* Annotated *

section 1

The Nature of Energy

Reading Guide

What You'll Learn

- **Distinguish** between kinetic and potential energy.
- **Calculate** kinetic energy.
- **Describe** different forms of potential energy.
- **Calculate** gravitational potential energy.

Why It's Important

All of the changes that occur around you every day involve the conversion of energy from one form to another.

Review Vocabulary

gravity: the attractive force between any two objects that have mass

New Vocabulary

- kinetic energy
- joule
- potential energy
- elastic potential energy
- chemical potential energy
- gravitational potential energy

What is energy?

Wherever you are sitting as you read this, changes are taking place—lightbulbs are heating the air around them, the wind might be rustling leaves, or sunlight might be glaring off a nearby window. Even you are changing as you breathe, blink, or shift position in your seat.

Every change that occurs—large or small—involves energy. Imagine a baseball flying through the air. It hits a window, causing the glass to break as shown in **Figure 1.** The window changed from a solid sheet of glass to a number of broken pieces. The moving baseball caused this change—a moving baseball has energy. Even when you comb your hair or walk from one class to another, energy is involved.

Figure 1 The baseball caused changes to occur when it hit the window.
Describe *the changes that are occurring.*

Change Requires Energy When something is able to change its environment or itself, it has energy. Energy is the ability to cause change. The moving baseball had energy. It certainly caused the window to change. Anything that causes change must have energy. You use energy to arrange your hair to look the way you want it to. You also use energy when you walk down the halls of your school between classes or eat your lunch. You even need energy to yawn, open a book, and write with a pen.

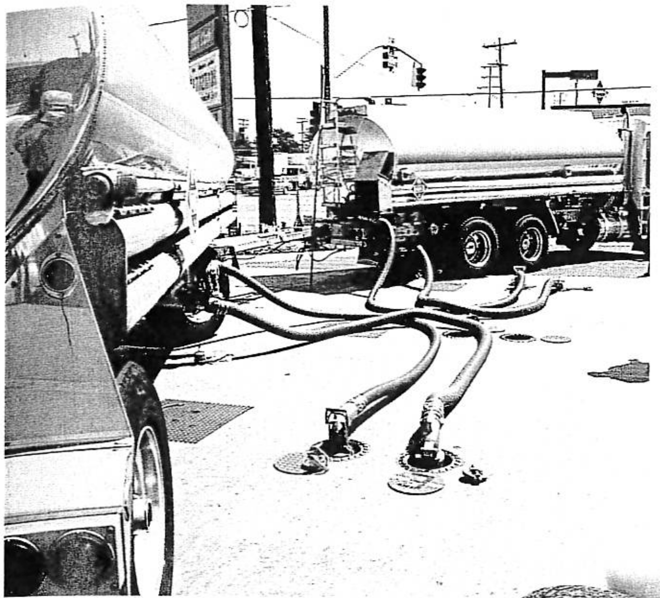


Figure 2 Energy can be stored and it can move from place to place.
Infer *which materials are storing chemical energy.*

Different Forms of Energy

Turn on an electric light, and a dark room becomes bright. Turn on your CD player, and sound comes through your headphones. In both situations, energy moves from one place to another. These changes are different from each other, and differ from the baseball shattering the window in **Figure 1.** This is because energy has several different forms—electrical, chemical, radiant, and thermal.

Figure 2 shows some examples of everyday situations in which you might notice energy. Is the chemical energy stored in food the same as the energy that comes from the Sun or the energy stored in gasoline? Radiant energy from the Sun travels a vast distance through space to Earth, warming the planet and providing energy that enables green plants to grow. When you make toast in the morning, you are using electrical energy. In short, energy plays a role in every activity that you do.

Reading Check *What are some different forms of energy?*

An Energy Analogy Money can be used in an analogy to help you understand energy. If you have $100, you could store it in a variety of forms—cash in your wallet, a bank account, travelers' checks, or gold or silver coins. You could transfer that money to different forms. You could deposit your cash into a bank account or trade the cash for gold. Regardless of its form, money is money. The same is true for energy. Energy from the Sun that warms you and energy from the food that you eat are only different forms of the same thing.

Science Online

Topic: Glacier Flow
Visit gpscience.com for Web links to information about the speeds at which glaciers flow.

