WHAT MAKES THESE SNOWBOARDERS "FLY" DOWNHILL?

Watch the **Untamed Science** video to learn more about energy.

How is energy conserved in a transformation?

These women are competing in the sport of snowboard cross. They "fly" down a narrow course, filled with jumps, steep sections, and ramps. Disaster looms at every turn. If they don't crash into each other or fall, then the first one across the finish line wins.

Develop Hypotheses **What do you think makes these snowboarders go so fast?**

TN

CHAPTER 1

Energy

Tennessee Academic Standards for Science

6.PS3.1 Analyze the properties and compare sources of mechanical, electrical, chemical, radiant, and thermal energy.
6.PS3.2 Construct a scientific explanation of the transformations between potential and kinetic energy.
6.PS3.3 Analyze and interpret data to show the relationship between kinetic energy and the mass of an object in motion and its speed.
6.ETS1.2 Design and test different solutions that impact energy transfer.

CHAPTER 1

Getting Started

Check Your Understanding

1. **Background** Read the paragraph below and then answer the question.

> Michael pulls his brother in a wagon. Suddenly, Michael's dog jumps on his brother's lap. Michael continues to pull the wagon, but it is more difficult now. The added **mass** of the dog means that Michael has to generate more **force** to accelerate the wagon to the same **speed**.

Mass is a measure of the amount of matter in an object.

A **force** is a push or pull.

The **speed** of an object is the distance the object travels per unit of time.

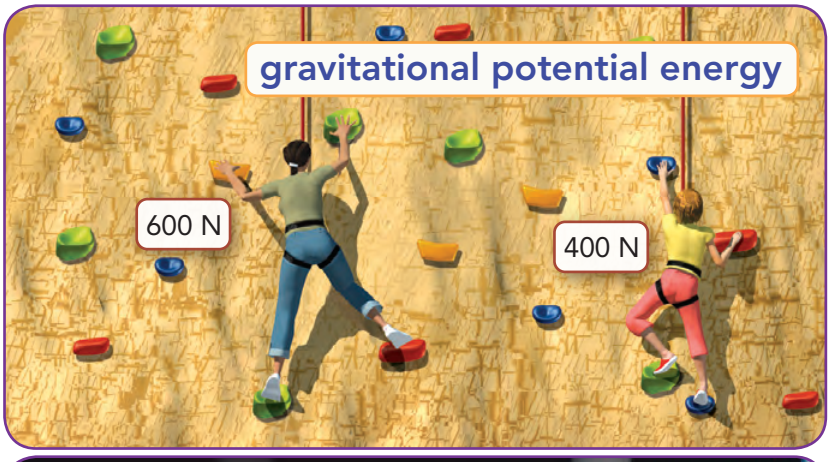
- Why is it harder to pull the wagon with the dog in it?

Vocabulary Skill

Identify Multiple Meanings Some familiar words may have different meanings in science. Look at the different meanings of the words below.

Word	Everyday Meaning	Scientific Meaning
energy	*n.* the ability to be active or take part in a vigorous activity **Example:** She had enough *energy* to run for miles.	*n.* the ability to do work or cause change **Example:** The wind can move objects because it has *energy*.
power	*n.* the ability to influence others **Example:** The coach has a lot of *power* over his young athletes.	*n.* the rate at which work is done **Example:** A truck's engine has more *power* than a car's engine.

2. **Quick Check** **Review the sentences below. Then circle the sentence that uses the scientific meaning of the word *energy*.**
   - A puppy has too much *energy* to be inside the house all day.
   - A wrecking ball has enough *energy* to knock down a building.



Chapter Preview

LESSON 1

- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy

Relate Cause and Effect
Calculate

LESSON 2

- mechanical energy
- nuclear energy
- thermal energy
- electrical energy
- electromagnetic energy
- chemical energy

Identify the Main Idea
Classify

LESSON 3

- energy transformation
- law of conservation of energy

Identify Supporting Evidence
Infer

CCC: Energy and Matter

Scenario Investigation

Stuck at the Top

SEP: Developing and Using Models

Purpose To investigate the amount of potential energy a roller coaster needs to make it over a hill

Materials

- 6 feet of pipe insulation, cut lengthwise
- masking tape
- 2 balls with similar diameters and different masses

Scenario

FIREFIGHTERS RESCUE CHILDREN STUCK ON ROLLER COASTER

Investigators to Determine Cause of Malfunction

SOMERDALE, NJ – With its low prices and family-friendly atmosphere, Kenny's Amusement Park has been a favorite summer tradition in New Jersey for nearly 30 years. With attractions including four roller coasters, bumper cars, and a water park, Kenny's stands for good, old-fashioned thrills, excitement, and fun. But is it safe?

Around 5 P.M. on Monday evening, a 12-year-old boy and 8-year-old girl got more excitement than they expected. Their four-person car on the popular Whirlwind roller coaster stalled on the tracks at the top of the highest hill, leaving the frightened children trapped for nearly an hour as firefighters worked to rescue them.

No one involved in the incident was hurt, but the ride will remain closed until state inspectors can determine what caused the car to stop on the tracks. When asked to comment on the incident, Ken Smarmy, owner of Kenny's Amusements, Inc., stated that the two small

(Story continued on page B6)

Ken Smarmy, owner of Kenny's Amusement Park, told officials that the ride malfunctioned because the two children did not weigh enough to keep their car moving. He said that it is against park policy to allow partially empty cars to run on the track, and he fired the ride's attendant immediately after the incident. However, some of Mr. Smarmy's employees have accused him of ignoring complaints that many of the rides need repairs and better maintenance. Is it true that there was not enough weight in the roller coaster car to keep it moving, or is that just Smarmy's excuse?

You and your partner are roller-coaster engineers. It's your job to find out whether the children's weight was the cause of the problem. Then, report your findings to the New Jersey inspectors.

Procedure

1. **Making It to the Top** A roller coaster car must have plenty of kinetic energy at the bottom of the first hill. Not only does the car need to climb to the top of the second hill, but it also must have enough energy left over to keep moving along the track. Use the materials supplied by your teacher to design a model roller coaster that has one drop and a hill that is lower than the drop. Using the heavier ball, find a starting point on the drop hill that always allows the ball to make it over the second hill. Mark the starting point with masking tape.

Procedure *(continued)*

2. A Lightweight Hypothesis When the boy and girl got stuck on the Whirlwind, they were the only two people riding in a four-person car. Perhaps with only two small passengers, the car wasn't heavy enough. If you test a lightweight ball at the starting point you marked on your roller coaster, will it make it over the hill? (This is your hypothesis.)

3. Why Do You Think So? A hypothesis is not a guess. A scientist bases a hypothesis on observations or theory. State the reason(s) you think your hypothesis is correct.

4. Try It Out Place the lighter ball at the start point and let it go. Test it two or three times. Use a complete sentence to describe what happened.

5. Evaluate Your Hypothesis Was your hypothesis supported by the results? Explain. (A hypothesis is never proven! It is either supported or not supported by the results of an experiment.)

Conclusion

Let's see what you learned about kinetic and potential energy.

1. What type of energy is the motion of an object? _____

2. What type of energy does an object store internally? _____

3. Which idea describes a change from potential energy to kinetic energy?

4. Not all of a roller coaster's energy transfers back and forth between potential energy and kinetic energy. According to the law of conservation of energy, however, the leftover potential energy must exist somewhere. Identify another form of energy that both potential and kinetic energy can become.

The New Jersey Department of Community Affairs is responsible for the safety of carnival and amusement park rides. Its roller-coaster inspectors are eager to see the results of your investigation. The director wants to either make the Whirlwind roller coaster an adult-only ride, or further investigate the claims of Ken Smarmy's employees. Write a report describing your results and explain what recommendation you will make based on your results.

TN

LESSON 1

6.PS3.2, 6.PS3.3

What Is Energy?

UNLOCK THE BIG ?

- How Are Energy, Work, and Power Related?
- What Are Two Types of Energy?

my planet Diary

Wind Farms

Did you know that wind can be used to produce electricity? A wind farm is a group of very large windmills, or turbines, placed in a location that gets a lot of wind. The energy of the wind causes the propellers of the turbines to spin. The turbines are connected to generators. When the turbines are spinning, the generators produce electricity. The amount of electricity produced depends on the size of the propellers, the number of turbines, and the strength of the wind.

FUN FACT

Write your answer to the question below.

Analyze Costs and Benefits What are some advantages and disadvantages of using wind energy to create electricity?

Lab zone® Do the Inquiry Warm-Up *How High Does a Ball Bounce?*

How Are Energy, Work, and Power Related?

