KEY TERMS

complex machine a machine that combines two or more simple machines
efficiency output work divided by input work
energy the ability to do work
gravitational potential energy energy acquired by doing work against gravity
ideal mechanical advantage the mechanical advantage of an idealized machine that loses no energy to friction
inclined plane a simple machine consisting of a slope
input work effort force multiplied by the distance over which it is applied
joule the metric unit for work and energy; equal to 1 newton meter (N•m)
kinetic energy energy of motion
law of conservation of energy states that energy is neither created nor destroyed
lever a simple machine consisting of a rigid arm that pivots on a fulcrum
mechanical advantage the number of times the input force is multiplied
mechanical energy kinetic or potential energy
output work output force multiplied by the distance over which it acts
potential energy stored energy
power the rate at which work is done
pulley a simple machine consisting of a rope that passes over one or more grooved wheels
screw a simple machine consisting of a spiral inclined plane
simple machine a machine that makes work easier by changing the amount or direction of force required to move an object
watt the metric unit of power; equivalent to joules per second
wedge a simple machine consisting of two back-to-back inclined planes
wheel and axle a simple machine consisting of a rod fixed to the center of a wheel
work force multiplied by distance
work–energy theorem states that the net work done on a system equals the change in kinetic energy

SECTION SUMMARY

9.1 Work, Power, and the Work–Energy Theorem

- Doing work on a system or object changes its energy.
- The work–energy theorem states that an amount of work that changes the velocity of an object is equal to the change in kinetic energy of that object.The work–energy theorem states that an amount of work that changes the velocity of an object is equal to the change in kinetic energy of that object.
- Power is the rate at which work is done.

9.2 Mechanical Energy and Conservation of Energy

- Mechanical energy may be either kinetic (energy of motion) or potential (stored energy).
- Doing work on an object or system changes its energy.
- Total energy in a closed, isolated system is constant.

9.3 Simple Machines

- The six types of simple machines make work easier by changing the $\mathbf{f}d$ term so that force is reduced at the expense of increased distance.
- The ratio of output force to input force is a machine's mechanical advantage.
- Combinations of two or more simple machines are called complex machines.
- The ratio of output work to input work is a machine's efficiency.

KEY EQUATIONS

9.1 Work, Power, and the Work–Energy Theorem

equation for work	$W = \mathbf{f}d$
force	$\mathbf{f} = w = m\mathbf{g}$
work equivalencies	$W = PE_e = \mathbf{f}m\mathbf{g}$
kinetic energy	$KE = \frac{1}{2}m\mathbf{v}^2$
work–energy theorem	$W = \Delta\text{KE} = \frac{1}{2}m\mathbf{v}_2^2 - \frac{1}{2}m\mathbf{v}_1^2$
power	$P = \frac{W}{t}$

9.2 Mechanical Energy and Conservation of Energy

conservation of energy	$KE_1 + PE_1 = KE_2 + PE_2$

9.3 Simple Machines

ideal mechanical advantage (general)	$IMA = \frac{\mathbf{F}_r}{\mathbf{F}_e} = \frac{d_e}{d_r}$
ideal mechanical advantage (lever)	$IMA = \frac{L_e}{L_r}$
ideal mechanical advantage (wheel and axle)	$IMA = \frac{R}{r}$
ideal mechanical advantage (inclined plane)	$IMA = \frac{L}{h}$
ideal mechanical advantage (wedge)	$IMA = \frac{L}{t}$
ideal mechanical advantage (pulley)	$IMA = N$
ideal mechanical advantage (screw)	$IMA = \frac{2\pi L}{P}$
input work	$W_i = \mathbf{F}_i d_i$
output work	$W_o = \mathbf{F}_o d_o$
efficiency output	$\%\ \text{efficiency} = \frac{W_o}{W_i} \times 100$

CHAPTER REVIEW

Concept Items

9.1 Work, Power, and the Work–Energy Theorem

1. Is it possible for the sum of kinetic energy and potential energy of an object to change without work having been done on the object? Explain.