Activity For the five fastest glaciers, calculate the kinetic energy a 1 kg block of ice in each glacier would have.

Kinetic Energy

When you think of energy, you might think of action—or objects in motion, like the baseball that shatters a window. An object in motion does have energy. **Kinetic energy** is the energy a moving object has because of its motion. The kinetic energy of a moving object depends on the object's mass and its speed.

Kinetic Energy Equation

$$\textbf{kinetic energy} \text{ (in joules)} = \frac{1}{2}\, \textbf{mass} \text{ (in kg)} \times [\text{speed (in m/s)}]^2$$

$$KE = \frac{1}{2}mv^2$$

The SI unit of energy is the **joule,** abbreviated J. If you dropped a softball from a height of about 0.5 m, it would have a kinetic energy of about one joule before it hit the floor.

Applying Math — Solve a Simple Equation

#20 - 23

CALCULATE KINETIC ENERGY A jogger whose mass is 60 kg is moving at a speed of 3 m/s. What is the jogger's kinetic energy?

IDENTIFY known values and the unknown value

Identify the known values:

a jogger whose mass is 60 kg → means → $m = 60$ kg

is moving at a speed of 3 m/s → means → $v = 3$ m/s

Identify the unknown value:

what is the jogger's kinetic energy → means → $KE = ?$ J

SOLVE the problem

Substitute the known values $m = 60$ kg and $v = 3$ m/s into the kinetic energy equation:

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(60\text{ kg})(3\text{ m/s})^2 = \frac{1}{2}(60)(9)\text{ kg m}^2/\text{s}^2 = 270\text{ J}$$

CHECK your answer

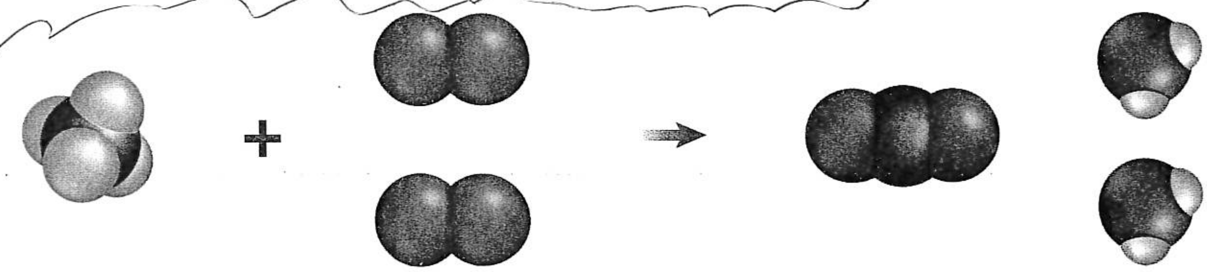
Does your answer seem reasonable? Check your answer by dividing the kinetic energy you calculate by the square of the given velocity, and then multiplying by 2. The result should be the mass given in the problem.

Practice Problems

1. What is the kinetic energy of a baseball moving at a speed of 40 m/s if the baseball has a mass of 0.15 kg?
2. A car moving at a speed of 20 m/s has a kinteic energy of 300,000 J. What is the car's mass?
3. A sprinter has a mass of 80 kg and a kinetic energy of 4,000 J. What is the sprinter's speed?

For more practice problems go to page 834, and visit gpscience.com/extra_problems.

Figure 3 As natural gas burns, it combines with oxygen to form carbon dioxide and water. In this chemical reaction, chemical potential energy is released.



Potential Energy

Energy doesn't have to involve motion. Even motionless objects can have energy. This energy is stored in the object. Therefore, the object has potential to cause change. A hanging apple in a tree has stored energy. When the apple falls to the ground, a change occurs. Because the apple has the ability to cause change, it has energy. The hanging apple has energy because of its position above Earth's surface. Stored energy due to position is called **potential energy.** If the apple stays in the tree, it will keep the stored energy due to its height above the ground. If it falls, that stored energy of position is converted to energy of motion.

Elastic Potential Energy Energy can be stored in other ways, too. If you stretch a rubber band and let it go, it sails across the room. As it flies through the air, it has kinetic energy due to its motion. Where did this kinetic energy come from? Just as the apple hanging in the tree had potential energy, the stretched rubber band had energy stored as elastic potential energy. **Elastic potential energy** is energy stored by something that can stretch or compress, such as a rubber band or spring.

