Solutions to Chapter 1 Exercises

1. The penalty for fraud is professional excommunication.
3. Aristotle's hypothesis was partially correct, for material that makes up the plant comes partly from the soil, but mainly from the air and water. An experiment would be to weigh a pot of soil with a small seedling, then weigh the potted plant later after it has grown. The fact that the grown plant will weigh more is evidence that the plant is composed of more material than the soil offers. By keeping a record of the weight of water used to water the plant, and covering the soil with plastic wrap to minimize evaporation losses, the weight of the grown plant can be compared with the weight of water it absorbs. How can the weight of air taken in by the plant be estimated?
5. The examples are endless. Knowledge of electricity, for example, has proven to be extremely useful. The number of people who have been harmed by electricity who understood it is far fewer than the number of people who are harmed by it who don't understand it. A fear of electricity is much more harmful than useful to one's general health and attitude.
7. What is likely being misunderstood is the distinction between theory and hypothesis. In common usage, "theory" may mean a guess or hypothesis, something that is tentative or speculative. But in science a theory is a synthesis of a large body of validated information (e.g., cell theory or quantum theory). The value of a theory is its usefulness (not its "truth").

Solutions to Chapter 2 Exercises

1. One.
3. The average speed of molecules increases.
5. The cat leaves a trail of molecules and atoms on the grass. These in turn leave the grass and mix with the air, where they enter the dog's nose, activating its sense of smell.
7. The atoms that make up a newborn baby or anything else in this world originated in the explosions of ancient stars. (See Figure 2.8, my daughter Leslie.) The *molecules* that make up the baby, however, were formed from atoms ingested by the mother and transferred to her womb.
9. Of the substances listed, H_2, He, Na, and U are pure elements. H_2O and NaCl are compounds made of two elements; three different elements contribute to H_2SO_4.
11. Brownian motion is the result of more atoms or molecules bumping against one side of a tiny particle than the other. This produces a net force on the particle, which is set in motion. Such doesn't occur for larger particles because the numbers of bumps on opposite sides is more likely equal, producing no net force. The number of bumps on a baseball is practically the same on all sides, with no net force and no change in the baseball's motion.
13. Individual carbon atoms have less mass than individual oxygen atoms, so equal masses of each means more carbons than oxygens.
15. Nine.
17. The element is copper, atomic number 29. Any atom having 29 protons is by definition copper.
19. Lead.
21. An atom gains an electron to become a negative ion. Then it has more electrons than protons.
23. The capsule would be arsenic.
25. Germanium has properties most like silicon, as it is in the same column, Group XIV, as silicon in the periodic table.
27. Protons contribute more to an atom's mass, and electrons more to an atom's size.
29. Letting the formula KE = $\frac{1}{2} mv^2$ guide your thinking, for the same speed the atom with greater mass has greater KE. Greater-mass carbon therefore has greater KE than hydrogen for the same speed.
31. You really are a part of every person around you in the sense that you are composed of atoms not only from every person around you, but from every person who ever lived on Earth! And the atoms that now compose you will make up the atomic pool that others will draw upon.
33. They assumed hydrogen and oxygen were single-atom molecules with water's formula being H_8O.
35. Open-ended.

Solutions to Chapter 2 Problems

1. There are 16 grams of oxygen in 18 grams of water. We can see from the formula for water, H_2O, there are twice as many hydrogen atoms (each of atomic mass 1) as oxygen atoms (each of atomic mass 16). So the molecular mass of H_2O is 18, with 16 parts oxygen by mass.
3. The atomic mass of element A is $\frac{3}{2}$ the mass of element B. Why? Gas A has three times the mass of Gas B. If the equal number of molecules in A and B had equal numbers of atoms, then the atoms in Gas A would simply be three times as massive. But there are twice as many atoms in A, so the mass of each atom must be half of three times as much—$\frac{3}{2}$.
5. From the hint:

$$\frac{\text{number of molecules in thimble}}{\text{number of molecules in ocean}} = \frac{\text{number of molecules in question}}{\text{number of molecules in thimble}}$$

$$\frac{10^{23}}{10^{46}} = \frac{x}{10^{23}}\,;\; x = \frac{10^{46}}{10^{46}} = 1$$

7. The total number of people who ever lived ($6 \times 10^9 \times 20 = 120 \times 10^9$; roughly 10^{11} people altogether) is enormously smaller than 10^{22}. How does 10^{22} compare to 10^{11}? 10^{22} is $(10^{11})^2$! Multiply the number of people who ever lived by the same number, and you'll get 10^{22}, the number of air molecules in a breath of air. Suppose each person on Earth journeyed to a different planet in the galaxy and every one of those planets contained as many people as the Earth now contains. The total number of people on all these planets would still be less than the number of molecules in a breath of air. Atoms are indeed small—and numerous!

Solutions to Chapter 3 Exercises

1. Aristotle would likely say the ball slows to reach its natural state. Galileo would say the ball is encountering friction, an unbalanced force that slows it.
3. When rolling down it is going with gravity. Going up, against. (There are force components in the direction of motion, as we shall see later.) When moving horizontally, gravity is perpendicular, neither speeding nor slowing the ball.
5. The piece of iron has more mass, but less volume. The answers are different because they address completely different concepts.
7. Like the massive ball that resists motion when pulled by the string, the massive anvil resists moving against Paul when hit with the hammer. Inertia in action.
9. The weight of a 10-kg object on the Earth is 98 N, and on the Moon $\frac{1}{6}$ of this, or 16.3 N. The mass would be 10 kg in any location.
11. From $\Sigma F = 0$, the upward forces are 400 N, and the downward forces are 250 N + weight of the staging. So the staging must weigh 150 N.
13. Each scale shows half her weight.
15. Yes, for it doesn't change its state of motion (accelerate). Strictly speaking, some friction does act so it is close to being in equilibrium.
17. The upward force, the support force, isn't the only force acting. Weight does also, producing a net force of zero.
19. Constant speed implies the net force on the cabinet is zero. So friction is 600 N in the opposite direction.
21. Constant velocity means constant direction, so your friend should say "at a constant *speed* of 100 km/h."
23. Not very, for his speed will be zero relative to the land.
25. 10 m/s.
27. The ball slows by 10 m/s each second, and gains 10 m/s when descending. The time up equals the time down if air resistance is nil.
29. Zero, for no change in velocity occurred. Misreading the question might mean missing the word "steady" (no change).
31. The ball on B finishes first, for its average speed along the lower part as well as the down and up slopes is greater than the average speed of the ball along track A.

Solutions to Chapter 3 Problems

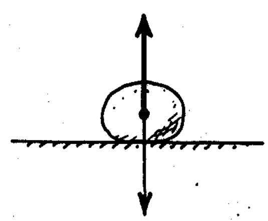
1. (a) 30 N + 20 N = 50 N. (b) 30 N – 20 N = 10 N.
3. From $\Sigma F = 0$, friction equals weight, mg, = (100 kg)(9.8 m/s^2) = 980 N.
5. $a = \dfrac{\textit{change in velocity}}{\textit{time interval}} = \dfrac{-100\text{ km/h}}{10\text{s}} = -10$ km/h·s. (The vehicle decelerates at 10 km/h·s.)
7. Since it starts going up at 30 m/s and loses 10 m/s each second, its time going up is 3 s. Its time returning is also 3 s, so it's in the air for a total of 6 s. Distance up (or down) is $\frac{1}{2}gt^2 = 5 \times 3^2 = 45$ m.
   Or from $d = vt$, where average velocity is (30 + 0)/2 = 15 m/s, and time is 3 s, d = 15 m/s × 3 s = 45 m.
9. $d = v_{\text{ave}}t = \dfrac{v_f + v_0}{2} \times \dfrac{v_f - v_0}{a} = \dfrac{v_f^2 + v_f v_0 + v_f v_0 - v_0^2}{2a} = \dfrac{v_f^2 - v_0^2}{2a}$.
   $d = v_{\text{ave}}t = \left(\dfrac{v_f + v_0}{2}\right) \times \left(\dfrac{v_f - v_0}{a}\right) = \dfrac{v_f^2 - v_0^2}{2a}$.

Solutions to Chapter 4 Exercises

1. Poke or kick the boxes. The one that more greatly resists a change in motion is the one with the greater mass—the one filled with sand.
3. The massive cleaver tends to keep moving when it encounters the vegetables, cutting them more effectively.
5. Newton's first law again—when the stone is released it is already moving as fast as the ship, and this horizontal motion continues as the stone falls. Much more about this in Chapter 6.
7. You exert a force to overcome the force of friction. This makes the net force zero, which is why the wagon moves without acceleration. If you pull harder, then net force will be greater than zero and acceleration will occur.
9. Let Newton's second law guide the answer to this; $a = F/m$. As m gets less (much the mass of the fuel), acceleration a increases for a constant force.
11. The sudden stop involves a large acceleration. So in accord with $a = F/m$, a large a means a large F. Ouch!
13. When air resistance affects motion, the ball thrown upward returns to its starting level with less speed than its initial speed, and also less speed than the ball tossed downward. So the downward thrown ball hits the ground below with a greater speed.
15. 100 N, the same reading it would have if one of the ends were tied to a wall instead of tied to the 100-N hanging weight. Although the net force on the system is zero, the tension in the rope within the system is 100 N, as shown on the scale reading.
17. (a) Two force pairs act; Earth's pull on the apple (action), and the apple's pull on the Earth (reaction). Hand pushes apple upward (action), and apple pushes hand downward (reaction).

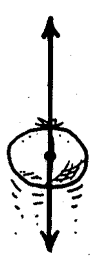
(b) If air resistance can be neglected, one force pair acts; Earth's pull on apple, and apple's pull on Earth. If air resistance counts, then air pushes upward on apple (action) and apple pushes downward on air (reaction).

19. Neither a stick of dynamite nor anything else "contains" force. We will see later that a stick of dynamite contains *energy*, which is capable of producing forces when an interaction of some kind occurs.
21. When the barbell is accelerated upward, the force exerted by the athlete is greater than the weight of the barbell. (The barbell, simultaneously, pushes with greater force against the athlete.) When acceleration is downward, the force supplied by the athlete is less.
23. 1000 N.
25. As in the preceding exercise, the force on each cart will be the same. But since the masses are different, the accelerations will differ. The twice-as-massive cart will undergo only half the acceleration of the less massive cart and will gain only half the speed.
27. In accord with Newton's third law, the force on each will be of the same magnitude. But the effect of the force (acceleration) will be different for each because of the different mass. The more massive truck undergoes less change in motion than the motorcycle.
29. The person with twice the mass slides half as far as the twice-as-massive person. That means the lighter one slides 4 feet and the heavier one slides 8 feet (for a total of 12 feet).
31. In accord with Newton's third law, Steve and Gretchen are touching each other. One may initiate the touch, but the physical interaction can't occur without contact between both Steve and Gretchen. Indeed, you cannot touch without being touched!
33. The terminal speed attained by the falling cat is the same whether it falls from 50 stories or 20 stories. Once terminal speed is reached, falling extra distance does not affect the speed. (The low terminal 33. The terminal speed attained by the falling cat is the same velocities of small creatures enables them to fall without harm from heights that would kill larger creatures.)
35. Before reaching terminal velocity, weight is greater than air resistance. After reaching terminal velocity both weight and air resistance are of the same magnitude. Then the net force and acceleration are both zero.
37. Air resistance is not really negligible for so high a drop, so the heavier ball does strike the ground first. (This idea is shown in Figure 4.15.) But although a twice-as-heavy ball strikes first, it falls only a little faster, and not twice as fast, which is what followers of Aristotle believed. Galileo recognized that the small difference is due to friction and would not be present if there were no friction.
39. A hammock stretched tightly has more tension in the supporting ropes than one that sags. The tightly stretched ropes are more likely to break.
41. No, for the component of your velocity in a direction perpendicular to the water flow (directly across the river) does not depend on stream speed. The total distance you travel while swimming across, however, *does* depend on stream speed. For a swift current you'll be swept farther downstream, but the crossing time will remain the same.
43. (a) The other vector is upward as shown.



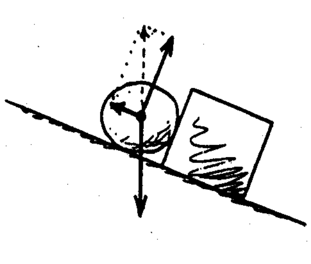
(b) It is called the normal force.

45. (a) As shown.



(b) Upward tension force is greater to result in upward net force.

47. The acceleration of the stone at the top of its path, or anywhere where the net force on the stone is *mg*, is *g*.
49. (a) As shown.



(b) Note the resultant of the normals is equal and opposite to the stone's weight.

