lambda = v/f$, so with the frequency constant and the speed increasing, the wavelength must increase.

3. No. Because the total energy is $E = \frac{1}{2}kA^2$, changing the mass of the object while keeping A constant has no effect on the total energy. When the object is at a displacement x from equilibrium, the potential energy is $\frac{1}{2}kx^2$, independent of the mass, and the kinetic energy is $KE = E - \frac{1}{2}kx^2$, also independent of the mass.

5. When the spring with two objects on opposite ends is set into oscillation in space, the coil at the exact center of the spring does not move. Thus, we can imagine clamping the center coil in place without affecting the motion. If we do this, we have two separate oscillating systems, one on each side of the clamp. The half-spring on each side of the clamp has twice the spring constant of the full spring, as shown by the following argument: The force exerted by a spring is proportional to the separation of the coils as the spring is extended. Imagine that we extend a spring by a given distance and measure the distance between coils. We then cut the spring in half. If one of the half-springs is now extended by the same distance, the coils will be twice as far apart as they were in the complete spring. Thus, it takes twice as much force to stretch the half-spring, from which we conclude that the half-spring has a spring constant which is twice that of the complete spring. Hence, our clamped system of objects on two half-springs will vibrate with a frequency that is higher than f by a factor of the square root of two.

7. The bouncing ball is not an example of simple harmonic motion. The ball does not follow a sinusoidal function for its position as a function of time. The daily movement of a student is also not simple harmonic motion, since the student stays at a fixed location—school—for a long time. If this motion were sinusoidal, the student would move more and more slowly as she approached her desk, and as soon as she sat down at the desk, she would start to move back toward home again.

9. We assume that the buoyant force acting on the sphere is negligible in comparison to its weight, even when the sphere is empty. We also assume that the bob is small compared with the pendulum length. Then, the frequency of the pendulum is $f = 1/T = (1/2\pi)\sqrt{g/L}$, which is independent of mass. Thus, the frequency will not change as the water leaks out.

11. As the temperature increases, the length of the pendulum will increase due to thermal expansion, and with a greater length, the period of the pendulum increases. Thus, it takes longer to execute each swing, so that each second according to the clock will take longer than an actual second. Consequently, the clock will run slow.

13. A pulse in a long line of people is longitudinal, since the movement of people is parallel to the direction of propagation of the pulse. The speed is determined by the reaction time of the people and the speed with which they can move once a space opens up. There is also a psychological factor, in that people will not want to fill a space that opens up in front of them too quickly, so as not to intimidate the person in front of them. The "wave" at a stadium is transverse, since the fans stand up vertically as the wave sweeps past them horizontally. The speed of this pulse depends on the limits of the fans' abilities to rise and sit rapidly and on psychological factors associated with the anticipation of seeing the pulse approach the observer's location.

15. A wave on a massless string would have an infinite speed of propagation, because the linear mass density of the string is zero.

17. The kinetic energy is proportional to the square of the speed, and the potential energy is proportional to the square of the displacement. Therefore, both must be positive quantities.

19. From $v = \sqrt{F/\mu}$, we see that increasing the tension by a factor of four doubles the wave speed.

PROBLEMS

1. (a) 24 N toward the equilibrium position (b) 60 m/s² toward the equilibrium position.
3. (b) 1.81 s (c) No, the force is not of the form of Hooke's law.
5. 0.242 kg
7. (a) 60 J (b) 49 m/s
9. 2.94×10^3 N/m
11. (a) $PE = E/4$ $KE = 3E/4$ (b) $x = A/\sqrt{2}$
13. 0.478 m
15. (a) 0.28 m/s (b) 0.26 m/s (c) 0.26 m/s (d) 3.5 cm
17. 39.2 N
19. (a) You observe uniform circular motion projected on a plane perpendicular to the motion. (b) 0.628 s
21. The horizontal displacement is described by $x(t) = A\cos\omega t$, where A is the distance from the center of the wheel to the crankpin.
23. 0.63 s
25. (a) 1.0 s (b) 0.28 m/s (c) 0.25 m/s
27. (a) 11.0 N toward the left (b) 0.881 oscillations
29. $v = \pm\,\omega A \sin\omega t$, $a = -\,\omega^2 A\cos\omega t$
31. 105 complete oscillations
33. (a) slow (b) 9:47 A.M.
35. (a) $L_{Earth} = 25$ cm, $L_{Mars} = 9.4$ cm, (b) $m_{Earth} = m_{Mars} = 0.25$ kg

37. (a) 9.00 cm (b) 20.0 cm (c) 40.0 ms (d) 5.00 m/s
39. (a) 11.4 ns (b) 3.41 m
41. 31.9 cm
43. 80.0 N
45. (a) 30.0 N (b) 25.8 m/s
47. 28.5 m/s
49. (a) 0.051 kg/m (b) 20 m/s
51. 13.5 N
53. (a) Constructive interference gives $A = 0.50$ m (b) Destructive interference gives $A = 0.10$ m
55. 6.62 cm
57. (a) 588 N/m (b) 0.700 m/s
59. 1.1 m/s
61. (a) 15.8 rad/s (b) 5.23 cm
63. $F_{\text{tangential}} = -[(\rho_{\text{air}} - \rho_{\text{He}})Vg/L]s$, $T = 1.40$ s
67. (a) 0.50 m/s (b) 8.6 cm
69. (a) the longitudinal wave (b) 11.1 min
71. (a) 0.50 m/s (b) 0.39 m/s (c) 5.0 cm