Chemical Potential Energy The cereal you eat for breakfast and the sandwich you eat at lunch also contain stored energy. Gasoline stores energy in the same way as food stores energy—in the chemical bonds between atoms. Energy stored in chemical bonds is **chemical potential energy. Figure 3** shows a molecule of natural gas. Energy is stored in the bonds that hold the carbon and hydrogen atoms together and is released when the gas is burned.

Reading Check *How is elastic potential energy different from chemical potential energy?*

Mini LAB

Interpreting Data from a Slingshot

Procedure

1. Using two fingers, carefully stretch a **rubber band** on a table until it has no slack.
2. Place a **nickel** on the table, slightly touching the midpoint of the rubber band.
3. Push the nickel back 0.5 cm into the rubber band and release. Measure the distance the nickel travels.
4. Repeat step 3, each time pushing the nickel back an additional 0.5 cm.

Analysis

1. How did the takeoff speed of the nickel seem to change relative to the distance that you stretched the rubber band?
2. What does this imply about the kinetic energy of the nickel?

INTEGRATE Language Arts

The Myth of Sisyphus In Greek mythology, a king named Sisyphus angered the gods by attempting to delay death. As punishment, he was doomed for eternity to endlessly roll a huge stone up a hill, only to have it roll back to the bottom again. Explain what caused the potential energy of the stone to change as it moved up and down the hill.

Gravitational Potential Energy Anything that can fall has stored energy called gravitational potential energy. **Gravitational potential energy** (GPE) is energy stored by objects due to their position above Earth's surface. The GPE of an object depends on the object's mass and height above the ground. Gravitational potential energy can be calculated from the following equation.

Gravitational Potential Energy Equation

gravitational potential energy (J) = **mass** (kg) × acceleration of gravity (m/s²) × **height** (m)

$$GPE = mgh$$

On Earth, the acceleration of gravity is 9.8 m/s² and has the symbol *g*. Like all forms of energy, gravitational potential energy is measured in joules.

↑ SI Units of energy = joules (J)

Applying Math — Solve a Simple Equation

CALCULATE GRAVITATIONAL POTENTIAL ENERGY What is the gravitational potential energy of a ceiling fan that has a mass of 7 kg and is 4 m above the ground?

IDENTIFY known values and the unknown value

Identify the known values:

has a mass of 7 kg → means → $m = 7$ kg

is 4 m above the ground → means → $h = 4$ m

Identify the unknown value:

what is the gravitational potential energy → means → $GPE = ?$ J

SOLVE the problem

Substitute the known values $m = 7$ kg, $h = 4$ m, and $g = 9.8$ m/s² into the gravitational potential energy equation:

$$GPE = mgh = (7\ \text{kg})(9.8\ \text{m/s}^2)(4\ \text{m}) = (274)\ \text{kg m}^2/\text{s}^2 = 274\ \text{J}$$

CHECK your answer

Does your answer seem reasonable? Check your answer by dividing the gravitational potential energy you calculate by the given mass, and then divide by 9.8 m/s². The result should be the height given in the problem.

Practice Problems

1. Find the height of a baseball with a mass of 0.15 kg that has a GPE of 73.5 J.
2. Find the GPE of a coffee mug with a mass of 0.3 kg on a 1-m high counter top.
3. What is the mass of a hiker 200 m above the ground if her GPE is 117,600 J?

For more practice problems go to page 834, and visit gpscience.com/extra_problems.

Changing GPE Look at the objects in the bookcase in **Figure 4.** Which of these objects has the most gravitational potential energy? According to the equation for gravitational potential energy, the GPE of an object can be increased by increasing its height above the ground. If two objects are at the same height, then the object with the larger mass has more gravitational potential energy.

In **Figure 4,** suppose the green vase on the lower shelf and the blue vase on the upper shelf have the same mass. Then the blue vase on the upper shelf has more gravitational potential energy because it is higher above the ground.

