Appendix D. Hints and Answers to Exercises

Chapter 1

1.1. This question is meant to be thought provoking and somewhat subjective, not to have a nice clean objective answer. But, here is the way one person saw it. (a) Reason and sensory data, (b) authority and intuition, (c) reason, (d) reason and sensory data, (e) intuition, (f) reason and sensory data, (g) reason, (h) reason and sensory data.

1.2. The “spinning earth” model offers a more economical explanation than the “moving sun” model. More on this in Chapter 8.

1.3. Possible hypotheses might be: (a) The mountain was originally part of a marine environment in which the organisms lived and died. (b) The fossil shells were transported by some agent from their marine environment to the mountain. Occam’s Razor would probably prefer not to introduce “some agent,” if it is not needed.

1.4. Astronomers assume that the same physical laws govern such things as the sources of light throughout the universe. By observing light from distant stars they can infer the star’s composition.

1.5. No. Position symmetry requires only that the governing law be the same on the earth and the moon. The numerical predictions of the law can be different.

1.6. Geologists assume that the physical laws governing the earth millions of years ago were the same as they are today—time symmetry.

1.7. No. The governing laws are the same from day to day.

1.8. Your own example.

1.9. Pythagoras, Aristotle, and Aquinas leaned toward authority, intuition, and reason for their models. Galileo and Newton leaned more toward sensory observation and reason.

Chapter 2

2.1. Refer to text.

2.2. The diameter of the atom is about 100,000 times the diameter of the nucleus. In size, the atom is to a football field as the nucleus is to the tip of a ballpoint pen.

2.3. Four light-years; 100,000 light-years; 1,000,000 light-years.

2.4. Refer to Exercise 2.1 and describe how smaller structures make up progressively larger structures.

2.5. Consider the following: (a) and (b) nuclear and atomic sizes. (c) distance between stars in a galaxy.

2.6. (d)

2.7. (b)

Chapter 3

3.1. You will want to think through the process by which we tried to convince you that the law is “true.” In general, you want to give some examples of phenomena which can be explained in terms of the law. Then you will need to be ready to discuss situations where the law doesn’t seem to hold. (A sliding object comes to rest, for example. It doesn’t seem to move with uniform motion even though it appears to be a free object.) If the friend is really interested in understanding, the friend will raise many of these until totally convinced that there are no exceptions in all the situations encountered.

3.2. Sometimes the word “frictionless” confuses people. It just means that we are imagining a situation where there is no frictional force. If this were really true, neither the elephant nor the ant would experience any forces. The First Law of Motion then describes their motion and neither would stop before the other.

3.3. (a) Prior to the accident, the car and child were
moving forward together at 20 miles per hour. Because of external forces, the car stops suddenly. If no forces act to restrain the child, the child continues forward as a free object, thus moving forward with respect to the car. (b) 20 miles per hour. This might mean more to you if you know that 20 miles per hour is just about the same speed as the world’s record in the 100-meter dash. The effect for the child is the same as for an adult running as fast as he can and running directly into a plate-glass door.

3.4. The passenger continues, momentarily, in straight-line motion while the car turns under him. Thus he finds himself further from the center of the turn, but only because he goes in a straight line and not because he is thrown outward. The car moves inward because of the forces acting upon it. Thus, the passenger and car go in different directions, but this is due to forces acting on the car and not to any forces on the passengers.

3.5. Your wording will probably be different than Newton’s or anyone else’s. It is probably not appropriate to memorize a particular statement of any of the laws we will study. However, your wording should contain the same important components of the law. In this case, these would be: (a) The law applies to “free” objects, those which have no forces acting upon them, and (b) such objects either remain at rest or move in uniform motion.

3.6. Uniform motion is motion in a straight line with unchanging speed.

3.7. The car is not moving in a straight line. Therefore, the motion is accelerated motion, not uniform motion.

3.8. Your answer should be something like this: (a) During the collision, the passenger had the sensation of having his head “thrown” backward, placing severe stress on his neck bones and muscles. Initially, the horizontal forces on the passenger’s head were very small. When the car was struck from behind, the car and the passenger’s body began moving forward. His head remained at rest in accordance with the First Law of Motion. Thus, his body and head were moving in different ways with the resulting traumatic experience. His head was not “thrown backward” at all, but remained essentially at rest. His body, however, was thrown forward by the force resulting from the collision. (b)–(f) Your answers will be similar to that for part (a). Note the similarity between (a) and (c) and also between (b) and (d).

3.9. The gas pedal, the brake, and the steering wheel. Do you see why each of these can correctly be called an accelerator?

3.10. There must be at least one force directed toward the center of the turn. Any other forces which might be present must cancel each other’s effects. In particular, there is probably not a force pushing the object away from the center of the turn.

3.11. Refer to the text. Your experiment should involve applying the same force to the objects in a situation where there are no other forces acting on either. The object with the smaller acceleration has the larger mass.

3.12. The object accelerates (increases its speed) with unchanging acceleration as long as the force is applied. The acceleration is unchanging because neither the mass nor the force changes. Unchanging acceleration means that the particle’s speed increases at a uniform rate. This result is sometimes surprising because it seems contrary to our experience. The problem is that we rarely encounter objects moving under the influence of a single force. Frictional forces almost always keep us from experiencing a simple case of this kind.

3.13. Increasing speed, decreasing speed, changing direction, or any combination of changing speed and direction.

3.14. No. It changes neither speed nor direction, so it is not accelerating. The net force on the car must be zero.

3.15. It initially accelerates to its travel speed. It then moves without acceleration until it nears the destination. It accelerates (becomes slower) and finally stops at the 20th floor.

3.16. They would be exactly the same. This is what we mean when we say that the mass of an object does not depend on its location.

3.17. It would accelerate at the same rate as before. The object’s mass still has not changed.

3.18. See the Study Guide at the end of the chapter for a statement of this fundamental principle.

3.19. The object would slow down and stop since the acceleration and velocity are in opposite directions. Remember, the acceleration is in the same direction as the force. Incidentally, if the force continues after the object stops, it will start moving in the direction of the force.
3.20. The rocket’s mass must be smaller at the later time. Rockets eject mass in the form of oxidized fuel out the rocket exhaust. We are not really comparing the same “object” at the two times, since some of the original rocket has been ejected.

3.21. Yes. Forces are required whenever there is acceleration. See also Exercise 3.7.

3.22. The bullet and gun interact with each other. The force acting backward on the gun has the same strength as the one acting forward on the bullet. The accelerations are different, however, because the two masses are not the same.

3.23. The bullet would have 500 times the acceleration of the gun if its mass were 1/500 that of the gun. The gun and bullet would have the same acceleration (and the same final speed) if they had the same mass. You should be able to see how these results are predicted by the Second Law and Third Law of Motion.

3.24. The drive mechanism of the car is designed to push backward on the road. (This backward force causes any loose material on the road, such as water, gravel or mud to fly backward.) The road, then, pushes forward on the drive wheels, causing the car to accelerate. The backward acceleration of the road is usually not noticed because of its large mass.

3.25. This is really the same as Exercise 3.22 with the rocket engine taking the place of the gun and the rocket fuel taking the place of the bullet.

3.26. The same question again. Now the man is the bullet and the boat is the gun (or the other way around if the boat has less mass than the man).

3.27. Once again, the same question. This time the interaction is between the air inside the balloon and the balloon itself.

3.28. This is a direct application of the Third Law of Motion. The force on the mosquito always has the same strength as the force on the truck, no matter what. If your answer to (b) is anything but “no,” you do not understand the Third Law. You should also understand why the accelerations of the truck and mosquito are quite different.

3.29. Notice the similarity between this situation and the one described in 3.24.

3.30. Through an inductive process. (See the Historical Perspectives section of Chapter 2.) No. It could be proved false by making observations that don’t fit its predictions.

3.31. (b), or so we thought when we wrote the question. The Third Law rules out an interaction between Person X and the frictionless ice. However, a clever student pointed out that Person X could spit or take off clothing and throw it away to create a Third Law interaction to propel (or stop) Person X. That would make (c) correct!

3.32. (e)

Chapter 4

4.1. You pull upward on the earth with a force which is exactly equal to the earth’s pull on you.

4.2. The acceleration of an object is determined by the applied force and its mass. Your pull on the earth has the same strength as the earth’s pull on you. The acceleration of the earth, however, is much, much smaller because of its enormous mass.

4.3. The mass of the moon is much less (about 1/100) than the mass of the earth. The gravitational pull on the object (its weight) depends on the mass of the object to which it is attracted. Of course, the moon is also smaller, so the object is closer to its center. These factors combine to give the ratio of 1/6 for moon weight vs. earth weight.

4.4. The gravitational force depends on size and distance. The sun, in fact, is about 23,000 times as far from us as is the center of the earth. The larger mass and larger distance combine to give a gravitational pull toward the sun which is about 6/10,000 the pull toward the earth.

4.5. Moon weight is about 1/6 earth weight. (See the text and Exercise 4.3.) Weight is zero if there are no gravitational forces.

4.6. The mass does not change. It is the same in all three locations.

4.7. Refer to Exercises 4.5 and 4.6.

4.8. (a) The two objects experience the same acceleration and, as a result, the same speed at any instant as they fall. (b) The weights are not the same (in accord with the gravitational force law since their masses are different). (c) and (d) However, force and mass both help to determine acceleration (the Second Law of Motion). In this case, nature conspires so that the ratio of force (weight) to mass is the same for all objects at a particular place. Perhaps a numerical answer would help. Suppose the smaller of two objects has a mass
given by 5 units and a weight given by 50 units. Its acceleration would be force/mass or 50/5 = 10 units. Now, suppose a second object has a mass of 150 units (30 times that of the first). Its weight would also be 30 times that of the first object; that is 30 ¥ 50 = 1500 units. Its acceleration would be force/mass or 1500/150 = 10 units, the same as for the smaller object. Notice that this result is predicted by two fundamental laws working together: The Universal Law of Gravitation and the Second Law of Motion.

4.9. This is a memory question. Its purpose is to make sure that, by now, you can describe the important content of this law without effort. This fundamental principle is stated in the Study Guide at the end of Chapter 4.

4.10. They both have the same acceleration. Since one has a head start, the other will always be slower than the first. Not only will it never catch up, but it also continues to get farther behind.

4.11. The experiments using the rubbed rods do this very nicely. The fact that both attractive and repulsive forces occur indicates that there must be at least two kinds of electric charge.

4.12. We mean that it has an excess of either positive or negative charge.

4.13. Some of the electrons in the rod are transferred to the silk, leaving behind an excess positive charge. Notice that it is the electrons that move, not the protons which remain rigidly fixed in the rod.


4.15. A particle with one unit of negative charge and a mass only 1/1836 times that of a proton.

4.16. This important model is defined in the Study Guide at the end of Chapter 4.

4.17. Electric charge exists only in multiples of the charge on a single electron or a single proton. Only specific values of electric charge occur in nature.

4.18. Electrons and protons attract each other through the electrical interaction, since they carry opposite charges. One possible arrangement is that atoms might be something like the solar system, with the electrons being attracted to the protons in the nucleus by the electrical force. Several other models of atoms have been proposed, but all depend on the electrical attraction between oppositely charged particles.

4.19. Electric charges in your hand interact with the electric charges in the table. The resulting forces initiate the nerve signals which you experience.

4.20. Moving electrically charged particles.

4.21. (a) The two rods repel each other. (b) The rubber rods both have a negative charge and, therefore, repel each other in accordance with the Electric Force Law. (c) The rubber rod gains electrons from the fur. (d) The glass rod would have a positive charge and would be attracted to the negatively charged rubber rod. (e) There are two different kinds of electrical charge. (f) The glass rod lost electrons to the silk.

4.22. This is another memory question just to reinforce your mental storage of these important ideas. This important principle is listed in the Study Guide at the end of Chapter 4.

4.23. Because they explain the phenomena described in the chapter as well as thousands of others which were not included. No experiment has ever been performed which is not in harmony with them.

4.24. (c)

Chapter 5

5.1. The acceleration is the same in all four cases. For justification, remember that acceleration depends only on force and mass. The relevant force in these cases is gravity (assuming that we ignore air resistance). The gravitational force depends only on mass and position, but not on motion. Mass does not change, and position does not change enough to have a significant effect on the strength of the gravitational force. Thus, force and mass are the same in all four cases; and, hence, according to the Second Law, the accelerations are all the same, both in amount (rate of change of speed) and direction (downward).

5.2. Cases (1), (3), and (4) are discussed in the text. Suppose the ball is thrown straight down with a speed of 30 kilometers/hour. At the end of each of the first 4 seconds of fall its speed would be 65, 100, 135, and 170 kilometers/hour (ignoring the effects of air resistance). You should see that this is the same acceleration as in the other cases.

5.3. Different points on the earth’s surface are farther from the center of the earth, and the gravitational force decreases with distance. Also, different surface points are underlain by rocks with different densities. These close materials sometimes affect the value of the
gravitational acceleration changes because its mass remains constant and the force changes. The Second Law of Motion predicts such changes.

5.4. The horizontal speed is always 60 kilometers/hour. Its upward speed at the end of subsequent seconds would be 105, 70, 35 and 0 kilometers/hour. Then it starts to fall and its downward speed increases at the same rate with values of 35, 70, 105, and 140 kilometers/hour just before it hits the ground. You should see that this is the same unchanging acceleration as that in the other examples we have discussed.