Chapter 14

QUICK QUIZZES

1. (c)
2. (c)
3. (b)
4. (b), (e)
5. (d)
6. (a)
7. (b)

CONCEPTUAL QUESTIONS

1. (a) higher (b) lower

3. The camera is designed to operate at an assumed speed of sound of 345 m/s, the speed of sound at a room temperature of 23°C. If the temperature should decrease to, say, 0°C, the speed of sound will also decrease, and the camera will respond to the fact that it takes longer for the sound to make its round trip. Thus, it will operate as if the object is farther away than it really is.

It is of interest to note that bats use echo sounding like this to locate insects or to avoid obstacles in front of them, something that they must do because of poor eyesight and the high speeds at which they fly. Likewise, blue whales use this technique to help them avoid objects in their path. The need here is obvious, because a typical whale has a mass of 10^5 kg and travels at a relatively fast speed of 20 mi/h, so it takes a long time for it to stop its motion or to change direction.

5. Sophisticated electronic devices break the frequency range of about 60 to 4 000 Hz used in telephone conversations into several frequency bands and then mix them in a predetermined pattern so that they become unintelligible. The descrambler, of course, moves the bands back into their proper order.

7. A rise in temperature will increase the dimensions of the wind instrument much less than it increases the speed of sound in the enclosed air. This effect will raise the resonant frequencies that are produced by the instrument, which will go sharp as the temperature increases and go flat as the temperature decreases.

9. The echo is Doppler shifted, and the shift is like both a moving source and a moving observer. The sound that leaves your horn in the forward direction is Doppler shifted to a higher frequency, because it is coming from a moving source. As the sound reflects back and comes towards you, you are a moving observer, so there is a second Doppler shift to an even higher frequency. If the sound reflects from the spacecraft coming towards you, there is a different moving-source shift to an even higher frequency. The reflecting surface of the spacecraft acts as a moving source.

11. The center of the string is a node for the second harmonic, as well as for every even-numbered harmonic. By placing the finger at the center and plucking, the guitarist is eliminating any harmonic which does not have a node at that point—that is, all the odd harmonics. The even harmonics can vibrate relatively freely with the finger at the center because they exhibit no displacement at that point. The result is a sound with a mixture of frequencies that are integer multiples of the second harmonic, which is one octave higher than the fundamental.

13. The bowstring is pulled away from equilibrium and released, in a manner similar to the way a guitar string is pulled and released when it is plucked. Thus, standing waves will be excited in the bowstring. If the arrow leaves from the exact center of the string, then a series of odd harmonics will be excited. Even harmonics will not be excited, because they have a node at the point where the string exhibits its maximum displacement.

15. At the instant at which there is no displacement of the string, the string is still moving. Thus, the energy is present at that instant entirely as kinetic energy of the string.

17. As the whistle is approaching you, the sound is Doppler shifted to a frequency higher than the natural frequency of the whistle. You will momentarily hear the natural frequency just as the whistle comes parallel with you and is in the act of passing. As soon as the whistle is past, you will hear sound that is Doppler shifted to a frequency lower than the natural frequency of the whistle. As the frequency of the sound steps down from one constant value to a second one, the intensity of the sound varies continuously. The loudness increases smoothly to a maximum and then decreases.

19. The two engines are running at slightly different frequencies, thus producing a beat frequency between them.

PROBLEMS

1. 5.56 km
3. 32°C
5. 516 m
7. 1.99 km
9. (a) 1.00×10^{-2} W/m^2 (b) 105 dB
11. 37 dB
13. 9 additional machines
15. 66.0 dB
17. (a) 1.3×10^2 W (b) 96 dB
21. (a) 75.2-Hz drop (b) 0.953 m
23. 595 Hz
25. 0.391 m/s
27. 19.3 m
29. 48°
31. 800 m
33. (a) 0.240 m (b) 0.855 m
35. (a) Nodes at 0, 2.67 m, 5.33 m, and 8.00 m; antinodes at 1.33 m, 4.00 m, and 6.67 m (b) 18.6 Hz

37. At 0.0891 m, 0.303 m, 0.518 m, 0.732 m, 0.947 m, and 1.16 m from one speaker.
39. (a) 79 N (b) 2.1×10^2 Hz
41. 19.976 kHz
43. 58 Hz
45. 3.0 kHz
47. (a) 0.552 m (b) 317 Hz
49. 5.26 beats/s
51. 3.79 m/s toward the station, 3.88 m/s away from the station
53. (a) 1.98 beats/s (b) 3.40 m/s
55. 1.76 cm
57. 262 kHz
59. 64 dB
61. 439 Hz and 441 Hz
63. 32.9 m/s
65. 3.97 beats/s
67. 1.34×10^4 N
69. 1 204 Hz
71. (a) 617 m (b) 154 m/s

Chapter 15

QUICK QUIZZES

1. (b)
2. (b)
3. (c)
4. (a)
5. (c) and (d)
6. (a)
7. (c)
8. (b)
9. (d)
10. (b) and (d)

CONCEPTUAL QUESTIONS

1. Electrons have been removed from the object.
3. The configuration shown is inherently unstable. The negative charges repel each other. If there is any slight rotation of one of the rods, the repulsion can result in further rotation away from this configuration. There are three conceivable final configurations shown below. Configuration (a) is stable: If the positive upper ends are pushed towards each other, their mutual repulsion will move the system back to the original configuration. Configuration (b) is an equilibrium configuration, but it is unstable: If the lower ends are moved towards each other, their mutual attraction will be larger than that of the upper ends, and the configuration will shift to (c), another possible stable configuration.