Did you put a book in your backpack this morning? If so, then you did work on the book. Recall that work is done when a force moves an object. The ability to do work or cause change is called **energy.**

Work and Energy When you do work on an object, some of your energy is transferred to that object. You can think of work as the transfer of energy. When energy is transferred, the object upon which the work is done gains energy. Energy is measured in joules—the same units as work.

Vocabulary

- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy

Skills

- Reading: Relate Cause and Effect
- Inquiry: Calculate

Power and Energy

You may recall that power is the rate at which work is done. **Since the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.**

$$\text{Power} = \frac{\text{Energy Transferred}}{\text{Time}}$$

Different machines have different amounts of power. For example, you could use either a hand shovel or a snowblower, like the one in **Figure 1,** to remove snow from your driveway. Each transfers the same amount of energy when it moves the snow the same distance. However, you could move the snow faster using a snowblower than a hand shovel. The snowblower has more power because it transfers the same amount of energy to the snow in less time.

FIGURE 1

Power

The snowblower has more power than the person with the hand shovel.

Apply Concepts **You could use an elevator or the stairs to lift a box to the tenth floor. Which has greater power? Why?**

Lab zone® Do the Lab Investigation *Can You Feel the Power?*

Assess Your Understanding

got it?

- ○ **I get it!** Now I know that since the transfer of energy is work, then power is _____
- ○ I need extra help with _____

What Are Two Types of Energy?

Moving objects, such as the vehicles shown in **Figure 2,** have one type of energy. A rock perched on the edge of a cliff or a stretched rubber band has another type of energy. **The two basic types of energy are kinetic energy and potential energy.** Whether energy is kinetic or potential depends on the motion, position, and shape of the object.

Kinetic Energy A moving object can do work when it strikes another object and moves it. For example, a swinging hammer does work on a nail as it drives the nail into a piece of wood. The hammer has energy because it can do work. The energy an object has due to its motion is called **kinetic energy.**

Factors Affecting Kinetic Energy The kinetic energy of an object depends on both its speed and its mass. Suppose you are hit with a tennis ball that has been lightly tossed at you. It probably would not hurt much. What if you were hit with the same tennis ball traveling at a much greater speed? It would hurt! The faster an object moves, the more kinetic energy it has.

Kinetic energy also increases as mass increases. Suppose a tennis ball rolls across the ground and hits you in the foot. Compare this with getting hit in the foot with a bowling ball moving at the same speed as the tennis ball. The bowling ball is much more noticeable because it has more kinetic energy than a tennis ball. The bowling ball has more kinetic energy because it has a greater mass.

FIGURE 2

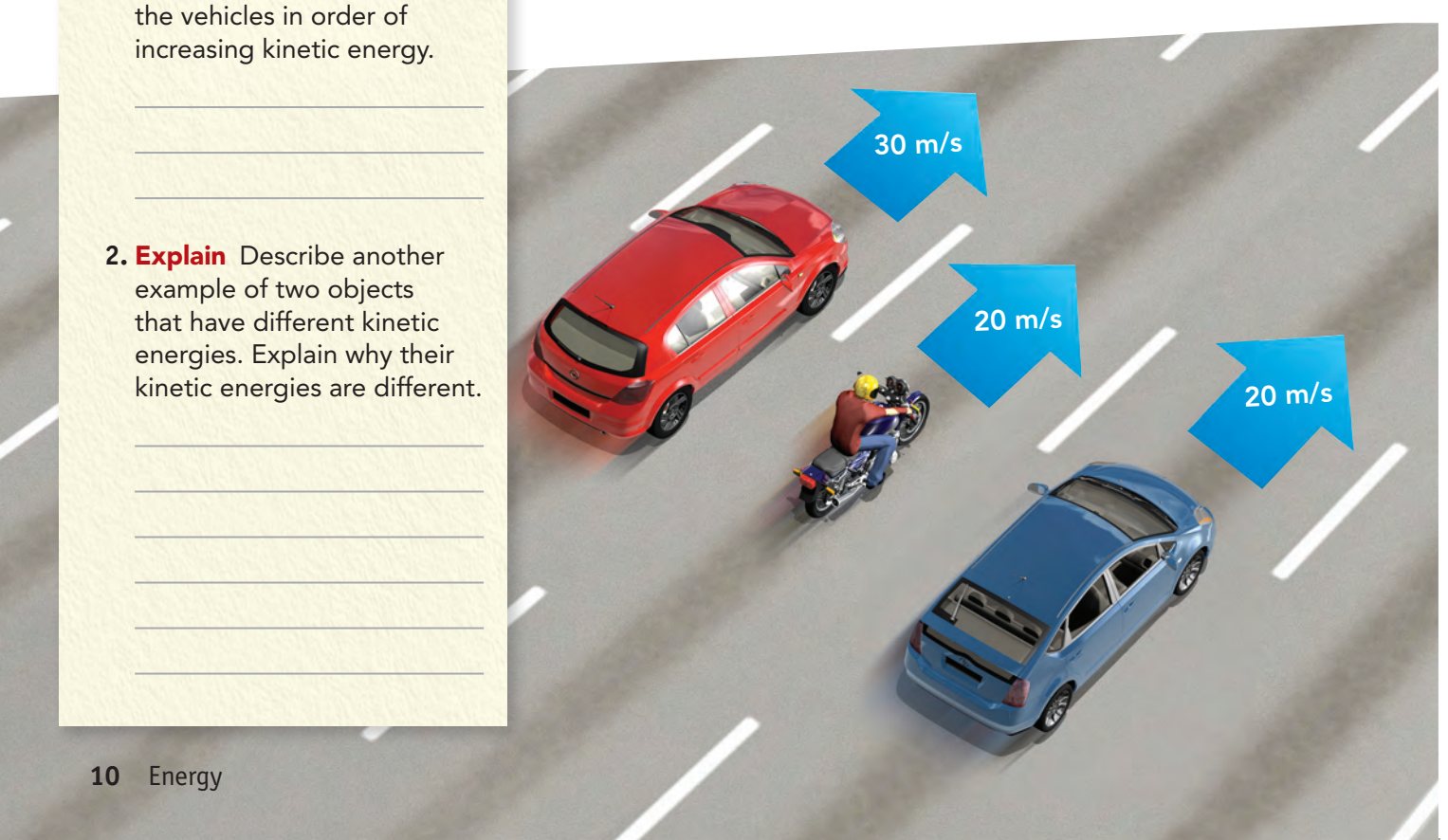
Kinetic Energy

The kinetic energy of an object depends on its speed and mass.

Use the diagram to answer the questions.

1. **Interpret Diagrams** List the vehicles in order of increasing kinetic energy.

2. **Explain** Describe another example of two objects that have different kinetic energies. Explain why their kinetic energies are different.



Calculating Kinetic Energy You can use the following equation to solve for the kinetic energy of an object.

$$\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times \text{Speed}^2$$

For example, suppose a boy is pulling a 10-kg wagon at a speed of 1 m/s.

$$\text{Kinetic energy of wagon} = \frac{1}{2} \times 10\ \text{kg} \times (1\ \text{m/s})^2$$

$$= 5\ \text{kg}\cdot\text{m}^2/\text{s}^2 = 5\ \text{joules}$$

$$\text{Note that } 1\ \text{kg}\cdot\text{m}^2/\text{s}^2 = 1\ \text{joule}$$

Do changes in speed and mass have the same effect on the kinetic energy of the wagon? No—changing the speed of the wagon will have a greater effect on its kinetic energy than changing its mass by the same factor. This is because speed is squared in the kinetic energy equation. For example, doubling the mass of the wagon will double its kinetic energy. Doubling the speed of the wagon will quadruple its kinetic energy.

Relate Cause and Effect
What has a greater effect on an object's kinetic energy—doubling its mass or doubling its speed? Explain.

do the math!

A girl and her dog are running. The dog has a mass of 20 kg. The girl has a mass of 60 kg.

1 **Calculate** Suppose both the dog and the girl run at a speed of 2 m/s. Calculate both of their kinetic energies.

Kinetic energy of dog =

Kinetic energy of girl =

2 **Calculate** Suppose the dog speeds up and is now running at a speed of 4 m/s. Calculate the dog's kinetic energy.

Kinetic energy of dog =

3 **Draw Conclusions** Are your answers to Questions 1 and 2 reasonable? Explain.

Review Write the SI unit for each quantity in the table.