5.5. The weight of an object near the moon’s surface is about 1/6 its weight near the earth. Its mass is the same as before. The acceleration, in accordance with the Second Law of Motion, is determined by the force acting upon it (its weight) divided by its mass. Since force is reduced by 1/6 and mass is not changed, the acceleration is also reduced by 1/6.

5.6. The gravitational force changes only slightly during the motion of these objects because the change in their distance from the center of the earth is a very, very small fraction of the earth’s radius. The surface of the earth is about 6400 kilometers from its center while the highest aircraft fly only about 30 kilometers higher. Even at these altitudes the gravitational force (and, hence, the gravitational acceleration) is only about 1 percent lower than at the earth’s surface.

5.7. This is a “contact” interaction between electric charges in your hand and in the table. See the discussion in the text. Of course, the charges in your hand don’t actually touch those in the table, so the word “contact” may be misleading. The charges act on each other at long range on the atomic scale. Since both hand and table have positive and negative charges, however, they must get quite close together (on the large scale of things we ordinarily deal with) before the repulsions between individual charges become important.

5.8. Gravity pulls down (and you pull up on the earth). There is “contact” between your feet and the floor. As a result, the floor pushes up on you (and you push down on the floor) and balances the gravitational force so that you do not accelerate vertically. In addition, the floor pushes forward on your feet whenever you push backward on the floor. This forward push causes you to accelerate horizontally. To stop, you push forward on the floor so that it pushes backward on you, reducing your speed to zero. Notice that these horizontal forces are also due to the “contact” interaction between your feet and the floor.

5.9. Remember that an electric current is moving electric charges. Two factors are required for a current. First, there must be some charges which are free to move, such as those in a metal or a plasma. Then there must be some other charges which can accelerate these by the electromagnetic interaction. Such interactions can be either short or long range. A battery, for example, has an excess negative charge at one terminal and an excess positive charge at the other. (These occur because of the chemical reactions inside the battery.) If a wire is connected across the two terminals, electrons near one end of the wire are repelled by those on the negative terminal. These move along the wire, in turn repelling their neighbors. The impulse moves along the wire until all the free electrons are moving. Those near the end of the wire are attracted to the positive charges on the positive terminal of the battery. These electrons enter the battery and are replaced by new electrons entering the wire from the negative terminal.

5.10. These are outlined in the section titled “Finding Forces” in the text. This is a memory question to see if you can recall the rules without looking them up.

5.11. Gravity pulls down. The only other interactions are “contact” interactions, so you must ask yourself what your head touches. Your neck, of course. The bones and muscles of your neck must supply all the other forces needed to balance gravity and to accelerate your head. Now the bones in the upper (cervical) spine do a pretty good job of providing a vertical force (unless poor posture relegates this job to the muscles which tire and ache before too long when they are required to maintain continuous forces). Unfortunately, the spine isn’t designed very well for horizontal forces. Thus, if your neck is called upon to provide a strong forward force to your head so that your head can accelerate along with the rest of your body as the car increases speed, the neck muscles often become overly strained and, in severe cases, dislocation of the spine can occur. A headrest can provide another interaction for your head and can supply a forward force when needed. The horizontal forces on your neck are thereby avoided.

5.12. The analysis might proceed as follows: A. Gravity? Yes. The earth pulls down on the car (its weight) and the car pulls up on the center of the earth.

B. Contact forces? Yes.
   1. The car touches the road. This interaction can be thought of in two parts: (a) The road pushes up on the car and the car pushes down on the road. (b) The car pushes back on the road and the road pushes forward on the car (frictional force). (There is actually one inter-
action of each kind for each wheel. We have combined these into one for simplicity.)

2. The car touches the air through which it moves. The air pushes backward on the car and the car pushes forward on the air.

C. Draw a diagram for the car. Notice that, of the eight forces described in A and B, only four appear on your force diagram. You should know why.

D. The acceleration is zero (velocity is not changing).

E. The resultant force is zero (since the acceleration is zero). This means that the upward push of the road just balances the weight. Also, the air resistance and friction forces have the same strength and add up to zero. The car’s engine must continue to operate in order to apply the force to counteract air resistance.

5.13. While she is in contact with the ground, the only forces on the girl are gravity, pulling down, and the force resulting from contact between her feet and the ground. To jump, she pushes down with a force greater than her weight. The ground pushes up on the girl with an equal force in a direction opposite to her push downward on the earth (Third Law). The net force (ground push minus weight) is upwards and she accelerates in that direction. After she leaves the ground, the only important force on the girl is gravity; so she slows down as she rises, finally stopping and falling to the ground, hopefully on the other side of the high-jump bar. The gravitational force on the girl arises in an interaction between the girl and the earth. The earth pulls down on the girl and the girl pulls up on the earth.

5.14. The interactions are the same as when you are standing on a floor which does not move, namely, gravity and the contact interaction between feet and floor. When the elevator accelerates upward, the floor force must increase so that the net force is upward. When the elevator accelerates downward, the floor force decreases so that it is less than your weight and the net force is downward. When the elevator is not accelerating, either because it is at rest or because it is moving up or down without changing speed, these two forces have equal strength and cancel each other so that the net force is zero.

5.15. Because air friction becomes important long before they strike the earth. In fact, air friction is more important for small objects like this than for larger objects. As a result, they reach an equilibrium speed sooner (at lowest speed) than do larger objects.

5.16. The parachute drag (air friction) provides an upward force which partially or fully balances the downward gravitational force. The downward acceleration is not as great as without the parachute. If the person jumps only a short distance, two problems are encountered. First, the amount of drag provided by the chute increases with speed through the air. If the speed is not very large, the drag is not very important and the downward acceleration is almost the same as without the parachute. Secondly, the drag may not even be large enough so that the chute will open, thus further decreasing its effectiveness.

5.17. The earth is pulled toward the sun by their mutual gravitational interaction. This is an unbalanced force and the earth is accelerated, changing its motion from a straight line (which would occur without the force) to a circle. The motion is predicted by the Second Law of Motion, since the gravitational force is causing an acceleration. There is another gravitational force as part of the same interaction. The earth pulls on the sun and causes it to accelerate slightly. The mass of the sun, however, is about 330,000 times the mass of the earth, so its acceleration caused by the earth’s pull is less than the earth’s acceleration in the same ratio.

5.18. The car is pulled down by gravity and pushed by the road. In addition, the road, through friction, pushes sideways on the car. This frictional force is a centripetal force which causes the car to change direction (accelerate). On a banked turn, the upward (perpendicular to the road surface) push of the road can provide some or all of this centripetal force. In every case, the net force is directed toward the center of the turn.

5.19. A centripetal force is any force whose direction is sideways to the motion of the object upon which it acts. It causes the object to change direction. All centripetal forces must come from interactions and always obey the Third Law of Motion.

5.20. (a) The boat goes faster. (b) The boat goes slower. (c) The boat changes direction.

5.21. (a) The string pulls the ball toward the center of the circle. (Gravity also pulls down on the ball, but this is balanced by a slight upward force from the string.) (b) The sideways (inward) force exerted by the string causes the ball to change direction continuously, changing its motion from a straight line to a circle. (c) No. There is no other interaction which could provide such a force. The ball does pull outward on the string, but this is not a force which affects the motion of the ball since it does not act on the ball itself.

5.22. (a) The satellite is pulled toward the earth by
the gravitational interaction. There are no other important forces if the satellite is high enough so the air friction is not significant. (b) The satellite is accelerating since the direction of its motion is constantly changing. (c) The gravitational force causes the centripetal acceleration. (d) The force is just the right strength to keep the satellite in a circle. If the forces were stronger (or if the satellite were slower), the satellite would come closer to the earth. If the force were weaker (or if the satellite were faster), it would move farther from the earth.

5.23. We say that a law is “true” if it has met the test of many experiments over a period of years. We must always allow the possibility that a new experiment, testing the validity of the “law” in new circumstances, will not be consistent with results predicted by the law.

5.24. Nature does not always behave in the ways that our reasoning would predict. There are many historical examples in which “logical” ideas do not accurately describe actual behavior which occurs in nature. Only by actually testing our ideas experimentally can we know if they, in fact, describe nature’s behavior.

5.25. There are several examples in the text. Most disciplines provide additional examples. It is interesting to consider the implications of religious thought, for example, in this context.

5.26. First, you might show the person some situations in which objects move in accord with the law. You would want to show enough variety so that you could demonstrate all features of the law—the dependence of the gravitational force on both masses and on distance, for example, and the nondependence on motion or any other factors. Then you might ask the person to suggest examples whose results are not in accord with the law. If he can think of some, you will need to show how these, too, can be explained in terms of the law (if they can). In no case can you demonstrate the law to be true in all possible situations, since it is simply not possible to test it in all situations. As the tests continue, we will likely find that this law, like most others, is not universally valid. It applies to a broad range of phenomena, but cannot accurately explain every situation in which gravity plays an important role. In fact, such limitations of Newton’s Universal Law of Gravitation have been discovered in the 20th century. It does not precisely determine experimental results when accelerating objects are moving very rapidly (near the speed of light) or when gravitational forces become very strong, such as near the surface of the sun or other massive stars. The more accurate law is called the General Theory of Relativity.

5.27. (d)

5.28. (c)

Chapter 6

6.1. The air around it must be pushing up with a force sufficiently strong to balance the weight of the piece of air.

6.2. Gravity is pulling down. Your muscles exert enough force to balance the downward gravitational force and, in addition, to accelerate your foot so that it catches up with your moving body and then stops again before touching the ground.

6.3. The necessary force to balance gravity and cause your stomach to accelerate must come from contact forces between the stomach and the things (or materials) which it touches. It is the adjustment of these internal parts which causes the sensations associated with elevator travel.

6.4. A buoyant force supplies part of the upward force needed to lift the rock.

6.5. An aircraft carrier is pretty heavy and yet does not sink under normal circumstances. A heavy object will not sink if the buoyant force acting upon it is large enough to balance its weight. This occurs if the object displaces a large enough volume so that the weight of the fluid pushed aside (the displaced fluid) is at least as great as the weight of the object.

6.6. The fluid displaced when the object is immersed has less weight than the object itself. The buoyant force on the object is not as strong as the object’s weight. The object experiences a net downward force and accelerates in that direction.

6.7. If the fluid were present instead of the object, the buoyant force would just balance its weight so that it would be in equilibrium. The buoyant force is the same when the object is in place as it is when the same space is occupied by fluid.

6.8. The buoyant force is the result of fluid pressure acting on the surface of the immersed object. This is a constant force. The other important vertical force is that due to the long-range gravitational interaction, otherwise known as the weight of the object.

6.9. The strength of the buoyant force depends only on the weight of displaced fluid. This, in turn, depends only on the volume of displaced fluid (the size
of the object) and the density of the fluid. The weight and density of the object have to do with the other important force, gravity, which determines the subsequent motion of the object.

6.10. The wood is less dense than iron and therefore occupies more volume than a piece of iron of the same mass. The larger piece of wood can displace a greater volume of water than the iron and therefore experiences a stronger buoyant force. The weights of the two are the same. The buoyant force acting on the wood is stronger than its weight, so it rises. The buoyant force on the iron is weaker than its weight, so it sinks.

6.11. Helium is less dense than air, so it rises in air for the same reason that wood rises to the surface when submerged in water (see Exercise 6.10). Since the density and air pressure of the atmosphere decrease with altitude, the balloon will eventually find an altitude where the buoyant force equals its weight or the balloon expands in the decreased external air pressure and bursts.


6.13. The density of a material divided by the density of a reference material, usually water.

6.14. Pressure increases with depth. For an extended object, the pressure on the bottom pushing up always exceeds the pressure on the top pushing down.

6.15. The surrounding earth may be loose enough, or have enough water content, to act as a fluid. If so, it would provide a buoyant force which would not depend on the weight of the pool. These two are in balance when the pool is full. When the weight is reduced by draining the pool, there is a net upward force which causes the pool to rise.

6.16. See Exercises 6.5 and 6.7.

6.17. Its weight is greater, so it must displace more fluid before the buoyant force again balances its weight.

6.18. When the earth was first formed, it was in a molten state. The denser materials moved lower for the same reason that more dense parts of a fluid always sink while less dense parts always rise, as discussed in the text.

6.19. The earth below the building would sink if greater weight is added and rise if less weight is replaced. This is due to the tendency of the earth to move toward isostatic equilibrium.

6.20. The warmer air is less dense than the surrounding air and “floats” upward, while the cooler air is more dense than the surrounding air and sinks.

6.21. (e)

Chapter 7

7.1. Wood and oxygen are transformed into carbon dioxide, water vapor, and ashes. The total mass of the wood and oxygen is equal to the total mass of the products.

7.2. Liquid water becomes water vapor with no change in mass.

7.3. Mass enters in the form of solid food, liquids you drink, and air you breathe. Gases are exhaled, fluids are ejected in urine and perspiration, and solid food wastes are removed in feces. Entering mass is equal to exit mass for constant body mass. Mass (and weight) increase if you take in more than you eject and decrease if you eject more than you consume.