a. No, because the work-energy theorem states that work done on an object is equal to the change in kinetic energy, and change in KE requires a change in velocity. It is assumed that mass is constant.

b. No, because the work-energy theorem states that work done on an object is equal to the sum of kinetic energy, and the change in KE requires a change in displacement. It is assumed that mass is constant.

c. Yes, because the work-energy theorem states that work done on an object is equal to the change in kinetic energy, and change in KE requires a change in velocity. It is assumed that mass is constant.

d. Yes, because the work-energy theorem states that work done on an object is equal to the sum of kinetic energy, and the change in KE requires a change in displacement. It is assumed that mass is constant.

2. Define work for one-dimensional motion.

a. Work is defined as the ratio of the force over the distance.

b. Work is defined as the sum of the force and the distance.

c. Work is defined as the square of the force over the distance.

d. Work is defined as the product of the force and the distance.

3. A book with a mass of 0.30 kg falls 2 m from a shelf to the floor. This event is described by the work–energy theorem: $W = fd = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$ Explain why this is enough information to calculate the speed with which the book hits the floor.

a. The mass of the book, m, and distance, d, are stated. F is the weight of the book mg . v_1 is the initial velocity and v_2 is the final velocity. The final velocity is the only unknown quantity.

b. The mass of the book, m, and distance, d, are stated. F is the weight of the book mg . v_1 is the final velocity and v_2 is the initial velocity. The final velocity is the only unknown quantity.

c. The mass of the book, m, and distance, d, are stated. F is the weight of the book mg . v_1 is the initial velocity and v_2 is the final velocity. The final velocity and the initial velocities are the only unknown quantities.

d. The mass of the book, m, and distance, d, are stated. F is the weight of the book mg . v_1 is the final velocity and v_2 is the initial velocity. The final velocity and the initial velocities are the only unknown quantities.

9.2 Mechanical Energy and Conservation of Energy

4. Describe the changes in KE and PE of a person jumping up and down on a trampoline.
   a. While going up, the person's KE would change to PE. While coming down, the person's PE would change to KE.
   b. While going up, the person's PE would change to KE. While coming down, the person's KE would change to PE.
   c. While going up, the person's KE would not change, but while coming down, the person's PE would change to KE.
   d. While going up, the person's PE would change to KE, but while coming down, the person's KE would not change.

5. You know the height from which an object is dropped. Which equation could you use to calculate the velocity as the object hits the ground?
   a. $v = h$
   b. $v = \sqrt{2h}$
   c. $v = gh$
   d. $v = \sqrt{2gh}$

6. The starting line of a cross country foot race is at the bottom of a hill. Which form(s) of mechanical energy of the runners will change when the starting gun is fired?
   a. Kinetic energy only
   b. Potential energy only
   c. Both kinetic and potential energy
   d. Neither kinetic nor potential energy

9.3 Simple Machines

7. How does a simple machine make work easier?
   a. It reduces the input force and the output force.
   b. It reduces the input force and increases the output force.
   c. It increases the input force and reduces the output force.
   d. It increases the input force and the output force.

8. Which type of simple machine is a knife?
   a. A ramp
   b. A wedge
   c. A pulley
   d. A screw

Critical Thinking Items

9.1 Work, Power, and the Work–Energy Theorem

9. Which activity requires a person to exert force on an object that causes the object to move but does not change the kinetic or potential energy of the object?
   a. Moving an object to a greater height with acceleration
   b. Moving an object to a greater height without acceleration
   c. Carrying an object with acceleration at the same height
   d. Carrying an object without acceleration at the same height

10. Which statement explains how it is possible to carry books to school without changing the kinetic or potential energy of the books or doing any work?
   a. By moving the book without acceleration and keeping the height of the book constant
   b. By moving the book with acceleration and keeping the height of the book constant
   c. By moving the book without acceleration and changing the height of the book
   d. By moving the book with acceleration and changing the height of the book