Solutions to Chapter 4 Problems

1. The given pair of forces produces a net force of 200 N forward, which accelerates the cart. To make the net force zero, a force of 200 N backward must be exerted on the cart.
3. Acceleration $a = F_{net}/m = (40\text{ N} - 24\text{ N})/4\text{ kg} = 16\text{ N}/4\text{ kg} = 4\text{ m/s}^2$.
5. Acceleration $a = F_{net}/m = (4 \times 250{,}000\text{ N})/330{,}000\text{ kg} = 3\text{ m/s}^2$.
7. $F_{net} = (mg - f) = (800\text{ N} - f) = ma = 80\text{ kg} \times 4\text{ m/s}^2 = 320\text{ N}$.
   So $f = 800\text{ N} - 320\text{ N} = 480\text{ N}$.
9. (a) Force of air resistance will be equal to her weight, *mg*, or 500 N.
   (b) She'll reach the same air resistance, but at a smaller speed, 500 N.
   (c) The answers are the same, but for different speeds. In each case she attains equilibrium (no acceleration).
11. By the Pythagorean theorem, $V = \sqrt{[(3\text{ m/s})^2 + (4\text{ m/s})^2]} = 5\text{ m/s}$.
13. By the Pythagorean theorem, $V = \sqrt{[(120\text{ m/s})^2 + (90\text{ m/s})^2]} = 150\text{ m/s}$.
    (b) $(m/M)a = (6.0\text{ kg}/5.0\text{ kg})\ 2.5\text{ m/s}^2 = 3.0\text{ m/s}^2$.
15. (a) The net force on the sled with only Phil on it is Ma, and remains the same when Zephram is added. Acceleration of sled = net force/total mass = $Ma/(M + m) = [M/(M + m)]a$.
    (b) Acceleration = $[M/(M + m)]a = 70\text{ kg}/(70 + 45\text{ kg})3.6\text{ m/s}^2 = 2.2\text{ m/s}^2$.
    (b) New acceleration = $(6/7)a = (6/7)1.2\text{ m/s}^2 = 1.0\text{ m/s}^2$.

Solutions to Chapter 5 Exercises

1. Supertankers are so massive, that even at modest speeds their motional inertia, or *momenta*, are enormous. This means enormous impulses are needed for changing motion. How can large impulses be produced with modest forces? By applying modest forces over long periods of time. Hence, the force of the water resistance over the time it takes to coast 25 kilometers sufficiently reduces the momentum.
3. The extra thickness extends the time during which momentum changes and reduces impact force.
5. Crumpling allows more time for reducing the momentum of the car, resulting in a smaller force of impact on the occupants.
7. Its momentum is the same (its weight might change, but not its mass).
9. The momentum of recoil of the world is 10 kg·m/s. Again, this is not apparent because the mass of the Earth is so enormous that its recoil velocity is imperceptible. (If the masses of Earth and person were equal, both would move at equal speeds in opposite directions.)
11. When a boxer hits his opponent, the opponent contributes to the impulse that changes the momentum of the punch. When punches miss, no impulse is supplied by the opponent—all effort that goes into reducing the momentum of the punches is supplied by the boxer himself. This tires the boxer. This is very evident to a boxer who can punch a heavy bag in the gym for hours and not tire, but who finds by contrast that a few minutes in the ring with an opponent is a tiring experience.
13. In jumping, you impart the same momentum to both you and the canoe. This means you jump from a canoe that is moving away from the dock, reducing your speed relative to the dock, so you don't jump as far as you expected to.
15. If no momentum is imparted to the ball, no oppositely directed momentum will be imparted to the thrower. Going through the motions of throwing has no net effect. If at the beginning of the throw you begin recoiling backward, at the end of the throw when you stop the motion of your arm and hold onto the ball, you stop moving too. Your position may change a little, but you end up at rest. No momentum given to the ball means no recoil momentum gained by you.
17. If the rocket and its exhaust gases are treated as a single system, the forces between rocket and exhaust gases are internal, and momentum in the rocket–gases system is conserved. So any momentum given to the gases is equal and opposite to momentum given to the rocket. A rocket attains momentum by giving momentum to the exhaust gases.
19. For the system comprised of ball + Earth, momentum is conserved, for the impulses acting are internal impulses. The momentum of the falling apple is equal in magnitude to the momentum of the Earth toward the apple.
21. This exercise is similar to the previous one. If we consider Bronco to be the system, then a net force acts and momentum changes. In the system composed of Bronco alone, momentum is not conserved. If, however, we consider the system to be Bronco and the world (including the air), then all the forces that act are internal forces and momentum is conserved. Momentum is conserved only in systems not subject to external forces.
23. If the air is brought to a halt by the sail, then the impulse against the sail will be equal and opposite to the impulse on the fan. There will be no net impulse and no change in momentum. The boat will remain motionless. Bouncing counts!
25. In terms of force: When the sand lands on the cart it is brought up to the cart's speed. This means a horizontal force provided by the cart acts on the sand. By action–reaction, the sand exerts a force on the cart in the opposite direction—which slows the cart. In terms of momentum conservation: Since no external forces act in the horizontal direction, the momentum after the cart catches sand equals the momentum before. Since mass is added, velocity must decrease.
27. We assume the equal strengths of the astronauts means that each throws with the same speed. Since the masses are equal, when the first throws the second, both the first and second move away from each other at equal speeds. Say the thrown astronaut moves to the right with velocity V, and the first recoils with velocity $-V$. When the third makes the catch, both she and the second move to the right at velocity $V/2$ (twice the mass moving at half the speed, like the freight cars in Figure 5.12). When the third makes her throw, she recoils at velocity V (the same speed she imparts to the thrown astronaut) which is added to the $V/2$ she acquired in the catch. So her velocity is $V + V/2 = 3V/2$, to the right—too fast to stay in the game. Why? Because the velocity

of the second astronaut is $V/2 - V = -V/2$, to the left—too slow to catch up with the first astronaut who is still moving at $-V$. The game is over. Both the first and the third got to throw the second astronaut only once!

29. Your friend does twice as much work ($4 \times \frac{1}{2} > 1 \times 1$).
31. Work done by each is the same, for they reach the same height. The one who climbs in 30 s uses more power because work is done in a shorter time.
33. Agree, because speed itself is relative to the frame of reference (Chapter 3). Hence, $\frac{1}{2}mv^2$ is also relative to a frame of reference.
35. KE depends on the square of speed, so the faster one, the lighter golf ball, has the greater KE.
37. If the ball is given an initial KE, it will return to its starting position with that KE (moving in the other direction!) and hit the instructor. (The usual classroom procedure is to release the ball from the nose at rest. Then when it returns it will have no KE and will stop short of bumping the nose.)
39. The 100 J of potential energy that doesn't go into increasing her kinetic energy goes into thermal energy—heating her bottom and the slide.
41. You agree with your second classmate. The coaster could just as well encounter a low summit before or after a higher one, so long as the higher one is enough lower than the initial summit to compensate for energy dissipation by friction.
43. If KEs are the same but masses differ, then the ball with smaller mass has the greater speed. That is, $\frac{1}{2}Mv^2 = \frac{1}{2}mV^2$. Likewise with molecules, where lighter ones move faster on the average than more massive ones. (We will see in Chapter 8 that temperature is a measure of average molecular KE—lighter molecules in a gas move faster than same-temperature heavier molecules.)
45. The information needed is the distance of rock penetration into the ground. The work that the rock does on the ground is equal to its PE before being dropped, mgh = 100 joules. Without knowing the distance the force acts upon the ground, the force of impact cannot be calculated. (If we knew the time during which the impulse occurs we could calculate the force from the impulse-momentum relationship—but not knowing the distance or time of the rock's penetration into the ground, we cannot calculate the force.)
47. The ball strikes the ground with the *same* speed, whether thrown upward or downward. The ball starts with the same energy at the same place, so they will have the same energy when they reach the ground. This means they will strike with the same speed. This is assuming negligible air resistance, for if air resistance is a factor, then the ball thrown upward will dissipate more energy in its longer path and strike with somewhat less speed. Both hit the ground at the same speed (but at different *times*).
49. The question can be restated; Is $(30^2 - 20^2)$ greater or less than $(20^2 - 10^2)$? We see that $(30^2 - 20^2) = (900 - 400) = 500$, which is considerably greater than $(20^2 - 10^2) = (400 - 100) = 300$. So KE changes more for a given Δv at the higher speed.
51. When the mass is doubled with no change in speed, both momentum and KE are doubled.
53. Both have the same momentum, but the 1-kg one, the faster one, has the greater KE.
55. Net momentum before the lumps collide is zero and is zero after collision. Momentum is indeed conserved. Kinetic energy after is zero, but was greater than zero before collision. The lumps are warmer after colliding because the initial kinetic energy of the lumps transforms into thermal energy. Momentum has only one form. There is no way to "transform" momentum from one form to another, so it is conserved. But energy comes in various forms and can easily be transformed. No single form of energy such as KE need be conserved.
57. An engine that is 100% efficient would not be warm to the touch, nor would its exhaust heat the air, nor would it make any noise, nor would it vibrate. This is because all these are transfers of energy, which cannot happen if all the energy given to the engine is transformed to useful work.
59. Your friend is correct, for changing KE requires work, which means more fuel consumption and decreased air quality.

Solutions to Chapter 5 Problems

1. $\frac{F}{m} = \frac{\Delta v}{\Delta t}$. Cross-multiply and get $F\Delta t = m\Delta v$. With m constant, $F\Delta t = \Delta(mv)$.
3. (a) $Ft = \Delta mv$; $F = \Delta mv/t$ = (8 kg)(2 m/s)/0.5 s = 32 N.
   (b) 32 N, in accord with Newton's third law.
5. Momentum of the caught ball is (0.15 kg)(40 m/s) = 6.0 kg·m/s.
   (a) The impulse to produce this change of momentum has the same magnitude, 6.0 N·s.
   (b) From $Ft = \Delta mv$, $F = \Delta mv/t$ = [(0.15 kg)(40 m/s)]/0.03 s = 200 N.
7. Let m be the mass of the freight car, and $4m$ the mass of the diesel engine, and v the speed after both have coupled together. Before collision, the total momentum is due only to the diesel engine, $4m$(5 km/h), because the momentum of the freight car is 0. After collision, the combined mass is $(4m + m)$, and combined momentum is $(4m + m)v$. By the conservation of momentum equation:
   $\text{Momentum}_{\text{before}} = \text{momentum}_{\text{after}}$
   $4m(5\text{ km/h}) + 0 = (4m + m)v$
   $v = \frac{(20m \cdot \text{km/h})}{5m} = 4\text{ km/h}$ (Note that you don't have to know m to solve the problem.)
9. By momentum conservation, asteroid mass × 800 m/s = Superman's mass × v.
   Since asteroid's mass is 1000 times Superman's,
   $(1000m)(800\text{ m/s}) = mv$
   v = 800,000 m/s. This is nearly 2 million miles per hour!

11. (a) PE + KE = Total E; KE = 10,000 J – 1000 J = 9000 J.
(b) When Bernie's KE is 9000 J, his PE is reduced to 1000 J, which places him 0.1 the flagpole height above water when his KE is 9000 J.
13. $(F \times d)_{\text{in}} = (F \times d)_{\text{out}}$
$50\text{ N} \times 1.2\text{ m} = W \times 0.2\text{ m}$
$W = [(50\text{ N})(1.2\text{ m})]/0.2\text{ m} = 300\text{ N}$.
15. $Fd = mad = ma(\tfrac{1}{2}at^2) = \tfrac{1}{2}maat^2 = \tfrac{1}{2}m(at)^2$. With $at = v$, we get $Fd = \tfrac{1}{2}mv^2$.
17. (a) The mass ends up at rest, so its momentum has changed by an amount mv. The magnitude of the impulse acting on the mass must also equal mv. From $Ft = \Delta(\text{momentum}) = mv \Rightarrow t = \dfrac{mv}{F}$.

(b) $t = \dfrac{mv}{F} = \dfrac{(20.0\,\text{kg})(3.0\,\frac{\text{m}}{\text{s}})}{(15.0\,\text{N})} = 4.0\dfrac{\text{kg}\cdot\frac{\text{m}}{\text{s}}}{\text{kg}\cdot\frac{\text{m}}{\text{s}^2}} = \mathbf{4.0\,s}$.

19. (a) Since no external forces act on the astronaut–hammer system the momentum of the system is conserved. The initial momentum of the system is zero. Afterward, the astronaut's momentum and the hammer's momentum are equal in magnitude but opposite in direction. If we use v to represent speeds we can write $(\text{momentum})_{\text{astronaut}} = (\text{momentum})_{\text{hammer}} \Rightarrow Mv_{\text{astronaut}} = mv_{\text{hammer}} \Rightarrow \text{speed}_{\text{astronaut}} = \dfrac{mv}{M}$.

(b) $\text{Speed}_{\text{astronaut}} = \dfrac{mv}{M} = \dfrac{(15\text{ kg})\left(4.5\dfrac{\text{m}}{\text{s}}\right)}{110\text{ kg}} = 0.6\dfrac{\text{m}}{\text{s}}$.

21. (a) Since speed $v = x/t$, momentum $= mv = \boldsymbol{mx/t}$.

(b) $\text{KE} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}M\left(\dfrac{x}{t}\right)^2 = \dfrac{\boldsymbol{Mx^2}}{\boldsymbol{2t^2}}$.

(c) For our units to work out we'll need to convert 250 km to m and 8.0 hours to seconds:

$250\,\text{km} \times \frac{1000\,\text{m}}{1\text{km}} = 250{,}000\text{ m};\ 8.0\,\text{h} \times \frac{3600\text{s}}{1\text{h}} = 28{,}800\text{ s}$.

$$\text{So KE} = \frac{Mx^2}{2t^2} = \frac{(9.0\times10^7\text{ kg})(250{,}000\,\text{m})^2}{2(28{,}800\text{ s})^2} = 1.4\times10^{10}\text{ kg}\cdot\tfrac{\text{m}^2}{\text{s}^2} = \mathbf{3.4\times10^9\,J}.$$

23. (a) $d = ?$ From $W = Fd$ and $W = \Delta\text{KE} \quad \Rightarrow Fd = \Delta\text{KE} \quad \Rightarrow d = \dfrac{\frac{1}{2}mv^2}{F} = \dfrac{\boldsymbol{mv^2}}{\boldsymbol{2F}}$.