7.4. This important fundamental principle is stated in the Study Guide at the end of Chapter 7.

7.5. Dynamite and oxygen are converted to solid fragments and gases. The total mass of the dynamite and oxygen is equal to the total mass of the products.

7.6. The ice cube has the same mass as the water, since mass is conserved.

7.7. Friction between shoe soles and carpet causes a separation of charge, some of the electrons from the rug being transferred to the body. When the person touches the doorknob, some of these excess electrons are transferred to the doorknob and it becomes charged. Eventually, the electrons will return to the carpet from whence they came. Charge is conserved in each transfer. When the body was negatively charged, the rug became positively charged in exactly the same amount. When the body lost some charge to the doorknob, the doorknob gained the same amount of charge as was lost by the body.

7.8. Before touching, the two objects have equal but opposite charge. The total charge, positive minus negative, is zero. Afterward, they are both neutral, so that total charge is still zero.

7.9. This important fundamental principle is stated in the Study Guide at the end of Chapter 7.

7.10. The cloud is originally uncharged. Because
of internal friction due to air turbulence within the cloud, part of the cloud becomes positively charged and part becomes negatively charged. The total charge within the cloud, however, is still zero since there is exactly the same amount of positive charge as there is negative charge.

7.11. Every part of the wire is electrically neutral, with equal amounts of positive and negative charge, whether the wire carries a current or not. When the negative charges move together in the same direction, a current flows. (Perhaps imagine a water pipe filled with gravel so that there are equal amounts of gravel and water in any section of the pipe. The water can move without disturbing the balance.) As charge leaves one end of the wire, an equal amount of charge must enter the other end if the current is to continue. This is usually done by connecting the wire into a closed circuit in which charge circulates in a closed path and from which charge does not escape.

7.12. In each case, we start with chemical potential energy (CPE) associated with gasoline stored in the fuel tank. This is converted to high-temperature internal energy (IE) in the cylinders of the engine. When the car travels on a level road at constant speed, this IE is converted to lower-temperature IE, manifest in the higher kinetic energy (KE) when the car increases speed.

7.13. The energy begins as high temperature IE at the sun’s surface. It is transmitted to the earth by light and absorbed by water on the surface of the lake or ocean. This additional energy allows the water to increase its internal energy, changing its state from liquid to gas. Buoyant forces cause it to rise high into the atmosphere, gaining GPE. (This added GPE is compensated by that lost by the air as it falls to fill the space vacated by the water vapor.) Later, the water vapor condenses into raindrops, giving up some of its internal energy as it changes state and warming the surrounding air and water in the process. It loses GPE and gains KE as it falls. Some of the energy is transformed to IE as the falling water interacts with the air through which it falls. The kinetic energy becomes mostly IE when the raindrops strike the ground, but it may still have some GPE if it falls on an elevated location. This changes to KE and then to IE as the water runs off and returns to the ocean.

7.14. The spacecraft has considerable GPE as it begins its return to the earth. This becomes KE as the earth is approached. At this point, the spacecraft is moving too fast for a comfortable landing, so the KE is converted to IE because of air friction. The purpose of the heat shield is to absorb this IE so that the spacecraft interior temperature will not become too high.

7.15. Most of our electrical energy comes from chemical potential energy associated with oil, coal or natural gas. Some comes from the GPE associated with water stored at high elevations behind hydroelectric dams. Smaller amounts come from nuclear potential energy in nuclear reactors or from the high-temperature internal energy associated with natural hot water which occurs in certain locations. In each case, some of the energy from the source is transformed to lower-temperature internal energy and some to electrical energy. The energy lost by the source is always equal to that gained by the electrical system plus that lost to low-temperature internal energy.

7.16. Kinetic, gravitational potential, electrical potential, radiant, and internal energy. Two important subclassifications of internal energy are thermal (molecular motion) and chemical potential. You should be able to describe each in your own words.

7.17. This important fundamental principle is stated in the Study Guide at the end of Chapter 7.

7.18. Kinetic energy increases with mass. The truck has more mass and therefore more kinetic energy. Kinetic energy is converted to other forms during the collision, so the object with more kinetic energy will do more damage.

7.19. Kinetic energy increases with square of the speed. In fact, the faster car (going two times as fast) could be expected to do four times (two squared) as much damage as the slower one.

7.20. The object starts with GPE and some IE. It loses GPE as it falls and gains KE and IE (due to air friction). The KE is then converted to IE upon impact. The total IE after the impact, distributed between ball, ground, and air, will be equal to the GPE and IE associated with the ball before it began its descent.

7.21. Energy is a conserved quantity associated with each situation or condition. Another definition which is not too bad is this: energy is a measure of motion or potential motion associated with matter and light. You may not find either of these to be as satisfying as some definitions you have seen before, but these have the advantage of being correct.

7.22. Internal energy leaves the house by heat conduction through the walls, windows, and ceiling. There
may also be losses by convection as warm air goes out through chimneys, cracks around doors and windows, etc. In each case, energy (IE) leaves the house. In the case of convective losses, the lost warm air may be replaced by colder air from the outside, but this is just air with less IE than that which is lost. There is no physical quantity called “cold.”

7.23. The food we eat contains chemical potential energy. This is converted, by chemical reactions similar to combustion (except slower), mainly to internal energy. The internal energy, in turn, is lost by conduction and radiation and must be constantly replaced by further chemical reactions if the temperature of the body is to be maintained. Some of the CPE is used by our muscles to do work either internally (to pump blood, for example) or externally. Some of this becomes KE as we walk or move about and some can be used to transfer energy to external objects. The total amount of energy used by the body for all these purposes, incidentally, is equivalent to about 3 kilowatt-hours of electrical energy, which costs about 20 cents these days.

7.24. The process is called “work.” The force of gravity acts downward on the falling rock as it moves downward.

7.25. Illustrations could include the transfer of kinetic energy to an accelerating car by the push of the road (work), energy transferred from a hot pan to a pizza (heat conduction), the transfer of energy from the sun to the earth (radiation), heat energy transferred from one place to another by the Gulf Stream current in the Atlantic (convection), and the transformation from chemical potential energy to heat energy (combustion).

7.26. All of these transfers are accomplished by work. Gravity, friction, and the earth’s surface act on the object as it moves. After it stops, the internal energy dissipates by heat conduction.

7.27. The CPE changes to high-temperature IE by chemical reaction (combustion). All other processes are work. Finally, IE dissipates by heat conduction.

7.28. High-temperature IE of the sun is transmitted to water by radiation. Evaporation is a reorganization of IE of the water, although some work is done on the air in the process. All other processes are work, with final IE dissipating by heat conduction and convection.

7.29. The most familiar example is the automobile engine. The hot gases in the cylinders do work on the pistons, thereby transforming some of their high-temperature internal energy into kinetic energy of the pistons. This, in turn, eventually becomes kinetic energy of the car as a whole as it gains speed or potential energy as it gains altitude. Steam engines, jet engines, and rocket engines accomplish the same transformation.

7.30. (c)

7.31. (c) and (d)

Chapter 8

8.1. You would not change your game at all. The Special Principle of Relativity implies that you could experience no effects of the uniform motion.

8.2. If you thought of one or more experiments, you don’t understand the Special Principle of Relativity (Motion Symmetry). If your answer suggested looking out the window at the passing scenery, this type of motion is easily simulated by moving the scenery as is done when movies are made. The question is not totally frivolous. Copernicus, in effect, has told us that all of our rooms (and grounds as well) are moving through space at almost 70,000 miles/hour.

8.3. The object would fall straight down as long as the boxcar moves uniformly. It would seem to fall backward if the train were speeding up. This may not be obvious to you, but the point we wish to make is that motion symmetry does not imply that the result for the accelerating boxcar is the same as when the motion is uniform (straight line, unchanging speed). The Principle of Motion Symmetry refers only to observers in uniform motion.

8.4. The Special Principle of Relativity is also called the Principle of Motion Symmetry. This important fundamental principle is stated in the Study Guide at the end of Chapter 8.

8.5. The situation illustrates the Principle of Motion Symmetry. As long as the platform moves uniformly, the object moves directly above the thrower, slowing down vertically until it stops, and accelerates back down to the person on the platform. Thus, the thrower sees the object do exactly what it would do if the platform were at rest, and he cannot decide from watching the motion of the object whether the platform is at rest or in uniform motion. If the platform accelerates (speeds up), the object will appear to the thrower to move in an arc-shaped path and fall behind the person or the platform. This apparent acceleration of the object (curved path) in the absence of any force (an apparent violation of the Second Law of Motion) allows the thrower to conclude that the platform must be accelerating since the laws of motion are supposed to hold for all observers in
uniform motion (Principle of Motion Symmetry).

8.6. As long as the plane continues in uniform motion, the pilot would observe the object to fall straight downward beneath the plane just as it would if the plane were at rest. See Exercise 8.5.

8.7. The motions which make us sick are non-uniform; that is, accelerations. (This answer treats only one part of motion sickness. We offer no explanation as to why some people experience motion sickness when they are not moving—for example, watching a wide-screen movie.)

8.8. This is really the same question as 8.2. Do you see why?

8.9. Can you see that this is really the same question as 8.5? Over the short period of time that the arrow is in the air, the earth’s motions (spin and revolution about the sun) are approximated very closely by uniform motions.

8.10. Build a small Foucault Pendulum in the room and observe its motion for an hour.

8.11. Motion of a Foucault pendulum provides evidence of the earth’s rotation.

8.12. Stellar parallax provides evidence of the earth’s revolution around the sun.

8.13. (e)

Chapter 9

9.1. The two postulates are described in the definition of the Special Theory of Relativity in the Study Guide for Chapter 9. Remember, once these two postulates are accepted, all the consequences of Special Relativity follow. The experimental verification of the predictions constitutes significant evidence that the postulates are, in fact, true descriptions of nature.

9.2. Time dilation is defined in the Study Guide for Chapter 9.

9.3. This explanation is contained in the text. Make sure you understand the logic involved in the discussion. For example, do you see why a stationary observer sees the light in the moving clock as following a zig-zag pattern? This is really the heart of the argument. Once you see this, it is usually easy to see why light would take longer to travel the zig-zag pattern than to follow the straight back-and-forth path seen when the clock is not moving. The light clock, of course, is imaginary. Do you see what it has to do with real clocks? Anything that creates a series of events in spacetime, such as your beating heart, will serve as a clock. How can we predict the behavior of real clocks by understanding the behavior of an imaginary light clock? Real clocks create a series of events just as the light clock does. It is the series of events that define time, not the thing that causes the events.

9.4. This experiment is described briefly in the text. The muons in the real experiment were created in the upper atmosphere and observed at the top of a mountain and then again at sea level. The important observation is that they travel, before decay, many times farther than is otherwise possible without time dilation.

9.5. He would be younger than those who did not travel. This result is consistent with time dilation as predicted by the Special Theory of Relativity. The stay-at-home remains at rest, so his observations are correctly predicted by the Special Theory. The traveler accelerates during the trip and so is not in uniform motion. His observations may be predicted with the Special Theory of Relativity, but the analysis is somewhat more detailed than we are prepared for with this brief introduction. The analysis shows that both observers agree that the traveler ages less during the trip than does the stay-at-home.


9.7. This is the same as for the space traveler described in the text. Imagine an observer moving with a muon as it approaches the earth. He sees the muon at rest, but the earth is moving toward him at high speed, say 99 percent the speed of light. The muon decays after its normal lifetime, about $2 \times 10^{-6}$ second. During that time, the earth moves toward the muon a distance of only 600 meters, as seen by our moving observer. However, the muon moves a distance of 4200 meters towards the earth, as seen by someone standing on the earth. Thus, the moving observer sees the 4200 meters “contracted” to only 600 meters as a result of his motion.

9.8. The statement is false. Everything moving with the spaceship has its normal size since the astronaut perceives them as being at rest. Only objects moving with respect to the spaceship seem contracted as seen by the astronaut.

9.9. The distance is contracted, as seen by the astronaut. If the spaceship moves fast enough, the distance to the nearest star could be contracted from a little over five
light-years to something under a few light-hours. (The accelerations and energy requirements of such a trip are far beyond our present technology, however.)

9.10. Say the star is 5 light-years away. Then at least ten years of earth time would elapse while the astronaut travels there and back.

9.11. A moving object is harder to accelerate than when it is at rest. Particle accelerators all over the world add experimental verification every working day to this phenomenon. Particles (electrons, protons, atoms, atomic nuclei) become harder to accelerate as they come closer and closer to the speed of light. This is true for all kinds of acceleration: increasing speed, decreasing speed, and turning corners.

9.12. It comes from the energy supplied by the force which accelerated the particle to its high speed.

9.13. Thermal energy escaped as the materials cooled. Thus the final energy of the system, and its mass, would be ever-so-slightly less than the initial energy or mass. As the thermal energy escapes, the molecules of the material slow down. It is this reversed “mass increase” (from the slowing down) of the individual molecules that results in less mass of the overall material. But the decrease in mass is very, very small for these small changes in molecular speed.

9.14. At first the speed increases at a uniform rate. When the object begins to move almost as fast as light, the speed increases more slowly even though there are no other forces. The speed never quite reaches the speed of light no matter how long the force is applied. We interpret this as implying that the mass of the object increases with speed. Energy is being supplied by the force, since it is doing work. The energy is represented as increased mass.