Quantity	SI Unit
Force	
Height	
Work	
Mass	
Energy	

Potential Energy

An object does not have to be moving to have energy. Some objects have energy as a result of their shapes or positions. When you lift a book up to your desk from the floor or compress a spring by winding a toy, you transfer energy to it. The energy you transfer is stored, or held in readiness. It might be used later if the book falls or the spring unwinds. Energy that results from the position or shape of an object is called **potential energy.** This type of energy has the potential to do work.

Gravitational Potential Energy

Potential energy related to an object's height is called **gravitational potential energy.** The gravitational potential energy of an object is equal to the work done to lift it to that height. Remember that work is equal to force multipled by distance. The force you use to lift the object is equal to its weight. The distance you move the object is its height above the ground. You can calculate an object's gravitational potential energy using this equation.

Gravitational potential energy = Weight × Height

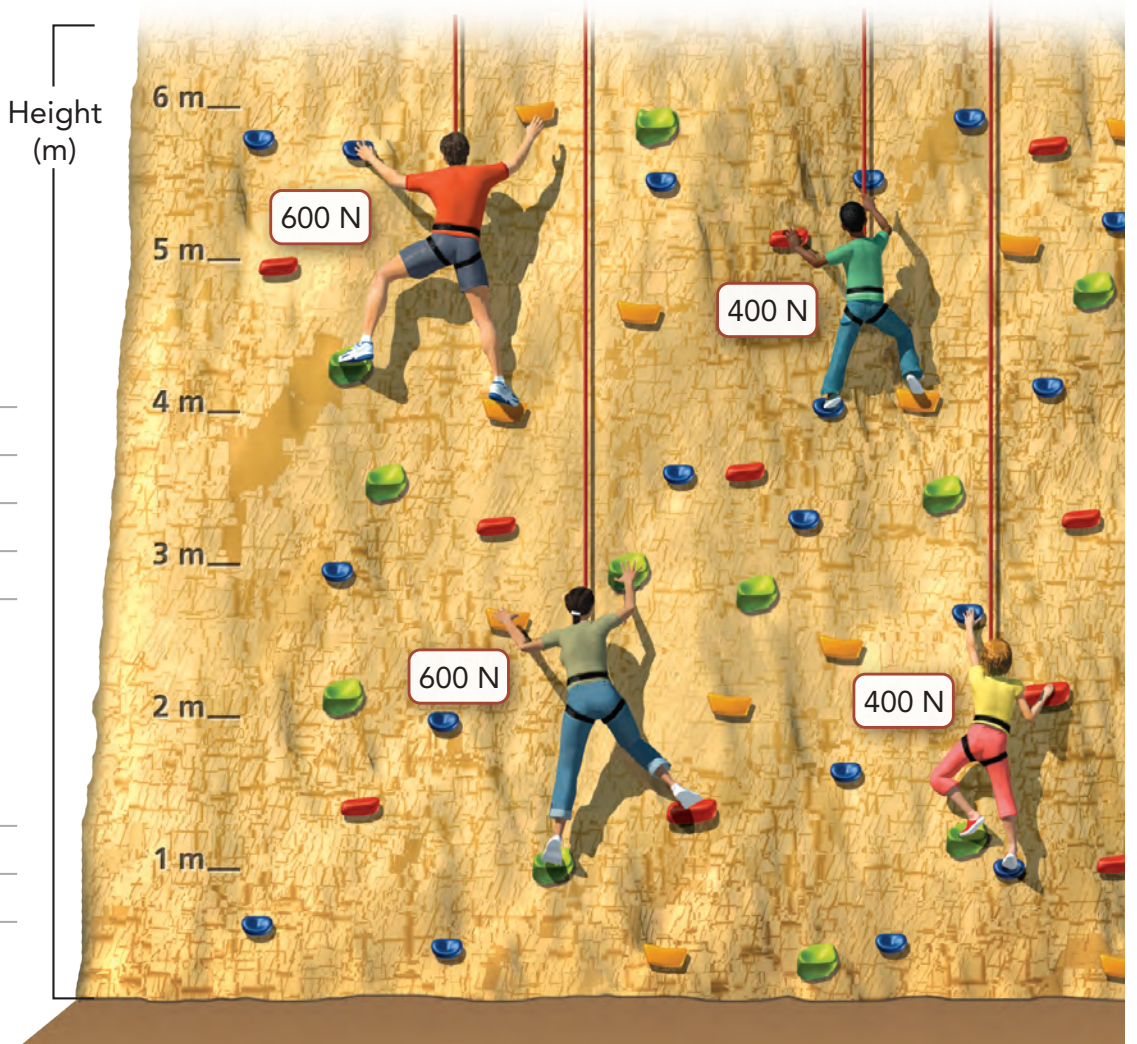
For example, suppose a book has a weight of 10 newtons (N). If the book is lifted 2 meters off the ground, the book has 10 newtons times 2 meters, or 20 joules, of gravitational potential energy.

FIGURE 3

Gravitational Potential Energy

The rock climbers have gravitational potential energy.

Use the diagram to answer the questions.



1. **Identify** Circle the rock climber with the greatest potential energy. Calculate this potential energy. The height to be used is at the rock climber's lowest foot.

2. CHALLENGE Where would the rock climbers at the top have to be to have half as much potential energy?

Elastic Potential Energy An object has a different type of potential energy due to its shape. **Elastic potential energy** is the energy associated with objects that can be compressed or stretched. For example, when the girl in **Figure 4** presses down on the trampoline, the trampoline changes shape. The trampoline now has potential energy. When the girl pushes off of the trampoline, the stored energy sends the girl upward.

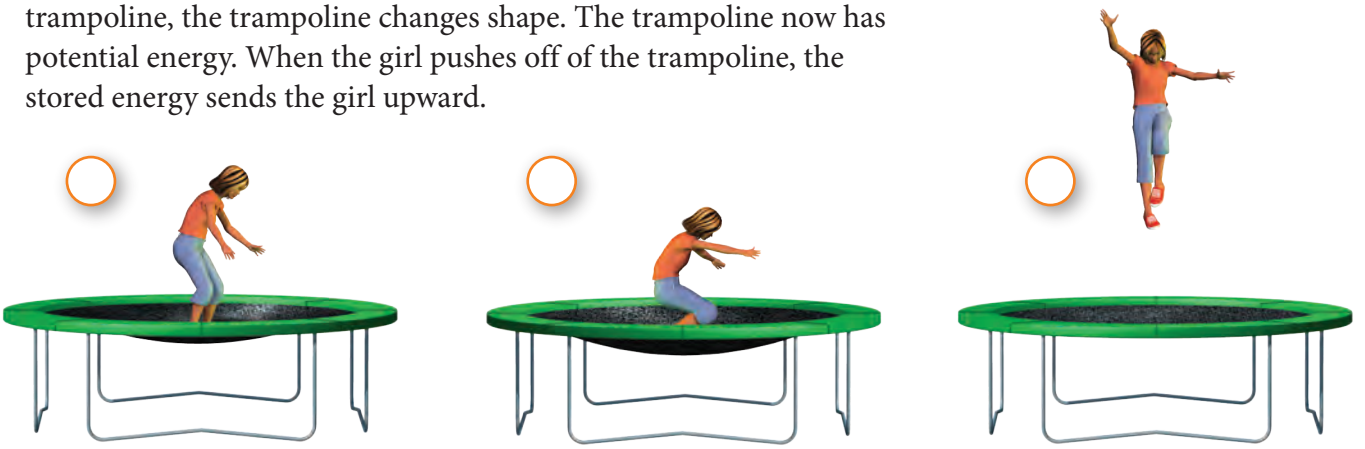


FIGURE 4

Elastic Potential Energy

The energy stored in a stretched object, such as the trampoline, is elastic potential energy.

Interpret Diagrams **Rank the amount of elastic potential energy of the trampoline from greatest to least. A ranking of one is the greatest. Write your answers in the circles. Then explain your answers in the space to the right.**

Lab zone® Do the Quick Lab *Mass, Velocity, and Kinetic Energy.*

Assess Your Understanding

1a. Identify The energy an object has due to its motion is called (kinetic/potential) energy. Stored energy that results from the position or shape of an object is called (kinetic/potential) energy.

b. Summarize What are the two factors that affect an object's kinetic energy?

c. Apply Concepts What type of energy does a cup sitting on a table have? Why?

got it?