(b) If both the distance and the force are doubled, four times as much work is done, which produces four times as much change in kinetic energy. Formally, $F_0d_0 = W_0 = (\Delta\text{KE})_0$ becomes $(2F_0)(2d_0) = 4(F_0d_0) = 4W_0 = \mathbf{4(\Delta KE)_0}$.

25. (a) Since the ice drops a vertical distance h its PE decreases by mgh. Its KE then increases by the same amount. From $\text{KE}_{\text{at bottom}} = \tfrac{1}{2}mv^2$ and $\text{KE}_{\text{at bottom}} = mgh \quad \Rightarrow \tfrac{1}{2}mv^2 = mgh \quad \Rightarrow v = \sqrt{\boldsymbol{2gh}}$. Note that the mass doesn't enter into the solution. *Any* mass of ice sliding friction free will arrive at the bottom of the ramp with the same speed.

(b) $v = \sqrt{2gh} = \sqrt{2\left(9.8\,\frac{\text{m}}{\text{s}^2}\right)(1.5\,\text{m})} = \mathbf{5.4\,\frac{m}{s}}$.

Solutions to Chapter 6 Exercises

1. Nothing to be concerned about on this consumer label. It simply states the universal law of gravitation, which applies to *all* products. It looks like the manufacturer knows some physics and has a sense of humor.
3. The force of gravity is the same on each because the masses are the same, as Newton's equation for gravitational force verifies.
5. Astronauts are weightless because they lack a support force, but they are well in the grips of Earth gravity, which accounts for them circling the Earth rather than going off in a straight line in outer space.
7. Less, because an object there is farther from Earth's center.
9. Letting the equation for gravitation guide your thinking, twice the mass means twice the force, and twice the distance means one-quarter the force. Combined, the astronaut weighs half as much.
11. By the geometry of Figure 6.6, tripling the distance from the small source spreads the light over 9 times the area, or 9 m^2. Five times the distance spreads the light over 25 times the area or 25 m^2, and for 10 times as far, 100 m^2.
13. The gravitational force on a body, its weight, depends not only on mass but distance. On Jupiter, this is the distance between the body being weighed and Jupiter's center—the radius of Jupiter. If the radius of Jupiter were the same as that of the Earth, then a body would weigh 300 times as much because Jupiter is 300 times more massive than Earth. But Jupiter is also much bigger than the Earth, so the greater distance between its center and the CG of the body reduces the gravitational force. The radius is great enough to make the weight of a body only 3 times its Earth weight. The radius of Jupiter is in fact 11 times that of Earth.

15. In a car that drives off a cliff you "float" because the car no longer offers a support force. Both you and the car are in the same state of free fall. But gravity is still acting on you, as evidenced by your acceleration toward the ground. So, by definition, you would be weightless (until air resistance becomes important).
17. The pencil has the same state of motion that you have. The force of gravity on the pencil causes it to accelerate downward alongside of you. Although the pencil hovers relative to you, it and you are falling relative to the Earth.
19. First of all, it would be incorrect to say that the gravitational force of the distant Sun on you is too small to be measured. It's small, but not immeasurably small. If, for example, the Earth's axis were supported such that the Earth could continue turning but not otherwise move, an 85-kg person would see a gain of ½ newton on a bathroom scale at midnight and a loss of ½ newton at noon. The key idea is *support*. There is no "Sun support" because the Earth and all objects on the Earth—you, your bathroom scale, and everything else—are continually falling around the Sun. Just as you wouldn't be pulled against the seat of your car if it drives off a cliff, and just as a pencil is not pressed against the floor of an elevator in free fall, we are not pressed against or pulled from the Earth by our gravitational interaction with the Sun. That interaction keeps us and the Earth circling the Sun, but does not press us to the Earth's surface. Our interaction with the Earth does that.
21. The misunderstanding here is not distinguishing between a theory and a hypothesis or conjecture. A theory, such as the theory of universal gravitation, is a synthesis of a large body of information that encompasses well-tested and verified hypothesis about nature. Any doubts about the theory have to do with its applications to yet untested situations, not with the theory itself. One of the features of scientific theories is that they undergo refinement with new knowledge. (Einstein's general theory of relativity has taught us that in fact there are limits to the validity of Newton's theory of universal gravitation.)
23. The crate will not hit the Porsche, but will crash a distance beyond it determined by the height and speed of the plane.
25. Minimum speed occurs at the top, which is the same as the horizontal component of velocity anywhere along the path.
27. Both balls have the same range (see Figure 6.22). The ball with the initial projection angle of 30°, however, is in the air for a shorter time and hits the ground first.
29. Any vertically projected object has zero speed at the top of its trajectory. But if it is fired at an angle, only its vertical component of velocity is zero and the velocity of the projectile at the top is equal to its horizontal component of velocity. This would be 100 m/s when the 141-m/s projectile is fired at 45°.
31. The hang time will be the same, in accord with the answer to the preceding exercise. Hang time is related to the vertical height attained in a jump, not on horizontal distance moved across a level floor.
33. Neither the speed of a falling object (without air resistance) nor the speed of a satellite in orbit depends on its mass. In both cases, a greater mass (greater inertia) is balanced by a correspondingly greater gravitational force, so the acceleration remains the same ($a = F/m$, Newton's second law).
35. Gravity changes the speed of a cannonball when the cannonball moves in the direction of Earth's gravity. At low speeds, the cannonball curves downward and gains speed because there is a component of the force of gravity along its direction of motion. Fired fast enough, however, the curvature matches the curvature of the Earth so the cannonball moves at right angles to the force of gravity. With no component of force along its direction of motion, its speed remains constant.
37. Consider "Newton's cannon" fired from a tall mountain on Jupiter. To match the wider curvature of much larger Jupiter, and to contend with Jupiter's greater gravitational pull, the cannonball would have to be fired significantly faster. (Orbital speed about Jupiter is about five times that for Earth.)
39. Hawaii is closer to the equator, and therefore has a greater tangential speed about the polar axis. This speed could be added to the launch speed of a satellite and thereby save fuel.
41. When the velocity of a satellite is everywhere perpendicular to the force of gravity, the orbital path is a circle.
43. If a wrench or anything else is "dropped" from an orbiting space vehicle, it has the same tangential speed as the vehicle and remains in orbit. If a wrench is dropped from a high-flying jumbo jet, it too has the tangential speed of the jet. But this speed is insufficient for the wrench to fall around and around the Earth. Instead it soon falls into the Earth.
45. Communication satellites only appear motionless because their orbital period coincides with the daily rotation of the Earth.
47. The half brought to rest will fall vertically to Earth. The other half, in accord with the conservation of linear momentum, will have twice the initial velocity, overshoot the circular orbit, and enter an elliptical orbit whose apogee (highest point) is farther from the Earth's center.
49. The satellite experiences the greatest gravitational force at A, where it is closest to the Earth; and the greatest speed and the greatest velocity at A, and by the same token the greatest momentum and greatest kinetic energy at A, and the greatest gravitational potential energy at the farthest point C. It would have the same total energy (KE + PE) at all parts of its orbit. It would have the greatest acceleration at A, where F/m is greatest.

Solutions to Chapter 6 Problems

1. From $F = GmM/d^2$, $^1/5$ of d squared is $^1/25$th d^2, which means the force is 25 times greater.
3. $$\frac{F \text{ on neutron star}}{F \text{ on Earth}} = \frac{GmM_n/d_n^2}{GmM_E/d_E^2} = \frac{M_n d_E^2}{M_E d_n^2} = \frac{(3.0\times10^{30}\text{ kg})(6380\text{ km})^2}{(6\times10^{24}\text{ kg})(8\text{ km})^2} = 3.2\times10^{11}.$$
   This is about 300 billion times the force of gravity on Earth's surface.
5. (a) From $y = 5t^2 = 5(30)^2 = 4500$ m, or 4.5 km high (4.4 km if we use $g = 9.8$ m/s^2).
   (b) In 30 seconds the falling engine travels horizontally 8400 m ($d = vt = 280$ m/s × 30 s = 8400 m).

(c) The engine is directly below the airplane. (In a more practical case, air resistance is overcome for the plane by its engines, but not for the falling engine, so the engine's speed is reduced by air drag and it covers less than 8400 horizontal meters, landing behind the plane.)

7. In accord with the work–energy theorem (Chapter 5), $W = \Delta KE$ the work done equals energy gained. The KE gain is 8 billion joules – 5 billion joules = 3 billion joules. The potential energy decreases by the same amount that the kinetic energy increases, 3 billion joules.
9. If we use the equation of the previous problem:

$$v = \sqrt{\frac{GM}{d}} = \frac{(6.67\times10^{-11})(2\times10^{30})}{1.5\times10^{11}} = 3\times10^{4}\ \text{m/s}.$$

Another way is $v = distance/time$ where distance is the circumference of the Earth's orbit and time is 1 year. Then,

$$v = \frac{d}{t} = \frac{2\pi r}{1\ \text{year}} = \frac{2\pi(1.5\times10^{11}\ \text{m})}{365\ \text{day}\times\frac{24\ \text{h}}{\text{day}}\times\frac{3600\ \text{s}}{\text{h}}} = 3\times10^{4}\ \text{m/s} = 30\ \text{km/s}.$$

11. (a) $a = \dfrac{F}{m} = G\dfrac{mM/d^2}{m} = G\dfrac{M}{d^2}$.

(b) Note that mass of the accelerating object, m, cancels for acceleration. Only the mass of the object M pulling on m affects acceleration (not the object being pulled).

13. (a) Because of the independence of horizontal and vertical components of velocity, the falling time depends only on height y. Since there is no initial velocity in the vertical direction, the vertical distance is simply $y = \frac{1}{2} gt^2$ (as we learned in Chapter 3).

(b) $y = \frac{1}{2} gt^2 = \frac{1}{2} (9.8\ \text{m/s}^2)(2\ \text{s})^2 = 19.6\ \text{m}$ (or 20 m for $g = 10\ \text{m/s}^2$).

(c) To solve this problem one needs to know that the horizontal and vertical components of velocity are independent of each other. That means falling distance is not affected by the horizontal component of velocity. Hence, the bridge height is simply the height required for a freely falling rock to fall a vertical distance y. And that's $y = \frac{1}{2} gt^2$ (as we learned in Chapter 3).

15. (a) $d = v_x t = vt$.

The time t is the same time for the penny to fall distance y.

From $y = \frac{1}{2}gt^2 \Rightarrow t^2 = \frac{2y}{g} \Rightarrow t = \sqrt{\frac{2y}{g}}$. So $d = v\sqrt{\frac{2y}{g}}$.

(b) $d = v\sqrt{\frac{2y}{g}} = 3.5\ \text{m/s}\sqrt{\frac{2(0.4\ \text{m})}{9.8\ \text{m/}^2}} = 1.0\ \text{m}$.

Solutions to Chapter 7 Exercises

1. The scale measures force, not pressure, and is calibrated to read your weight. That's why your weight on the scale is the same whether you stand on one foot or both.
3. Like the loaf of bread in Figure 7.1, its volume is decreased. Its mass stays the same so the density increases. A whale is denser when it swims deeper in the ocean.
5. A person lying on a waterbed experiences less body weight pressure because more of the body is in contact with the supporting surface. The greater area reduces the support pressure.
7. A woman with spike heels exerts considerably more pressure on the ground than an elephant! Example: A 500-N woman with 1-cm^2 spike heels puts half her weight on each foot, distributed (let's say) half on her heel and half on her sole. So the pressure exerted by each heel will be (125 N/1 cm^2) = 125 N/cm^2. A 20,000-N elephant with 1000 cm^2 feet exerting $\frac{1}{4}$ its weight on each foot produces (5000 N/1000 cm^2) = 5 N/cm^2; about 25 times less pressure. (So a woman with spike heels will make greater dents in a new linoleum floor than an elephant will.)
9. In deep water, you are buoyed up by the water displaced and as a result, you don't exert as much pressure against the stones on the bottom. When you are up to your neck in water, you hardly feel the bottom at all.
11. As per the Floating Mountains in the chapter, mountain ranges are very similar to icebergs: Both float in a denser medium, and extend farther down into that medium than they extend above it.
13. Heavy objects may or may not sink, depending on their densities (a heavy log floats while a small rock sinks, or a boat floats while a paper clip sinks, for example). People who say that heavy objects sink really mean that dense objects sink. Be careful to distinguish between how heavy an object is and how dense it is.
15. The water level will fall. This is because the iron will displace a greater amount of water while being supported than when submerged. A floating object displaces its weight of water, which is more than its own volume, while a submerged object

displaces only its volume. (This may be illustrated in the kitchen sink with a dish floating in a dishpan full of water. Silverware in the dish takes the place of the scrap iron. Note the level of water at the side of the dishpan, and then throw the silverware overboard. The floating dish will float higher and the water level at the side of the dishpan will fall. Will the volume of the silverware displace enough water to bring the level to its starting point? No, not as long as it is denser than water.)