9.15. This is the mass of an object when it is not moving. Notice that things like photons and neutrinos have zero rest mass, since no observer could move fast enough so that they would appear to be at rest. (This would violate the second postulate.) These can, however, have energy and its associated mass. They just obey different rules than do the particles with which we are more familiar.

9.16. The statement is false. The explanation is similar to that for 9.8.

9.17. The relationship is summarized by the equation $E = mc^2$. The fundamental principle of Conservation of Mass-Energy is defined in the Study Guide.

9.18. See Exercise 9.17. Energy is released and escapes after the explosion. The total rest mass of the fragments after the explosion is slightly less than that before the explosion by exactly the amount predicted by Einstein’s equation, $E = mc^2$.

9.19. See the answer to Exercise 9.13. The molecules of the heated marble are moving faster and therefore experience a mass increase. Objects with greater mass have more weight than objects with less mass. (Mass associated with internal energy seems to participate in the gravitational interaction the same as mass associated with rest mass or any other form of energy.) But, for the increase of molecular speeds achieved by heating a marble, the overall mass increase is very, very small. You won’t see it on the bathroom scales!

9.20. The mass change associated with the release of chemical potential energy is so small that it is not ordinarily measurable in experiment unless very precise observations are made.

9.21. (e)

9.22. (a)

Chapter 10

10.1. A fluid is a substance that flows. Liquids (water, gasoline, oil) and gases (air, oxygen, hydrogen) are fluids.

10.2. Solids become liquids above their melting temperature. Liquids become gases above their boiling temperature. Gasoline is usually a liquid because its melting temperature is below and its boiling temperature is above ordinary ambient temperatures. Copper is normally a solid because its melting temperature is well above normal ambient temperatures.

10.3. These have the same density, presuming that they are both made of pure water. (Dissolved materials can change density.) The iceberg has greater mass, but also greater volume. Density is mass divided by volume and is the same for both.

10.4. Iron, wood, rock.

10.5. Water, milk, mercury.

10.6. Air, hydrogen, helium.

10.7. A plasma is a gas in which there are free electric charges. The gas in an operating neon sign or fluorescent lamp is a plasma. The air which emits light
when lightning flashes and the hot gas on the surface of the sun are other examples.

10.8. Density is mass per unit volume.

10.9. Table 10.1 gives one list. Perhaps you can make another, using your ordinary experience as a guide. Remember, you are not asked to list heavy objects but dense objects. For example, an aircraft carrier is pretty heavy but it is not very dense (since it floats on water).

10.10. Mercury vapor emits almost no red light. The spectrum is discrete, with the main colors being purple, green, and orange. Since there is no red light to be reflected, normally red objects seem black.

10.11. The colors of light which are reflected tell us something about the materials we see.


10.14. The one which stretches 0.01 millimeter has the larger elastic constant. In the calculation using the definition of elastic constant the same strength force is divided by a smaller number (0.01 millimeter is the deformation in this case) for the smaller deformation. This gives a larger result if the calculation were to be done.

10.15. Most obviously, materials must be used in such a way that they sustain the loads placed upon them without exceeding their elastic limits. Otherwise they collapse, a most embarrassing circumstance. Second, all materials deform when forces are exerted upon them (and they exert forces on something else). If this is not taken into account, the structure will sag and shift as it is built. Doors and windows won’t fit, floors won’t be flat, and walls will crack.


10.17. Make sketches with all forces pushing inward (compression), all forces pulling outward (tension), and forces moving in opposite directions (shear).

10.18. Elastic constants of compression exist for fluids and, like solids, may be very large, at least for liquids. However, unlike solids, elastic constants of fluids for tension and shear are very small or nonexistent.


10.20. Conductors must contain charged particles which are free to move; nonconductors do not.

10.21. The ionic materials must be made of charged particles which are not free to move in the solid state but which become free in the liquid. The charges in nonionic materials are never free; positive and negative particles are always combined so that neither is free to move independently.


10.23. Figures 10.8 and 10.9 suggest some possible experiments.

10.24. Tap water is a conductor because of the ionic materials dissolved in it.

10.25. The body is a good conductor. An electric shock is just an electric current passing through the body. This implies that there are free charged particles inside the body, probably in the body fluids.

10.26. (e)

10.27. No. Multiple-choice questions, including many of our own, test classification. Aristotle thought of classification as a preliminary activity which preceded “understanding.” To understand is to explain the differences and similarities of classification in terms of a few fundamental laws and principles.

Chapter 11

11.1. Tiny particles of dust or smoke moving around randomly that are barely large enough to be seen through an optical microscope. Molecules themselves are too small to be seen with a microscope and are not seen in Brownian motion.

11.2. The motions would be more erratic and violent, since the observed particles are colliding with faster molecules.


11.4. Invisible molecules of a fluid collide with visible particles of dust or smoke suspended in the fluid to cause an observed jittery motion of the visible particles.

11.5. The molecules in gases, being relatively far apart, can easily be pushed so that they are closer together. Molecules in liquids and solids are actually in contact, so any attempt to compress them is resisted by strong electrical repulsive forces. Said another way, the
compression of solids and liquids requires that the molecules themselves be compressed. This is much more difficult than just bringing them closer together.

11.6. Molecules in solids are held in rigid orientations by the attractive forces between neighbors. Molecules in liquids are moving fast enough that they cannot be held by these forces.

11.7. More molecules have enough energy to escape the attractive forces which hold them in the liquid.

11.8. This fundamental model is defined in the Study Guide.

11.9. This is just another name for the Molecular Model of Matter.

11.10. Within gases, the molecules are separated by relatively large spaces and only interact significantly with one another by the Electric Force Law when they get very close to one another in a collision. In fluids, the molecules are much closer to one another and closest neighbors are weakly bound to one another by the Electric Force Law. They are somewhat like ball bearings rolling around each other. In solids, the molecules are held more rigidly to one another by the Electric Force Law and, although still able to move, they retain an average relative position to one another.

11.11. When internal energy is added to a solid, the molecules gain kinetic energy and break free from the rigid connection to one another that constitutes a solid to form a fluid.

11.12. Evaporation takes place when the fastest moving molecules in a liquid (or, sometimes, solid) break free from the liquid to form a gas surrounding the liquid. Since the fastest molecules have escaped, the average kinetic energy of the molecules in the liquid is reduced and its temperature decreases.

11.13. The molecules with less mass must travel faster to have the same average kinetic energy.

11.14. Most of it goes into electrical potential energy as the molecules get farther apart, changing from liquid to gas. This energy which must be supplied to change the water from liquid to gas at a fixed temperature is called the latent heat.

11.15. As water freezes in the clouds to make snowflakes, internal energy (latent heat) is released. This warms the surrounding air. (However, there are also other significant things going on in stormy weather, including the movement of warm air masses which can dominate this more subtle effect.)

11.16. The ice gains internal energy, some of which is used to give the molecules enough electrical potential energy to break their attractions to their neighbors and some of which becomes kinetic energy, increasing their temperature. The water loses internal energy, the molecules have less kinetic energy than before, and the water temperature is reduced.

11.17. The molecules in the water vapor have more kinetic energy than do those in the ice. They also have more electrical potential energy, being farther apart.

11.18. Initially the glass and the mercury are at a lower temperature than the water. Molecules of water, with more kinetic energy, collide with the outer layers of molecules in the glass bulb. These experience an increase in kinetic energy which is transmitted, by collisions between molecules within the glass, through the entire layer of glass between the water and the mercury. Now there are collisions between the energetic molecules just inside the glass and the less energetic mercury molecules adjacent to that surface. These collisions transmit kinetic energy to the mercury molecules. Eventually all the molecules in water, glass, and mercury have the same average kinetic energy and thus the same temperature. The materials are said to be in thermal equilibrium. Mercury expands at this higher temperature. Its volume is then an indication of its new temperature and the temperature of the water.

11.19. The transfer of thermal energy to the central air space and from there to the second glass panel is inefficient because there are comparatively few collisions with these air molecules, mainly because there are fewer of them than if the space were filled with glass.

11.20. Molecules with greater kinetic energy give up part of their kinetic energy when colliding with molecules with lower kinetic energy.

11.21. The internal energy of a gas is just the random kinetic energy of the molecules. The molecules move faster when the internal energy is higher.

11.22. The higher-temperature molecules are moving faster, so they strike the walls of the tires harder. They also collide with the walls more often.

11.23. Temperature is a measure of the average kinetic energy of any collection of molecules. Molecules are faster when temperature is higher.

11.24. Pressure is a manifestation of the collisions
between the molecules of the gas and the molecules of the container.

11.25. The temperature at which all materials have their minimum internal energy.

11.26. (a) B. (b) A. (c) B. (d) The pressure is the same in the two samples.

Chapter 12

12.1. There is order at first because the energy is divided so that molecules in the hot object have, on the average, more energy than those in the cold object. When equilibrium is reached, the energy is more evenly distributed so that the average energy is the same for both objects. This is like the example of the two colors of sand in a way, except that here we have an energy distribution rather than a color distribution. Also, you should notice that the molecules from one object do not mix with the molecules in the other. Energy is transferred in this case, not molecules.

12.2. The original motion is organized so that all the molecules in the sliding block are moving in the same direction. When this kinetic energy becomes internal energy, the motion is random in direction. The original organization of direction has been lost.

12.3. Ice cubes in warm water melt rather than become larger because the separation of ice and water represents an organization of energy. Disorder increases as the ice melts. Disorder would decrease, violating the Law of Increasing Disorder, if the ice were to become larger, even though energy would be conserved in the process.

12.4. See the glossary in the Study Guide for a definition. The processes are not reversible because the reversal would require increasing order and, according to the Law of Increasing Disorder, this cannot occur spontaneously.

12.5. See the Study Guide for a statement of this fundamental principle.

12.6. Put a drop of ink into a glass of water. The molecules of ink gradually mix with the molecules of water in such a way that they will never again spontaneously unmix.

12.7. This is another name for the Law of Conservation of Energy.

12.8. This is the more common name for the Law of Increasing Disorder.

12.9. Entropy is a mathematically defined quantity which is a quantitative measure of disorder.

12.10. A steam engine uses the internal energy of high-temperature steam to do work, converting some of the energy to other forms such as electrical energy (the steam generator) or kinetic energy (the steam locomotive). The automobile engine is another example.

12.11. There must be some order associated with the energy. In the cases mentioned, the order is the hot-cold order similar to that associated with ice cubes in water or the situation in 12.3. The useful internal energy in these cases is at a higher temperature than the surroundings. If everything were the same temperature, no matter how high that temperature might be, neither the steam engine nor the gasoline engine would function.

12.12. The separation of hot and cold energy represents organization of energy. If heat were to flow spontaneously from a cold object to a warmer one, the total order would be increased. This would be a violation of the Law of Increasing Disorder.

12.13. Not if there is some organization, such as a separation of hot and cold regions, associated with the thermal energy.

12.14. The refrigerator works by causing heat to flow from a cold region (inside the refrigerator) to a warmer region (outside). This cannot happen spontaneously (see 12.12). “Ordered” energy must be introduced. Real refrigerators use either electrical energy (and require being plugged into an electrical outlet) or chemical energy (gas refrigerators), both of which are degraded to thermal energy as the refrigeration process takes place.

12.15. The ordered list of energies found in the section on “Order and Energy” is the table you need. Nuclear potential energy is released in the processes that power the sun. Some of this energy reaches earth as sunlight and is stored by photosynthesis as chemical potential energy in plants. Some of these hydrocarbon molecules may eventually be concentrated into oil and refined into gasoline which, when burned, releases the energy as disordered ambient temperature thermal energy.

12.16. The atoms of the metal are initially distributed randomly through the ore. There may be only a few ounces in a ton of ore. The refining process represents an organization of these materials, separating the metal atoms from the other materials in the ore. The Law of Increasing Disorder implies that something else
must become disorganized to compensate for the desired organization of the metal. Thus, the mining and refining processes trade the order of highly organized forms of energy for the order associated with the separation of materials.

12.17. This is really the same problem discussed in 12.16, except here we wish to separate salt and water rather than metal and ore. The technology is available in both cases, but the cost in high-quality energy may be too high.

12.18. The chemical potential energy associated with gasoline is already partly disorganized. A 100 percent efficient engine could convert all of it to kinetic energy which has no disorder at all. This would clearly violate the Law of Increasing Disorder.

12.19. The water’s internal energy is totally disorganized (presuming the water to have a uniform temperature) so there is no order to trade for kinetic energy of the ship. (There is some order, however, if there are temperature differences in the ocean water. Engineers are studying the possibility of devices which use these as practical sources of high-quality energy.)

12.20. Equilibrium occurs when the stove has cooled and the room becomes warmer until everything is at the same temperature. Atoms and molecules are still moving at high speed, so nothing is really at rest. No large scale changes are taking place, but molecular collisions still occur so that the energy of each individual molecule changes at each collision. Only the average energy of the collection does not change.

12.21. Pollution control represents an organization of materials. This represents the same problem discussed in 12.16 and 12.17.

12.22. (d)

Chapter 13

13.1. A disturbance in an elastic medium. Matter itself is not transmitted by a wave. Energy is transmitted with the wave.