○ **I get it!** Now I know that the two basic types of energy are

○ I need extra help with

TN

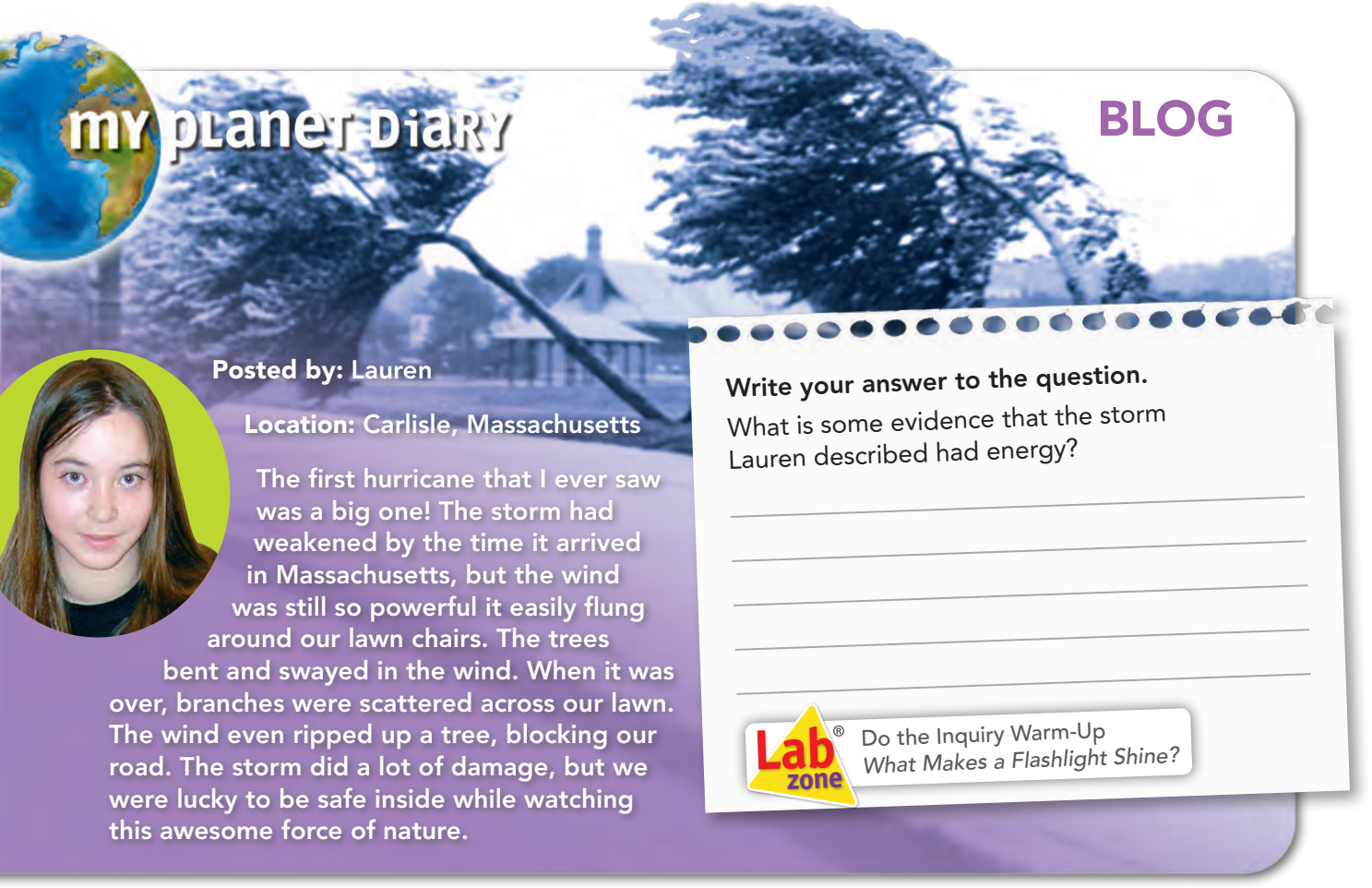
LESSON 2

6.PS3.1

Forms of Energy

UNLOCK THE BIG QUESTION

- How Can You Find an Object's Mechanical Energy?
- What Are Other Forms of Energy?



How Can You Find an Object's Mechanical Energy?

What do a falling basketball, a moving car, and a trophy on a shelf all have in common? They all have mechanical energy. The form of energy associated with the motion, position, or shape of an object is called **mechanical energy.**

Vocabulary

- mechanical energy
- nuclear energy
- thermal energy
- electrical energy
- electromagnetic energy
- chemical energy

Skills

Reading: Identify the Main Idea

Inquiry: Classify

Calculating Mechanical Energy

An object's mechanical energy is a combination of its potential energy and its kinetic energy. For example, the basketball in Figure 1 has both potential energy and kinetic energy. The higher the basketball moves, the greater its potential energy. The faster the basketball moves, the greater its kinetic energy. You can find an object's mechanical energy by adding together the object's kinetic energy and potential energy.

Mechanical energy = Potential energy + Kinetic energy

Sometimes an object's mechanical energy is its kinetic energy or potential energy only. A car moving along a flat road has kinetic energy only. A trophy resting on a shelf has gravitational potential energy only. But both have mechanical energy.

FIGURE 1

Mechanical Energy

The basketball has mechanical energy because of its speed and position above the ground.

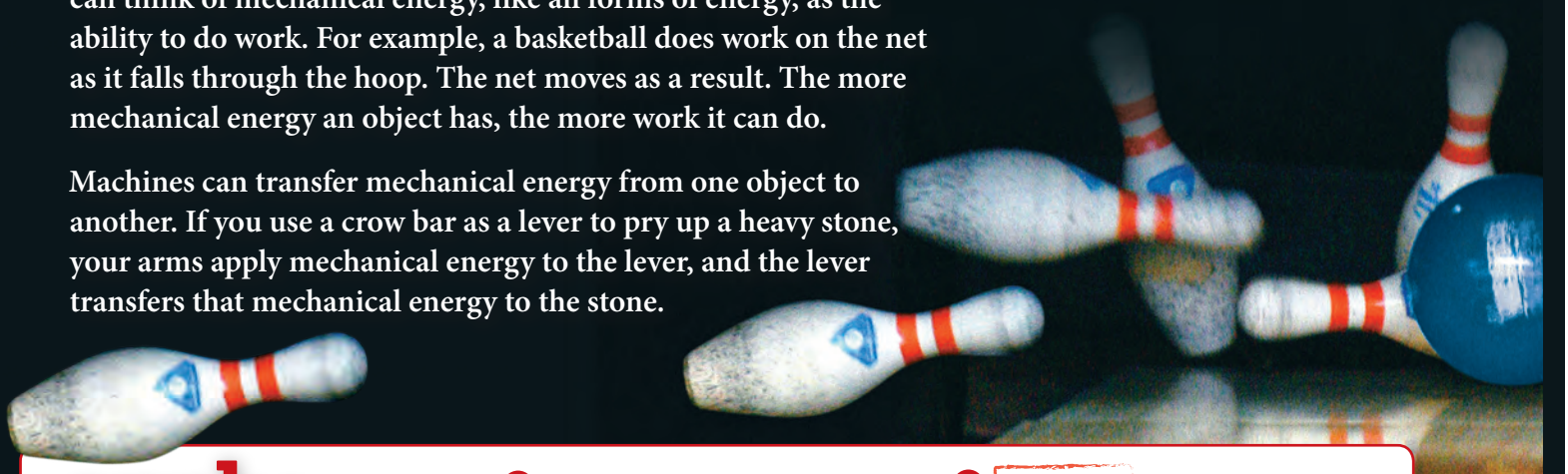
Calculate Solve for the mechanical energy of the basketball at point A and point B.

Draw Conclusions Why does the ball's gravitational potential energy increase from points A to B?

Mechanical Energy and Work

An object with mechanical energy can do work on another object. In fact, you can think of mechanical energy, like all forms of energy, as the ability to do work. For example, a basketball does work on the net as it falls through the hoop. The net moves as a result. The more mechanical energy an object has, the more work it can do.

Machines can transfer mechanical energy from one object to another. If you use a crow bar as a lever to pry up a heavy stone, your arms apply mechanical energy to the lever, and the lever transfers that mechanical energy to the stone.



apply it!

The bowling ball does work on the pins when it hits them.

1. Why can the ball do work?

2. How should you throw the ball to maximize the amount of work it does on the pins?

3. CHALLENGE The bowling ball in the photo has a mass of 7.0 kg. A candlepin bowling ball has a mass of about 1.0 kg. Does the 7 kg ball always have the greater mechanical energy? Explain.

