Chapter 4 Review, pages 198–203

Knowledge

1. (c)
2. (b)
3. (a)
4. (d)
5. (a)
6. (b)
7. (d)
8. (c)
9. (c)
10. (d)
11. (c)
12. (a) (iii)
(b) (i)
(c) (iv)
(d) (ii)

13. A force field is a region of space surrounding an object that can exert a force on other objects that are placed within that region and are able to interact with that force.

14. (a) Weight represents a force.
(b) Mass does not depend on gravity.

15. Static friction is a type of friction that prevents two surfaces from sliding relative to one another.

16. Kinetic friction replaces static friction.

17. A car's braking system utilizes static friction between the turning wheels and the ground below. This is a net force increase because other horizontal forces acting on the car are small compared to the friction force of the wheels. As static friction is applied to the road, the net force on the car is increased, thereby decreasing the car's speed.

18. (a) An antilock braking system and electronic traction control are systems that combine sensors and controls to increase the safety of a car. They both intermittently adjust the car's controls to decrease the amount of time the car slides instead of grips the road. The difference between the two systems is that an ABS applies its control to the braking system to prevent sliding while the car is slowing down, but electronic traction control applies its control during a car's acceleration to keep the car from over-accelerating and losing traction.
(b) By combining an ABS and electronic traction control, an ESC system prevents the car from losing its traction while accelerating and slowing down, ensuring safety during the car's operation.

Understanding

19. (a) If they both hit the ground at the same time, the object with the greater mass has a larger cross-sectional area.
(b) If they have the same cross-sectional area, the object with the greater mass will hit the ground first.
(c) If both objects were dropped in a vacuum, where there is no air resistance, they would hit the ground at the same time.

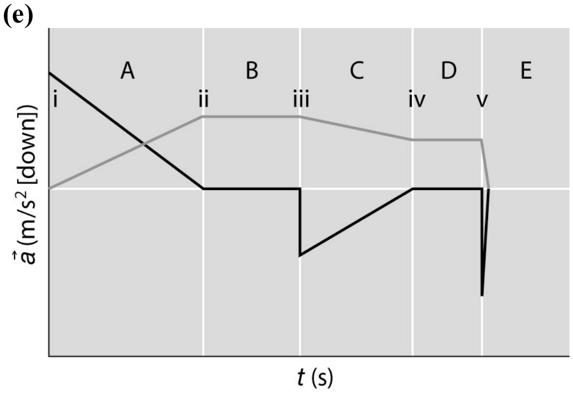
20. (a) The force of gravity and air resistance are the two forces acting on a ball dropped through the air.
(b) As the ball is initially dropped, the force of gravity acts more strongly.
(c) As the ball moves at terminal speed, the force of gravity and air resistance are equal in magnitude and acting in opposite directions.
(d) At terminal speed:

$$\begin{aligned} F_\text{f} &= F_\text{g} \\ &= mg \\ &= (25\text{ kg})(9.8\text{ m/s}^2) \\ F_\text{f} &= 250\text{ N} \end{aligned}$$

The magnitude of the friction force is 250 N.

21. (a) Interval A: The skydiver jumps out of the plane. Gravity is greater than air resistance.
Interval B: The skydiver has reached terminal speed without the parachute deployed. Gravity and air resistance are equal.
Interval C: The skydiver has deployed her parachute. Gravity is less than air resistance.
Interval D: The skydiver has reached terminal speed with the parachute deployed. Gravity and air resistance are equal.
Interval E: The skydiver has reached the ground. Gravity equals normal force.
(b) The skydiver reaches maximum speed throughout interval B.
(c) The force of air resistance is greatest at the beginning of interval C.
(d) The skydiver is travelling at terminal speed throughout interval B (parachute not deployed) and interval D (parachute deployed).