13.2. Review the illustrations of the kinetic energy transmitted by water waves or waves on a rope in the text. The energy from the sun that reaches the earth is transmitted mostly by light and other waves.

13.3. See the Study Guide glossary.

13.4. In a compression wave, the matter in the medium moves back and forth along the same direction as the wave moves. In a shear wave, the medium moves back and forth but perpendicular to the direction the wave is moving.

13.5. Fluids are not elastic with respect to shear, while all materials are elastic with respect to compression. (See 13.6 if you don’t see why this answers the question.)

13.6. The process is described in the text, for example in the discussion related to Figures 13.2 and 13.3. Any medium which is elastic with respect to compression will transmit a compression wave. A medium must be elastic with respect to shear to transmit a shear wave.

13.7. The buoy would move up and down more often for the wave in which the waves are closer together. The distance between wave crests is the wavelength for each wave. The wavelength is longer if the wave crests are farther apart. Longer wavelength is associated with lower frequency. But frequency describes the number of times per minute that the water at one place would move up and down—one cycle for each wave which passed by. Thus, longer wavelength means lower frequency and shorter wavelength (crests closer together) is associated with higher frequency.

13.8. Frequency is the number of repeated disturbances per second that pass an observer. The wavelength is the length of each disturbance. Multiplying the frequency by the wavelength tells you how fast each disturbance is moving, i.e., its speed.


13.10. The relationship between frequency and wavelength implies that long wavelength is associated with low frequency and vice versa. Thus, blue light has the higher frequency and red light the lower frequency. This presumes that the speeds of red and blue light are the same, which they are in free space.

13.11. We say that these are unique wave properties because no one has yet thought of other energy transfer mechanisms which exhibit these behaviors. We are open to suggestions.

13.12. Sound diffracts. (We can hear around corners.) Sound also exhibits interference, much to the chagrin of architects who find unintentional acoustic effects in newly constructed auditoriums and other rooms.

13.14. See Study Guide glossary. The bending of light as it passes through a lens is an example.

13.15. See the Study Guide glossary. If long straight water waves encounter a barrier with a narrow slit, the waves spread out on the opposite side of the slit in a semicircular pattern centered on the slit.

13.16. See Study Guide glossary. If long straight water waves encounter a barrier with two narrow slits, the waves issuing from the two slits on the opposite side of the barrier form a pattern of annihilation and enhancement of the mutually interfering waves.

13.17. See Figure 13.11 for our representation.

13.18. (a)

13.19. (e)

Chapter 14

14.1. Both measure the same speed, $3 \times 10^8$ meters/second or 1 foot every billionth of a second

14.2. Still the same. The speed of light is the same for all observers, no matter how they or the light source are moving.

14.3. 70 miles per hour.

14.4. Apparently light does not obey the same rules for the addition of speeds as do slower-moving objects like balls. Actually, the answer to 14.3 would be more complicated if the speeds of the truck and ball were closer to the speed of light.

14.5. Make sure you understand the rotating toothed-wheel method described in the text and Figure 14.1.

14.6. They both have the same speed (in empty space). Blue light has a higher frequency and shorter wavelength than red light.

14.7. The blurred light passing through almost closed eyelids or the pattern which occurs when light passes through a small circular hole are both described in the text.

14.8. The pattern seen when a distant light is observed through a curtain or handkerchief is due to interference. The two-slit interference pattern is also described in the text.

14.9. Experiments involving diffraction and interference cannot successfully be explained by any other model.

14.10. See Figure 14.3 and the accompanying discussion.

14.11. See Figure 14.4 and the accompanying discussion.

14.12. The pattern becomes broader, just as the pattern in Figure 14.3 becomes larger when the hole becomes smaller.

14.13. See Figure 14.4 and the accompanying discussion.

14.14. The two light beams, one from each slit, must interfere as they overlap at the screen. Only waves exhibit this behavior.

14.15. See Figure 14.6 and the accompanying discussion. This strongly suggests that light is absorbed by the photographic film in discrete lumps rather than as a diffuse wave.

14.16. The photoelectric effect and the appearance of low-intensity photographs, both described in the text, are pretty convincing to most people who think the problem through.

14.17. Light shows properties of both waves and particles. Exercises 14.9 and 14.16 summarize the evidence.

14.18. A photon is a particle of light or, if you like, the smallest lump of energy in a beam of light.

14.19. One way is to measure the energy of electrons which are emitted from metal surfaces after absorbing energy from a beam of light. Each electron seems to absorb the energy of a single photon.

14.20. See Figure 14.7 and the accompanying discussion. This experiment provides strong evidence for the particle model of light.

14.21. Blue. Blue light has the higher frequency (see 14.6) and therefore contains the higher energy photons. Notice that blue and red photons both travel at the same speed (the speed of light) even though each blue photon has more energy than a red photon. If a photon somehow is given more energy it changes color (frequency) rather than speed. In this way photons are not the same as the other particles (protons, neutrons, and
electrons) with which we are familiar.

14.22. (d)

14.23. (e)

Chapter 15

15.1. According to the equation in Chapter 15, kinetic energy is equal to one-half the mass times speed squared. If the kinetic energies of ions are the same and their masses are different, the calculation will show equality only if we are dividing by different speeds for the ions. Another way to view the problem is to say the massive ions have more inertia and so the expenditure of the same amount of energy will not accelerate them to such a high speed.

15.2. $^{14}\text{N}^+$ will have a higher speed than $^{16}\text{O}^+$ with the same kinetic energy because it is less massive. The kinetic energy equation can be rearranged to:

\[ (\text{speed})^2 = 2 \times \frac{\text{(kinetic energy)}}{\text{(mass)}} \]

to show that small mass results in large speed for constant kinetic energy.

15.3. Because electrical force is proportional to charge size, the doubly charged ion, $^{12}\text{C}^{2+}$, will experience more force and achieve more speed in the mass spectrometer than will $^{12}\text{C}^+$. The difference in mass between the two is negligible.

15.4. An alpha particle is nearly 4 atomic mass units (amu) more massive than an electron, or $4 \times 1837 = 7348$ times as massive. In a collision the alpha particle will not change course very much but the electron will be knocked off in a new direction (answer (b)).

15.5. The mass of the gold nucleus is 197 amu, so it is $197/4 = 49.2$ times as massive as the alpha particle and will not move much, but rather deflect the alpha particle (answer (a)).

15.6. The electrostatic experiments involving glass rods, fur, etc. showed electrical charges could be separated from matter. The mass spectrometer also separated negative and positive charges as do gas discharge tube experiments. Charged alpha particles are also electrically deflected from charged particles in gold atoms.

15.7. The mass spectrometer showed that electrons move much faster than protons when given the same amount of kinetic energy; therefore, the protons must be heavier. Positively charged alpha particles sometimes bounce almost straight back from the heavy particles in gold, so the latter must be positively charged to cause repulsion and very massive to cause a direct rebound.

15.8. There is a large energy difference between the lowest and highest orbits, so blue or violet light would be required.

15.9. Red light would probably have sufficient energy to lift an electron from the lowest to the middle orbit.

15.10. For converting color to energy, use the equation:

\[ \text{energy} = (\text{Planck's constant}) \times (\text{frequency}) \]

15.11. By looking at the sun with the proper instruments containing prisms or gratings, it is possible to see the emission lines of He and Ne, and to distinguish the two sets of lines.

Chapter 16

16.1. The success of the molecular and atomic model of matter, Brownian motion, and the detection of individual electrons on a TV screen are all consistent with a particle model of matter.

16.2. The diffraction and interference of beams of electrons provide the most convincing evidence. Be sure you understand the experiments described in the text. You should also think through the reasoning which leads from the experimental results to their interpretation in terms of a wave model of matter.

16.3. Matter is both wavelike and particlelike. The evidence has already been summarized in 16.1 and 16.2.

16.4. Wave-particle duality refers to the dual nature of both matter and electromagnetic radiation. All constituents of the universe demonstrate both a wave nature and a particle nature. Neither a wave model nor a particle model can successfully explain all of the experimental evidence.

16.5. Interference occurs even when only one electron at a time is allowed to pass through the two-slit apparatus. See the text for a more complete discussion. Be sure you understand the significance of interference of electrons.

16.6. This is done to make certain that charged particles are causing the observed interference and diffraction patterns. When the pattern is changed by electromagnetic forces that bend the paths of charged particles
but not light, it becomes clear that the effects are not due to electromagnetic radiation emitted near the slits or anywhere else.

16.7. Their motions are described by rules governing the motion of waves. Newton’s laws cannot be used.


16.9. Electrons can be made to have wavelengths about as short as the diameter of atoms and can, therefore, distinguish between individual atoms. Visible light has wavelengths which are much too long for this.

16.10. A wave must have a wavelength shorter than the volume in which it is confined. A matter wave must have a high speed if it is to have a short wavelength.

16.11. The minimum uncertainty in the determination of position and the minimum uncertainty in the determination of speed are related. Their product must exceed a number about the size of Planck’s constant. If the position is very precisely determined, the speed cannot be precisely determined. If the speed is measured precisely, the position cannot be measured as precisely as before.

16.12. The Newtonian Model presumes that position and speed are both known precisely and can be measured with as much accuracy as is permitted by the measuring instruments which are used. The Uncertainty Principle implies that precision is limited by nature, and that this limit cannot be violated even with perfect measuring instruments.

16.13. This fundamental principle is defined in the Study Guide.

16.14. Planck’s constant is so small that the normal imprecision in measuring the position and speed of ordinary objects greatly exceeds the limits imposed by the Uncertainty Principle.

16.15. An object which is completely at rest would have a vanishing uncertainty of speed and could not be localized because its uncertainty in position would be larger than the whole universe.

16.16. Newtonian physics presumes that the future is exactly predicted by the present condition of matter in the universe. Quantum physics provides a statistical prediction of the future. Thus, in quantum physics, there are many possible future arrangements for any particular situation. The rules allow computation of the probability of each one but not a prediction of the exact one which will actually occur.

16.17. Wave mechanics allows the prediction of possible points at which electrons will arrive and the probabilities that a single electron will arrive at each point. It does not allow us to predict, with certainty, the exact arrival point for each electron.

16.18. See 16.16. This is really the same question phrased in a different way.

16.19. We do not ordinarily experience such objects, so we do not become accustomed to their behavior by direct experience.

16.20. The Newtonian laws and quantum physics should agree inside the shaded region in Figure 16.11 which is the region of our common experience and observations. The predictions would differ significantly whenever the motions are observed or confined to regions which are comparable in size to the wavelengths predicted by the de Broglie equation.

16.21. (e)
16.22. (b)

Chapter 17

17.1. Electrons do not travel on the surfaces shown in Figure 17.4, but there is a 90 percent probability of finding the electron inside the volume enclosed by the surface at any given time.

17.2. The Uncertainty Principle suggests that it is impossible to know simultaneously both the position and velocity of an electron in an atom.

17.3. The “cloverleaf” orbital is the d-orbital.

17.4. An electron at rest outside the nucleus would be attracted by the positive charge of the nucleus and fall quickly to the center of the atom.

17.5. An orbiting electron would have angular acceleration which would cause it to radiate energy. As energy was lost, the electron would spiral into the nucleus.

17.6. An electron in a spherical orbital has a 10 percent probability of being found outside the “skin” of the orbital at any given time according to the definition in the chapter of what the skin means.
17.7. There is a small but nonzero probability that any earthly electron could be found on Mars because the orbitals have “fuzzy edges” that describe a probability that gradually diminishes with distance from the nucleus, but never vanishes completely.

17.8. Li has three electrons. It requires eight more electrons to fill orbitals until there is an electron in the 3s orbital. Na (sodium) has this many electrons and is a metal very similar to Li. Both have low ionization energies (5.4 and 5.1 eV).

17.9. Electrons in neon can only be raised to certain levels. When they return they only emit photons of certain energies, red being one of the resulting colors. Xenon has its own unique set of energy levels and therefore its own unique set of colors.

17.10. In Figure 17.7, He and Ne have filled shells. All others have unfilled shells. More energy would be required to remove the highest energy electron from a filled shell.

17.11. F has the lowest energy vacancy (the 2p orbitals have only five rather than six electrons).

17.12. He and Ne have no vacancies and no partially filled orbitals so they would be expected to be chemically inert. Their ionization energies are high.

17.13. Mg has the same number of electrons in an s-orbital as Be at about the same energies.

17.14. Al has the same number of electrons in a p-orbital as B.

17.15. Nitrogen (atomic number 7) has seven electrons if the atom is neutral. It always has seven protons and, according to Table 17.2, seven neutrons. There is a pattern of light atoms having the same number of electrons, protons, and neutrons, but there are many exceptions to the pattern (e.g., lithium, beryllium, boron, and sodium).

17.16. To calculate the atomic mass of an atom, you must know how many neutrons it has as well as how many protons. (Neutrons + protons = mass in amu.)

17.17 See Table 17.2 below.

17.18. (a) Lead is an element, (b) arsenic is an element, (c) bronze is not an element, (d) radon is an element, (e) potash is not an element, (f) platinum is an element, (g) mercury is an element, (h) freon is not an element.

17.19. (d)

Chapter 18

18.1. Rb is larger than Cl because it is nearer the lower left corner of the Periodic Table.

18.2. Zn and Ag are nearly the same size—they are near one another in the Periodic Table.

18.3. Gold is more dense than magnesium because it has more protons and neutrons packed into the same size atomic volume.