17. The balloon will sink to the bottom because its density increases with depth. The balloon is compressible, so the increase in water pressure beneath the surface compresses it and reduces its volume, thereby increasing its density. Density is further increased as it sinks to regions of greater pressure and compression. This sinking is understood also from a buoyant force point of view. As its volume is reduced by increasing pressure as it descends, the amount of water it displaces becomes less. The result is a decrease in the buoyant force that initially was sufficient to barely keep it afloat.
19. Since both preservers are the same size, they will displace the same amount of water when submerged and be buoyed up with equal forces. Effectiveness is another story. The amount of buoyant force exerted on the heavy lead-filled preserver is much less than its weight. If you wear it, you'll sink. The same amount of buoyant force exerted on the lighter Styrofoam preserver is greater than its weight and it will keep you afloat. The *amount* of the force and the *effectiveness* of the force are two different things.
21. When the ice cube melts, the water level at the side of the glass is unchanged (neglecting temperature effects). To see this, suppose the ice cube to be a 5-gram cube; then while floating it will displace 5 grams of water. But when melted it becomes the same 5 grams of water. Hence the water level is unchanged. The same occurs when the ice cube with the air bubbles melts. Whether the ice cube is hollow or solid, it will displace as much water floating as it will melted. If the ice cube contains grains of heavy sand, however, upon melting, the water level at the edge of the glass will drop. This is similar to the case of the scrap iron of Exercise 15.
23. Because of surface tension, which tends to minimize the surface of a blob of water, its shape without gravity and other distorting forces will be a *sphere*—the shape with the least surface area for a given volume.
25. Some of the molecules in the Earth's atmosphere *do* go off into outer space—those like helium with speeds greater than escape speed. But the average speeds of most molecules in the atmosphere are well below escape speed, so the atmosphere is held to Earth by Earth gravity.
27. The density of air in a deep mine is greater than at the surface. The air filling up the mine adds weight and pressure at the bottom of the mine, and according to Boyle's law, greater pressure in a gas means greater density.
29. If the item is sealed in an airtight package at sea level, then the pressure in the package is about 1 atmosphere. Cabin pressure is reduced somewhat for high altitude flying, so the pressure in the package is greater than the surrounding pressure and the package therefore puffs outwards.
31. The can collapses under the weight of the atmosphere. When water was boiling in the can, much of the air inside was driven out and replaced by steam. Then, with the cap tightly fastened, the steam inside cooled and condensed back to the liquid state, creating a partial vacuum in the can which could not withstand the crushing force of the atmosphere outside.
33. A vacuum cleaner wouldn't work on the Moon. A vacuum cleaner operates on Earth because the atmospheric pressure pushes dust into the machine's region of reduced pressure. On the Moon there is no atmospheric pressure to push the dust anywhere.
35. Drinking through a straw is slightly more difficult atop a mountain. This is because the reduced atmospheric pressure is less effective in pushing soda up into the straw.
37. One's lungs, like an inflated balloon, are compressed when submerged in water, and the air within is compressed. Air will not of itself flow from a region of low pressure into a region of higher pressure. The diaphragm in one's body reduces lung pressure to permit breathing, but this limit is strained when nearly 1 m below the water surface. The limit is exceeded at more than a 1-m depth.
39. An object rises in air only when buoyant force exceeds its weight. A steel tank of anything weighs more than the air it displaces, so it won't rise. A helium-filled balloon weighs less than the air it displaces and rises.
41. The force of the atmosphere is on both sides of the window; the net force is zero, so windows don't normally break under the weight of the atmosphere. In a strong wind, however, pressure will be reduced on the windward side (Bernoulli's Principle) and the forces no longer cancel to zero. Many windows are blown *outward* in strong winds.
43. (a) Speed increases (so that the same quantity of gas can move through the pipe in the same time).
    (b) Pressure decreases (Bernoulli's principle).
    (c) The spacing between the streamlines decreases, because the same number of streamlines fit in a smaller area.
45. The air density and pressure are less at higher altitude, so the wings (and, with them, the whole airplane) are tilted to a greater angle to produce the needed pressure difference between the upper and lower surfaces of the wing. In terms of force and air deflection, the greater angle of attack is needed to deflect a greater volume of lower-density air downward to give the same upward force.
47. The troughs are partially shielded from the wind, so the air moves faster over the crests than in the troughs. Pressure is therefore lower at the top of the crests than down below in the troughs. The greater pressure in the troughs pushes the water into even higher crests.

Solutions to Chapter 7 Problems

1. A 5-kg ball weighs 49 N, so the pressure is 49 $N/cm^2 \times (100\ cm/1\ m)^2 = 490{,}000\ N/m^2$ = 490 kPa.
3. Pressure = weight density × depth = 9800 $N/m^3 \times 406\ m = 3{,}978{,}800\ N/m^2$ = 3978.8 kPa. Total pressure, add that due to atmospheric: 3978.8 kPa + 101.3 = 4080.1 kPa.

5. Now $A = 5 \text{ m} \times 2 \text{ m} = 10 \text{ m}^2$; to find the volume V of barge pushed into the water by the weight of the block, which equals the volume of water displaced, we know that density $= \frac{m}{V}$.

   Or from this, $V = \frac{\text{mass}}{\text{density}} = \frac{400 \text{ kg}}{1000 \text{ kg/m}^3} = 0.4 \text{ m}^3$.

   So $h = \frac{V}{A} = \frac{0.4 \text{ m}^3}{10 \text{ m}^2} = 0.04$ m, which is 4 cm deeper.

   (b) If each block will push the barge 4 cm deeper, the question becomes: How many 4-cm increments will make 15 cm? 15/4 = 3.75, so three blocks can be carried without sinking. Four blocks of the same weight will sink the barge.
7. 10% of ice extends above water. So 10% of the 9-cm thick ice would float above the water line; 0.9 cm. So the ice pops up. Interestingly, when mountains erode they become lighter and similarly pop up! Hence it takes a long time for mountains to wear away.
9. According to Boyle's law, the product of pressure and volume is constant (at constant temperature), so one-tenth the volume means ten times the pressure.
11. Since weight = mg, the mass of the displaced air is $m = W/g = (20{,}000 \text{ N})/(10 \text{ m/s}^2) = 2000$ kg. Since density is mass/volume, the volume of the displaced air is volume = mass/density = $(2000 \text{ kg})/(1.2 \text{ kg/m}^3) = 1700 \text{ m}^3$ (same answer to two figures if $g = 9.8 \text{ m/s}^2$ is used).
13. Lift will equal the difference in force below and above the wing surface. The difference in force will equal the difference in air pressure × wing area.

    Lift = $0.04\,PA = (0.04)(10^5 \text{ N/m}^2)(100 \text{ m}^2) = 4 \times 10^5$ N. (That's about 44 tons.)

Solutions to Chapter 8 Exercises

1. Gas molecules move haphazardly at random speeds. They continually run into one another, sometimes giving kinetic energy to neighbors, sometimes receiving kinetic energy. In this continual interaction, it would be statistically impossible for any large number of molecules to have the same speed. Temperature has to do with average speeds.
3. You cannot establish by your own touch whether or not you are running a fever because there would be no temperature difference between your hand and forehead. If your forehead is a couple of degrees higher in temperature than normal, your hand is also a couple of degrees higher.
5. The hot coffee has a higher temperature, but not a greater internal energy. Although the iceberg has less internal energy per mass, its enormously greater mass gives it a greater total energy than that in the small cup of coffee. (For a smaller volume of ice, the fewer number of more energetic molecules in the hot cup of coffee may constitute a greater total amount of internal energy—but not compared to an iceberg.)
7. No, for a difference of 273 in 10,000,000 is insignificant.
9. Work is done in compressing the air, which in accord with the first law of thermodynamics, increases its thermal energy. This is evident by its increased temperature.
11. You do work on the liquid when you vigorously shake it, which increases its thermal energy. The temperature change should be noticeable.
13. The tires heat up, which heats the air within. The molecules in the heated air move faster, which increases air pressure in the tires.
15. The brick will cool off too fast and you'll be cold in the middle of the night. Bring a jug of hot water with its higher specific heat to bed and you'll make it through the night.
17. Different substances have different thermal properties due to differences in the way energy is stored internally in the substances. When the same amount of heat produces different changes in temperatures in two substances of the same mass, we say they have different specific heat capacities. Each substance has its own characteristic specific heat capacity. Temperature measures the average kinetic energy of random motion, but not other kinds of energy.
19. The higher specific heat of the water results in water absorbing more heat than the metal pan.
21. In winter months when the water is warmer than the air, the air is warmed by the water to produce a seacoast climate warmer than inland. In summer months when the air is warmer than the water, the air is cooled by the water to produce a seacoast climate cooler than inland. This is why seacoast communities and especially islands do not experience the high and low temperature extremes that characterize inland locations.
23. Water is an exception. Below 4 degrees Celsius, it expands when cooled.
25. When the rivets cool they contract. This tightens the plates being attached.
27. Cool the inner glass and heat the outer glass. If it's done the other way around, the glasses will stick even tighter (if not break).
29. Every part of a metal ring expands when it is heated—not only the thickness, but the outer and inner circumference as well. Hence the ball that normally passes through the hole when the temperatures are equal will more easily pass through the expanded hole when the ring is heated. (Interestingly, the hole will expand as much as a disk of the same metal undergoing the same increase in temperature. Blacksmiths mounted metal rims in wooden wagon wheels by first heating the rims. Upon cooling, the contraction resulted in a snug fit.)

31. The gap in the ring will become wider when the ring is heated. Try this: draw a couple of lines on a ring where you pretend a gap to be. When you heat the ring, the lines will be farther apart—the same amount as if a real gap were there. Every part of the ring expands proportionally when heated uniformly—thickness, length, gap, and all.
33. Water has the greatest density at 4°C; therefore, either cooling or heating at this temperature will result in an expansion of the water. A small rise in water level would be ambiguous and make a water thermometer impractical in this temperature region.
35. At 0°C it will contract when warmed a little; at 4°C it will expand, and at 6°C it will expand.
37. If cooling occurred at the bottom of a pond instead of at the surface, ice would still form at the surface, but it would take much longer for ponds to freeze. This is because all the water in the pond would have to be reduced to a temperature of 0°C rather than 4°C before the first ice would form. Ice that forms at the bottom where the cooling process is occurring would be less dense and would float to the surface (except for ice that may form on material anchored to the bottom of the pond).

Solutions to Chapter 8 Problems

1. (a) The amount of heat absorbed by the water is $Q = cm\Delta T$ = (1.0 cal/g °C)(50.0 g)(50°C – 22°C) = 1400 cal. At 40% efficiency only 0.4 the energy from the peanut raises the water temperature, so the calorie content of the peanut is 1400/0.4 = 3500 cal.
   (b) The food value of a peanut is 3500 cal/0.6 g = 5.8 kilocalories per gram.
3. Each kilogram requires 1 kilocalorie for each degree change, so 100 kg needs 100 kilocalories for each degree change. Twenty degrees means twenty times this, which is 2000 kcal.

By formula, $Q = cm\Delta T$ = (1 cal/g°C)(100,000 g)(20°C) = 2000 kcal. We can convert this to joules knowing that 4.18 J = 1 cal. In joules this quantity of heat is 8360 kJ.

5. Heat gained by water = heat lost by nails
   $(cm\Delta T)_{water} = (cm\Delta T)_{nails}$
   $(1)(100)(T - 20) = (0.12)(100)(40 - T)$, giving $T = 22.1$°C.
7. By formula: $\Delta L = L_0 a\Delta T = (1300\text{ m})(11 \times 10^{-6}/°\text{C})(15°\text{C}) = 0.21\text{ m}$.

Solutions to Chapter 9 Exercises

1. No, the coat is not a source of heat, but merely keeps the thermal energy of the wearer from leaving rapidly.
3. Copper and aluminum are better conductors than stainless steel, and therefore more quickly transfer heat to the cookware's interior.
5. In touching the tongue to very cold metal, enough heat can be quickly conducted away from the tongue to bring the saliva to sub-zero temperature where it freezes, locking the tongue to the metal. In the case of relatively nonconducting wood, much less heat is conducted from the tongue and freezing does not take place fast enough for sudden sticking to occur.
7. Heat from the relatively warm ground is conducted by the gravestone to melt the snow in contact with the gravestone. Likewise for trees or any materials that are better conductors of heat than snow, and that extend into the ground.
9. The conductivity of wood is relatively low whatever the temperature—even in the stage of red-hot coals. You can safely walk barefoot across red-hot wooden coals if you step quickly (like removing the wooden-handled pan with bare hands quickly from the hot oven in the previous exercise) because very little heat is conducted to your feet. Because of the poor conductivity of the coals, energy from within the coals does not readily replace the energy that transfers to your feet. This is evident in the diminished redness of the coal after your foot has left it. Stepping on red-hot *iron* coals, however, is a different story. Because of the excellent conductivity of iron, very damaging amounts of heat would transfer to your feet. More than simply ouch!
11. Disagree, for having the same KE does not mean having the same speed, unless all gas molecules have equal masses.
13. The smoke, like hot air, is less dense than the surroundings and is buoyed upward. It cools with contact with the surrounding air and becomes more dense. When its density matches that of the surrounding air, its buoyancy and weight balance and rising ceases.
15. If they have the same temperature, then by definition, they have the same kinetic energies per molecule.
17. As in the explanation of the previous exercise, the molecules of gas with the lesser mass will have the higher average speeds. A look at the periodic table will show that argon (A = 18) has less massive atoms than krypton (A = 36). The faster atoms are those of argon. This is the case whether or not the gases are in separate containers.
19. When we warm a volume of air, we add energy to it. When we expand a volume of air, we normally take energy out of it (because the expanding air does work on its surroundings). So the conditions are quite different and the results will be different. Expanding a volume of air actually lowers its temperature.
21. The heat you received was from radiation.
23. A good reflector is a poor radiator of heat, and a poor reflector is a good radiator of heat.
25. Put the cream in right away for at least three reasons. Since black coffee radiates more heat than white coffee, make it whiter right away so it won't radiate and cool so quickly while you are waiting. Also, by Newton's law of cooling, the higher the temperature of the coffee above the surroundings, the greater will be the rate of cooling—so again add cream right away and lower the temperature to that of a reduced cooling rate, rather than allowing it to cool fast and then bring the temperature down still further by adding the cream later. Also—by adding the cream, you increase the total amount of liquid, which for the same surface area, cools more slowly.
27. Turn your heater off altogether and save fuel. When it is cold outside, your house is constantly losing heat. How much is lost depends on the insulation and the difference in inside and outside temperatures (Newton's law of cooling). Keeping ΔT high consumes more fuel. To consume less fuel, keep ΔT low and turn your heater off altogether. Will more fuel be required to reheat the house when you return than would have been required to keep it warm while you were away? Not at all. When you return, you are replacing heat lost by the house at an average temperature below the normal setting, but if you had left the heater on, it

would have supplied more heat, enough to make up for heat lost by the house at its normal, higher temperature setting. (Perhaps your instructor will demonstrate this with the analogy of leaking water buckets.)