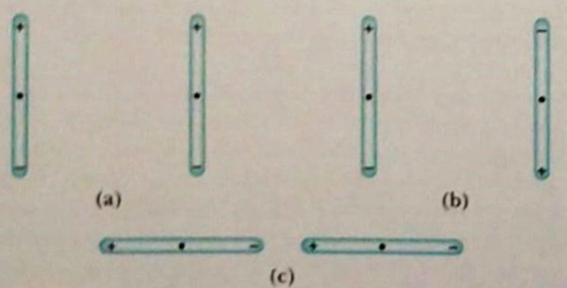


Figure Q15.3

5. Move an object *A* with a net positive charge so it is near, but not touching, a neutral metallic object *B* that is insulated from the ground. The presence of *A* will polarize *B*, causing an excess negative charge to exist on the side nearest *A* and an excess positive charge of equal magnitude to exist on the side farthest from *A*. While *A* is still near *B*, touch *B* with your hand. Additional electrons will then flow from ground, through your body and onto *B*. With *A* continuing to be near but not in contact with *B*, remove your hand from *B*, thus trapping the excess electrons on *B*. When *A* is now removed, *B* is left with excess electrons, or a net negative charge. By means of mutual repulsion, this negative charge will now spread uniformly over the entire surface of *B*.
7. An object's mass decreases very slightly (immeasurably) when it is given a positive charge, because it loses electrons. When the object is given a negative charge, its mass increases slightly because it gains electrons.
9. Electric field lines start on positive charges and end on negative charges. Thus, if the fair-weather field is directed into the ground, the ground must have a negative charge.
11. The two charged plates create a region with a uniform electric field between them, directed from the positive toward the negative plate. Once the ball is disturbed so as to touch one plate (say, the negative one), some negative charge will be transferred to the ball and it will be acted upon by an electric force that will accelerate it to the positive plate. Once the ball touches the positive plate, it will release its negative charge, acquire a positive charge, and accelerate back to the negative plate. The ball will continue to move back and forth between the plates until it has transferred all their net charge, thereby making both plates neutral.
13. The electric shielding effect of conductors depends on the fact that there are two kinds of charge: positive and negative. As a result, charges can move within the conductor so that the combination of positive and negative charges establishes an electric field that exactly cancels the external field within the conductor and any cavities inside the conductor. There is only one type of gravitation charge, however, because there is no negative mass. As a result, gravitational shielding is not possible.
15. The electric field patterns of each of these three configurations do not have sufficient symmetry to make the calculations practical. Gauss's law is useful only for calculating the electric fields of highly symmetric charge distributions, such as uniformly charged spheres, cylinders, and sheets.
17. No, the wall is not positively charged. The balloon induces a charge of opposite sign in the wall, causing the balloon and the wall to be attracted to each other. The balloon eventually falls because its charge slowly diminishes as it leaks to ground. Some of the balloon's charge could also be lost due to positive ions in the surrounding atmosphere, which would tend to neutralize the negative charges on the balloon.
19. When the comb is nearby, charges separate on the paper, and the paper is attracted to the comb. After contact, charges from the comb are transferred to the paper, so that it has the same type of charge as the comb. The paper is thus repelled.
21. The attraction between the ball and the object could be an attraction of unlike charges, or it could be an attrac-

tion between a charged object and a neutral object as a result of polarization of the molecules of the neutral object. Two additional experiments could help us determine whether the object is charged. First, a known neutral ball could be brought near the object, and if there is an attraction, the object is negatively charged. Another possibility is to bring a known negatively charged ball near the object. In that case, if there is a repulsion, then the object is negatively charged. If there is an attraction, then the object is neutral.

PROBLEMS

1. 1.1×10^{-8} N (attractive)
3. 91 N (repulsion)
5. (a) 36.8 N (b) 5.54×10^{27} m/s^2
7. 5.12×10^5 N
9. (a) 2.2×10^{-5} N (attraction) (b) 9.0×10^{-7} N (repulsion)
11. 1.38×10^{-5} N at 77.5° below the negative x-axis
13. 0.872 N at 30.0° below the positive x-axis
15. 7.2 nC
17. 1.5×10^{-3} C
19. 7.20×10^5 N/C (downward)
21. 1.2×10^4 N/C
23. (a) 6.12×10^{10} m/s^2 (b) 19.6 μs (c) 11.8 m (d) 1.20×10^{-15} J
25. zero
27. 1.8 m to the left of the -2.5-μC charge
33. (a) 0 (b) 5 μC inside, -5 μC outside (c) 0 inside, -5 μC outside (d) 0 inside, -5 μC outside
35. 1.3×10^{-3} C
37. (a) 4.8×10^{-15} N (b) 2.9×10^{12} m/s^2
39. (a) 858 N·m^2/C (b) 0 (c) 657 N·m^2/C
41. 4.1×10^6 N/C
43. (a) 0 (b) $k_e q/r^2$ outward
47. 57.5 N
49. 24 N/C in the positive x-direction
51. (a) $E = 2k_e qb\,(a^2 + b^2)^{-3/2}$ in the positive x-direction (b) $E = k_e Qb(a^2 + b^2)^{-3/2}$ in the positive x-direction
53. (a) 0 (b) 7.99×10^7 N/C (outward) (c) 0 (d) 7.34×10^6 N/C (outward)
55. 3.55×10^5 N·m^2/C
57. 4.4×10^5 N/C
59. (a) 10.9 nC (b) 5.44×10^{-3} N
61. $\sim 10^{-7}$ C
63. (a) 1.00×10^3 N/C (b) 3.37×10^{-8} s (c) accelerate at 1.76×10^{14} m/s^2 in the direction opposite that of the electric field