9.2 Mechanical Energy and Conservation of Energy

11. True or false—A cyclist coasts down one hill and up another hill until she comes to a stop. The point at which the bicycle stops is lower than the point at which it started coasting because part of the original potential energy has been converted to a quantity of heat and this makes the tires of the bicycle warm.
   a. True
   b. False

9.3 Simple Machines

12. We think of levers being used to decrease effort force. Which of the following describes a lever that requires a large effort force which causes a smaller force to act over a large distance and explains how it works?
   a. Anything that is swung by a handle, such as a hammer or racket. Force is applied near the fulcrum over a short distance, which makes the other end move rapidly over a long distance.
   b. Anything that is swung by a handle, such as a hammer or racket. Force is applied far from the fulcrum over a large distance, which makes the other end move rapidly over a long distance.
   c. A lever used to lift a heavy stone. Force is applied near the fulcrum over a short distance, which

makes the other end lift a heavy object easily.

d. A lever used to lift a heavy stone. Force is applied far from the fulcrum over a large distance, which makes the other end lift a heavy object easily

13. A baseball bat is a lever. Which of the following explains how a baseball bat differs from a lever like a pry bar?
   a. In a baseball bat, effort force is smaller and is applied over a large distance, while the resistance force is smaller and is applied over a long distance.
   b. In a baseball bat, effort force is smaller and is applied over a large distance, while the resistance force is smaller and is applied over a short distance.
   c. In a baseball bat, effort force is larger and is applied over a short distance, while the resistance force is smaller and is applied over a long distance.
   d. In a baseball bat, effort force is larger and is applied over a short distance, while the resistance force is smaller and is applied over a short distance.

Problems

9.1 Work, Power, and the Work–Energy Theorem

14. A baseball player exerts a force of 100 N on a ball for a distance of 0.5 m as he throws it. If the ball has a mass of 0.15 kg, what is its velocity as it leaves his hand?
   a. -36.5 m/s
   b. -25.8 m/s
   c. 25.8 m/s
   d. 36.5 m/s

15. A boy pushes his little sister on a sled. The sled accelerates from 0 to 3.2 m/s . If the combined mass of his sister and the sled is 40.0 kg and 18 W of power were generated, how long did the boy push the sled?
   a. 205 s
   b. 128 s
   c. 23 s
   d. 11 s

9.2 Mechanical Energy and Conservation of Energy

16. What is the kinetic energy of a 0.01 kg bullet traveling at a velocity of 700 m/s?
   a. 3.5 J
   b. 7 J
   c. $2.45 \times 10^3 \text{ J}$
   d. $2.45 \times 10^5 \text{ J}$

17. A marble rolling across a flat, hard surface at 2 m/s rolls up a ramp. Assuming that $g = 10 \text{ m/s}^2$ and no energy is lost to friction, what will be the vertical height of the marble when it comes to a stop before rolling back down? Ignore effects due to the rotational kinetic energy.
   a. 0.1 m
   b. 0.2 m
   c. 0.4 m
   d. 2 m

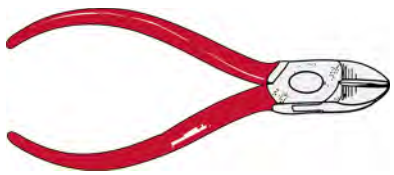
18. The potential energy stored in a compressed spring is $U = \frac{1}{2}kx^2$, where k is the force constant and x is the distance the spring is compressed from the equilibrium position. Four experimental setups described below can be used to determine the force constant of a spring. Which one(s) require measurement of the fewest number of variables to determine k? Assume the acceleration due to gravity is known.
   I. An object is propelled vertically by a compressed spring.
   II. An object is propelled horizontally on a frictionless surface by a compressed spring.
   III. An object is statically suspended from a spring.
   IV. An object suspended from a spring is set into oscillatory motion.