Lab zone® Do the Quick Lab *Determining Mechanical Energy.*

Assess Your Understanding

1a. Define Mechanical energy is the form of energy associated with the _____, _____, or _____ of an object.

b. Calculate At a certain point the kinetic energy of a falling apple is 5.2 J and its potential energy is 3.5 J. What is its mechanical energy?

c. Infer If an object's mechanical energy is equal to its potential energy, how much kinetic energy does the object have? Explain.

got it?

- ○ **I get it!** Now I know you can find an object's mechanical energy by _____
- ○ I need extra help with _____

What Are Other Forms of Energy?

So far, you have read about energy that involves the motion, position, or shape of an object. But an object can have other forms of kinetic and potential energy. These other forms are associated with the particles that make up objects. These particles are far too small to see with the naked eye. **Forms of energy associated with the particles of objects include nuclear energy, thermal energy, electrical energy, electromagnetic energy, and chemical energy.**

Identify the Main Idea
Underline the main idea under the red heading Nuclear Energy.

Nuclear Energy

All objects are made up of particles called atoms. The region in the center of an atom is called the nucleus. A type of potential energy called **nuclear energy** is stored in an atom's nucleus. Nuclear energy is released during a nuclear reaction. One kind of nuclear reaction, nuclear fission, occurs when a nucleus splits. A nuclear power plant uses fission reactions to produce electricity. Another kind of reaction, nuclear fusion, occurs when the nuclei of atoms join together. Nuclear fusion reactions occur constantly in the sun, releasing huge amounts of energy. Only a tiny portion of this energy reaches Earth as heat and light.

Thermal Energy

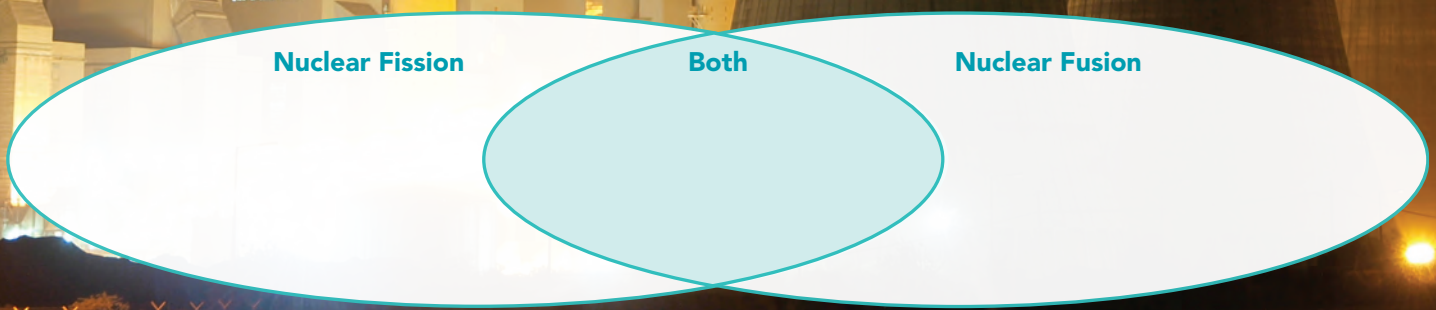
The particles that make up objects are constantly in motion. This means that they have kinetic energy. These particles are arranged in specific ways in different objects, so they also have potential energy. The total kinetic and potential energy of the particles in an object is called thermal energy.

FIGURE 2

Nuclear Energy

Controlled nuclear fission reactions occur at some power plants. Nuclear fusion reactions occur in the sun.

Compare and Contrast **Use the Venn diagram to compare and contrast nuclear fission and nuclear fusion.**



The higher the temperature of an object, the more thermal energy the object has. For example, suppose you heat a pot of water. As heat is applied to the water, the particles in the water move faster on average. The faster the particles move, the greater their kinetic energy and the higher the temperature. Therefore, a pot of water at 75°C, for example, has more thermal energy than the same amount of water at 30°C.

Temperature is not a direct measure of an object's total thermal energy. The thermal energy of an object also depends on the amount of matter (mass) in the object. Different materials can hold different amounts of thermal energy. So, thermal energy depends on what an object is made of. Thermal energy also varies with the state of matter. For example, a pot of liquid water at 0°C has much more thermal energy than the same amount of water frozen into ice at 0°C.

Thermal energy always moves from a warmer object to a cooler object. That is why you can warm your cold hands in front of a fire. The amount of thermal energy it takes to raise the temperature of an object depends on the object's mass, material, and size.

FIGURE 3

Forms of Energy

Many objects in this restaurant have more than one form of energy.

Classify Circle three objects. Describe two forms of energy each object has.

Electrical Energy

When you receive a shock from a metal doorknob, you experience electrical energy. The energy of electric charges is **electrical energy**. Depending on whether the charges are moving or stored, electrical energy can be a form of kinetic or potential energy. Lightning, batteries, and electrical lines are forms of electrical energy.

Electromagnetic Energy

The light you see is one type of electromagnetic energy. **Electromagnetic energy**, also called radiant energy, is a form of energy that travels through space in waves. The source of these waves is vibrating electric charges. These waves do not require a medium, so they can travel through a vacuum, or empty space. This is why you can see the sun and stars.

Microwaves and X-rays are also types of electromagnetic energy. Other forms of electromagnetic energy include ultraviolet rays, infrared (or heat) waves, and radio waves. Cell phones send and receive messages using microwaves.

Chemical Energy

Chemical energy is in food, matches, and body cells. **Chemical energy** is potential energy stored in chemical bonds. Chemical bonds are what hold atoms together. Often when these bonds are broken, this stored energy is released. For example, bonds are broken in your cells and release energy for your body to use.

Vocabulary Identify Multiple Meanings Review the multiple meaning words in the Getting Started section and complete the sentence. During a lightning storm, electric charges move between the clouds and the ground, releasing stored _____

Lab zone® Do the Quick Lab *Sources of Energy.*

Assess Your Understanding

2a. Explain Why do the particles of objects have both kinetic and potential energy?

_____

_____

_____

_____

_____

_____

_____

b. Classify The energy you get from eating a peanut butter and jelly sandwich is in the form of _____ energy.

got it?

○ **I get it!** Now I know the forms of energy associated with the particles of objects include _____

_____

_____

_____

○ I need extra help with _____

TN

LESSON 3

6.PS3.2, 6.ETS1.2

Energy Transformations and Conservation

UNLOCK THE BIG ?

- How Are Different Forms of Energy Related?
- What Is the Law of Conservation of Energy?

Science Day at the Amusement Park

During science days at Great America Amusement Park™ in Santa Clara, California, the park becomes a giant laboratory! Here is how one investigation might work. You choose a ride like the Drop Tower, which drops you 68 meters in less than four seconds, or the Fire Fall, which contains a series of vertical twists and turns. You observe how your speed and height change during the ride. Then you use your observations to learn about transformations between potential and kinetic energy.

FIELD TRIP

Write your answer to the question below.

How do you think energy is transformed in the Drop Tower?

Lab zone® Do the Inquiry Warm-Up *What Would Make a Card Jump?*

How Are Different Forms of Energy Related?

What does flowing water have to do with electricity? In a hydroelectric power plant, the mechanical energy of moving water is transformed into electrical energy. **All forms of energy can be transformed into other forms of energy.** A change from one form of energy to another is called an **energy transformation.** Some energy changes involve single transformations, while others involve many transformations.

Vocabulary

- energy transformation
- law of conservation of energy

Skills

Reading: Identify Supporting Evidence

Inquiry: Infer

Single Transformations

Sometimes, one form of energy needs to be transformed into another to get work done. For example, a toaster transforms electrical energy to thermal energy to toast your bread. A cell phone transforms electrical energy to electromagnetic energy that travels to other phones.

Your body transforms the chemical energy in food to the mechanical energy you need to move your muscles. Chemical energy in food is also transformed to the thermal energy your body uses to maintain its temperature.

Identify Supporting Evidence
Underline the energy transformation that must occur for you to talk on your cell phone.

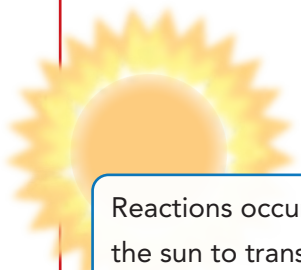
Multiple Transformations

Often, a series of energy transformations is needed to do work. In a car engine, a series of energy conversions occurs. Electrical energy produces a spark. The thermal energy of the spark releases chemical energy in the fuel.