Chapter 16

QUICK QUIZZES

1. (b)
2. (b), (d)
3. (d)
4. (c)
5. (a)
6. (c)
7. (a) C decreases. (b) Q stays the same. (c) E stays the same. (d) ΔV increases. (e) The energy stored increases.
8. (a) C increases. (b) Q increases. (c) E stays the same. (d) ΔV remains the same. (e) The energy stored increases.
9. (a)

CONCEPTUAL QUESTIONS

1. (a) The proton moves in a straight line with constant acceleration in the direction of the electric field. (b) As its velocity increases, its kinetic energy increases and the electric potential energy associated with the proton decreases.
3. The work done in pulling the capacitor plates farther apart is transferred into additional electric energy stored in the capacitor. The charge is constant and the capacitance decreases, but the potential difference between the plates increases, which results in an increase in the stored electric energy.
5. If the power line makes electrical contact with the metal of the car, it will raise the potential of the car to 20 kV. It will also raise the potential of your body to 20 kV, because you are in contact with the car. In itself, this is not a problem. If you step out of the car, however, your body at 20 kV will make contact with the ground, which is at zero volts. As a result, a current will pass through your body and you will likely be injured. Thus, it is best to stay in the car until help arrives.
7. If two points on a conducting object were at different potentials, then free charges in the object would move and we would not have static conditions, in contradiction to the initial assumption. (Free positive charges would migrate from locations of higher to locations of lower potential. Free electrons would rapidly move from locations of lower to locations of higher potential.) All of the charges would continue to move until the potential became equal everywhere in the conductor.
9. The capacitor often remains charged long after the voltage source is disconnected. This residual charge can be lethal. The capacitor can be safely handled after discharging the plates by short-circuiting the device with a conductor, such as a screwdriver with an insulating handle.
11. Field lines represent the direction of the electric force on a positive test charge. If electric field lines were to cross, then, at the point of crossing, there would be an ambiguity regarding the direction of the force on the test charge, because there would be two possible forces there. Thus, electric field lines cannot cross. It is possible for equipotential surfaces to cross. (However, equipotential surfaces at different potentials cannot intersect.) For example, suppose two identical positive charges are at diagonally opposite corners of a square and two negative charges of equal magnitude are at the other two corners. Then the planes perpendicular to the sides of the square at their midpoints are equipotential surfaces. These two planes cross each other at the line perpendicular to the square at its center.
13. You should use a dielectric-filled capacitor whose dielectric constant is very large. Further, you should make the dielectric as thin as possible, keeping in mind that dielectric breakdown must also be considered.
15. (a) ii (b) i
17. It would make no difference at all. An electron volt is the kinetic energy gained by an electron in being accelerated through a potential difference of 1 V. A proton accelerated through 1 V would have the same kinetic energy, because it carries the same charge as the electron (except for the sign). The proton would be moving in the opposite direction and more slowly after accelerating through 1 V, due to its opposite charge and its larger mass, but it would still gain 1 electron volt, or 1 proton volt, of kinetic energy.