   a. I only
   b. III only
   c. I and II only
   d. III and IV only

9.3 Simple Machines

19. A man is using a wedge to split a block of wood by hitting the wedge with a hammer. This drives the wedge into the wood creating a crack in the wood. When he hits the wedge with a force of 400 N it travels 4 cm into the wood. This caused the wedge to exert a force of 1,400 N sideways increasing the width of the crack by 1 cm . What is the efficiency of the wedge?
   a. 0.875 percent
   b. 0.14
   c. 0.751
   d. 87.5 percent

20. An electrician grips the handles of a wire cutter, like the one shown, 10 cm from the pivot and places a wire between the jaws 2 cm from the pivot. If the cutter blades are 2 cm wide and 0.3 cm thick, what is the overall IMA of this complex machine?

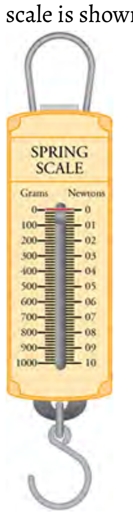


a. 1.34
b. 1.53
c. 33.3
d. 33.5

Performance Task

9.3 Simple Machines

21. Conservation of Energy and Energy Transfer; Cause and Effect; and S&EP, Planning and Carrying Out Investigations
Plan an investigation to measure the mechanical advantage of simple machines and compare to the *IMA* of the machine. Also measure the efficiency of each machine studied. Design an investigation to make these measurements for these simple machines: lever, inclined plane, wheel and axle and a pulley system. In addition to these machines, include a spring scale, a tape measure, and a weight with a loop on top that can be attached to the hook on the spring scale. A spring scale is shown in the image.



A spring scale measures weight, not mass.

LEVER: Beginning with the lever, explain how you would measure input force, output force, effort arm, and resistance arm. Also explain how you would find the distance the load travels and the distance over which the effort force is applied. Explain how you would use this data to determine *IMA* and efficiency.
INCLINED PLANE: Make measurements to determine *IMA* and efficiency of an inclined plane. Explain how you would use the data to calculate these values. Which property do you already know? Note that there are no effort and resistance arm measurements, but there are height and length measurements.
WHEEL AND AXLE: Again, you will need two force measurements and four distance measurements. Explain how you would use these to calculate *IMA* and efficiency.
SCREW: You will need two force measurements, two distance traveled measurements, and two length measurements. You may describe a screw like the one shown in Figure 9.10 or you could use a screw and screw driver. (Measurements would be easier for the former). Explain how you would use these to calculate *IMA* and efficiency.
PULLEY SYSTEM: Explain how you would determine the *IMA* and efficiency of the four-pulley system shown in Figure 9.11. Why do you only need two distance measurements for this machine?
Design a table that compares the efficiency of the five simple machines. Make predictions as to the most and least efficient machines.

TEST PREP

Multiple Choice

9.1 Work, Power, and the Work–Energy Theorem

22. Which expression represents power?
a. fd
b. mgh
c. $\frac{mv^2}{2}$
d. $\frac{W}{t}$

23. The work–energy theorem states that the change in the kinetic energy of an object is equal to what?
a. The work done on the object
b. The force applied to the object
c. The loss of the object's potential energy
d. The object's total mechanical energy minus its kinetic energy

24. A runner at the start of a race generates 250 W of power as he accelerates to 5 m/s . If the runner has a mass of 60 kg, how long did it take him to reach that speed?
a. 0.33 s
b. 0.83 s
c. 1.2 s
d. 3.0 s

25. A car's engine generates 100,000 W of power as it exerts a force of 10,000 N. How long does it take the car to travel 100 m?
   a. 0.001 s
   b. 0.01 s
   c. 10 s
   d. 1,000 s

9.2 Mechanical Energy and Conservation of Energy

26. Why is this expression for kinetic energy incorrect? $\mathrm{KE} = (m)(v)^2$.
   a. The constant g is missing.
   b. The term v should not be squared.
   c. The expression should be divided by 2.
   d. The energy lost to friction has not been subtracted.