(e)



22. (a) The slowing of a skydiver after the deployment of the parachute indicates that the gravitational force is less than the air resistance.
(b) As the skydiver slows towards terminal speed, the air resistance decreases until its magnitude equals that of the gravitational force.
23. The magnitudes of the gravitational field strength and the gravitational acceleration at Earth's surface are both 9.8 m/s^2.
24. (a) Answers may vary. Sample answer:
One way to measure gravitational field strength is to measure the weight of a known mass and divide the weight by the mass. A second way is to measure the acceleration of an object falling from a known height.
(b) Use the equation $F_g = mg$ to determine g.

$$F_g = mg$$
$$g = \frac{F_g}{m} = \frac{14.67\text{ N}}{1.50\text{ kg}}$$
$$g = 9.78\text{ N/kg}$$

The gravitational field strength at that altitude is 9.78 N/kg.
(c) This altitude is likely above sea level because the gravitational field strength is less than that at sea level.
25. (a) The object will have the greatest weight at the North Pole.
(b) The object will have the least weight at the peak of Mount Everest.
(c)

Location	Weight
North Pole	124.74 N
equator	124.09 N
Mount Everest	123.88 N

26. (a) Mass is the quantity of matter in an object.
(b) It is possible to change the mass of an object by adding or removing material from that object.
(c) Weight is a measure of the force of gravity acting on an object.
(d) To change the weight of an object, but not the mass, move the object to a location with a different gravitational field strength.
(e) The magnitudes of an object's mass and weight will be equal when the gravitational field strength equals 1 N/kg.
27. (a) The terms "weightlessness" and "microgravity" are misapplied when discussing astronauts aboard the International Space Station because the astronauts and the space station are both experiencing a large force of gravity towards Earth's centre.
(b) The appropriate term to describe the state that makes them appear to float within the space station is that they are both experiencing free fall.
28. Choose up as positive. So down is negative. Determine the force of gravity acting on the person.

$$F_g = mg$$
$$= (60.0\text{ kg})(-9.8\text{ m/s}^2)$$
$$F_g = -588\text{ N}$$

Then determine the normal force of the person.

$$F_{net} = F_g + F_N$$
$$ma = -588\text{ N} + F_N$$
$$(60.0\text{ kg})(-1.6\text{ m/s}^2) = -588\text{ N} + F_N$$
$$F_N = +490\text{ N}$$

The reading on the scale is 490 N.
29. Choose up as positive. So down is negative.
(a) Since the person is moving at a constant velocity, the net force is zero.

$$F_N + F_g = 0$$
$$F_N = -F_g$$

The reading on the scale is 58 kg.
(b) Calculate the normal force of the person accelerating at 2.7 m/s^2 [up].

$$F_{net} = F_g + F_N$$
$$ma = mg + F_N$$
$$(58\text{ kg})(+2.7\text{ m/s}^2) = (58\text{ kg})(-9.8\text{ m/s}^2) + F_N$$
$$F_N = 725\text{ N}$$

Divide the normal force by 9.8 m/s^2 to find the reading on the scale.

$$\frac{725\text{ N}}{9.8\text{ m/s}^2} = 74\text{ kg}$$

The reading on the scale is 74 kg.

(c) Calculate the normal force of the person accelerating at 3.8 m/s^2 [down].

$$F_{net} = F_g + F_N$$
$$ma = mg + F_N$$
$$(58\text{ kg})(-3.8\text{ m/s}^2) = (58\text{ kg})(-9.8\text{ m/s}^2) + F_N$$
$$F_N = 348\text{ N}$$

Divide the normal force by 9.8 m/s^2 to find the reading on the scale.

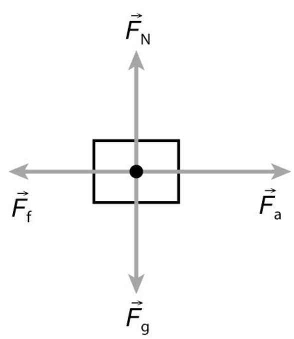
$$\frac{348\text{ N}}{9.8\text{ m/s}^2} = 36\text{ kg}$$

The reading on the scale is 36 kg.

30. Static friction prevents two stationary surfaces from sliding relative to each other, whereas kinetic friction is exerted by one surface on another when the two surfaces are sliding relative to each other.

31. (a) The force of gravity, the normal force, the applied force, and static friction are acting on the box.

(b)



(c) Consider the magnitude of the vertical forces on the box.

$$F_N = F_g$$
$$= mg$$
$$= (7.5\text{ kg})(9.8\text{ m/s}^2)$$
$$F_N = 74\text{ N}$$

The normal force acting on the box at sea level is 74 N.

32. (a) If the object is slowing, F_a is less than F_f.
(b) If the object travels at a constant velocity, F_a is equal to F_f.
(c) If the object is speeding up, F_a is greater than F_f.