29. When it is desirable to reduce the radiant energy coming into a greenhouse, whitewash is applied to the glass simply to reflect much of the incoming sunlight. Energy reflected is energy not absorbed by the greenhouse.
31. For maximum warmth, wear the plastic coat on the outside and utilize the greenhouse effect.
33. In this hypothetical case evaporation would not cool the remaining liquid because the energy of exiting molecules would be no different than the energy of molecules left behind. Although internal energy of the liquid would decrease with evaporation, energy per molecule would not change. No temperature change of the liquid would occur. (The surrounding air, on the other hand, would be cooled in this hypothetical case. Molecules flying away from the liquid surface would be slowed by the attractive force of the liquid acting on them.)
35. A bottle wrapped in wet cloth will cool by the evaporation of liquid from the cloth. As evaporation progresses, the average temperature of the liquid left behind in the cloth can easily drop below the temperature of the cool water that wet it in the first place. So to cool a bottle of beer, soda, or whatever at a picnic, wet a piece of cloth in a bucket of cool water. Wrap the wet cloth around the bottle to be cooled. As evaporation progresses, the temperature of the water in the cloth drops, and cools the bottle to a temperature below that of the bucket of water.
37. As the bubbles rise, less pressure is exerted on them.
39. When the jar reaches the boiling temperature, further heat does not enter it because it is in thermal equilibrium with the surrounding 100°C water. This is the principle of the "double boiler."
41. As in the answer to the previous exercise, high temperature and the resulting internal energy given to the food are responsible for cooking—if the water boils at a low temperature (presumably under reduced pressure), the food isn't hot enough to cook.
43. The lid on the pot traps heat, which quickens boiling; the lid also slightly increases pressure on the boiling water which raises its boiling temperature. The hotter water correspondingly cooks food in a shorter time, although the effect is not significant unless the lid is held down as on a pressure cooker.
45. The wood, because its greater specific heat capacity means it will release more energy in cooling.
47. The answer to this is similar to the previous answer, and also the fact that the coating of ice acts as an insulating blanket. Every gram of water that freezes releases 80 calories, much of it to the fruit; the thin layer of ice then acts as an insulating blanket against further loss of heat.

Solutions to Chapter 9 Problems

1. From −273°C "ice" to 0°C ice requires (273)(0.5) = 140 calories.
   From 0°C ice to 0°C water requires 80 calories.
   From 0°C water to 100°C water requires 100 calories.
   The total is 320 calories.
   Boiling this water at 100°C takes 540 calories, considerably more energy than it took to bring the water all the way from absolute zero to the boiling point! (In fact, at very low temperature, the specific heat capacity of ice is less than 0.5 cal/g°C, so the true difference is even greater than calculated here.)
3. $0.5mgh = cm\Delta T$
   $\Delta T = 0.5mgh/cm = 0.5gh/c = (0.5)(9.8\text{ m/s}^2)(100\text{ m})/450\text{ J/kg} = 1.1°\text{C}$.
   Note that the mass cancels, so the same temperature would hold for any mass ball, assuming half the heat generated goes into warming the ball. Note that the units check since 1 J/kg = 1 m^2/s^2.
5. The final temperature of the water will be the same as that of the ice, 0°C. The quantity of heat given to the ice by the water is $Q = cm\Delta T$ = (1 cal/g°C)(50 g)(80°C) = 4000 cal. This heat melts ice. How much?
   From $Q = mL$, $m = Q/L$ = (4000 cal)/(80 cal/g) = 50 grams. So water at 80°C will melt an equal mass of ice at 0°C.
7. Note that the heat of vaporization of ethyl alcohol (200 cal/g) is 2.5 times more than the heat of fusion of water (80 cal/g), so in a change of phase for both, 2.5 times as much ice will change phase; 2.5 × 2 kg = 5 kg.
   Or via formula, the refrigerant would draw away $Q = mL$ = (2000 g)(200 cal/g) = 4×10^5 calories. The mass of ice formed is then (4×10^5 cal)/(80 cal/g) = 5000 g, or 5 kg.

Solutions to Chapter 10 Exercises

1. **There are no positives and negatives in gravitation—the interactions between masses are only attractive, whereas electrical interactions may be attractive as well as repulsive. The mass of one particle cannot "cancel" the mass of another, whereas the charge of one particle can cancel the effect of the opposite charge of another particle.**
3. Excess electrons rubbed from your hair leave it with a positive charge; excess electrons on the comb give it a negative charge.
5. Cosmic rays produce ions in air, which offer a conducting path for the discharge of charged objects. Cosmic-ray particles streaming downward through the atmosphere are attenuated by radioactive decay and by absorption, so the radiation and the ionization are stronger at high altitude than at low altitude. Charged objects more quickly lose their charge at higher altitudes.
7. Electrons are easily dislodged from the outer regions of atoms, but protons are held tightly within the nucleus.
9. The electrons don't fly out of the penny because they are attracted to the five thousand billion billion positively charged protons in the atomic nuclei of atoms in the penny.
11. The inverse-square law is at play here. At half the distance the electric force field is four times as strong; at ¼ the distance, 16 times stronger. At four times the distance, one-sixteenth as strong.

13. For both electricity and heat, the conduction is via electrons, which in a metal are loosely bound, easy flowing, and easy to get moving. (Many fewer electrons in metals take part in heat conduction than in electric conduction, however.)
15. The forces on the electron and proton will be equal in magnitude, but opposite in direction. Because of the greater mass of the proton, its acceleration will be less than that of the electron, and be in the direction of the electric field. How much less? Since the mass of the proton is nearly 2000 times that of the electron, its acceleration will be about $^{1}/_{2000}$ that of the electron. The greater acceleration of the electron will be in the direction opposite to the electric field. The electron and proton accelerate in opposite directions.
17. Voltage = $\dfrac{0.5\text{ J}}{0.0001\text{ C}}$ = 5000 V.
19. The cooling system of an automobile is a better analogy to an electric circuit because like an electric system it is a closed system, and it contains a pump, analogous to the battery or other voltage source in a circuit. The water hose does not recirculate the water as the auto cooling system does.
21. Your tutor is wrong. An ampere measures current, and a volt measures electric potential (electric pressure). They are entirely different concepts; voltage produces amperes in a conductor.
23. Current flows *through* electrical devices, just as water flows through a plumbing circuit of pipes. If a water pump produces water pressure, water flows through both the pump and the circuit. Likewise with electric current in an electric circuit. For example, in a simple circuit consisting of a battery and a lamp, the electric current that flows in the lamp is the same electric current that flows through the wires that connect the lamp and the same electric current that flows through the battery. Current flows through these devices. (As a side point, it is common to speak of electric current flowing in a circuit, but strictly speaking, it is electric *charge* that flows in an electric circuit; the flow of charge *is* current. So if you want to be precisely correct grammatically, say that current *is* in a circuit and charge *flows* in a circuit.)
25. A lie detector circuit relies on the likelihood that the resistivity of your body changes when you tell a lie. Nervousness promotes perspiration, which lowers the body's electrical resistance, and increases whatever current flows. If a person is able to lie with no emotional change and no change in perspiration, then such a lie detector will not be effective. (Better lying indicators focus on the eyes.)
27. The thick filament has less resistance and will draw (carry) more current than a thin wire connected across the same potential difference. (Important point: It is common to say that a certain resistor "draws" a certain current, but this may be misleading. A resistor doesn't "attract" or "draw" current, just as a pipe in a plumbing circuit doesn't "draw" water; it instead "allows" or "provides for" the passage of current when an electrical pressure is established across it.)
29. Current will be greater in the bulb connected to the 220-volt source. Twice the voltage would produce twice the current if the resistance of the filament remained the same. (In practice, the greater current produces a higher temperature and greater resistance in the lamp filament, so the current is greater than that produced by 110 volts, but appreciably less than twice as much for 220 volts. A bulb rated for 110 volts has a very short life when operated at 220 volts.)
31. In the first case the current passes through your chest; in the second case current passes only through your arm. You can cut off your arm and survive, but you cannot survive without your heart.
33. Auto headlights are wired in parallel. Then when one burns out, the other remains lit. If you've ever seen an automobile with one burned out headlight, you have evidence they're wired in parallel.
35. (a) volt, (b) ampere, (c) joule.
37. The equivalent resistance of resistors in parallel is less than the smaller resistance of the two. So connect a pair of resistors in parallel for less resistance.
39. Agree with your friend, for in series, more resistances add to the circuit resistance. But in parallel, the multiple paths provide less resistance (just as more lines at a checkout counter lessen resistance to flow).
41. Zero. Power companies do not sell electrons; they sell energy. Whatever number of electrons flow into a home, the same number flows out.
43. Bulbs will glow brighter when connected in parallel, for the voltage of the battery is impressed across each bulb. When two identical bulbs are connected in series, half the voltage of the battery is impressed across each bulb. The battery will run down faster when the bulbs are in parallel.
45. Bulb C is the brightest because the voltage across it equals that of the battery. Bulbs A and B share the voltage of the parallel branch of the circuit and have half the current of bulb C (assuming resistances are independent of voltages). If bulb A is unscrewed, the top branch is no longer part of the circuit and current ceases in both A and B. They no longer give light, while bulb C glows as before. If bulb C is instead unscrewed, then it goes out and bulbs A and B glow as before.
47. The three circuits are equivalent. Each branch is individually connected to the battery.
49. Current divides in a branch with more passing in the branch of lower resistance. But current in a branch never reduces to zero unless the resistance of the branch becomes infinite. In a non-infinite resistor, a voltage across it will produce current in accord with Ohm's law.
51. Some current flows in every branch of a parallel circuit.

Solutions to Chapter 10 Problems

1. From Coulomb's law, $F = k\dfrac{q_1 q_2}{d^2} = \left(9 \times 10^9\right)\dfrac{\left(1.0 \times 10^{-6}\right)^2}{\left(0.03\right)^2} = 10\text{ N}.$

   This is the same as the weight of a 1-kg mass.

3. From Coulomb's law, the force is given by $F = \frac{kq^2}{d^2}$, so the square of the charge is

$$q^2 = \frac{Fd^2}{k} = \frac{(20\ \text{N})(0.06\ \text{m})^2}{9 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2} = 8.0 \times 10^{-12}\ \text{C}^2.$$

   Taking the square root of this gives $q = 2.8 \times 10^{-6}$ C, or 2.8 microcoulombs.

5. a. $\Delta V = \frac{\text{energy}}{\text{charge}} = \frac{12\ \text{J}}{0.0001\ \text{C}}$ = 120,000 volts.

   b. ΔV for twice the charge is $\frac{24\ \text{J}}{0.0002}$ = same 120 kV.

7. From $I_{\text{total}} = I_1 + I_2 + I_3 \ldots I_n$ a substitution of $I = \frac{V}{R}$ for each current gives $\frac{V}{R_{\text{eq}}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \ldots + \frac{V}{R_n}$. Dividing each term by V gives $\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots + \frac{1}{R_n}$.

9. From current = $\frac{\text{voltage}}{\text{resistance}}$, resistance = $\frac{\text{voltage}}{\text{current}} = \frac{120\text{V}}{20\text{A}}$ = 6 Ω.

11. Ohm's law can be stated $V = IR$. Then $P = IV = I(IR) = I^2R$.

13. First, 100 watts = 0.1 kilowatt. Second, there are 168 hours in one week (7 days × 24 h/day = 168 hours). So 168 hours × 0.1 kilowatt = 16.8 kilowatt-hours, which at 20 cents per kWh comes to $3.36.

15. Since current is charge per unit time, charge is current × time: $q = It$ = (9 A)(60 s) = (9 C/s)(60 s) = 540 C. (Charges of this magnitude on the move are commonplace, but this quantity of charge accumulated in one place would be incredibly large.)

17. The resistance of the toaster is $R = V/I$ = (120 V)/(10 A) = 12 Ω. So when 108 V is applied, the current is $I = V/R$ = (108 V)/(12 Ω) = 9.0 A and the power is $P = IV$ = (9.0 A)(108 V) = 972 W, only 81% of the normal power. (Can you see the reason for 81%? Current and voltage are both decreased by 10%, and 0.9 × 0.9 = 0.81.)