27. What is the kinetic energy of a $10\mathrm{kg}$ object moving at $2.0\ \mathrm{m/s}$?
   a. $10\ \mathrm{J}$
   b. $20\ \mathrm{J}$
   c. $40\ \mathrm{J}$
   d. $100\ \mathrm{J}$

28. Which statement best describes the PE-KE transformations for a javelin, starting from the instant the javelin leaves the thrower's hand until it hits the ground.
   a. Initial PE is transformed to KE until the javelin reaches the high point of its arc. On the way back down, KE is transformed into PE. At every point in the flight, mechanical energy is being transformed into heat energy.
   b. Initial KE is transformed to PE until the javelin reaches the high point of its arc. On the way back down, PE is transformed into KE. At every point in the flight, mechanical energy is being transformed into heat energy.
   c. Initial PE is transformed to KE until the javelin reaches the high point of its arc. On the way back down, there is no transformation of mechanical energy. At every point in the flight, mechanical energy is being transformed into heat energy.
   d. Initial KE is transformed to PE until the javelin reaches the high point of its arc. On the way back down, there is no transformation of mechanical energy. At every point in the flight, mechanical energy is being transformed into heat energy.

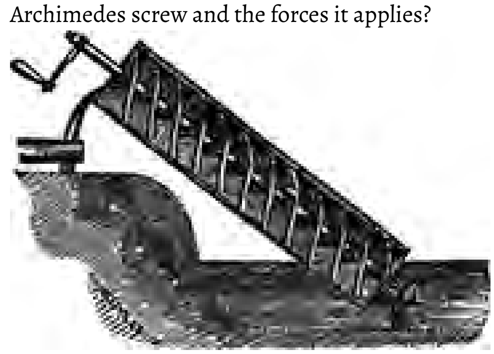
29. At the beginning of a roller coaster ride, the roller coaster car has an initial energy mostly in the form of PE. Which statement explains why the fastest speeds of the car will be at the lowest points in the ride?
   a. At the bottom of the slope kinetic energy is at its maximum value and potential energy is at its minimum value.
   b. At the bottom of the slope potential energy is at its maximum value and kinetic energy is at its minimum value.
   c. At the bottom of the slope both kinetic and potential energy reach their maximum values
   d. At the bottom of the slope both kinetic and potential energy reach their minimum values.

9.3 Simple Machines

30. A large radius divided by a small radius is the expression used to calculate the IMA of what?
   a. A screw
   b. A pulley
   c. A wheel and axle
   d. An inclined plane.

31. What is the IMA of a wedge that is $12\ \mathrm{cm}$ long and $3\ \mathrm{cm}$ thick?
   a. 2
   b. 3
   c. 4
   d. 9

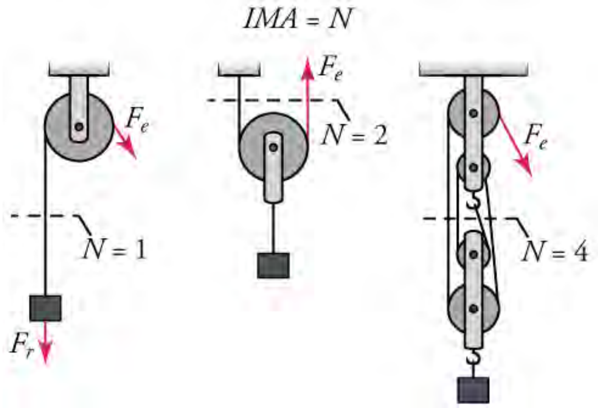
32. Which statement correctly describes the simple machines, like the crank in the image, that make up an Archimedes screw and the forces it applies?



   a. The crank is a wedge in which the IMA is the length of the tube divided by the radius of the tube. The applied force is the effort force and the weight of the water is the resistance force.
   b. The crank is an inclined plane in which the IMA is the length of the tube divided by the radius of the tube. The applied force is the effort force and the weight of the water is the resistance force.
   c. The crank is a wheel and axle. The effort force of the crank becomes the resistance force of the screw.
   d. The crank is a wheel and axle. The resistance force of the crank becomes the effort force of the screw.