33. (a) Divide the friction force by the normal force.

$$\mu = \frac{F_f}{F_N}$$
$$= \frac{6.6\text{ N}}{30.0\text{ N}}$$
$$\mu = 0.22$$

The coefficient of friction is 0.22.
(b) The object is not moving because the value of the coefficient of friction is high enough that it is more likely to be a coefficient of static friction than kinetic friction.

34. (a) To make the steel block start sliding across the horizontal surface, a force equal in magnitude to the force of static friction is required.

$$F_{S_{max}} = \mu_S F_N$$
$$= (0.78)(15\text{ N})$$
$$F_{S_{max}} = 12\text{ N}$$

The force required is 12 N.
(b) To maintain the steel block sliding at a constant speed, a force equal in magnitude to the force of kinetic friction is required.

$$F_K = \mu_K F_N$$
$$= (0.42)(15\text{ N})$$
$$F_K = 6.3\text{ N}$$

The force required is 6.3 N.

35. Answers may vary.
(a) Students' answers should describe any two objects that come in contact with one another but do not move due to friction. Sample answer: When sitting in a chair, static friction prevents me from sliding off.
(b) Students' answers should describe any two objects that slide against each other. Sample answer: When sliding with socks on a slippery floor, kinetic friction stops me from sliding forever.
(c) Students' answers should explain how the friction in each example in part (a) and part (b) helps something move or stops it from moving. Sample answer: In part (a), static friction helps a person sitting in a chair from moving out of a chair. In part (b), kinetic friction helps stop a person from continuously sliding on the floor.

36. Use the equations $F_f = F_K = \mu_K F_N$ and $F_{net} = ma$ to determine the applied force F_a.

$$F_{net} = F_a - F_f$$
$$ma = F_a - \mu_K F_N$$
$$ma = F_a - \mu_K mg$$
$$(4.4 \text{ kg})(1.5 \text{ m/s}^2) = F_a - (0.25)(4.4 \text{ kg})(9.8 \text{ m/s}^2)$$
$$F_a = 17 \text{ N}$$

The magnitude of the horizontal force being applied to move the object is 17 N.

37. (a) Use the equation $F_f = \mu_S F_N$ to determine the force F_a required. Since the couch is not moving, $F_{net} = 0$.

$$F_{net} = F_a - F_f$$
$$0 = F_a - \mu_S F_N$$
$$F_a = \mu_S F_N$$
$$= \mu_S F_g$$
$$= (0.31)(620 \text{ N})$$
$$F_a = 190 \text{ N}$$

The maximum force required to set the couch in motion is 190 N.

(b) Use the equation $F_f = \mu_K F_N$ to determine the force F_a required. Since the couch is moving at a constant speed, $F_{net} = 0$.

$$F_{net} = F_a - F_f$$
$$0 = F_a - \mu_K F_N$$
$$F_a = \mu_K F_N$$
$$= \mu_K F_g$$
$$= (0.21)(620 \text{ N})$$
$$F_a = 130 \text{ N}$$

The force required to maintain the couch moving at a constant speed is 130 N.

38. Use the equation $F_f = \mu_S F_N$ to determine the maximum coefficient of static friction μ_S required. At the start of the motion, $F_{net} = 0$.

$$F_{net} = F_a - F_f$$
$$0 = F_a - \mu_S F_N$$
$$F_a = \mu_S F_N$$
$$F_a = \mu_S mg$$
$$\mu_S = \frac{F_a}{mg}$$
$$= \frac{18 \text{ N}}{(2.7 \text{ kg})(9.8 \text{ m/s}^2)}$$
$$\mu_S = 0.68$$

The maximum coefficient of static friction between the brick and the wood is 0.68.

39. (a) Rubber is an exception to the concept that static friction and kinetic friction acting on an object is independent of the surface area in contact with another surface.

(b) This difference affects the design of car tires in that tires requiring more friction are made with an increased surface area. An example of this can be found on the wide tires used on race cars.

40. Answers may vary. Sample answer:
When the driver starts to speed up on a wet road, the water in front of the tire moves through the grooves and is squeezed out at the back of the tire. If the speed continues to increase, the water might not have enough time to pass through the grooves. The water level in front of the tire will increase, causing the tire to lose contact with the road surface. This hydroplaning stage is dangerous as the driver may lose control and not be able to stop the car due to the very low friction acting on the tires.