Solutions to Chapter 11 Exercises

1. All iron materials are not magnetized because the tiny magnetic domains are most often oriented in random directions and cancel one another's effects.
3. Refrigerator magnets have narrow strips of alternating north and south poles. These magnets are strong enough to hold sheets of paper against a refrigerator door, but have a very short range because the north and south poles cancel a short distance from the magnetic surface.
5. An electron always experiences a force in an electric field because that force depends on nothing more than the field strength and the charge. But the force an electron experiences in a magnetic field depends on an added factor: velocity. If there is no motion of the electron through the magnetic field in which it is located, no magnetic force acts. Furthermore, if motion is along the magnetic field direction, and not at some angle to it, then no magnetic force acts also. Magnetic force, unlike electric force, depends on the velocity of the charge relative to the magnetic field.
7. Apply a small magnet to the door. If it sticks, your friend is wrong because aluminum is not magnetic. If it doesn't stick, your friend might be right (but not necessarily—there are lots of nonmagnetic materials).
9. The net force on a compass needle is zero because its north and south poles are pulled in opposite directions with equal forces in the Earth's magnetic field. When the needle is not aligned with the magnetic field of the Earth, then a pair of torques (relative to the center of the compass) is produced (Figure 11.4). This pair of equal torques, called a "couple," rotates the needle into alignment with the Earth's magnetic field.
11. Yes, for the compass aligns with the Earth's magnetic field, which extends from the magnetic pole in the Southern Hemisphere to the magnetic pole in the Northern Hemisphere.
13. Back to Newton's third law! Both A and B are equally pulling on each other. If A pulls on B with 50 newtons, then B also pulls on A with 50 newtons. Period!
15. Newton's third law again: Yes, the paper clip, as part of the interaction, certainly does exert a force on the magnet—just as much as the magnet pulls on it. The magnet and paper clip pull equally on each other to comprise the single interaction between them.
17. An electron has to be moving across lines of magnetic field in order to feel a magnetic force. So an electron at rest in a stationary magnetic field will feel no force to set it in motion. In an electric field, however, an electron will be accelerated whether or not it is already moving. (A combination of magnetic and electric fields is used in particle accelerators such as cyclotrons. The electric field accelerates the charged particle in its direction, and the magnetic field accelerates it perpendicular to its direction, causing it to follow a nearly circular path.)
19. Associated with every moving charged particle, electrons, protons, or whatever, is a magnetic field. Since a magnetic field is not unique to moving electrons, there is a magnetic field about moving protons as well. However, it differs in direction. The field lines about the proton beam circle in one direction whereas the field lines about an electron beam circle in the opposite direction.

(Physicists use a "right-hand rule." If the right thumb points in the direction of motion of a positive particle, the curved fingers of that hand show the direction of the magnetic field. For negative particles, the left hand can be used.)

21. If the particles enter the field moving in the same direction and are deflected in opposite directions (say one left and one right), the charges must be of opposite sign.
23. Cosmic ray intensity at the Earth's surface would be greater when the Earth's magnetic field passed through a zero phase. Fossil evidence suggests the periods of no protective magnetic field may have been as effective in changing life forms as X-rays have been in the famous heredity studies of fruit flies.
25. Magnetic levitation will reduce surface friction to near zero. Then only air friction will remain. It can be made relatively small by aerodynamic design, but there is no way to eliminate it (short of sending vehicles through evacuated tunnels). Air friction gets rapidly larger as speed increases.
27. The two pulses are opposite in direction. When the wire enters the magnetic field between the poles of the magnet, a pulse of voltage is induced in the wire, which is indicated by movement of the galvanometer needle. When the wire is lifted a pulse in the opposite direction is induced, and the needle moves in the opposite direction.
29. A cyclist will coast farther if the lamp is disconnected from the generator. The energy that goes into lighting the lamp is taken from the bike's kinetic energy, so the bike slows down. The work saved by not lighting the lamp will be the extra "force × distance" that lets the bike coast farther.
31. As in the previous answer, eddy currents induced in the metal change the magnetic field, which in turn changes the ac current in the coils and sets off an alarm.
33. Input and output are reversed for the two devices. When mechanical energy is put into the device and electricity is produced, we call it a generator. When electrical energy is put in and it spins and does mechanical work, we call it a motor. (While there are usually some practical differences in the designs of motors and generators, some devices are designed to operate either as motors or generators, depending only on whether the input is mechanical or electrical.)
35. In accord with electromagnetic induction, if the magnetic field alternates in the hole of the ring, an alternating voltage will be induced in the ring. Because the ring is metal, its relatively low resistance will result in a correspondingly high alternating current. This current is evident in the heating of the ring.
37. If the lightbulb is connected to a wire loop that intercepts changing magnetic field lines from an electromagnet, voltage will be induced which can illuminate the bulb. Change is the key, so the electromagnet should be powered with ac.
39. The iron core increases the magnetic field of the primary coil. The greater field means a greater magnetic field change in the primary, and a greater voltage induced in the secondary. The iron core in the secondary further increases the changing magnetic field through the secondary and further increases the secondary voltage. Furthermore, the core guides more magnetic field lines from the primary to the secondary. The effect of an iron core in the coils is the induction of appreciably more voltage in the secondary.
41. When the secondary voltage is twice the primary voltage and the secondary acts as a source of voltage for a resistive "load," the secondary current is half the value of current in the primary. This is in accord with energy conservation, or since the time intervals for each are the same, "power conservation." Power input = power output; or $(\text{current} \times \text{voltage})_{\text{primary}} = (\text{current} \times \text{voltage})_{\text{secondary}}$: with numerical values, $(1 \times \text{V})_{\text{primary}} = (\tfrac{1}{2} \times 2\text{ V})_{\text{secondary}}$. (The simple rule power = current × voltage is strictly valid only for dc circuits and ac circuits where current and voltage oscillate in phase. When voltage and current are out of phase, which can occur in a transformer, the net power is less than the product current × voltage. Voltage and current are then not "working together." When the secondary of a transformer is open, for example, connected to nothing, current and voltage in both the primary and the secondary are completely out of phase—that is, one is maximum when the other is zero—and no net power is delivered even though neither voltage nor current is zero.)
43. The voltage impressed across the lamp is 120 V and the current through it is 0.1 A. We see that the first transformer steps the voltage down to 12 V and the second one steps it back up to 120 V. The current in the secondary of the second transformer, which is the same as the current in the bulb, is one-tenth of the current in the primary, or 0.1 A.
45. By symmetry, the voltage and current for both primary and secondary are the same. So 12 V is impressed on the meter, with a current of 1 A ac.
47. The bar magnet induces current loops in the surrounding copper as it falls. The current loops produce magnetic fields that tend to repel the magnet as it approaches and attract it as it leaves, exerting a vertical upward force on it, opposite to gravity. The faster the magnet falls, the stronger is this upward force. At some speed, it will match gravity and the magnet will be at terminal speed. From an energy point of view, some of the gravitational potential energy is being transformed to heat in the copper pipe. The plastic pipe, on the other hand, is an insulator. So no current and therefore no magnetic field are induced to oppose the motion of the falling magnet.
49. Agree with your friend, for light is electromagnetic radiation having a frequency that matches the frequency to which our eyes are sensitive.

Solutions to Chapter 11 Problems

1. (120 V)/(500 turns) = (12 V)/x, so x = 50 turns.
3. From the transformer relationship,

$$\frac{\text{primary voltage}}{\text{primary turns}} = \frac{\text{secondary voltage}}{\text{secondary turns}}, \quad \frac{\text{primary voltage}}{\text{secondary voltage}} = \frac{\text{primary turns}}{\text{secondary turns}}; \frac{120\text{ V}}{24\text{ V}} = \frac{5}{1}.$$

So there are five times as many primary turns as secondary turns.

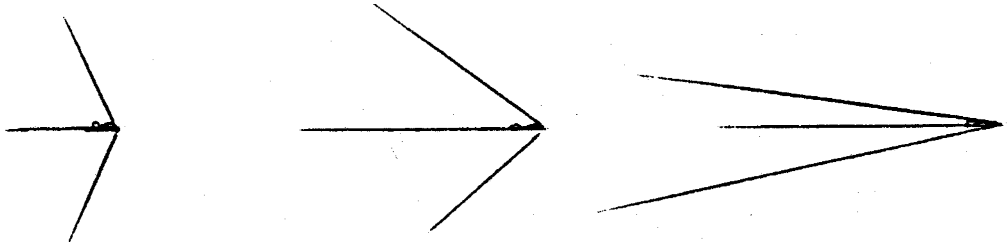
5. The transformer steps up voltage by a factor 36/9 = 4. Therefore a 12-V input will be stepped up to 4 × 12 V = 48 V.
7. From $\frac{\text{primary voltage}}{\text{primary turns}} = \frac{\text{secondary voltage}}{\text{secondary turns}}$, simple rearrangement gives

$$\frac{\text{primary voltage}}{\text{secondary voltage}} = \frac{\text{primary turns}}{\text{secondary turns}} = \frac{120\text{V}}{12000\text{V}} = \frac{1}{100}.$$

Solutions to Chapter 12 Exercises

1. Something that vibrates.
3. As you dip your fingers more frequently into still water, the waves you produce will be of a higher frequency (we see the relationship between "how frequently" and "frequency"). The crests of the higher-frequency waves will be closer together—their wavelengths will be shorter.
5. Shake the garden hose to-and-fro in a direction perpendicular to the hose to produce a sine-like curve.
7. The fact that gas can be heard escaping from a gas tap before it is smelled indicates that the pulses of molecular collisions (the sound) travel more quickly than the molecules migrate. (There are three speeds to consider: (1) the average speed of the molecules themselves, as evidenced by temperature—quite fast, (2) the speed of the pulse produced as they collide—about ¾ the speed of the molecules themselves, and (3) the very much slower speed of molecular migration.)
9. The carrier frequency of electromagnetic waves emitted by the radio station is 101.1 MHz.
11. The wavelength of the electromagnetic wave will be much longer because of its greater speed. You can see this from the equation speed = wavelength × frequency, so for the same frequency greater speed means greater wavelength. Or you can think of the fact that in the time of one period—the same for both waves—each wave moves a distance equal to one wavelength, which will be greater for the faster wave.
13. The electronic starting gun does not rely on the speed of sound through air, which favors closer runners, but gets the starting signal to all runners simultaneously.
15. Because snow is a good absorber of sound, it reflects little sound—which is responsible for the quietness.
17. The Moon is described as a silent planet because it has no atmosphere to transmit sounds.
19. If the speed of sound were different for different frequencies, say, faster for higher frequencies, then the farther a listener is from the music source, the more jumbled the sound would be. In that case, higher-frequency notes would reach the ear of the listener first. The fact that this jumbling doesn't occur is evidence that sounds of all frequencies travel at the same speed. (Be glad this is so, particularly if you sit far from the stage, or if you like outdoor concerts.)
21. Sound travels faster in warm air because the air molecules that compose warm air themselves travel faster and therefore don't take as long before they bump into each other. This lesser time for the molecules to bump against one another results in a faster speed of sound.
23. An echo is weaker than the original sound because sound spreads and is therefore less intense with distance. If you are at the source, the echo will sound as if it originated on the other side of the wall from which it reflects (just as your image in a mirror appears to come from behind the glass). Also contributing to its weakness is the wall, which likely is not a perfect reflector.
25. The rule is correct: This is because the speed of sound in air (340 m/s) can be rounded off to ⅓ km/s. Then, from distance = speed × time, we have distance = (⅓) km/s × (number of seconds). Note that the time in seconds divided by 3 gives the same value.
27. Marchers at the end of a long parade will be out of step with marchers nearer the band because time is required for the sound of the band to reach the marchers at the end of a parade. They will step to the delayed beat they hear.
29. A harp produces relatively softer sounds than a piano because its sounding board is smaller and lighter.
31. The lower strings are resonating with the upper strings.
33. Waves of the same frequency can interfere destructively or constructively, depending on their relative phase, but to *alternate* between constructive and destructive interference, two waves have to have different frequencies. Beats arise from such alternation between constructive and destructive interference.
35. The piano tuner should loosen the piano string. When 3 beats per second is first heard, the tuner knows he was 3 hertz off the correct frequency. But this could be either 3 hertz above or 3 hertz below. When he tightened the string and increased its frequency, a lower beat frequency would have told him he was on the right track. But the greater beat frequency told him he should have been loosening the string. When there is no beat frequency, the frequencies match.
37. No, the effects of shortened waves and stretched waves would cancel one another.

39. The Doppler shifts show that one side approaches while the other side recedes, evidence that the Sun is spinning.
41. The conical angle of a shock wave becomes narrower with greater speeds. We see this in the sketches:



43. A shock wave and the resulting sonic boom are produced whenever an aircraft is supersonic, whether or not the aircraft has just become supersonic or has been supersonic for hours. It is a popular misconception that sonic booms are principally produced at the moment an aircraft becomes supersonic. This is akin to saying that a boat produces a bow wave at the moment it exceeds the wave-speed of water. It begins to produce a bow wave at this crucial moment, but if it moved no faster, the overlapping pattern of waves would not extend very far from the bow. Likewise with an aircraft. Both the boat and the aircraft must appreciably exceed wave speed to produce an ample bow and shock wave.
45. Resonance.

Solutions to Chapter 12 Problems

1. f = (72 beats)/(60 s) = 1.2 Hz.; $T = 1/f = 1/(1.2\ \text{s}^{-1}) = 0.83$ s.
3. From $v = \lambda f$, $\lambda = v/f = (3.00 \times 10^8\ \text{m/s})/(2.45 \times 10^9\ \text{Hz}) = 0.122$ m = 12.2 cm.
5. The ocean floor is 4590 meters down. The 6-second time delay means that the sound reached the bottom in 3 seconds. Distance = speed × time = 1530 m/s × 3 s = 4590 m.
7. Speed = distance traveled/time taken = (2 × 85 m)/0.5 s = 170 m/0.5 s = 340 m/s.
9. (a) Period = 1/frequency = 1/(256 Hz) = 0.00391 s, or 3.91 ms.