33. Refer to the pulley system on right in the image. Assume this pulley system is an ideal machine.
How hard would you have to pull on the rope to lift a 120 N

load?
How many meters of rope would you have to pull out of the system to lift the load 1 m?



a. 480 N
4 m
b. 480 N
$\frac{1}{4}$ m
c. 30 N
4 m
d. 30 N
$\frac{1}{4}$ m

Short Answer

9.1 Work, Power, and the Work–Energy Theorem

34. Describe two ways in which doing work on an object can increase its mechanical energy.
  a. Raising an object to a higher elevation does work as it increases its PE; increasing the speed of an object does work as it increases its KE.
  b. Raising an object to a higher elevation does work as it increases its KE; increasing the speed of an object does work as it increases its PE.
  c. Raising an object to a higher elevation does work as it increases its PE; decreasing the speed of an object does work as it increases its KE.
  d. Raising an object to a higher elevation does work as it increases its KE; decreasing the speed of an object does work as it increases its PE.

35. True or false—While riding a bicycle up a gentle hill, it is fairly easy to increase your potential energy, but to increase your kinetic energy would make you feel exhausted.
  a. True
  b. False

36. Which statement best explains why running on a track with constant speed at 3 m/s is not work, but climbing a mountain at 1 m/s is work?
  a. At constant speed, change in the kinetic energy is zero but climbing a mountain produces change in the potential energy.
  b. At constant speed, change in the potential energy is zero, but climbing a mountain produces change in the kinetic energy.
  c. At constant speed, change in the kinetic energy is finite, but climbing a mountain produces no change in the potential energy.
  d. At constant speed, change in the potential energy is finite, but climbing a mountain produces no change in the kinetic energy.

37. You start at the top of a hill on a bicycle and coast to the bottom without applying the brakes. By the time you reach the bottom of the hill, work has been done on you and your bicycle, according to the equation: $W = \frac{1}{2}m(v_2^2 - v_1^2)$ If m is the mass of you and your bike, what are v_1 and v_2?
  a. v_1 is your speed at the top of the hill, and v_2 is your speed at the bottom.
  b. v_1 is your speed at the bottom of the hill, and v_2 is your speed at the top.
  c. v_1 is your displacement at the top of the hill, and v_2 is your displacement at the bottom.
  d. v_1 is your displacement at the bottom of the hill, and v_2 is your displacement at the top.

9.2 Mechanical Energy and Conservation of Energy

38. True or false—The formula for gravitational potential energy can be used to explain why joules, J, are equivalent to kg × mg^2 / s^2 . Show your work.
  a. True
  b. False

39. Which statement best explains why accelerating a car from 20 mph to 40 mph quadruples its kinetic energy?
  a. Because kinetic energy is directly proportional to the square of the velocity.
  b. Because kinetic energy is inversely proportional to the square of the velocity.
  c. Because kinetic energy is directly proportional to the fourth power of the velocity.
  d. Because kinetic energy is inversely proportional to

the fourth power of the velocity.

40. A coin falling through a vacuum loses no energy to friction, and yet, after it hits the ground, it has lost all its potential and kinetic energy. Which statement best explains why the law of conservation of energy is still valid in this case?