The chemical energy in the fuel originated with nuclear reactions within the sun that reached Earth as electromagnetic energy. Plants transformed the energy in sunlight into chemical energy, which was stored in the fossilized remains of living organisms that made up the fuel. As the fuel burns, it expands as it is broken down into smaller particles. The expansion of the fuel produces pressure on parts of the car. The increased pressure eventually causes the wheels to turn, transforming chemical energy into mechanical energy.

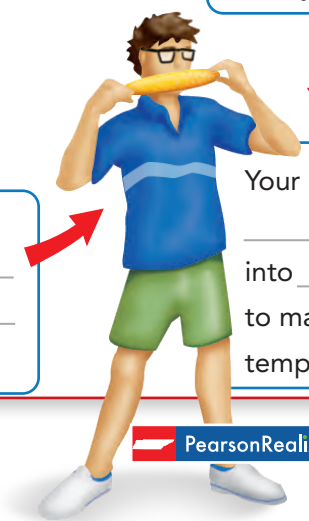
apply it!

A series of energy transformations must occur for you to ride your bike. Write the forms of energy involved in each transformation.



Reactions occur within the sun to transform _____ energy into _____ energy.

Plants transform _____ energy into _____ energy.



Your body transforms _____ energy into _____ energy to maintain your body temperature.

Your body also transforms _____ energy into _____ energy when you ride your bike.

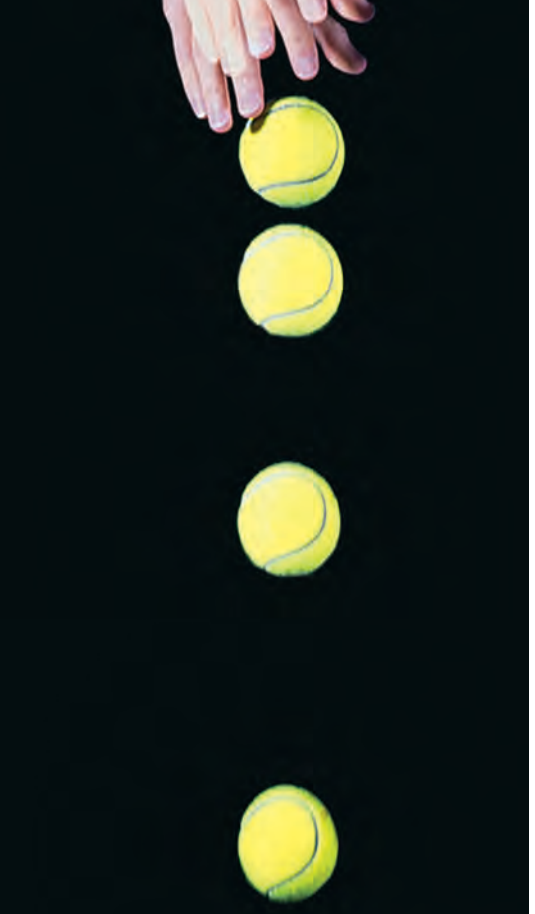


FIGURE 1

Falling Ball

The ball was photographed at equal time intervals as it fell.

Interpret Photos **How can you tell that the ball's kinetic energy is increasing?**

Kinetic and Potential Energy

The transformation between potential and kinetic energy is one of the most common energy transformations. For example, when you stretch a rubber band, you give it elastic potential energy. If you let it go, the rubber band flies across the room. When the rubber band is moving, it has kinetic energy. The potential energy of the stretched rubber has transformed to the kinetic energy of the moving rubber band. Transformations between kinetic and potential energy can also occur in any object that rises or falls. A falling object, a pendulum, and a pole vault are all examples of these transformations.

Falling Object

A transformation between potential and kinetic energy occurs in the ball in **Figure 1.** As the height of the ball decreases, it loses potential energy. At the same time, its kinetic energy increases because its speed increases. Its potential energy is transformed into kinetic energy.

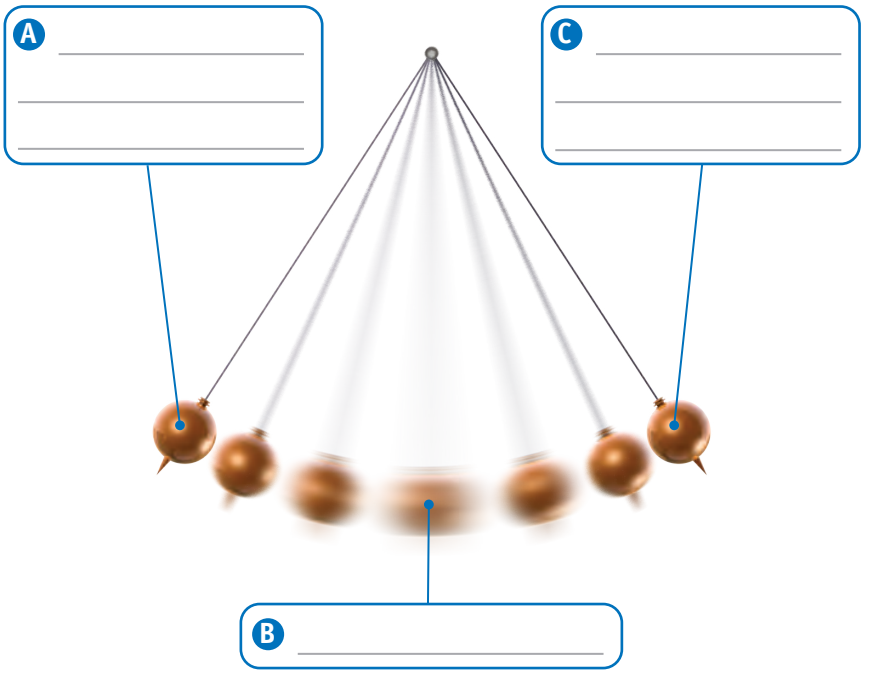
Pendulum

A pendulum like the one in **Figure 2** swings back and forth. At the highest point in its swing, the pendulum has no movement. As it swings downward, it speeds up. The pendulum is at its greatest speed at the bottom of its swing. As the pendulum swings to the other side, its height increases and its speed decreases. At the top of its swing, it comes to a stop again.

FIGURE 2

Pendulum

A continuous transformation between potential and kinetic energy occurs in a pendulum. **Interpret Diagrams** **Label the type of energy the pendulum has at positions A, B, and C.**



Pole Vault The pole-vaulter in Figure 3 starts out by running forward. When the pole-vaulter plants the pole to jump, his speed decreases and the pole bends. As the pole straightens out, the pole-vaulter is lifted high into the air. Once he is over the bar, the pole-vaulter's speed increases as he falls toward the safety cushion.

FIGURE 3

Pole Vault

Energy transformations enable this athlete to vault more than 6 meters into the air.

Sequence **Identify the main forms of energy present at points A through D.**

Lab zone® Do the Quick Lab *Soaring Straws.*

Assess Your Understanding

1a. Define A change in one form of energy to another form of energy is called a(n) _____

b. Relate Cause and Effect When you turn on an iron, _____ energy is transformed into _____ energy.

c. Apply Concepts Describe the energy transformation that occurs in a waterfall.

_____

_____

_____

_____

got it?

○ **I get it!** Now I know that all forms of energy can be transformed into _____

○ I need extra help with _____

What Is the Law of Conservation of Energy?

Once you set a pendulum in motion, does it swing forever? No, it does not. Then what happens to its energy? Is the energy destroyed? Again, the answer is no. The **law of conservation of energy** states that when one form of energy is transformed to another, no energy is lost in the process. **According to the law of conservation of energy, energy cannot be created or destroyed.** The total amount of energy is the same before and after any transformation. If you add up all of the new forms of energy after a transformation, all of the original energy will be accounted for. So what happens to the energy of the pendulum once it stops moving?