PROBLEMS

1. (a) 6.40×10^{-19} J (b) -6.40×10^{-19} J (c) -4.00 V
3. 1.4×10^{-20} J
5. 1.7×10^{6} N/C
7. (a) 1.13×10^{5} N/C (b) 1.80×10^{-14} N (c) 4.38×10^{-17} J
9. (a) 0.500 m (b) 0.250 m
11. (a) 1.44×10^{-7} V (b) -7.19×10^{-8} V
13. (a) 2.67×10^{6} V (b) 2.13×10^{6} V
15. (a) 103 V (b) -3.85×10^{-7} J; positive work must be done to separate the charges.
17. -11.0 kV
19. 2.74×10^{-14} m
21. 0.719 m, 1.44 m, 2.88 m. No. The equipotentials are not uniformly spaced. Instead, the radius of an equipotenial is inversely proportional to the potential.
23. (a) 1.1×10^{-8} F (b) 27 C
25. (a) 11.1 kV/m toward the negative plate (b) 3.74 pF (c) 74.7 pC and -74.7 pC
27. (a) 90.4 V (b) 9.04×10^{4} V/m
29. (a) 13.3 μC on each (b) 20.0 μC, 40.0 μC
31. (a) 2.00 μF (b) $Q_3 = 24.0\ \mu C$, $Q_4 = 16.0\ \mu C$, $Q_2 = 8.00\ \mu C$, $(\Delta V)_2 = (\Delta V)_4 = 4.00$ V, $(\Delta V)_3 = 8.00$ V
33. (a) 5.96 μF (b) $Q_{20} = 89.5\ \mu C$, $Q_6 = 63.2\ \mu C$, $Q_3 = Q_{15} = 26.3\ \mu C$
35. $Q_1 = 16.0\ \mu C$, $Q_5 = 80.0\ \mu C$, $Q_8 = 64.0\ \mu C$, $Q_4 = 32.0\ \mu C$
37. (a) $Q_{25} = 1.25$ mC, $Q_{40} = 2.00$ mC (b) $Q'_{25} = 288\ \mu C$, $Q'_{40} = 462\ \mu C$, $\Delta V = 11.5$ V
39. $Q'_1 = 3.33\ \mu C$, $Q'_2 = 6.67\ \mu C$
41. 83.6 μC
43. 2.55×10^{-11} J
45. 3.2×10^{10} J
47. $\kappa = 4.0$
49. (a) 8.13 nF (b) 2.40 kV
51. (a) volume 9.09×10^{-16} m^3, area 4.54×10^{-10} m^2 (b) 2.01×10^{-13} F (c) 2.01×10^{-14} C, 1.26×10^{5} electronic charges
55. 4.29 μF
57. 6.25 μF
59. 4.47 kV
61. 0.75 mC on C_1, 0.25 mC on C_2
65. 50 N

Chapter 17

QUICK QUIZZES

1. (d)
2. (b)
3. (c), (d)
4. (b)
5. (b)
6. (a)
7. (b)
8. (a)

CONCEPTUAL QUESTIONS

1. Charge. Because an ampere is a unit of current (1 A = 1 C/s) and an hour is a unit of time (1 h = 3 600 s), then 1 A·h = 3 600 C.
3. The gravitational force pulling the electron to the bottom of a piece of metal is much smaller than the electrical repulsion pushing the electrons apart. Thus, free electrons stay distributed throughout the metal. The concept of charges residing on the surface of a metal is true for a metal with an excess charge. The number of free electrons in an electrically neutral piece of metal is the same as the number of positive ions—the metal has zero net charge.
5. A voltage is not something that "surges through" a completed circuit. A voltage is a potential difference that is applied across a device or a circuit. It would be more correct to say "1 ampere of electricity surged through the victim's body." Although this amount of current would have disastrous results on the human body, a value of 1 (ampere) doesn't sound as exciting for a newspaper article as 10 000 (volts). Another possibility is to write "10 000 volts of electricity were applied across the victim's body," which still doesn't sound quite as exciting.
7. We would conclude that the conductor is nonohmic.
9. The shape, dimensions, and the resistivity affect the resistance of a conductor. Because temperature and impurities affect the conductor's resistivity, these factors also affect resistance.
11. The radius of wire B is the square root of three times the radius of wire A. Therefore the cross-sectional area of B three times larger than that of A.
13. The drift velocity might increase steadily as time goes on, because collisions between electrons and atoms in the wire would be essentially nonexistent and the conduction electrons would move with constant acceleration. The current would rise steadily without bound also, because I is proportional to the drift velocity.
15. Once the switch is closed, the line voltage is applied across the bulb. As the voltage is applied across the cold filament when it is first turned on, the resistance of the filament is low, the current is high, and a relatively large amount of power is delivered to the bulb. As the filament warms, its resistance rises and the current decreases. As a result, the power delivered to the bulb decreases. The large current spike at the beginning of the bulb's operation is the reason that lightbulbs often fail just after they are turned on.

PROBLEMS

1. 3.00×10^{20} electrons move past in the direction opposite to the current.
3. 2.00 C
5. 1.05 mA
7. 27 yr
9. (a) n is unaffected (b) v_d is doubled
11. 32 V is 200 times larger than 0.16 V
13. 0.17 mm
15. (a) 30 Ω (b) 4.7×10^{-4} Ω·m
17. silver ($\rho = 1.59 \times 10^{-8}$ Ω·m)
19. 256 Ω
21. 1.98 A
23. 26 mA
25. (a) 5.89×10^{-2} Ω (b) 5.45×10^{-2} Ω
27. (a) 3.0 A (b) 2.9 A
29. (a) 1.2 Ω (b) 8.0×10^{-4} (a 0.080% increase)
31. 5.00 A, 24.0 Ω
33. 18 bulbs
35. 11.2 min
37. 34.4 Ω
39. 1.6 cm
41. 295 metric tons/h

43. 26 cents
45. 23 cents
47. \$1.2
49. 1.1 km
51. $1.47 \times 10^{-6}\ \Omega \cdot m$; differs by 2.0% from value in Table 17.1
53. (a) \$3.06 (b) No. The circuit must be able to handle at least 26 A.
55. (a) 667 A (b) 50.0 km
57. $3.77 \times 10^{28}/m^3$
59. (a) 144 Ω (b) 26 m (c) To fit the required length into a small space. (d) 25 m
61. 37 MΩ
63. 0.48 kg/s
65. (a) $2.6 \times 10^{-5}\ \Omega$ (b) 76 kg
67. (a) 470 W (b) 1.60 mm or more (c) 2.93 mm or more