   (b) Speed = wavelength × frequency, so wavelength = speed/frequency = (340 m/s)/(256 Hz) = 1.33 m.
11. There are three possible beat frequencies, 2 Hz, 3 Hz, and 5 Hz. The beats consist of differences in fork frequencies: 261–259 = 2 Hz; 261–256 = 5 Hz; 259–256 = 3 Hz.

Solutions to Chapter 13 Exercises

1. The fundamental source of electromagnetic radiation is oscillating electric charges, which emit oscillating electric and magnetic fields.
3. Ultraviolet has shorter waves than infrared. Correspondingly, ultraviolet also has the higher frequencies.
5. Sound requires a physical medium in which to travel. Light does not.
7. Radio waves and light are both electromagnetic, transverse, move at the speed of light, and are created and absorbed by oscillating charge. They differ in their frequency and wavelength and in the type of oscillating charge that creates and absorbs them.
9. The greater number of interactions per distance tends to slow the light and the result is a smaller average speed.
11. Clouds are transparent to ultraviolet light, which is why clouds offer no protection from sunburn. Glass, however, is opaque to ultraviolet light, and will therefore shield you from sunburn.
13. The customer is being reasonable in requesting to see the colors in the daylight. Under fluorescent lighting, with its predominant higher frequencies, the bluer colors rather than the redder colors will be accented. Colors will appear quite different in sunlight.
15. We see not only yellow and green, but also red and blue. All together, they mix to produce the white light we see.
17. If the yellow clothes of stage performers are illuminated with a complementary blue light, they will appear black.
19. Red and green produce yellow; red and blue produce magenta; red, blue, and green produce white.
21. The red shirt in the photo is seen as cyan in the negative, and the green shirt appears magenta—the complementary colors. When white light shines through the negative, red is transmitted where cyan is absorbed. Likewise, green is transmitted where magenta is absorbed.
23. Blue illumination produces black. A yellow banana reflects yellow and the adjacent colors, orange and green, so when illuminated with any of these colors it reflects that color and appears that color. A banana does not reflect blue, which is too far from yellow in the spectrum, so when illuminated with blue it appears black.
25. You see the complementary colors due to retina fatigue. The blue will appear yellow, the red cyan, and the white black. Try it and see!
27. At higher altitudes, there are fewer molecules above you and therefore less scattering of sunlight. This results in a darker sky. The extreme, no molecules at all, results in a black sky, as on the Moon.
29. Clouds are composed of atoms, molecules, and particles of a variety of sizes. So not only are high-frequency colors scattered from clouds, but middle and low frequencies as well. A combination of all the scattered colors produces white.
31. If we assume that Jupiter has an atmosphere which is similar to that of the Earth in terms of transparency, then the Sun would appear to be a deep reddish orange, just as it would when sunlight grazes 1000 kilometers of the Earth's atmosphere for a sunset from an elevated position. Interestingly enough, there is a thick cloud cover in Jupiter's atmosphere that blocks all sunlight from reaching its "surface." And it doesn't even have a solid surface! Your grandchildren may visit one of Jupiter's moons, but will not "land" on Jupiter itself—not intentionally, anyway. (Incidentally, there are only 3⅓ planets with "solid" surfaces: Mercury, Venus, Mars, and ⅓ of Earth! Dwarf planet Pluto also has a solid surface.)

33. The wavelengths of AM radio waves are hundreds of meters, much larger than the size of buildings, so they are easily diffracted around buildings. FM wavelengths are a few meters, borderline for diffraction around buildings. Light, with wavelengths a tiny fraction of a centimeter, shows no appreciable diffraction around buildings.
35. Young's interference experiment produces a clearer fringe pattern with slits than with pinholes because the pattern is of parallel straight-line-shaped fringes rather than the fringes of overlapping circles. Circles overlap in relatively smaller segments than the broader overlap of parallel straight lines. Also, the slits allow more light to get through; the pattern with pinholes is dimmer.
37. There must be two reflecting surfaces for interference by reflection to occur. Light reflecting from the gasoline surface interferes with light reflected from the water surface beneath.
39. Blue, the complementary color. The blue is white minus the yellow light that is seen above.

Solutions to Chapter 13 Problems

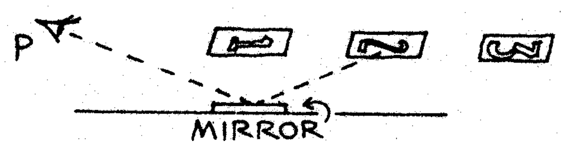
1. $f = c/\lambda = (3.00 \times 10^8 \text{ m/s})/(670 \times 10^{-9} \text{ m}) = 4.48 \times 10^{14}\text{Hz}$.
3. $v_{\text{Hydra}}/c = (6.0 \times 10^7 \text{ m/s})/(3.0 \times 10^8 \text{ m/s}) = 0.2$, or 20% the speed of light.
5. As in the previous problem, $t = \dfrac{d}{v} = \dfrac{4.2 \times 10^{16} \text{ m}}{3 \times 10^8 \text{ m/s}} = 1.4 \times 10^8 \text{ s}$.

   Converting to years by dimensional analysis,

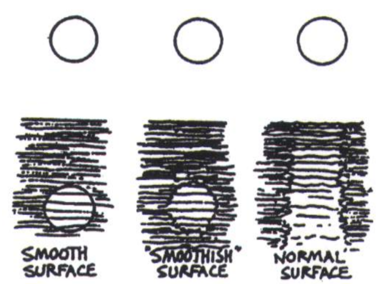
   $$1.4 \times 10^8 \text{ s} \times \frac{1 \text{ h}}{3600 \text{ s}} \times \frac{1 \text{ day}}{24 \text{ h}} \times \frac{1 \text{ yr}}{365 \text{ day}} = 4.4 \text{ yr.}$$
7. From $v = \lambda f$, $f = v/\lambda = (3.00 \times 10^8 \text{ m/s})/(360 \times 10^{-9} \text{ m}) = 8.33 \times 10^{14}$ Hz.

Solutions to Chapter 14 Exercises

1. Only light from card number 2 reaches her eye.



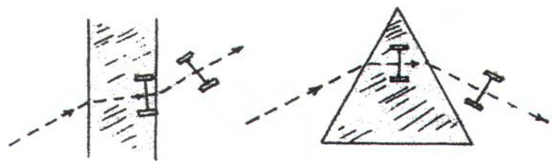
3. Light that takes a path from point A to point B will take the same reverse path in going from point B to point A, even if reflection or refraction is involved. So if you can't see the driver, the driver can't see you. (This independence of direction along light's path is the "principle of reciprocity.")
5. When you wave your right hand, the image of the waving hand is still on your right, just as your head is still up and your feet still down. Neither left and right nor up and down are inverted by the mirror—but *front and back* are, as the author's sister Marjorie illustrates in Figure 14.3. (Consider three axes at right angles to each other, the standard coordinate system; horizontal *x*, vertical *y*, and perpendicular-to-the-mirror *z*. The only axis to be inverted is *z*, where the image is –*z*.)
7. When the source of glare is somewhat above the horizon, a vertical window will reflect it to people in front of the window. By tipping the window inward at the bottom, glare is reflected downward rather than into the eyes of passersby. (Note the similarity of this exercise and the previous one.)
9. The pebbly uneven surface is easier to see. Light reflected back from your headlights is what lets you see the road. The mirror-smooth surface might reflect more light, but it would reflect it forward, not backward, so it wouldn't help you see.
11. First of all, the reflected view of a scene is different than an inverted view of the scene, for the reflected view is seen from lower down. Just as a view of a bridge may not show its underside where the reflection does, so it is with the bird. The view reflected in water is the inverted view you would see if your eye were positioned as far beneath the water level as your eye is above it (and there were no refraction). Then your line of sight would intersect the water surface where reflection occurs. Put a mirror on the floor between you and a distant table. If you are standing, your view of the table is of the top. But the reflected view shows the table's bottom. Clearly, the two views are not simply inversions of each other. Take notice of this whenever you look at reflections (and of paintings of reflections—it's surprising how many artists are not aware of this).



13. The half-height mirror works at any distance, as shown in the sketch. This is because if you move closer, your image moves closer as well. If you move farther away, your image does the same. Many people must actually try this before they believe it. The confusion arises because people know that they can see whole distant buildings or even mountain ranges in a hand-held pocket mirror. Even then, the distance the object is from the mirror is the same as the distance of the virtual image on the other side of the mirror. You can see all of a distant person in your mirror, but the distant person cannot see all of herself in your mirror.
15. The wiped area will be half as tall as your face.
17. If the water were perfectly smooth, you would see a mirror image of the round Sun or Moon, an ellipse on the surface of the water. If the water were slightly rough, the image would be wavy. If the water were a bit more rough, little glimmers of portions of the Sun or Moon would be seen above and below the main image. This is because the water waves act like tiny parallel

mirrors. For small waves only light near the main image reaches you. But as the water becomes choppier, there is a greater variety of mirror facets that are oriented to reflect sunlight or moonlight into your eye. The facets do not radically depart from an average flatness with the otherwise smooth water surface, so the reflected Sun or Moon is smeared into a long vertical streak. For still rougher water there are facets off to the side of the vertical streak that are tilted enough for Sun or Moon light to be reflected to you, and the vertical streak is wider.

19.



21. During a lunar eclipse the Moon is not totally dark, even though it is in the Earth's shadow. This is because the atmosphere of the Earth acts as a converging lens that refracts light into the Earth's shadow. It is the low frequencies that pass more easily through the long grazing path through the Earth's atmosphere to be refracted finally onto the Moon. Hence its reddish color—the refraction of the whole world's sunups and sunsets.
23. You would throw the spear below the apparent position of the fish, because the effect of refraction is to make the fish appear closer to the surface than it really is. But in zapping a fish with a laser, make no corrections and simply aim directly at the fish. This is because the light from the fish you see has been refracted in getting to you, and the laser light will refract along the same path in getting to the fish. A slight correction may be necessary, depending on the colors of the laser beam and the fish—see the next exercise.
25. A fish sees the sky (as well as some reflection from the bottom) when it looks upward at 45°, for the critical angle is 48° for water. If it looks at and beyond 48° it sees only a reflection of the bottom.
27. Total internal reflection occurs only for light rays that would gain speed in crossing the boundary they encounter. For light in air encountering a water surface, there is no total reflection. You can see this by sketching rays that go from water to air, and noting that light can travel in the other direction along all of these rays.
29. We cannot see a rainbow "off to the side," for a rainbow is not a tangible thing "out there." Colors are refracted in infinite directions and fill the sky. The only colors we see that aren't washed out by others are those that are along the conical angles between 40° and 42° to the Sun–anti-Sun axis. To understand this, consider a paper-cone cup with a hole cut at the bottom. You can view the circular rim of the cone as an ellipse when you look at it from a near side view. But if you view the rim only with your eye at the apex of the cone, through the hole, you can see it only as a circle. That's the way we view a rainbow. Our eye is at the apex of a cone, the axis of which is the Sun-anti-Sun axis, and the "rim" of which is the bow. From every vantage point, the bow forms part (or all) of a circle.
31. When the Sun is high in the sky and people on the airplane are looking down toward a cloud opposite to the direction of the Sun, they may see a rainbow that makes a complete circle. The shadow of the airplane will appear in the center of the circular bow. This is because the airplane is directly between the Sun and the drops or rain cloud producing the bow.
33. A projecting lens with chromatic aberration casts a rainbow-colored fringe around a spot of white light. The reason these colors don't appear inside the spot is because they overlap to form white. Only at the edges, which act as a circular prism, do they not overlap.
35. The average intensity of sunlight at the bottom is the same whether the water is moving or is still. Light that misses one part of the bottom of the pool reaches another part. Every dark region is balanced by a bright region—"conservation of light."
37. Normal sight depends on the amount of refraction that occurs for light traveling from air to the eye. The speed change ensures normal vision. But if the speed change is from water to eye, then light will be refracted less and an unclear image will result. A swimmer uses goggles to make sure that the light travels from air to eye, even if underwater.
39. If light had the same average speed in glass lenses that it has in air, no refraction of light would occur in lenses, and no magnification would occur. Magnification depends on refraction, which in turn depends on speed changes.
41. Your image is twice as far from the camera as the mirror frame. So although you can adjust the focus of your camera to clearly photograph your image in a mirror, and you can readjust the focus to clearly photograph the mirror frame, you cannot in the same photograph focus on both your image and the mirror frame. This is because they are at different distances from the camera.
43. Moon maps are upside-down views of the Moon to coincide with the upside-down image that Moon watchers see in a telescope.
45. The displays are polarized and depending on the angle of viewing, may not be seen at all. This is a serious liability of Polaroid sunglasses.
47. If the sheet is aligned with the polarization of the light, all the light gets through. If it is aligned perpendicular to the polarization of the light, none gets through. At any other angle, some of the light gets through because the polarized light can be "resolved" (like a vector) into components parallel and perpendicular to the alignment of the sheet.
49. You can determine that the sky is partially polarized by rotating a single sheet of Polaroid in front of your eye while viewing the sky. You'll notice the sky darken when the axis of the Polaroid is perpendicular to the polarization of the skylight.