41. (a) The friction force is applied to the rotor attached to a wheel.

(b) The rotor experiences a friction force by coming into contact with the brake pads.

42. Crumple zones in a car's body and frame increases the distance travelled by the car when a collision occurs. This decreases the magnitude of acceleration experienced, thereby decreasing the force felt by the car's passengers.

43. When the force of the club's swing is greater than the friction force between golfer's hand and the golf club, the golf club will fly out of the golfer's hand. Golf club manufacturers use materials with high coefficient of static friction, such as rubber and leather, to make grips to increase the friction force on the golfer's hand.

44. (a) Roller bearings and ball bearings have been used for years to reduce wear and friction.

(b) Fluid bearings using a film or fluid are a newer type of bearing that reduces friction to negligible levels.

(c) Magnetic levitation systems reduce friction almost completely. They are expensive to operate and require back-up bearings in case of failure.

(d) Near-frictionless carbon allows for very low coefficients of friction and very hard wear surfaces. Initial applications for this material include the space program and aircraft design.

45. First calculate the total mass of the books:
$m_T = 6.5 \text{ kg} + 6.5 \text{ kg} = 13 \text{ kg}$
Consider all forces acting on the bottom book. Let F_{ft} represent the friction force exerted by the table surface and F_{fb} represent the friction force exerted by the book at the top. Since the book is not moving, $F_{net} = 0$.

$$F_{net} = F_{ft} - F_{fb}$$
$$0 = F_{ft} - F_{fb}$$
$$F_{ft} = F_{fb}$$
$$\mu_{St} m_T g = \mu_{Sb} m_b g$$
$$\mu_{St} m_T = \mu_{Sb} m_b$$
$$\mu_{Sb} = \frac{\mu_{St} m_T}{m_b} = \frac{(0.15)(13 \text{ kg})}{6.5 \text{ kg}}$$
$$\mu_{Sb} = 0.30$$

The minimum coefficient of static friction between the books is 0.30.

Analysis and Application

46. (a) When a person is riding an elevator, the acceleration of the elevator combines with the acceleration of gravity to make the person feel a net force that is different than the net force caused by gravity alone. When the elevator is accelerating upward, the acceleration brings the person closer to the floor. This acceleration combines with the acceleration due to gravity to create an increased net force toward the floor so the person feels heavier. When the elevator is accelerating downward, the acceleration brings the person farther away from the floor. This acceleration combines with the acceleration due to gravity to create a decreased net force toward the floor so the person feels lighter.
(b) Answers may vary. Sample answer:
Riding a roller coaster or a vehicle quickly over hills increases and decreases a person's acceleration in similar ways to riding an elevator.
47. Answers may vary. Sample answer:
In the diagram, the cannonball falls back to Earth's surface due to the gravitational force directed towards the centre of Earth. Since it is falling under the influence of gravity only, it is said to be in free fall. As the velocity of the cannonball increases from (a), the trajectory of the cannonball curves away from Earth's surface and travels farther and farther before it returns to Earth. At (e), the cannonball is fired with the right velocity to travel around Earth under the influence of Earth's gravitational field, but never returning to Earth. At (f), the cannonball can travel fast enough to escape from Earth's gravitational field. So trajectory (f) is the fastest.
48. Answers may vary. Sample answer:
From the photograph, the metal surface is not really levelled and there are grooves, cracks, and holes that will exert friction force on another surface that is in contact with it. It seems that no matter how smooth a surface appears to be, it is not perfectly smooth. That is why the coefficients of friction for materials are never zero.
49. (a) Use the equations $F_f = F_K = \mu_K F_N$ and $F_{net} = ma$ to determine the mass.

$$F_{net} = F_a - F_f$$
$$ma = F_a - \mu_K F_N$$
$$ma = F_a - \mu_K mg$$
$$ma + \mu_K mg = F_a$$
$$m(a + \mu_K g) = F_a$$
$$m = \frac{F_a}{a + \mu_K g} = \frac{150 \text{ N}}{2.53 \text{ m/s}^2 + (0.15)(9.8 \text{ m/s}^2)} = 37.5 \text{ kg}$$
$$m = 38 \text{ kg}$$

The mass of the block is 38 kg.
(b) Since the block moves with a constant velocity, $F_{net} = 0$. Use the equation $F_f = F_K = \mu_K F_N$ to determine μ_K.

$$0 = F_a - F_f$$
$$F_f = F_a$$
$$\mu_K F_N = F_a$$
$$\mu_K mg = F_a$$
$$\mu_K = \frac{F_a}{mg} = \frac{150 \text{ N}}{(37.5 \text{ kg})(9.8 \text{ m/s}^2)}$$
$$\mu_K = 0.41$$

The coefficient of kinetic friction between the block and the new surface is 0.41.
50. (a) Use the equations $F_f = \mu_K F_N$ and $F_{net} = ma$ to determine the acceleration of each team.