Chapter 18

QUICK QUIZZES

1. (a), (d)
2. (b)
3. (a)
4. *Parallel*: (a) unchanged (b) unchanged (c) increase (d) decrease
5. *Series*: (a) decrease (b) decrease (c) decrease (d) increase
6. (c)

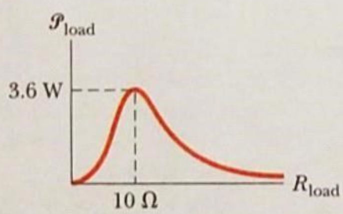
CONCEPTUAL QUESTIONS

1. No. When a battery serves as a source and supplies current to a circuit, the conventional current flows through the battery from the negative terminal to the positive one. However, when a source having a larger emf than the battery is used to charge the battery, the conventional current is forced to flow through the battery from the positive terminal to the negative one.
3. The total amount of energy delivered by the battery will be less than *W*. Recall that a battery can be considered an ideal, resistanceless battery in series with the internal resistance. When the battery is being charged, the energy delivered to it includes the energy necessary to charge the ideal battery, plus the energy that goes into raising the temperature of the battery due to I^2r heating in the internal resistance. This latter energy is not available during discharge of the battery, when part of the reduced available energy again transforms into internal energy in the internal resistance, further reducing the available energy below *W*.
5. The starter in the automobile draws a relatively large current from the battery. This large current causes a significant voltage drop across the internal resistance of the battery. As a result, the terminal voltage of the battery is reduced, and the headlights dim accordingly.
7. An electrical appliance has a given resistance. Thus, when it is attached to a power source with a known potential difference, a definite current will be drawn, and the device can therefore be labeled with both the voltage and the current. Batteries, however, can be applied to a number of devices. Each device will have a different resistance, so the current will vary with the device. As a result, only the voltage of the battery can be specified.
9. Connecting batteries in parallel does not increase the emf. A high-current device connected to two batteries in parallel can draw currents from both batteries. Thus, connecting the batteries in parallel increases the possible current output and, therefore, the possible power output.
11. The lightbulb will glow for a very short while as the capacitor is being charged. Once the capacitor is almost totally charged, the current in the circuit will be nearly zero and the bulb will not glow.
13. The bird is resting on a wire of fixed potential. In order to be electrocuted, a large potential difference is required between the bird's feet. The potential difference between the bird's feet is too small to harm the bird.
15. The junction rule is a statement of conservation of charge. It says that the amount of charge that enters a junction in some time interval must equal the charge that leaves the junction in that time interval. The loop rule is a statement of conservation of energy. It says that the increases and decreases in potential around a closed loop in a circuit must add to zero.
17. A few of the factors involved are as follows: the conductivity of the string (is it wet or dry?); how well you are insulated from ground (are you wearing thick rubber- or leather-soled shoes?); the magnitude of the potential difference between you and the kite; and the type and condition of the soil under your feet.
19. She will not be electrocuted if she holds onto only one high-voltage wire, because she is not completing a circuit. There is no potential difference across her body as long as she clings to only one wire. However, she should release the wire immediately once it breaks, because she will become part of a closed circuit when she reaches the ground or comes into contact with another object.
21. (a) The intensity of each lamp increases because lamp C is short circuited and there is current (which increases) only in lamps A and B. (b) The intensity of lamp C goes to zero because the current in this branch goes to zero. (c) The current in the circuit increases because the total resistance decreases from $3R$ (with the switch open) to $2R$ (after the switch is closed). (d) The voltage drop across lamps A and B increases, while the voltage drop across lamp C becomes zero. (e) The power dissipated increases from $\mathcal{E}^2/3R$ (with the switch open) to $\mathcal{E}^2/2R$ (after the switch is closed).
23. The statement is false. The current in each bulb is the same, because they are connected in series. The bulb that glows brightest has the larger resistance and hence dissipates more power

PROBLEMS

1. 4.92 Ω
3. 73.8 W. Your circuit diagram will consist of two 0.800-Ω resistors in series with the 192-Ω resistance of the bulb.
5. (a) 17.1 Ω (b) 1.99 A for 4.00 Ω and 9.00 Ω, 1.17 A for 7.00 Ω, 0.818 A for 10.0 Ω
7. $2.5R$
9. (a) 0.227 A (b) 5.68 V
11. 55 Ω
13. 0.43 A
15. (a) Connect two 50-Ω resistors in parallel, and then connect this combination in series with a 20-Ω resistor.
    (b) Connect two 50-Ω resistors in parallel, connect two 20-Ω resistors in parallel, and then connect these two combinations in series with each other.