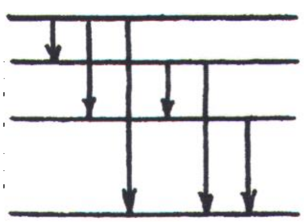
Solutions to Chapter 14 Problems

1. Set your focus for 6 m, for your image will be as far in back of the mirror as you are in front.
3. 4 m/s. You and your image are both walking at 2 m/s.

5. When a mirror is rotated, its normal rotates also. See in the sketch how if the normal rotates 10°, the beam reflects at twice this, 20°. This is one reason that mirrors are used to detect delicate movements in instruments such as galvanometers. The more important reason is the amplification of displacement by having the beam arrive at a scale some distance away.
7. Use ratios: (1440 min)/(360 deg) = (unknown time)/(0.53 deg). So the unknown time is $0.53 \times 1440/360 = 2.1$ minutes. So the Sun moves a solar diameter across the sky every 2.1 minutes. At sunset, time is somewhat extended, depending on the extent of refraction. Then the disk of the setting Sun disappears over the horizon in a little longer than 2.1 minutes.

Solutions to Chapter 15 Exercises

1. Higher-frequency ultraviolet light has more energy per photon.
3. Higher-frequency green light has more energy per photon.
5. Doubling the wavelength of light halves its frequency. Light of half frequency has half the energy per photon. Think in terms of the equation $c = f\lambda$. Since the speed of light c is constant, λ is inversely proportional to f.
7. The energy of red light is too low per photon to trigger the chemical reaction in the photographic crystals. Very bright light simply means more photons that are unable to trigger a reaction. Blue light, on the other hand, has sufficient energy per photon to trigger a reaction. Very dim blue light triggers fewer reactions only because there are fewer photons involved. It is safer to have bright red light than dim blue light.
9. The kinetic energy of ejected electrons depends on the frequency of the illuminating light. With sufficiently high frequency, the number of electrons ejected in the photoelectric effect is determined by the number of photons incident upon the metal. So whether or not ejection occurs depends on frequency, and how many electrons are ejected depends on the brightness of the sufficiently high-frequency light.
11. Ultraviolet photons are more energetic.
13. Particle nature.
15. The moving star will show a Doppler shift. Since the star is receding, it will be a redshift (to lower frequency and longer wavelength).
17. Atomic excitation occurs in solids, liquids, and gases. Because atoms in a solid are closely packed, radiation from them (and liquids) is smeared into a broad distribution to produce a continuous spectrum, whereas radiation from widely spaced atoms in a gas is in separate bunches that produce discrete "lines" when diffracted by a grating.
19. The same energy is needed both ways.
21. The acronym says it: microwave *a*mplification by *s*timulated *e*mission of *r*adiation.
23. Its energy is very concentrated in comparison with that of a lamp.
25. Your friend's assertion violates the law of energy conservation. A laser or any device cannot put out more energy than is put into it. Power, on the other hand, is another story, as is treated in the following exercise.
27. The metal is glowing at all temperatures, whether we can see the glow or not. As its temperature is increased, the glow reaches the visible part of the spectrum and is visible to human eyes. Light of the lowest energy per photon is red. So the heated metal passes from infrared (which we can't see) to visible red. It is red hot.
29. Star's relative temperatures—lowish for reddish; middish for whitish; and hottish for bluish.
31. Six transitions are possible, as shown. The highest-frequency transition is from quantum level 4 to level 1. The lowest-frequency transition is from quantum level 4 to level 3.



33. [illegible] when in transit, and like particles when they interact with a surface.
35. [illegible]
37. [illegible] more momentum, while the electron with its smaller momentum has the longer wavelength.
39. [illegible] velocity increases, momentum increases, so wavelength decreases.
41. [illegible] microscope.
43. If somebody looks at an electron on the tip of your nose with an electron beam or a light beam, then its motion as well as that of surrounding electrons will be altered. We take the view here that passively looking at light after it has reflected from an object does not alter the electrons in the object. We distinguish between passive observation and probing. The uncertainty principle applies to probing, not to passive observation. (This view, however, is not held by some physicists who assert any measure, passive or probing, alters that being measured at the quantum level. These physicists argue that passive observation provides knowledge, and that without this knowledge, the electron might be doing something else or might be doing a mixture, a superposition, of other things.)
45. Heisenberg's uncertainty principle applies *only* to quantum phenomena. However, it serves as a popular metaphor for the macro domain. Just as the way we measure affects what's being measured, the way we phrase a question often influences the answer we get. So to various extents we alter that which we wish to measure in a public opinion survey. Although there are countless examples of altering circumstances by measuring them, the uncertainty principle has meaning only in the submicroscopic world.
47. The question is absurd, with the implication that eradicating butterflies will prevent tornadoes. If a butterfly can, in principle, cause a tornado, so can a billion other things. Eradicating butterflies will leave the other 999,999,999 causes untouched. Besides, a butterfly is as likely to *prevent* a tornado as to cause one.
49. What waves is the probability amplitude.

51. Some of the behavior of light, such as interference and diffraction, can only be satisfactorily explained in terms of the wave model; while behavior such as the photoelectric effect can be satisfactorily explained only in terms of the particle model. Hence we say that light has both wave and particle properties.
53. Bohr's correspondence principle says that quantum mechanics must overlap and agree with classical mechanics in the domain where classical mechanics has been shown to be valid.
55. This is perhaps the extreme in altering that which is being measured by the process of measuring itself, as well as an extreme case of criminal stupidity and academic arrogance. The bristlecone pine, Old Methuselah, was the oldest known living thing in the world.

Solutions to Chapter 15 Problems

1. (a) The B-to-A transition has twice the energy and twice the frequency of the C-to-B transition. Therefore it will have half the wavelength, or 300 nm. Reasoning: Since $c = f\lambda$, $\lambda = c/f$. Wavelength is inversely proportional to frequency. Twice the frequency means half the wavelength.
   (b) The C-to-A transition has three times the energy and three times the frequency of the C-to-B transition. Therefore it will have one-third the wavelength, or 200 nm.
3. De Broglie wavelength = Planck's constant/momentum, so we need the electron's momentum. It is $p = mv = (9.1 \times 10^{-31}\text{ kg})(3.0 \times 10^{7}\text{ m/s}) = 2.7 \times 10^{-23}$ kg m/s. The de Broglie wavelength is then $\lambda = h/p = (6.6 \times 10^{-34})/(2.7 \times 10^{-23}) = 2.4 \times 10^{-11}$ m.

Solutions to Chapter 16 Exercises

1. Radioactivity is a part of nature, going back to the beginning of time.
3. A radioactive sample is always a little warmer than its surroundings because the radiating alpha or beta particles impart internal energy to the atoms of the sample. (Interestingly enough, the heat energy of the Earth originates with radioactive decay of the Earth's core and surrounding material.)
5. Alpha and beta rays are deflected in opposite directions in a magnetic field because they are oppositely charged—alpha are positive and beta negative. Gamma rays have no electric charge and are therefore undeflected.
7. The alpha particle has twice the charge, but almost 8000 times the inertia (since each of the four nucleons has nearly 2000 times the mass of an electron). Hence it bends very little compared to the much less massive beta particles (electrons). Gamma rays carry no electric charge and so are not affected by an electric field.
9. Gamma radiation produces not only the least change in mass and atomic numbers, but produces no change in mass number, atomic number, or electric charge. Both alpha and beta radiation do produce these changes.
11. The proton "bullets" need enough momentum to overcome the electric force of repulsion they experience once they get close to the atomic nucleus.
13. The strong nuclear force holds the nucleons of the nucleus together while the electric force pushes these nucleons apart.
15. No, it will not be entirely gone. Rather, after 1 day one-half of the sample will remain while after 2 days, one-fourth of the original sample will remain.
17. When radium (A = 88) emits an alpha particle, its atomic number reduces by 2 and becomes the new element radon (A = 86). The resulting atomic mass is reduced by 4. If the radium were of the most common isotope 226, then the radon isotope would have atomic mass number 222.
19. Deuterium has 1 proton and 1 neutron; carbon has 6 protons and 6 neutrons; iron has 26 protons and 30 neutrons; gold has 79 protons and 118 neutrons; strontium has 38 protons and 52 neutrons; uranium has 92 protons and 146 neutrons.
21. The elements below uranium in atomic number with short half-lives exist as the product of the radioactive decay of uranium. As long as uranium is decaying, their existence is assured.
23. Although there is significantly more radioactivity in a nuclear power plant than in a coal-fired power plant, the absence of shielding for coal plants results in more radioactivity in the environment of a typical coal plant than in the environment of a typical nuclear plant. All nukes are shielded; coal plants are not.
25. Film badges monitor gamma radiation, which is very high-frequency X-rays. Like photographic film, the greater the exposure, the darker the film upon processing.
27. There are no fast-flying subatomic particles in gamma rays that might collide with the nuclei of the atoms within the food. Transformations within the nuclei of the atoms of the food, therefore, are not possible. Rather, the gamma rays are lethal to any living tissues within the food, such as those of pathogens. The gamma rays kill these pathogens, which helps to protect us from dangerous diseases such as botulism.
29. Stone tablets cannot be dated by the carbon dating technique. Nonliving stone does not ingest carbon and transform that carbon by radioactive decay. Carbon dating pertains to organic material.
31. A neutron makes a better "bullet" for penetrating atomic nuclei because it has no electric charge and is therefore not deflected from its path by electrical interactions, nor is it electrically repelled by an atomic nucleus.
33. Because plutonium triggers more reactions per atom, a smaller mass will produce the same neutron flux as a somewhat larger mass of uranium. So plutonium has a smaller critical mass than a similar shape of uranium.
35. Plutonium has a short half-life (24,360 years), so any plutonium initially in the Earth's crust has long since decayed. The same is true for any heavier elements with even shorter half-lives from which plutonium might originate. Trace amounts of plutonium can occur naturally in U-238 concentrations, however, as a result of neutron capture, where U-238 becomes U-239 and after beta emission becomes Np-239, and further beta emission to Pu-239. (There are elements in the Earth's crust with half-lives even shorter than plutonium's, but these are the products of uranium decay.)

37. A nucleus undergoes fission because the electric force of repulsion overcomes the strong nuclear force of attraction. This electric force of repulsion is of the very same nature as static electricity. So, in a way, your friend's claim that the explosive power of a nuclear bomb is due to static electricity is valid.
39. If the difference in mass for changes in the atomic nucleus increased tenfold (from 0.1% to 1.0%), the energy release from such reactions would increase tenfold as well.
41. Both convert mass to energy.
43. Energy would be released by the fissioning of gold and from the fusion of carbon, but by neither fission nor fusion for iron. Neither fission nor fusion will result in a decrease of mass for iron nucleons.
45. The radioactive decay of radioactive elements found under the Earth's surface warms the insides of the Earth and is responsible for the molten lava that spews from volcanoes. The thermonuclear fusion of our Sun is responsible for warming everything on our planet's surface exposed to the Sun.
47. Such speculation could fill volumes. The energy and material abundance that is the expected outcome of a fusion age will likely prompt several fundamental changes. Obvious changes would occur in the fields of economics and commerce, which would be geared to relative abundance rather than scarcity. Already our present price system, which is geared to and in many ways dependent upon scarcity, often malfunctions in an environment of abundance. Hence we see instances where scarcity is created to keep the economic system functioning. Changes at the international level will likely be worldwide economic reform, and at the personal level a re-evaluation of the idea that scarcity ought to be the basis of value. A fusion age will likely see changes that will touch every facet of our way of life.
49. To create an abundant supply of molecular hydrogen will require an abundant source of energy, such as fusion power.

Solutions to Chapter 16 Problems

1. At 2 meters the reading will be about 90 counts per minute. At 3 meters the reading will be about 40 counts per minute.
3. At 3:00 P.M. there are 0.125 grams left. At 6:00 P.M. there are 0.0156 grams left. At 10:00 P.M. there are 0.000977 grams left.
5. It will take four half-lives to decrease to one-sixteenth the original amount. Four half-lives of cesium-137 corresponds to 120 years.
7. Six percent corresponds to about one-sixteenth, which means that the carbon-14 has undergone about four half-lives. Four half-lives of carbon-14 equals 5730 years times 4 equals 22,920 years, about 23,000 years old.
9. $(2 \times 10^{10}\ \text{kcal}) = (1\ \text{kcal}/1°\text{C}\ 1\ \text{kg})(\text{mass})(50°\text{C})$.

Solutions to Appendix D Questions to Ponder

1. The pond was half covered on the 29th day, and one-quarter covered on the 28th day.
3. At a steady inflation rate of 7%, the doubling time is 70/7% = 10 years; so every 10 years the prices of these items will double. This means the $20 theater ticket in 10 years will cost $40, in 20 years will cost $80, in 30 years will cost $160, in 40 years will cost $320, and in 50 years will cost $640. The $200 suit of clothes will similarly jump each decade to $400, $800, $1600, $3200, and $6400. For a $20,000 car the decade jumps will be $40,000, $80,000, $160,000, $320,000, and $640,000. For a $200,000 home, the decade jumps in price are $400,000, $800,000, $1,600,000, $3,200,000, and $6,400,000! Inflation often increases earnings more than prices, so we'll be able to pay for these things—and more.
5. All things being equal, doubling of food for twice the number of people simply means that twice as many people will be eating, and twice as many will be starving as are starving now!
7. On the 30th day your wages will be $5,368,709.12, which is one penny more than the $5,368,709.11 total from all the preceding days.