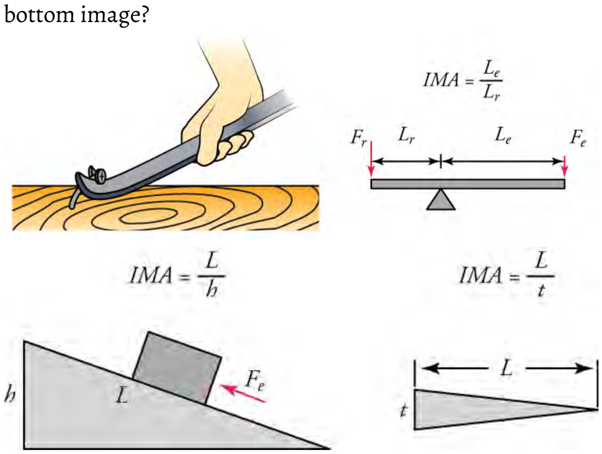
a. When the coin hits the ground, the ground gains potential energy that quickly changes to thermal energy.
b. When the coin hits the ground, the ground gains kinetic energy that quickly changes to thermal energy.
c. When the coin hits the ground, the ground gains thermal energy that quickly changes to kinetic energy.
d. When the coin hits the ground, the ground gains thermal energy that quickly changes to potential energy.

41. True or false—A marble rolls down a slope from height h_1 and up another slope to height h_2, where ($h_2 < h_1$). The difference $mg(h_1 - h_2)$ is equal to the heat lost due to the friction.

a. True
b. False

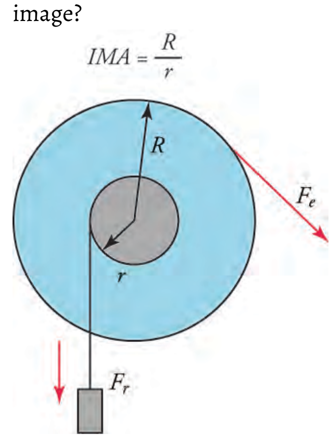
9.3 Simple Machines

42. Why would you expect the lever shown in the top image to have a greater efficiency than the inclined plane shown in the bottom image?



a. The resistance arm is shorter in case of the inclined plane.
b. The effort arm is shorter in case of the inclined plane.
c. The area of contact is greater in case of the inclined plane.

43. Why is the wheel on a wheelbarrow **not** a simple machine in the same sense as the simple machine in the image?



a. The wheel on the wheelbarrow has no fulcrum.
b. The center of the axle is not the fulcrum for the wheels of a wheelbarrow.
c. The wheelbarrow differs in the way in which load is attached to the axle.
d. The wheelbarrow has less resistance force than a wheel and axle design.

44. A worker pulls down on one end of the rope of a pulley system with a force of 75 N to raise a hay bale tied to the other end of the rope. If she pulls the rope down 2.0 m and the bale raises 1.0 m, what else would you have to know to calculate the efficiency of the pulley system?

a. the weight of the worker
b. the weight of the hay bale
c. the radius of the pulley
d. the height of the pulley from ground

45. True or false—A boy pushed a box with a weight of 300 N up a ramp. He said that, because the ramp was 1.0 m high and 3.0 m long, he must have been pushing with force of exactly 100 N.

a. True
b. False

Extended Response

9.1 Work, Power, and the Work–Energy Theorem

46. Work can be negative as well as positive because an object or system can do work on its surroundings as well as have work done on it. Which of the following statements describes:
a situation in which an object does work on its surroundings by decreasing its velocity and
a situation in which an object can do work on its surroundings by decreasing its altitude?

a. A gasoline engine burns less fuel at a slower speed. Solar cells capture sunlight to generate electricity.

b. A hybrid car charges its batteries as it decelerates.
   Falling water turns a turbine to generate electricity.
c. Airplane flaps use air resistance to slow down for landing.
   Rising steam turns a turbine to generate electricity.
d. An electric train requires less electrical energy as it decelerates.
   A parachute captures air to slow a skydiver's fall.

47. A boy is pulling a girl in a child's wagon at a constant speed. He begins to pull harder, which increases the speed of the wagon. Which of the following describes two ways you could calculate the change in energy of the wagon and girl if you had all the information you needed?

a. Calculate work done from the force and the velocity.
   Calculate work done from the change in the potential energy of the system.
b. Calculate work done from the force and the displacement.
   Calculate work done from the change in the potential energy of the system.
c. Calculate work done from the force and the velocity.
   Calculate work done from the change in the kinetic energy of the system.
d. Calculate work done from the force and the displacement.
   Calculate work done from the change in the kinetic energy of the system.