Team 1:

$$F_{net} = F_1 - F_f$$
$$m_1 a_1 = F_1 - \mu_K F_N$$
$$m_1 a_1 = F_1 - \mu_K m_1 g$$
$$a_1 = \frac{F_1 - \mu_K m_1 g}{m_1}$$
$$= \frac{230\ \text{N} - (0.01)(170\ \text{kg})(9.8\ \text{m/s}^2)}{170\ \text{kg}}$$
$$a_1 = 1.25\ \text{m/s}^2$$

Team 2:

$$F_{net} = F_2 - F_f$$
$$m_2 a_2 = F_2 - \mu_K F_N$$
$$m_2 a_2 = F_2 - \mu_K m_2 g$$
$$a_2 = \frac{F_2 - \mu_K m_2 g}{m_2}$$
$$= \frac{250\ \text{N} - (0.01)(195\ \text{kg})(9.8\ \text{m/s}^2)}{195\ \text{kg}}$$
$$a_2 = 1.18\ \text{m/s}^2$$

The acceleration of team 1 is faster so team 1 will have a quicker start.

(b) For each team, the applied force is the same as the force of static friction and the acceleration is calculated as follows.

$$F_{net} = F_a - F_f$$
$$ma = \mu_S F_N - \mu_K F_N$$
$$ma = \mu_S mg - \mu_K mg$$
$$a = (\mu_S - \mu_K)g$$

The accelerations are independent of the mass of the sleds so both sleds have the same acceleration.

51. (a) Since there is no applied force, $F_{net} = F_{S_{max}}$.

$$F_{net} = F_{S_{max}}$$
$$ma = \mu_S F_N$$
$$ma = \mu_S mg$$
$$a = \mu_S g$$
$$= (0.05)(9.8\ \text{m/s}^2)$$
$$a = 0.49\ \text{m/s}^2$$

The broomball player is expected to create a maximum acceleration of 0.5 m/s^2.

(b) For a different value of μ_S,

$$F_{net} = F_{S_{max}}$$
$$ma = \mu_S F_N$$
$$ma = \mu_S mg$$
$$a = \mu_S g$$
$$= (0.85)(9.8\ \text{m/s}^2)$$
$$a = 8.3\ \text{m/s}^2$$

The maximum possible acceleration is 8.3 m/s^2.

(c) If a player of greater mass were on the same surface, the values above would not change.

52. Tread pattern could play a role in preventing hydroplaning. An example could be a tread pattern that sheds water away from the tire instead of requiring it to channel through the entire tread pattern.

53. If friction were reduced on all axes of an ice skate, the skater would never be able to use friction to increase her speed while skating or be able to turn.

Evaluation

54. Answers may vary. Sample answers:

(a) Advantages of creating an infrastructure in a lower gravitational field may include lower costs of building materials, transportation, and maintenance. Infrastructure would weigh less and therefore could be made smaller as it does not have to carry as much of it own weight. Transportation of a lighter and smaller structure would be easier. Friction wear on many components would be less and so repair and replacement costs would be lower. Disadvantages may include decreased stopping capabilities of vehicles and material manipulation via gravity. For example, extruding metal sheets through rollers would be more difficult.

(b) In a lower gravitational field, the human body would benefit from less joint wear. However, there could be some possible disadvantages. With lower gravitational field strength, the cells of the bones and muscles may adjust themselves so that the bones are no longer as strong as they are in Earth's gravitational field. Problems such as low bone density would occur.

(c) The obvious effect is that sports would have to be completely retooled. Regular-sized baseballs would be hit for home-runs each time players went for the ball. Basketball players would be able to jump to the rim without much skill or effort.