18.4. S is smaller than Sr. Small atoms are in the upper right portion of the Periodic Table.

18.5. Au (gold) is more dense than Ti (titanium) because more protons and neutrons are packed into approximately the same atomic volume.

18.6. Li has the lowest ionization energy and He has the highest.

18.7. (a) H, hydrogen is a nonmetal.

---

### Table 17.2

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Mass(amu)</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{12}\text{Carbon}$</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>6 for C°</td>
</tr>
<tr>
<td>$^{16}\text{Oxygen}$</td>
<td>8</td>
<td>8</td>
<td>16</td>
<td>8 for C°</td>
</tr>
<tr>
<td>$^{20}\text{Neon}$</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>$^{4}\text{Helium}^{2+}$</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>$^{14}\text{Nitrogen}$</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>$^{19}\text{Fluorine}^{-}$</td>
<td>9</td>
<td>10</td>
<td>19</td>
<td>10 for N°</td>
</tr>
<tr>
<td>$^{27}\text{Aluminum}^{3+}$</td>
<td>13</td>
<td>14</td>
<td>27</td>
<td>10</td>
</tr>
</tbody>
</table>
(b) Li, lithium is a metal.  
(c) B, boron; can’t tell (by other standards it is a nonmetal).  
(d) Ne, neon is a nonmetal.  
(e) Mg, magnesium is a metal.

18.8. Lithium loses the highest energy electron (alone in an orbital) to become Li$^{+}$. Beryllium loses both of the electrons in the top orbital to become Be$^{2+}$.

18.9. The second electron to leave a lithium atom must come from much deeper in the energy well, so its ionization energy is greater than that of the first electron.

18.10. (c) N and As are most like P because they are directly above and below it in the Periodic Table.

18.11. Cl is most similar to F because Cl is below F in the Periodic Table. H is above F, but it is also in column IA above Li, with which it chemically has more in common.

18.12. Based on the properties of its neighbors and its position in the Periodic Table, technetium should be a solid metal, and it is.

18.13. Rn, radon is the gaseous element with the most protons (86).

18.14. Pd should be a silver metal not subject to corrosion. It lies between platinum and nickel in the Periodic Table.

18.15. Cl and I are most like Br. They are above and below it in the Periodic Table.

18.16. Because Mo is directly below Cr in the Periodic Table, it should have the following properties: same oxidation state (+6), larger density, and should be a silver metal like Cr.

18.17. Ca–Mg; Li–Na; Br–F; Ne–Ar; N–As.

18.18. S and P are nonmetals (above the jagged line in Appendix C).

18.19. Hydrogen is the gaseous element which has the fewest electrons per atom.

18.20. (e)

18.21. (e)

18.22. (e)

18.23. (c) and (e)

18.24. (c)

18.25. (d)

18.26. (a)

Chapter 19

19.1. H$^{+}$ caused the peak at 1 amu and H–H$^{+}$ (and possibly a small amount of $^2$H$^{+}$) caused the peak at 2 amu.

19.2. The 16 amu peak corresponds to the O$^{1+}$ ion. N$^{1+}$ is the peak at 14, and NO$^{1+}$ is the peak at 30 amu.

19.3. The compound CO (carbon monoxide) would give the peaks shown in Figure 19.12.

19.4. In the mass spectrometer, water would form the following fragments: 
\[
\text{HOH}^+, 18 \text{ amu}; \text{OH}^+, 17 \text{ amu}; \text{O}^+, 16 \text{ amu}; \text{and H}^+, 1 \text{ amu}.
\]

19.5. (a) Aluminum cans “rust” extremely slowly.  
(b) Gasoline vapor in air burns explosively to yield water vapor and carbon dioxide.  
(c) Burning diamonds yields carbon dioxide fairly slowly.  
(d) Without ignition, diamonds do not react with air.  
(e) Large amounts of gunpowder burn explosively.  
(f) Silver reacts slowly with sulfur-containing vapors which are common around cooking foods.  
(g) Dyes in clothes fade slowly in sunlight.  
(h) It takes years for DDT to decay in the environment.


19.7. (a) 2CH$_4$, (b) 3HI, (c) 3N$_2$H$_4$ or 3H$_2$NNH$_2$, (d) H$_2$SO$_4$

19.8. There are eight atoms of hydrogen in H$_2$CCH$_2$CH$_3$. The drawing looks something like polyethylene in Figure 19.8, except that there are three hydrogens on the two endmost carbons.

19.9. Three molecules of N$_2$O contain six atoms of nitrogen. Fifteen atoms of oxygen are found in 5Al$_2$O$_3$. 

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19.10. Equations (a) and (c) are balanced.

19.11. The promoter is probably a crackpot because his process allegedly turns four atoms of silver into eight atoms of silver.

19.12. Crushing merely makes smaller pieces of the same material which would still taste the same, have the same melting point, etc. Electrolysis produces materials with entirely new properties.


19.14. HCN would give the peaks listed. HCN (hydrogen cyanide) is the gas used for executing people in the gas chamber.

19.15. There are 18 atoms of F in 3SF₆.

19.16. Equations (b) and (c) are balanced.

Chapter 20

20.1. The density of a gold-silver alloy is intermediate between that of pure silver and pure gold. So are other properties such as electrical conductivity and thermal conductivity. Any of these could be used to distinguish the alloy from pure gold.

20.2. (b) Sn (tin) and Pb (lead) are most likely to form alloys of all compositions because they are vertically adjacent in the Periodic Table. This is the alloy used in common solder.

20.3. Electrical conductivity is the ability of a material to carry electricity (electrons). Metallic luster is the high reflectivity of most of the visible wavelengths of light. Malleability is the ability to deform without breaking when force is applied. Thermal conductivity is a measure of a material’s ability to transfer heat within itself when one part is at a higher temperature than another.

20.4. (b) Platinum and gold are most likely to form alloys in all proportions because they are neighbors in the Periodic Table.

20.5. The distance between diagonal lines in Figure 20.4 is generally about eight atoms, both horizontally and vertically.

20.6. Of the 23 atoms in the left half of Figure 20.4, 14 have only a single oxidation state.

20.7. (a) +1 for K, column IA (b) O for Ne, column VIIIA, noble gases (c) +1 for Cu, column IB (d) –1 for Br, column VIIA (e) –3 for P, column VA

20.8. (a) B: +3, (b) Ca: +2, (c) Cl: –1, (d) H: +1 (or possibly –1), (e) Ar: 0, (f) Ni: +2 or +3 (can’t tell which from the rules), (g) Cr: +6.

20.9. Two atoms with high ionization energies and negative oxidation states are O and F.

20.10. A pair of atoms with low ionization energies is Li and Na. Their uppermost electrons are near the top of the well and their primary oxidation state is +1.

20.11. Common oxidation states: (a) N: –3, +1, +2, +3, +4, +5; (b) P: –3, +3, and +5; (c) O: –2; (d) S: –2, +4, and +6; (e) Ne: 0; (f) Ar: 0.

20.12. Lithium loses the highest energy electron (alone in a 2s orbital) to become Li⁺. Beryllium loses both of its 2s electrons to become Be²⁺.

20.13. Three I⁻ ions will be required to neutralize the charge on Al³⁺.

20.14. Two Al³⁺ and three O²⁻ must be combined to achieve neutrality.

20.15. (a) KF, (b) Na₂S, (c) Mg₃N₂

20.16. (a) Be²⁺ and Br⁻ yield BeBr₂ (b) Ga³⁺ and O²⁻ yield Ga₂O₃

20.17. (a) beryllium oxide (b) calcium chloride (c) lithium fluoride (d) sodium sulfide
20.18.
(a) chromium (II) oxide
(b) chromium (VI) oxide
(c) chromium (III) oxide
(d) nitrogen dioxide
(e) sulfur trioxide

20.19. See completed Table 20.1 below.

20.20. (e)

20.21. (b)

20.22. (e). The primary oxidation state of Rb is +1.

Chapter 21

21.1.
(a) incorrect—needs a total of 14 electrons
(b) correct
(c) correct

21.2
(a) incorrect—needs 14 electrons and a single bond
(b) correct
(c) incorrect—needs 14 electrons
(d) incorrect—needs 20 electrons and single bonds

21.3.

21.4.

21.5. (c) P and O is the only pair of nonmetals and should be covalently bonded.

21.6. There is no valid electron-dot structure for SO. The electron-dot structures shown for SO and SO are valid. In addition, there are two resonance structures for SO not shown.

21.7. Very long chains with carbon backbones can indeed be formed. The ones proposed here exist as polyethylene.

21.8.

Table 20.1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Luster or Color</th>
<th>Form</th>
<th>Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium fluoride</td>
<td>NaF</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Iron-cobalt alloy</td>
<td>indefinite</td>
<td>metallic luster</td>
<td>solid</td>
<td>yes</td>
</tr>
<tr>
<td>Copper(II) chloride</td>
<td>CuCl₂</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Calcium oxide</td>
<td>CaO</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>CaCl₂</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Silver-gold alloy</td>
<td>indefinite</td>
<td>metallic luster</td>
<td>solid</td>
<td>yes</td>
</tr>
<tr>
<td>Chromium(III) oxide</td>
<td>Cr₂O₃</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Iron(II) oxide</td>
<td>FeO</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Magnesium bromide</td>
<td>MgBr₂</td>
<td>transparent</td>
<td>solid salt</td>
<td>no</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>metallic luster</td>
<td>solid</td>
<td>yes</td>
</tr>
</tbody>
</table>
21.9. CCl\textsubscript{4} is a volatile liquid rather than a solid. It does not conduct electricity under any conditions and is a poor conductor of heat. It is transparent rather than lustrous.

21.10. (a) Cl and I and (c) Si and F would be expected to be covalently bonded because they are nonmetals.

21.11. Oxygen has six electrons in the incomplete second shell. Two more would complete the shell and picking them up is energetically favorable for oxygen, so it has an oxidation number of –2. Fluorine has seven electrons in the second shell, and it is energetically favorable for it to add one more electron to complete the shell. Fluorine therefore has an oxidation number of –1.

21.12.  

21.13. Ammonium nitrate

21.14. H\textsubscript{2}SO\textsubscript{4}

21.15. (e)

21.16. (a)

21.17. (b)


---

**Table 21.1.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type of Elements</th>
<th>Formula</th>
<th>Bonding</th>
<th>Physical State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>nonmetal</td>
<td>CO</td>
<td>covalent</td>
<td>transparent gas</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>nonmetal</td>
<td>CO\textsubscript{2}</td>
<td>covalent</td>
<td>transparent gas</td>
</tr>
<tr>
<td>Calcium bromide</td>
<td>metal and nonmetal</td>
<td>CaBr\textsubscript{2}</td>
<td>ionic</td>
<td>solid salt</td>
</tr>
<tr>
<td>Silicon tetrachloride</td>
<td>nonmetal</td>
<td>SiCl\textsubscript{4}</td>
<td>covalent</td>
<td>transparent gas</td>
</tr>
<tr>
<td>Phosphorus fluoride</td>
<td>nonmetal</td>
<td>PF\textsubscript{3}</td>
<td>covalent</td>
<td>transparent gas</td>
</tr>
<tr>
<td>Copper-zinc alloy</td>
<td>metal</td>
<td>indefinite</td>
<td>metallic</td>
<td>solid</td>
</tr>
<tr>
<td>Nitrogen (N\textsubscript{2})</td>
<td>nonmetal</td>
<td>N\textsubscript{2}</td>
<td>covalent</td>
<td>transparent gas</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>metal and nonmetal</td>
<td>MgCO\textsubscript{3}</td>
<td>covalent and ionic</td>
<td>solid salt</td>
</tr>
</tbody>
</table>

---

Chapter 22

22.1. The arrangement of the orbitals of four H atoms about the central C atom gives methane its tetrahedral shape. Wave-particle duality leads to the existence of the orbital shapes. An orbital is a standing wave of probability.

22.2. (b)

22.3. Refer to Figure 22.2. Propane has three carbon atoms in a chain.
22.4. Refer to Figure 22.4.

22.5. Refer to Figure 22.6.

22.6. (a)

22.7. (d)

22.8. (e)

22.9. (d)

22.10. (b)

22.11. (d)

22.12. (b)

22.13. (c)

22.14. (c) and (d)

22.15. (b)

22.16. (a)

22.17. The equal amounts of G and C in DNA provided a clue to the G-C pairing and the double stranding in DNA.

22.18. (b)

22.19. (e)

22.20. DNA and RNA have the bases G, C, and A in common. DNA has the base T and is double stranded; RNA has the base U and is single stranded.

22.21. Refer to Figure 22.12.

22.22. (c)

22.23. (a)

Chapter 23

23.1. The one-celled organism needs sugar for energy; methane, carbon dioxide, and ammonia for building and repairing; water for solution; and various other elements. The cell absorbs these from the environment.

(a) A heterotroph cannot make its own organic compounds from sunlight, carbon dioxide, and water.

(b) An autotroph can make its own organic compounds.

(c) Chlorophyll is a molecule found in autotrophs that enables them to make sugar from carbon dioxide and water with the sun as an energy source.