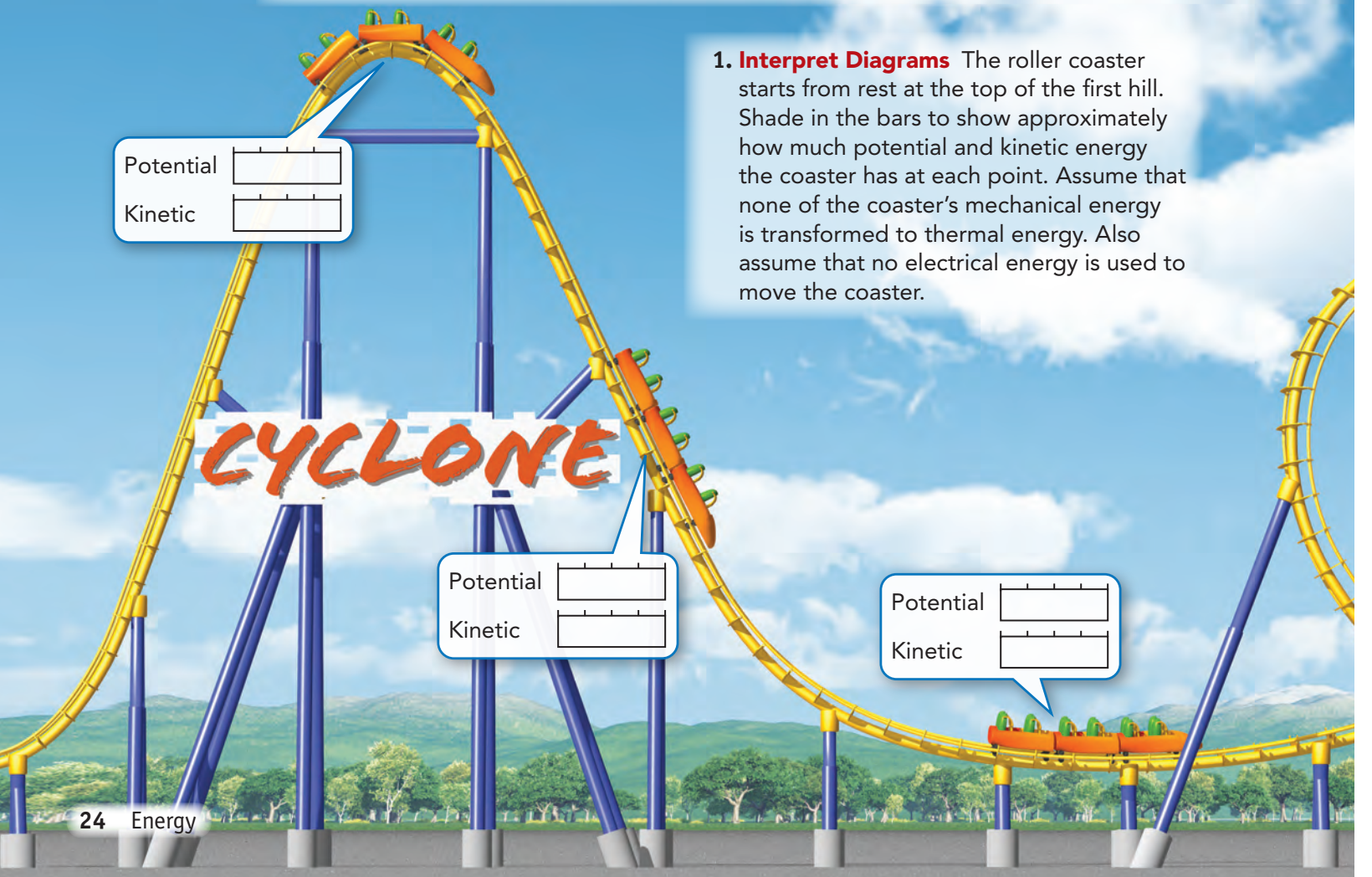
EXPLORE THE BIG ?

Conserving Energy While You Ride

How is energy conserved in a transformation?

FIGURE 4

Transformations between potential and kinetic energy occur during a roller coaster ride. **Use what you have learned about energy transformations to answer Questions 1–3.**



1. **Interpret Diagrams** The roller coaster starts from rest at the top of the first hill. Shade in the bars to show approximately how much potential and kinetic energy the coaster has at each point. Assume that none of the coaster's mechanical energy is transformed to thermal energy. Also assume that no electrical energy is used to move the coaster.

As the pendulum swings, it encounters friction at the pivot of the string and from the air through which it moves. Whenever a moving object experiences friction, some of its kinetic energy is transformed into thermal energy. So the mechanical energy of the pendulum is not destroyed. It is transformed to thermal energy.

The fact that friction transforms mechanical energy to thermal energy should not surprise you. After all, you take advantage of such thermal energy when you rub your cold hands together to warm them up. Friction is also the reason why no machine is 100 percent efficient. You may recall that the output work of any real machine is always less than the input work. This reduced efficiency occurs because some mechanical energy is always transformed into thermal energy due to friction.

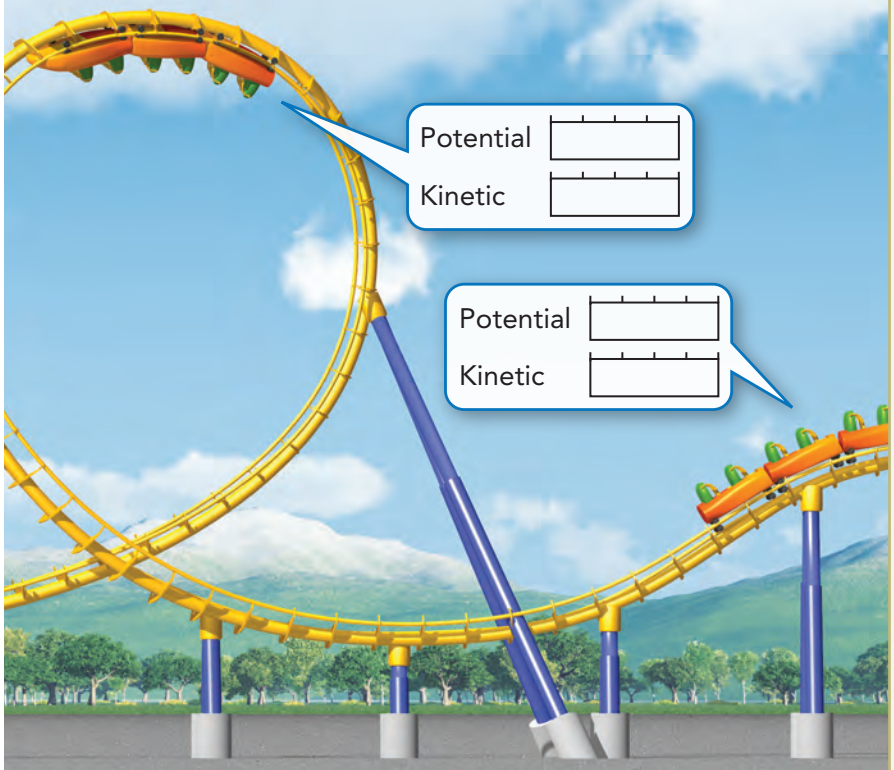
did you know?

When ancient animals and plants died, the chemical energy they had stored was trapped within their remains. This trapped energy is the chemical energy found in coal.

2. Infer Suppose you had taken thermal energy into account in Step 1. Would the total length of the shaded portion of the bars increase, decrease, or stay the same as as result?

○ Increase ○ Decrease ○ Stay the same

3. CHALLENGE Why is the first hill of a roller coaster always the tallest?



Lab zone® Do the Quick Lab *Law of Conservation of Energy.*

Assess Your Understanding

2. ANSWER THE BIG ? How is energy conserved in a transformation?

got it?

○ **I get it!** Now I know that according to the law of conservation of energy, energy _____

○ I need extra help with _____

CHAPTER 1

Study Guide

REVIEW THE BIG QUESTION

The total amount of _____ is the same before and after any transformation.

LESSON 1 What Is Energy?

Since the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.

The two basic types of energy are kinetic energy and potential energy.

Vocabulary

- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy

LESSON 2 Forms of Energy

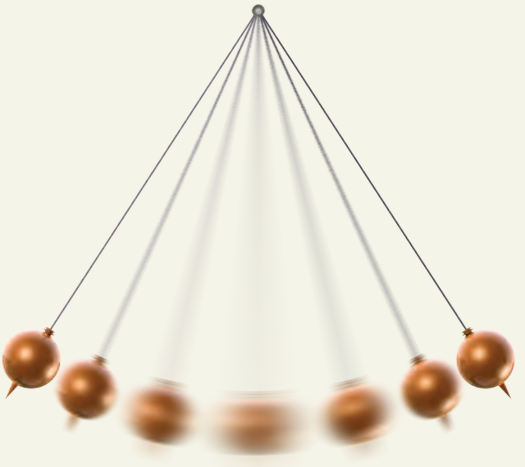
You can find an object's mechanical energy by adding together the object's kinetic energy and potential energy.

Forms of energy associated with the particles of objects include nuclear energy, thermal energy, electrical energy, electromagnetic energy, and chemical energy.

Vocabulary

- mechanical energy
- nuclear energy
- thermal energy
- electrical energy
- electromagnetic energy
- chemical energy

LESSON 3 Energy Transformations and Conservation



All forms of energy can be transformed into other forms of energy.