55. (a) If the Moon were closer to Earth, tidal shifts would be greater because the pull by the Moon's gravitational field increases as the distance from the Moon's surface decreases.
(b) If the Moon had less gravitational pull, the magnitude of the tidal shifts would be smaller.
(c) Answers may vary. Sample answer:
One possible effect of having multiple moons would be multiple tidal shifts of varying magnitude based on the gravitational field strength and the distance of each of the moons.
56. Answers may vary. Sample answer:
To determine the coefficients of friction, the experimental procedure should include measuring the normal force, the applied force, and the acceleration of an object on a surface very accurately. Surface conditions such as humidity, wetness, dust, or dirt would affect results. These variables could be catalogued with their associated friction coefficients so as to characterize a more complete description of the friction interaction of the materials.
57. Answers may vary. Sample answer:
Without friction, driving as we know it would not be possible. Car tires would not be able to push against the road, leaving the car in place. Other propulsion methods would have to be substituted for the friction between tires and road. Perhaps rockets could be used for automobile propulsion.
58. Answers may vary. Sample answers:
(a) Friction loss has an impact on the fuel efficiency of the engine of a car. Some energy coming from the fuel is wasted in the form of heat due to friction. As a result the fuel efficiency of the car decreases.
(b) Friction could be minimized by decreasing the number of moving parts or by adding bearings and lubricants between sliding parts to reduce friction.
59. Answers may vary. Sample answers:
(a) Table 1 shows that there are challenges with predicting forces between two parts of greasy steel because the coefficients of friction are shown as ranges. To predict a force accurately, the coefficient of friction must be known exactly. A range of coefficients will create a range of possible forces.
(b) Engineers might overcome the uncertainty by using in their designs materials that have more certain coefficients of friction.
(c) Many variables go into the forces experienced by a golf club. These include the speed of the club, the swing angle at which the club hits the ball, the face angle at which the ball hits the club, and the location of impact.

Reflect on Your Learning

60. Answers may vary. Sample answer:
(a) Car tires take advantage of gravity-induced friction to move cars and allow people to travel much longer distances than they otherwise would be able to.
(b) The soles of boots are manufactured with rubber that has a high coefficient of kinetic friction to increase the grip as we walk on icy or slippery surfaces.
61. (a) Mass and weight can be used interchangeably because there is a direct correlation between mass and weight if the gravitational field is consistent, which it is on Earth's surface.
(b) In the context of physics, the assumption cannot be made that a specific mass corresponds to a specific weight. This assumption is wrong when the gravitational force changes. Further, the mass is related to the net force by the mass's acceleration. This means that mathematically, mass and force are different. Since weight is the product of mass and gravitational acceleration, weight is a force.
62. Answers may vary. The first part of the answer may be as follows: Air resistance can be used to our advantage as a transportation mode in sailing. Sailboats use air resistance as their primary propulsion force. Many other vehicles, such as planes and cars have to use large quantities of energy to overcome the forces that air resistance applies in the direction opposite to the vehicle's motion. The second part of the answer should include a discussion about students' introduction to air resistance before reading this chapter. It could be some real world scenarios such as riding a bike into the wind or a classroom oriented introduction.
63. Answers may vary. The safety features known before reading this chapter may include seat belts and airbags, and others discussed in this chapter. Safety features seen advertised (which is popular among auto makers) or outside of this chapter may also be included. A thoughtful answer should indicate that these safety features do not make cars completely safe or accident resistant so drivers should always drive with utmost caution.

Research

64. Answers may vary. Students' answers should state the mathematical formula for the gravitational force between two objects and describe the variables involved in the equation. The force should be explained in words in accompaniment to the equation.

65. Answers may vary. Students' answers should demonstrate a thorough understanding of regenerative braking and how it relates to energy conservation.

66. Answers may vary. Students' answers should include events such as Leonardo da Vinci's initial concept, the first soft parachute created, the first manned parachute, parachute uses in pre-airplane context, and other historical developments.

67. Answers may vary. Students' answers should include other scientific contributions, such as Amontons' hygrometer improvement and his work with an implication of absolute zero.

68. Answers may vary. Students' answers should include, along with his standard biographical information, a discussion of Coulomb's contributions to electricity regarding the relationship between force and distance of electric currents.

69. Answers may vary. Students' answers should describe how matches work (with a special focus on friction) and include a history of matches.