23.2. A one-celled organism fabricates amino acids and nucleotides from raw materials.

(a) The raw materials come from breaking down nutrients.

(b) The raw materials are sugar, ammonia, and phosphates.

(c) Enzymes catalyze the reactions.

23.3. Enzymes get energy from nutrients.

(a) Nutrient energy released directly would be too disordered.

(b) The nutrient energy converts ADP molecules into higher energy ATP molecules.

(c) The energy of one sugar molecule is used to carry out about 40 ADP to ATP conversions.

(d) The special molecule is ATP.

23.4. The organism makes proteins by chaining amino acids together.

(a) The master plans are kept in DNA.

(b) The plans are coded as three-base sequences in the DNA.

(c) The proteins are assembled at the ribosomes.

23.5. The amino acids are delivered to the ribosomes by tRNA.

(a) Specific tRNA attaches to specific amino acids.

(b) The tRNA line the amino acids up in the proper sequence at the ribosomes.

23.6. The blueprints are delivered to the ribosomes by mRNA.

(a) mRNA carries a complementary code of the DNA code.

(b) The double-stranded DNA is unzipped and the single-stranded mRNA makes a complementary copy of the DNA code which it then carries to the ribosomes.

23.7. The mRNA is inserted into the ribosomes and as it slides along tRNA with attached amino acids associate with matching mRNA links. This results in an amino acid chain giving rise to the specified protein.

23.8. An enzyme unzips the DNA molecule into two halves. Other enzymes assemble from nucleotides the pieces to restore the “missing” halves. Two complete and identical DNA molecules result.

23.9. Favorable conditions for organic life on a planet include an atmosphere with water, methane,
ammonia, carbon dioxide, and hydrogen sulfide; and a stable temperature of the proper magnitude and “day-night” variation.

23.10. Some people think organic life in our universe is inevitable because the raw materials are everywhere, there is an abundance of organized energy, and there has been adequate time for it to develop.

23.11. Accidental changes in the DNA code of organic life can produce changes in an organism either favorable or unfavorable to its survival. Changes favorable to survival could result in evolution of the species.

Chapter 24

24.1. The number of neutrons (21) plus the number of protons (19) must add to the total number of nucleons, in this case 40.

24.2. They both have six protons. Carbon-14 has eight neutrons and carbon-12 has six in each nucleus.

24.3. Review the Rutherford experiment in Chapter 15.

24.4. Nuclei are made up of protons and neutrons. Protons have a positive charge; neutrons have no charge. Neutrons are very slightly more massive than protons. Both “feel” the strong force. Protons and neutrons are both composed of three quarks, but the charges on the quarks that make up a proton add up to +1 while the charges on the quarks that make up a neutron add up to zero.

24.5. The atomic number of an atom is the number of protons in each nucleus and also the number of orbiting electrons in each neutral atom.

24.6. Mass number refers to the total number of nucleons, neutrons plus protons, in an atomic nucleus.

24.7. All have the same number of protons. Different isotopes have different numbers of neutrons and, therefore, different mass numbers.

24.8. Radon-222. The alpha is a helium nucleus with two protons and two neutrons. Radium is atomic number 88 (see Appendix B or C), so each radium nucleus starts with 88 protons. Two of these are taken by the alpha, so there are 88 – 2 = 86 left. The new nucleus has atomic number 86 and is therefore a radon nucleus (look up 86 on the Periodic Table of Appendix C for this assignment). The original mass number is 226, with four nucleons being carried away by the alpha. Thus there are 226 – 4 = 222 nucleons left. The new nucleus, then, is radon-222.

24.9. Xenon-131. Iodine has 53 protons. One neutron changes to a proton during beta decay, so the new nucleus has 54 protons and is therefore a xenon nucleus. Beta decay does not change mass number, since the total number of nucleons is the same as before.

24.10. An electron with a positive charge. These combine with regular negative electrons in electron-positron annihilation to yield two high-energy photons (gamma rays).


24.12. Gold-195. Mercury has 80 protons. One changes to a neutron during electron capture, so there are 79 left. The element with 79 protons is gold. Again, electron capture does not change the total number of nucleons, so the mass number does not change.

24.13. Such particles exert relatively large forces, by the electrical interaction, on electrons in atoms near their paths. The forces are strong enough to force atomic electrons from their atoms, leaving electrically unbalanced atoms behind.

24.14. We have already seen that chemical reactions are governed by the outer electrons in atoms. These configurations are different when electrons are removed from atoms, so the chemical reactions in which they participate are different than before.

24.15. 50,000 after one half-life, 25,000 after two, and 12,500 after three. The total number decreases by a factor of two during each half-life.

24.16. Any process which either adds or subtracts electrons from otherwise neutral atoms, leaving behind atoms which are electrically unbalanced.

24.17. An atom with a net electric charge.

24.18. Comparatively large amounts of energy are concentrated in the resulting “rays.” These then can cause ionization and change the chemical reactions which are essential to life.


24.20. The amount of carbon-14 to carbon-12 in the remains of a formerly living object is compared to the constant carbon-14/carbon-12 ratio that characterizes atmospheric carbon and which is maintained by solar
radiation. Some assumptions and limitations to the method are mentioned in the section on “Radioactive Dating” in Chapter 24.

24.21. The amount of argon-40 in a rock sample is measured to determine how much potassium-40 has decayed to argon-40 by electron capture within the rock. The method measures the time from the solidification of an igneous rock. Some assumptions and limitations to the method are mentioned in the section on “Radioactive Dating”.

24.22. Refer to Exercise 24.20.

24.23. Radium-dial watches, treatment of cancer, and power cells. Refer to text for descriptions. Ionizing radiation can upset the normal chemistry of living systems.

24.24. No. Carbon-14 has a half-life of about 6000 years. Its usefulness for radioactive dating extends to only about 12 half-lives or 70,000 years.

24.25. (d)

24.26. (c)

Chapter 25

25.1. The strong force is the strongest of the fundamental forces at sufficiently short range. It is a short-range force which “cuts off” at a distance comparable to the diameter of a nucleus. It is an interaction that only affects certain particles, such as protons and neutrons.

25.2. The electrical interaction, causing the repulsion, is a long-range force. The strong interaction, causing an attractive force, acts only at short range.

25.3. The nucleus has lost energy and therefore mass, since mass and energy are equivalent. (You may want to review the discussion regarding the equivalence of mass and energy in Chapter 9.) Mass-energy is conserved in the process, since nuclear potential energy is lost while the same amount of energy appears as a high-energy photon, the gamma ray.

25.4. The nucleus loses nuclear potential energy, in this case enough to create an electron with kinetic energy and a neutrino.

25.5. Nuclear particles lose nuclear potential energy when they come close enough to each other so that they are held together by the strong interaction. This energy must be resupplied if they are to be separated. Nuclei do not usually break apart very easily because of the large amount of energy that would be required. That much energy is rarely concentrated in one nucleus during chemical explosions.

25.6. Before the reaction, there is kinetic energy of the colliding nuclei and a certain amount of nuclear potential energy. Afterward, there is less nuclear potential energy and more kinetic energy than before. The total energy remains the same, the increase in kinetic energy being just balanced by the decrease in nuclear potential energy.

25.7. The same answer as for Exercise 25.6 except in this case there is also a small change in electrical potential energy during the reaction.

25.8. The mass loss in each case is due to the energy transferred to other atoms or nuclei. Nuclear potential energy is first transformed to kinetic energy. This, in turn, is lost to other particles by collision so that the particles involved in the reaction have less total energy than before. The equivalence of mass and energy predicted by Einstein leads us to the conclusion that these particles then have less mass as well as less energy. The prediction is verified by experimental measurements.


25.10. See Study Guide glossary.

25.11. There is a loss of nuclear potential energy in both cases.

25.12. Neutrons released in an induced fission of a nucleus are slowed down and then captured by a second fissionable nucleus to cause that nucleus to fission, which releases more neutrons, etc., etc. If enough neutrons are released at each step, the process snowballs.

25.13. Control rods are made of a substance such as cadmium that absorbs neutrons without fissioning. The control rods are inserted into an operating reactor to absorb neutrons and thus slow down and control the chain reaction that releases energy in a nuclear power plant.

25.14. Nuclei repel each other because of the long-range electrical interaction. They can come close enough to interact by the strong interaction only if they initially approach each other at very high speed. Raising a plasma to a very high temperature seems to be the most efficient way to do this on a scale large enough to be useful.

25.15. The fuel is plentiful, radioactive byproducts
are much more easily controlled, and there cannot be a runaway (a reactor going out of control and exploding).

25.16. No one has yet succeeded in confining the high-temperature plasma long enough to provide more energy than is required to actually run the device (breakeven). However, modern devices do work and are getting very close to breakeven.

25.17. More energy is released in nuclear reactions because of the strength of the strong interaction.

25.18. (e)

25.19. (b)

Chapter 26


26.2. The sound has a higher tone (higher frequency) when the car is approaching and a lower tone (lower frequency) after the car passes.

26.3. The star is moving toward the earth (or the earth is moving toward the star). The Doppler effect for light implies that light will be bluer than normal when source and receiver are moving toward each other.

26.4. The earth’s orbit represents the one known length in the triangulation establishing the distance to close stars. These distances, in turn, become the basis for the intensity versus distance estimates for more distant stars. The entire system of astronomical distances hinges upon an accurate value of the diameter of the earth’s orbit.

26.5. By triangulation, using the same technique described in the text for measuring the distance across a river. You might want to know that surveyors don’t really draw a small triangle every time they want to use the triangulation method. Relationships between the sides and angles of triangles are contained in mathematical formulae studied in trigonometry. Surveyors use these, together with calculators and computers, to compute trigonometric functions and to calculate unknown distances and angles.

26.6. The time required for a beam of light or microwave radiation (radar) to travel to one of the planets and back can be measured. This, together with the speed of light, allows a computation of distances between objects in the solar system.

26.7. Light from distant objects, stars and galaxies, is redder than the light from similar objects nearby. The amount that the frequency is shifted increases with distance from the earth.

26.8. The cosmological redshift is interpreted as a Doppler effect frequency shift indicating that the galaxies are all moving apart.

26.9. Gravity would be pulling the universe inward, thus decreasing the speeds at which objects would move away from the center. This is just like the decreasing speed of a ball thrown upward from the earth. Dark energy causes an accelerated expansion.

26.10. This is the same question as 26.8.

26.11. This important model is defined in the Study Guide. Basically, it describes an expanding universe, beginning with matter in the form of elementary particles concentrated at extremely high density and temperature but then rarifying, cooling, and forming the composite structures of the universe as the matter expands.

26.12. The cosmological redshift, the fact that the rate of expansion seems to be slowing, the existence of microwave radiation which is similar to that which would be expected as the remains of a primordial “fireball”, and the ability of the model to predict the 75/25 mass ratio for hydrogen to helium all strongly support the Big Bang cosmology.

26.13. It cannot explain the observed microwave radiation from space and it cannot explain the hydrogen/helium ratio. The Steady State Model also does not seem to be consistent with the slowing in the rate of expansion.

26.14. Nucleons form 0.0001 to 0.001 second after the Big Bang. Neutron/proton ratio frozen at three minutes. 500,000 years. 500,000 years.


26.16. This important model, now discredited, is defined in the Study Guide.

26.17. If the universe were infinite in space and time we would see a star in every direction. But we do not, so the universe must be finite in space or time or both.

26.18. It would collapse under gravitational forces.

26.19. It would be in precarious balance—the slightest perturbation would cause its collapse.

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26.20. The surface of a sphere. An ever-expanding universe. The average density of mass in the universe is thought to determine whether it is open or closed. Too little luminous (visible) mass to close the universe.

26.21. (a)

26.22. Why is the universe homogeneous on the largest scale? How do the lumpy galaxies form from the early smooth distribution of matter? Why is there an apparent imbalance between matter and antimatter in the universe?

26.23. (c)

Chapter 27

27.1. The mutual gravitational attraction of the atoms for each other.

27.2. The atoms “fall” toward each other, losing gravitational potential energy and gaining kinetic energy. This becomes randomized as the atoms collide with each other, converting the directed kinetic energy to thermal energy which is manifest as increased temperature.

27.3. The protostar emits light because its atoms become ionized, the gas becoming a plasma. The energy comes from the thermal energy mentioned in 27.2 when the atoms collide with each other strongly enough to cause ionization. The energy is converted to light in two ways. Some electrons are recaptured by nuclei and fall back into lower energy states, emitting their excess energy as light. Other free electrons are accelerated by collisions in the hot plasma. These emit light with a continuous spectrum in harmony with Maxwell’s prediction that all accelerating electric charges emit electromagnetic radiation.

27.4. The gravitational forces causing the contraction are greater in stars with greater mass.

27.5. Energy is lost as light is emitted, so temperature of the star decreases. This reduces the outward pressure which opposes gravitational collapse.

27.6. Nuclear fusion begins. This replaces the thermal energy lost by radiation and maintains the internal temperature of the star.

27.7. It emits light because the atoms making up the star are mostly ionized. This answer is the same as for 27.3, except the energy now comes from nuclear potential energy released by nuclear fusion.

27.8. Gravity pulls inward, tending to shrink the star. The hot core exerts outward pressure, tending to expand the star. These two just balance each other during the hydrogen fusion part of the star’s life.