9.2 Mechanical Energy and Conservation of Energy

48. Acceleration due to gravity on the moon is 1.6 m/s^2 or about 16% of the value of *g* on Earth.
If an astronaut on the moon threw a moon rock to a height of 7.8 m, what would be its velocity as it struck the moon's surface?
How would the fact that the moon has no atmosphere affect the velocity of the falling moon rock? Explain your answer.

a. The velocity of the rock as it hits the ground would be 5.0 m/s. Due to the lack of air friction, there would be complete transformation of the potential energy into the kinetic energy as the rock hits the moon's surface.
b. The velocity of the rock as it hits the ground would be 5.0 m/s. Due to the lack of air friction, there would be incomplete transformation of the potential energy into the kinetic energy as the rock hits the moon's surface.
c. The velocity of the rock as it hits the ground would be 12 m/s. Due to the lack of air friction, there would be complete transformation of the potential energy into the kinetic energy as the rock hits the moon's surface.
d. The velocity of the rock as it hits the ground would be 12 m/s. Due to the lack of air friction, there would be incomplete transformation of the potential energy into the kinetic energy as the rock hits the moon's surface.

49. A boulder rolls from the top of a mountain, travels across a valley below, and rolls part way up the ridge on the opposite side. Describe all the energy transformations taking place during these events and identify when they happen.

a. As the boulder rolls down the mountainside, KE is converted to PE. As the boulder rolls up the opposite slope, PE is converted to KE. The boulder rolls only partway up the ridge because some of the PE has been converted to thermal energy due to friction.
b. As the boulder rolls down the mountainside, KE is converted to PE. As the boulder rolls up the opposite slope, KE is converted to PE. The boulder rolls only partway up the ridge because some of the PE has been converted to thermal energy due to friction.
c. As the boulder rolls down the mountainside, PE is converted to KE. As the boulder rolls up the opposite slope, PE is converted to KE. The boulder rolls only partway up the ridge because some of the PE has been converted to thermal energy due to friction.
d. As the boulder rolls down the mountainside, PE is converted to KE. As the boulder rolls up the opposite slope, KE is converted to PE. The boulder rolls only partway up the ridge because some of the PE has been converted to thermal energy due to friction.

9.3 Simple Machines

50. To dig a hole, one holds the handles together and thrusts the blades of a posthole digger, like the one in the image, into the ground. Next, the handles are pulled apart, which squeezes the dirt between them, making it possible to remove the dirt from the hole. This complex machine is composed of two pairs of two different simple machines. Identify and describe the parts that are simple machines and explain how you would find the IMA of each type of simple machine.

a. Each handle and its attached blade is a lever with the

fulcrum at the hinge. Each blade is a wedge.
The IMA of a lever would be the length of the handle divided by the length of the blade. The IMA of the wedges would be the length of the blade divided by its width.

b. Each handle and its attached to blade is a lever with the fulcrum at the end. Each blade is a wedge.
The IMA of a lever would be the length of the handle divided by the length of the blade. The IMA of the wedges would be the length of the blade divided by its width.

c. Each handle and its attached blade is a lever with the fulcrum at the hinge. Each blade is a wedge.
The IMA of a lever would be the length of the handle multiplied by the length of the blade. The IMA of the wedges would be the length of the blade multiplied by its width.

d. Each handle and its attached blade is a lever with the fulcrum at the end. Each blade is a wedge.
The IMA of a lever would be the length of the handle multiplied by the length of the blade. The IMA of the wedges would be the length of the blade multiplied by its width.

51. A wooden crate is pulled up a ramp that is 1.0 m high and 6.0 m long. The crate is attached to a rope that is wound around an axle with a radius of 0.020 m . The axle is turned by a 0.20 m long handle. What is the overall IMA of the complex machine?

A. 6
B. 10
C. 16
D. 60