17. 0.846 A downwards in the 8.00-Ω resistor; 0.462 A downwards in the middle branch; 1.31 A upwards in the right-hand branch
19. (a) 3.00 mA (b) − 19.0 V (c) 4.50 V
21. 10.7 V
23. (a) 0.385 mA, 3.08 mA, 2.69 mA
(b) 69.2 V, with *c* at the higher potential
25. $I_1 = 3.5$ A, $I_2 = 2.5$ A, $I_3 = 1.0$ A
27. $I_{30} = 0.353$ A, $I_5 = 0.118$ A, $I_{20} = 0.471$ A
29. $\Delta V_2 = 3.05$ V, $\Delta V_3 = 4.57$ V, $\Delta V_4 = 7.38$ V, $\Delta V_5 = 1.62$ V
31. (a) 12 s (b) 1.2×10^{-4} C
33. 1.3×10^{-4} C
35. 0.982 s
37. (a) heater, 10.8 A; toaster, 8.33 A; grill, 12.5 A
(b) $I_{\text{total}} = 31.6$ A, so a 30-A breaker is insufficient.
39. (a) 6.25 A (b) 750 W
41. (a) 1.2×10^{-9} C, 7.3×10^{9} K^+ ions. Not large, only $1e/290\ \text{A}^2$
(b) 1.7×10^{-9} C, 1.0×10^{10} Na^+ ions (c) 0.83 μA
(d) 7.5×10^{-12} J
43. 11 nW
45. 7.5 Ω
47. (a) 15 Ω
(b) $I_1 = 1.0$ A, $I_2 = I_3 = 0.50$ A, $I_4 = 0.30$ A, and $I_5 = 0.20$ A
(c) $(\Delta V)_{ac} = 6.0$ V, $(\Delta V)_{ce} = 1.2$ V, $(\Delta V)_{ed} = (\Delta V)_{fd} = 1.8$ V, $(\Delta V)_{cd} = 3.0$ V, $(\Delta V)_{db} = 6.0$ V
(d) $\mathcal{P}_{ac} = 6.0$ W, $\mathcal{P}_{ce} = 0.60$ W, $\mathcal{P}_{ed} = 0.54$ W, $\mathcal{P}_{fd} = 0.36$ W, $\mathcal{P}_{cd} = 1.5$ W, $\mathcal{P}_{db} = 6.0$ W
49. (a) 12.4 V (b) 9.65 V
51. $I_1 = 0$, $I_2 = I_3 = 0.50$ A,
53. 112 V, 0.200 Ω
55. (a) $R_x = R_2 - \frac{1}{4}R_1$
(b) $R_x = 2.8\ \Omega$ (inadequate grounding)
59. $\mathcal{P} = \dfrac{(144\ \text{V}^2)R}{(R + 10.0\ \Omega)^2}$



61. (a) 5.68 V (b) 0.227 A
63. 0.395 A; 1.50 V

Chapter 19

QUICK QUIZZES

1. (b)
2. (c)
3. (c)
4. (a)
5. (b)

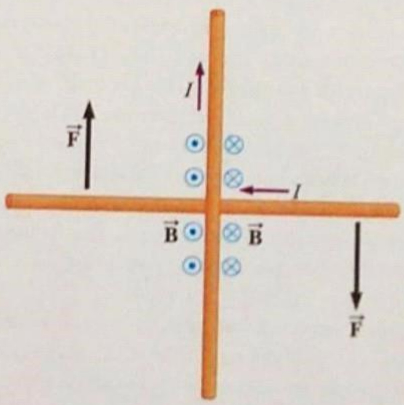
CONCEPTUAL QUESTIONS

1. The set should be oriented such that the beam is moving either toward the east or toward the west.
3. The proton moves in a circular path upwards on the page. After completing half a circle, it exits the field and moves in a straight-line path back in the direction from whence it came. An electron will behave similarly, but the direction of traversal of the circle is downward, and the radius of the circular path is smaller.
5. The magnetic force on a moving charged particle is always perpendicular to the particle's direction of motion. There is no magnetic force on the charge when it moves parallel to the direction of the magnetic field. However, the force on a charged particle moving in an electric field is never zero and is always parallel to the direction of the field. Therefore, by projecting the charged particle in different directions, it is possible to determine the nature of the field.
7. The magnetic field produces a magnetic force on the electrons moving toward the screen that produce the image. This magnetic force deflects the electrons to regions on the screen other than the ones to which they are supposed to go. The result is a distorted image.
9. Such levitation could never occur. At the North Pole, where Earth's magnetic field is directed downward, toward the equivalent of a buried south pole, a coffin would be repelled if its south magnetic pole were directed downward. However, equilibrium would be only transitory, as any slight disturbance would upset the balance between the magnetic force and the gravitational force.
11. If you were moving along with the electrons, you would measure a zero current for the electrons, so they would not produce a magnetic field according to your observations. However, the fixed positive charges in the metal would now be moving backwards relative to you, creating a current equivalent to the forward motion of the electrons when you were stationary. Thus, you would measure the same magnetic field as when you were stationary, but it would be due to the positive charges presumed to be moving from your point of view.
13. A compass does not detect currents in wires near light switches, for two reasons. The first is that, because the cable to the light switch contains two wires, one carrying current to the switch and the other carrying it away from the switch, the net magnetic field would be very small and would fall off rapidly with increasing distance. The second reason is that the current is alternating at 60 Hz. As a result, the magnetic field is oscillating at 60 Hz also. This frequency would be too fast for the compass to follow, so the effect on the compass reading would average to zero.
15. The levitating wire is stable with respect to vertical motion: If it is displaced upward, the repulsive force weakens, and the wire drops back down. By contrast, if it drops lower, the repulsive force increases, and it moves back up. The wire is not stable, however, with respect to lateral movement: If it moves away from the vertical position directly over the lower wire, the repulsive force will have a sideways component that will push the wire away.