27.9. The star loses energy by emitting light. Nuclear potential energy is converted to thermal energy and eventually to light. The star is in balance when energy is supplied from nuclear potential energy at the same rate that it is lost by light. The temperature of the star does not change under this circumstance.

27.10. See the discussion of nuclear fusion in Chapter 25. Nuclear potential energy is lost during the fusion of these particles. It is released in the form of positrons, neutrinos, and kinetic energy of these particles and the final helium nuclei.

27.11. Remember that the gravitational forces tending to collapse the star are large if the star has more mass. This means that a higher internal temperature is needed to keep the star from collapsing. The rate at which nuclear fusion occurs increases very rapidly at higher temperatures, so the more massive stars convert their hydrogen to helium at a much faster rate than stars with less mass.

27.12. The outward pressure of the very hot hydrogen-fusion region of the star becomes greater than the inward forces due to gravity.

27.13. For the same reason that it became hotter during its initial collapse. As it expands, the particles gain gravitational potential energy. In effect, they convert thermal energy to gravitational potential energy and the temperature falls.

27.14. Its outer layers are cooler than before. Cooler objects emit a continuous spectrum that is redder than hotter objects. For example, compare the red light emitted by an electric hot plate on a stove with the white light by the much hotter filament of an electric lightbulb.

27.15. They have more mass. Therefore, the gravitational force pulling them to the center of the star is greater than for hydrogen nuclei.

27.16. Helium nuclei have more electric charge than hydrogen nuclei—in fact, twice as much. The repulsive force between two helium nuclei is then four times the repulsive force between two protons. The initial speeds and temperatures of the helium nuclei must therefore be much greater if they are to get close enough so that the strong interaction can be significant.

27.17. Remember that the high internal energy
(high temperature) of a star initially comes from gravitational potential energy. Also, stars with more mass have more gravitational potential energy. Finally, higher temperatures are required to overcome the electrical repulsion of larger nuclei. More massive stars start with enough gravitational potential energy to create high enough internal temperature so that larger nuclei can fuse; less massive stars do not.

27.18. Remember that the strength of the gravitational force depends on mass and on distance. A white dwarf is about the same size as the earth with a mass about that of the sun. An object on its surface would be attracted to a much more massive object than when near the earth.

27.19. The gravitational forces tending to cause less massive stars to collapse can be balanced by electrical repulsive forces between atomic nuclei and electrons. Gravitational forces in more massive stars are greater and cannot be balanced by electromagnetic forces between the particles.

27.20. A white dwarf is a dying star about the size of the earth with a mass about equal to that of the sun. It is white because it is very (white) hot, its internal temperature being maintained by helium fusion.

27.21. It does not have enough gravitational potential energy to raise the internal temperature high enough to initiate the next stage of fusion after helium fusion stops.

27.22. A black hole is a star whose surface gravity is so high that light cannot escape. It is black because it emits no light.

27.23. These three kinds of stars are the end results of the gravitational collapse and “death” of stars of different mass. Stars of modest mass (like our sun) collapse to objects about the size of earth (white dwarf), stars several times as massive as our sun collapse to the size of an object a few tens of miles across in a state of matter similar to a nucleus, and the most massive stars are believed to collapse without limit as a black hole.

27.24. It doesn’t have enough gravitational potential energy (because it doesn’t have enough mass) to initiate nuclear fusion.

27.25. Present theories suggest that all the heavy elements (with mass numbers greater than about 50 or 60) are formed in supernova explosions associated with the last stages of the life of very massive stars.


27.27. Quasars. The effects of a black hole’s intense gravitational field.

27.28. (e)

27.29. (d)

Chapter 28

28.1. (c) Stable platforms are found on the continents, not in the oceans.

28.2. Catastrophe theories require that some unusual and presumably rare event occur in order to form a system of planets about a star; this might be the nearby passage of another star, for example. Nebular theories assume that the formation of planets is a natural, possibly common result of stellar formation and occurs as a cloud of dust and gases (a protostar) condenses gravitationally.

28.3. (c) If a spinning object is contracting in a direction perpendicular to its spin axis, then it must spin faster to conserve angular momentum. A spinning object that is spreading out perpendicular to its spin axis will slow down.

28.4. Igneous rocks form from molten material (lava if it erupts onto the surface of the earth, magma if it remains below the surface) that cools and crystallizes. Sedimentary rocks consist of debris, eroded from other rocks, that has been deposited in layers and cemented together by chemicals dissolved in groundwater, or of chemical precipitates deposited at the bottoms of bodies of water. When igneous or sedimentary rocks are subjected to great pressures and temperatures, they are altered, producing metamorphic rocks; new metamorphic rocks can also be produced, of course, by subjecting old metamorphic rocks to these conditions.

28.5. All continents have features in common. Among these are shields, stable platforms, and fold mountain belts.

28.6. (d)

28.7. A topographically high ridge winds through the ocean basins, near the middle in some places but far off-center in others, and it is flanked on either side by the abyssal hills. These hills become smaller the farther one moves away from the ridge, because they become covered with sediment that has accumulated on the seafloor. Given enough sediment, they are completely covered, and the resulting flat areas are the abyssal plains. In various locations, but generally far from the ridges, are deep trenches; and these are always adjacent to island arcs (or volcanic mountain ranges if the ridge is adjacent to a continent).
28.8. The continents are made of a great variety of rock types, but if the chemical compositions of all of them are averaged together, the result is close to the chemical composition of granite, an igneous rock. The rocks of the ocean floor are all of essentially one type—basalt, a different type of igneous rock.

28.9. (b)

Chapter 29

29.1. Relative dating establishes only a sequence of events, without providing information about the actual times or dates of those events. The determination of those times or dates is absolute dating.

29.2. (a) Radioactive isotopes are used in absolute dating.

29.3. The Principle of Superposition establishes that the sedimentary layer is younger than the lava flow, and the Principle of Cross-Cutting Relationships requires that it be older than the igneous body, so the correct answer is (d).

29.4. The Geologic Column evolved over a period of many years, before there was a way to determine absolute ages. The periods of the Column were delineated on the basis of the appearance and disappearance of particular fossils in the rock record, but there was no way to know whether the fossils chosen yielded periods of anywhere near uniform length. It turned out that they didn't.

29.5. The key to this question is the meaning of "half-life": the period of time required for one-half of the amount of radioactive isotope initially present to decay. A decay curve is simply a graph relating amount of parent isotope left to time elapsed (see Fig. 29.9). If the time elapsed is expressed in numbers of half-lives rather than in years, then the same decay curve will do for any radioactive isotope. Only the length of the half-life makes one decay curve different from another.

29.6. If a radioactive isotope is not fairly common, there will not be enough of it in a rock to be reliably useful. If the half-life is too short, then the parent material will decay rapidly, leaving too little in the rock for reliable analysis. Thus, the correct answer is (c).

29.7. Carbon-14 has a half-life of only 5730 years—far too short to use for dating anything older than very recent material (about 70,000 years old, at most). In addition, carbon-14 dating measures the time since an object died and stopped replenishing its complement of radioactive carbon, so objects dated in this way must once have been alive.

29.8. The oldest lunar rocks have radiometric ages of 4.6 billion years, as do the oldest meteorites. The moon is thought to have undergone little change since its formation in the early solar system, and this is also true of meteorites. Because there appears to be no reason to suppose that the earth was formed at a different time, the age of the earth is taken to be 4.6 billion years also, even though rocks of that age on earth have been lost to erosion or tectonic processes.

29.9. (a)

Chapter 30

30.1. (b)

30.2. (a)

30.3. A wave changes direction when it encounters a different medium than the one in which it is traveling—a phenomenon we know as refraction. For seismic waves, different media are characterized by different densities and rigidities (stiffnesses). As seismic waves travel through a layer like the mantle, in which density and rigidity are slowly changing with depth, their directions are slowly changed so that the waves follow curved paths. At a seismic discontinuity, say the boundary between the mantle and the outer core, the density and rigidity change abruptly, causing sharp changes in the directions of the waves. The velocities of seismic waves also change abruptly at discontinuities.

30.4. One discontinuity is found at the base of the crust and is the crust-mantle boundary. Another is the boundary between the mantle and the outer core, and another is between the outer core and the inner core. Finally, seismic discontinuities bound the low-velocity zone within the upper mantle.

30.5. The inner core is indeed at a higher temperature than the outer core, but it is also under higher pressure. The pressure is so large that, at the prevailing temperatures, the core is solid.

30.6. A differentiated planet is a layered planet, and the densities of the layers decrease as distance from the center of the planet increases. Thus the inner core is denser that the outer core, the outer core is denser than the mantle, and so on out to the atmosphere, which is least dense of all the layers. How this came about is a subject for another chapter.
30.7. (d) Be sure that you understand the distinction between chemically distinct layers and mechanically different layers.

30.8. At the locations of fold mountain belts the crust is particularly thick. Because of that, it projects down into the mantle further than crust that is thin, displacing a volume of mantle rock whose weight is equal to the crustal weight. The situation is analogous to floating icebergs: thicker icebergs project higher above the surface of the water than do thinner ones, even though the same proportion of the iceberg is immersed. You recognize this as a statement of Archimedes' Principle; when applied to the lithosphere of the earth, the concept is called isostasy.

30.9. (b)

Chapter 31

31.1. The continental shelves are those portions of the continents that happen to be below sea level at this time. They consist of continental rocks, however, and are not part of the ocean basins.

31.2. (c)

31.3. (d) The geometrical fits of some continents constitute good evidence for continental drift, but not of North America and Australia.

31.4. If the directions of the inherent magnetic fields of ancient lava flows on different continents are measured, it is found that they do not all point toward the same north pole. However, if the continents are rearranged so that their continental shelves fit best, then the magnetic directions all point toward a single location. In answering this question, you should be sure that you can discuss the origin of these magnetic fields in the rocks, including the concept of Curie temperature.

31.5. (a) Note, however, that while the magnetic stripes are parallel to the oceanic ridges, they indicate that the movement has been perpendicular to the ridges.

31.6. If the seafloor is spreading, then the oldest parts of it should be far from the ridges and the youngest parts closest to them. In addition, the thickness of sediment on the ocean floor should increase away from the ridges, because there has been more time for older sea floor to accumulate sediment. Both predictions are confirmed by observation.

Chapter 32

32.1. (c) Creation of new oceanic lithosphere occurs at oceanic spreading centers.

32.2. (b) Continental shields are the ancient cores of the continents and are generally geologically quiet.

32.3. As the oceanic lithosphere spreads away from the oceanic ridges, it cools, becomes denser, and subsides. What had once been topographically high ridges become low hills—the abyssal hills. As sediment rains down upon them, low areas are filled in, and eventually the hills may be completely covered in some places, forming the abyssal plains.

32.4. (a) The theory does predict that continents can be pulled apart, but it cannot currently predict where or when that will happen for any given continent.

32.5. (b) The California coast is the location of a major transform fault (the San Andreas Fault), Iceland is situated astride the Mid-Atlantic Ridge, and Japan sits above a subduction zone. See the answer to Exercise 32.2.

32.6. Fold mountain belts come into existence when a continental mass located on a plate boundary becomes involved in plate convergence—particularly a continent-against-continent collision. As two continents collide, they tend to do so along a relatively long collision zone (a former subduction zone), and this is where the fold mountain belts are generated as a result of collision.

Chapter 33

33.1. Because special conditions must be satisfied for an organism to be preserved as a fossil, the vast majority of organisms that have lived on the earth must never have been preserved. There may even be many entire species that lived but left no record of their existence. Certainly, the fossils that now exist represent only a small fraction of all life that has populated the earth.

33.2. (d) Worms have no hard parts, and hard parts greatly enhance the chances of fossilization.

33.3. (b) Organisms that live in water are much more likely to be fossilized than those that live on land because their remains are more likely to be covered by sediment that protects them from predators and bacterial attack. Thus, the fish and the clam are more likely to be fossilized than the bird. We have already established in Exercise 33.2 that the worm is the least likely to be
fossilized.

33.4. First, in, on, or above the sediment is where most organisms live. Second, the processes by which igneous and metamorphic rocks are formed (see Chapter 28) are not conducive to the preservation of fossils.

33.5. (a) Coal beds are formed from fossil plant matter from a lush tropical or subtropical forest.

33.6. (c) Organisms that reproduce slowly provide fewer candidates for fossilization.

Chapter 34

34.1. In your discussion, you should be able to include and discuss evaporation, precipitation, surface runoff, glaciers, groundwater, and the contribution of the plate tectonic system to the hydrologic system.

34.2. (a)

34.3. In order to erode at all, water must be able to flow; and thus the stream channels must have some slope. Moreover, as that slope decreases through erosional lowering of the land, erosion also slows because water velocity decreases. Thus, there is an erosional level, called base level, below which the land is not lowered.

34.4. (d)

34.5. There is not enough oxygen in volcanic emanations to account for the oxygen in the atmosphere. That must have been provided by plants, through photosynthesis.

34.6. Some mountain ranges are considerably older than late Paleozoic (the time when Pangaea was formed) and are also far from any plate boundaries related to Pangaea. For example, the Urals, which lie in the middle of the Eurasian plate, are not close enough to any plate boundaries to have been caused by convergence of present tectonic plates; they are of early Paleozoic (pre-Pangaea) age.