According to the law of conservation of energy, energy cannot be created or destroyed.

Vocabulary

- energy transformation
- law of conservation of energy

Review and Assessment

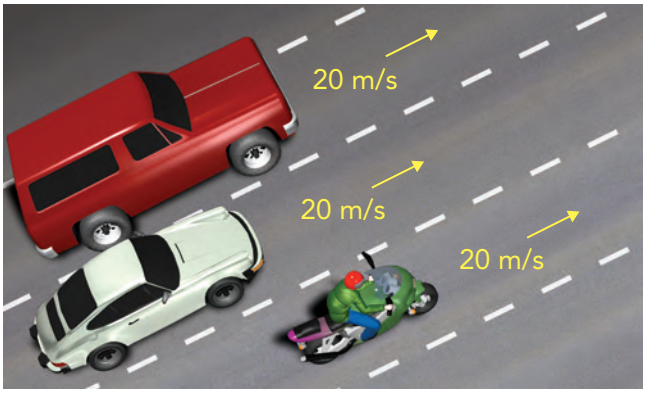
LESSON 1 What Is Energy?

1. When you stretch a rubber band, you give it

a. kinetic energy. **b.** electrical energy.
c. potential energy. **d.** chemical energy.

2. To calculate power, divide the amount of energy transferred by _____

3. **Compare and Contrast** In the illustration below, which vehicle has the greatest kinetic energy? Explain your answer.



4. **Apply Concepts** If a handsaw does the same amount of work on a log as a chainsaw does, which has more power? Why?

5. **math!** A 1,350-kg car travels at 12 m/s. What is its kinetic energy?

LESSON 2 Forms of Energy

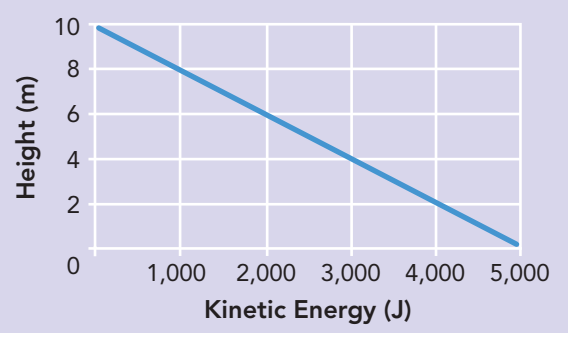
6. What is the energy stored in the nucleus of an atom called?

a. electrical energy **b.** chemical energy
c. thermal energy **d.** nuclear energy

7. An object's mechanical energy is the sum of its

8. **Classify** When you heat a pot of water over a flame, what form of energy is added to the water?

The graph shows the kinetic energy of a 500-N diver during a dive from a 10-m platform. Use the graph to answer Questions 9 and 10.



9. **Read Graphs** How does the diver's kinetic energy change as the diver falls? Why?

10. **Calculate** What is the diver's gravitational potential energy just before the dive?

CHAPTER 1

Review and Assessment

LESSON 3 Energy Transformations and Conservation

11. As a car skids to a stop, friction transforms kinetic energy to

a. thermal energy. **b.** potential energy.

c. chemical energy. **d.** electrical energy.

12. The law of conservation of energy states that

13. Classify Describe the energy transformation that occurs in a digital clock.

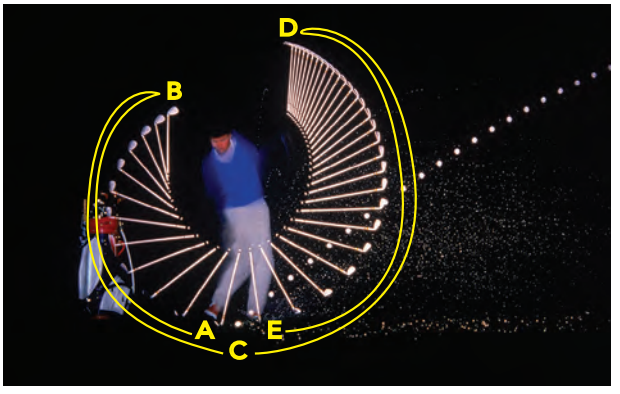
14. Apply Concepts Explain why a spinning top will not remain in motion forever.

15. Infer Why does a bouncing ball rise to a lower height with each bounce?

16. Write About It An eagle flies from its perch in a tree to the ground to capture and eat its prey. Describe its energy transformations.

APPLY THE BIG IDEA How is energy conserved in a transformation?

17. The golfer in the photo is taking a swing. The golf club starts at point A and ends at point E. (1) Describe the energy transformations of the club from points A to E. (2) The kinetic energy of the club at point C is more than the potential energy of the club at point B. Does this mean that the law of conservation of energy is violated? Why or why not?



TNReady Prep

6.PS.3.1, 6.PS3.2, 6.PS3.3, 6.ETS1.2

Read each question and choose the best answer.

1. The table gives the kinetic and potential energy of a 6-kg cat doing various activities.

Activity	Kinetic Energy (J)	Potential Energy (J)
Running	200	0
Leaping	150	100
Climbing a tree	3	300
Sleeping on a chair	0	30

During which activity does the cat have the greatest mechanical energy?

A climbing a tree **B** leaping
C running **D** sleeping on a chair

2. Why does wind have energy?

A It can change direction.
B It can do work.
C It moves through space as waves.
D It is electrically charged.

3. A gardener uses a wheelbarrow to haul a load of mulch. How does the wheelbarrow transfer energy to the mulch?

A The wheelbarrow applies potential energy to the mulch.
B The mulch applies gravitational force to the wheelbarrow.
C The gardener uses chemical energy to move the wheelbarrow.
D The wheelbarrow transfers energy of motion to the mulch.

4. Why does a pendulum eventually slow down and stop swinging?

A Friction transforms some of the mechanical energy to thermal energy.
B Kinetic energy changes to potential energy.
C Gravity pulls the pendulum toward Earth's center.
D Potential energy changes to kinetic energy.

5. Which energy transformation takes place when wood is burned?

A Nuclear energy is transformed to thermal energy.
B Thermal energy is transformed to electrical energy.
C Chemical energy is transformed to thermal energy.
D Mechanical energy is transformed to thermal energy.

Constructed Response

Use the table below to answer Question 6. Write your answer on a separate sheet of paper.

Time	Speed at Bottom of Swing (m/s)
8:00 a.m.	2.2
10:00 a.m.	1.9
12:00 p.m.	1.7
2:00 p.m.	1.6

6. A large pendulum at a science museum is set in motion at the beginning of the day. The table shows how its speed at the bottom of the swing changes during the day. Use this data to determine how the height of the pendulum's swing changes. Explain your answer.

CHARGE IT!

Have you ever noticed how many batteries you use every day? There are batteries in cars, flashlights, cell phones, laptop computers, and even bug zappers! Discarded batteries add up to a lot of waste. Fortunately, rechargeable batteries can help keep the energy flowing and reduce the number of batteries that get thrown out. Can you imagine how many nonrechargeable batteries a cell phone would go through in a month?

Batteries transform chemical energy into electrical energy. To refuel a rechargeable battery, you plug it into a power source—such as an outlet in the wall. The electrical energy reverses the chemical changes, storing the electrical energy as chemical energy. The battery is once again "charged up" and ready to go!

Research It **Gasoline-powered cars and hybrid cars have rechargeable batteries. Research how the batteries in gasoline-powered cars and hybrid cars are recharged.**

▲ The inside of this rechargeable battery has three long thin layers. A separator separates a positive electrode from a negative electrode. Using the battery causes lithium ions to move from the positive material to the negative one. Applying an electrical charge moves the ions back to the positive electrode.

Museum of Science®

Think Like a Scientist

Converting Potential Energy to Kinetic Energy

An object at rest has potential energy while an object in motion has kinetic energy. An example of a conversion of potential energy to kinetic energy is a toy car rolling down a ramp. Before the toy car moves from its position at the top of the ramp, it has only potential energy. As it moves down the ramp, its potential energy is converted to kinetic energy. One way to test how much kinetic energy the toy car has it to have the car hit a small block of wood at the bottom of the ramp and measure how far the block of wood moved. The distance the block of wood moves changes with the amount of kinetic energy in the car.

Research It Set up an experiment like the one described. Think of different ways to increase and decrease the kinetic energy of the toy car. Test your different ways of increasing and decreasing the kinetic energy. Keep careful notes about what you tried and the results. Write a brief report about how your different ideas increased or decreased the kinetic energy of the toy car.