In the case of the attracting wires, the hanging wire is not stable with respect to vertical movement. If it rises, the attractive force increases, and the wire moves even closer to the upper wire. If the hanging wire falls, the attractive force weakens, and the wire falls farther. If the wire moves to the right, it moves farther from the upper wire and the attractive force decreases. Although there is a restoring force component pulling it back to the left, the vertical force component is not strong enough to hold the wire up, and it falls.
17. Each coil of the Slinky® will become a magnet, because a coil acts as a current loop. The sense of rotation of the

current is the same in all coils, so each coil becomes a magnet with the same orientation of poles. Thus, all of the coils attract, and the Slinky® will compress.

19. There is no net force on the wires, but there is a torque. To understand this distinction, imagine a fixed vertical wire and a free horizontal wire (see the figure below). The vertical wire carries an upward current and creates a magnetic field that circles the vertical wire, itself. To the right, the magnetic field of the vertical wire points into the page, while on the left side it points out of the page, as indicated. Each segment of the horizontal wire (of length ℓ) carries current that interacts with the magnetic field according to the equation $F = BI\ell \sin\theta$. Apply the right-hand rule on the right side: point the fingers of your right hand in the direction of the horizontal current and curl them into the page in the direction of the magnetic field. Your thumb points downward, the direction of the force on the right side of the wire. Repeating the process on the left side gives a force upward on the left side of the wire. The two forces are equal in magnitude and opposite in direction, so the net force is zero, but they create a net torque around the point where the wires cross.



21. (a) The field is into the page. (b) The beam would deflect upwards.

PROBLEMS

1. (a) horizontal and due east (b) horizontal and 30° N of E (c) horizontal and due east (d) zero force
3. (a) into the page (b) toward the right (c) toward the bottom of the page
5. $F_g = 8.93 \times 10^{-30}$ N (downward), $F_e = 1.60 \times 10^{-17}$ N (upward), $F_m = 4.80 \times 10^{-17}$ N (downward)
7. 2.83×10^7 m/s west
9. 0.021 T in the $-y$-direction
11. 8.0×10^{-3} T in the $+z$-direction
13. (a) into the page (b) toward the right (c) toward the bottom of the page
15. 7.50 N
17. 0.131 T (downward)
19. 0.20 T directed out of the page
21. *ab*: 0, *bc*: 0.040 0 N in $-x$-direction, *cd*: 0.040 0 N in the $-z$-direction *da*: 0.056 6 N parallel to the *xz*-plane and at 45° to both the $+x$- and the $+z$-directions
23. 9.05×10^{-4} N·m, tending to make the left-hand side of the loop move toward you and the right-hand side move away.
25. (a) 3.97° (b) 3.39×10^{-3} N·m
27. 6.56×10^{-2} T
31. 1.77 cm
33. $r = 3R/4$
35. 20.0 μT
37. 2.4 mm
39. 20.0 μT toward bottom of page
41. 0.167 μT out of the page
43. (a) 4.00 m (b) 7.50 nT (c) 1.26 m (d) zero
45. 4.5 mm
47. 31.8 mA
49. 2.26×10^{-4} N away from the center, zero torque
51. 1.7 N·m
53. (a) 0.500 μT out of the page (b) 3.89 μT parallel to *xy*-plane and at 59.0° clockwise from $+x$-direction
55. 2.13 cm
57. (a) 1.33 m/s (b) the sign of the emf is independent of the charge
59. 1.41×10^{-6} N
61. 13.0 μT toward the bottom of the page
63. 53 μT toward the bottom of the page, 20 μT toward the bottom of the page, and 0
65. (a) -8.00×10^{-21} kg·m/s (b) 8.90°
67. 1.29 kW
69. (a) 12.0 cm to the left of wire 1 (b) 2.40 A, downward

Chapter 20

QUICK QUIZZES

1. *b, c, a*
2. (a)
3. (b)
4. (c)
5. (b)

CONCEPTUAL QUESTIONS

1. According to Faraday's law, an emf is induced in a wire loop if the magnetic flux through the loop changes with time. In this situation, an emf can be induced either by rotating the loop around an arbitrary axis or by changing the shape of the loop.
3. As the spacecraft moves through space, it is apparently moving from a region of one magnetic field strength to a region of a different magnetic field strength. The changing magnetic field through the coil induces an emf and a corresponding current in the coil.
5. If the bar were moving to the left, the magnetic force on the negative charges in the bar would be upward, causing an accumulation of negative charge on the top and positive charges at the bottom. Hence, the electric field in the bar would be upward, as well.
7. If, for any reason, the magnetic field should change rapidly, a large emf could be induced in the bracelet. If the bracelet were not a continuous band, this emf would cause high-voltage arcs to occur at any gap in the band. If the bracelet were a continuous band, the induced emf would produce a large induced current and result in resistance heating of the bracelet.
11. As the aluminum plate moves into the field, eddy currents are induced in the metal by the changing magnetic field at the plate. The magnetic field of the electromagnet interacts with this current, producing a retarding force on the plate that slows it down. In a similar fashion, as the plate leaves the magnetic field, a current is induced, and once again there is an upward force to slow the plate.