Imagine what would happen if the two vases were to fall. As they fall and begin moving, they have kinetic energy as well as gravitational potential energy. As the vases get closer to the ground, their gravitational potential energy decreases. At the same time, they are moving faster, so their kinetic energy increases. The vase that was higher above the floor has fallen a greater distance. As a result, the vase that initially had more gravitational potential energy will be moving faster and have more kinetic energy when it hits the floor.

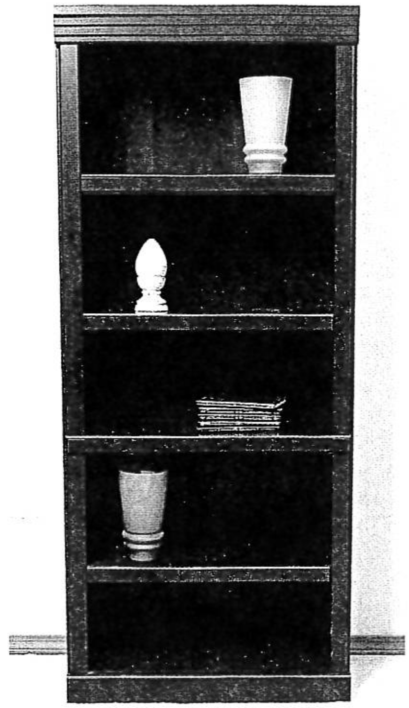


Figure 4 An object's gravitational potential energy increases as its height increases.

section 1 review

Summary

Energy

- Energy is the ability to cause change.
- Forms of energy include electrical, chemical, thermal, and radiant energy.

Kinetic Energy

- Kinetic energy is the energy a moving object has because of its motion.
- The kinetic energy of a moving object can be calculated from this equation:

$$KE = \frac{1}{2}mv^2$$

Potential Energy

- Potential energy is stored energy due to the position of an object.
- Different forms of potential energy include elastic potential energy, chemical potential energy, and gravitational potential energy.
- Gravitational potential energy can be calculated from this equation:

$$GPE = mgh$$

Self Check

1. **Explain** whether an object can have kinetic energy and potential energy at the same time.
2. **Describe** three situations in which the gravitational potential energy of an object changes.
3. **Explain** how the kinetic energy of a truck could be increased without increasing the truck's speed.
4. **Think Critically** The different molecules that make up the air in a room have on average the same kinetic energy. How does the speed of the different air molecules depend on their masses?

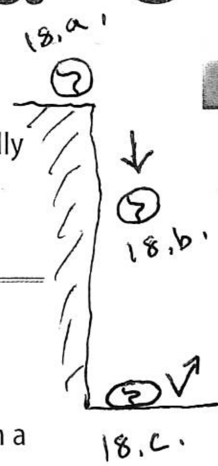
Applying Math

5. **Calculate Kinetic Energy** Find the kinetic energy of a ball with a mass of 0.06 kg moving at 50 m/s.
6. **Use Ratios** A boulder on top of a cliff has potential energy of 8,800 J, and has twice the mass of a boulder next to it. What is the GPE of the smaller boulder?
7. **Calculate GPE** An 80-kg diver jumps from a 10-m high platform. What is the gravitational potential energy of the diver halfway down?

LAB

Bouncing Balls

What happens when you drop a ball onto a hard, flat surface? It starts with potential energy. It bounces up and down until it finally comes to a rest. Where did the energy go?



Real-World Question

Why do bouncing balls stop bouncing?

Goals

- **Identify** the forms of energy observed in a bouncing ball.
- **Infer** why the ball stops bouncing.

Materials

tennis ball	masking tape
rubber ball	cardboard box
balance	**shoe box*
meterstick	**Alternate materials*

Safety Precautions

Procedure

1. **Measure** the mass of the two balls.
2. Have a partner drop one ball from 1 m. 18, a. Measure how high the ball bounced. Repeat this two more times so you can calculate an average bounce height. Record your values on the data table.
3. Repeat step 2 for the other ball.
4. **Predict** whether the balls would bounce higher or lower if they were dropped onto the cardboard box. Design an experiment to measure how high the balls would bounce off the surface of a cardboard box.

Bounce Height

Type of Ball	Surface	Trial	Height (cm)
Tennis	Floor	1	
Tennis	Floor	2	
Tennis	Floor	3	
Rubber	Floor	1	
Rubber	Floor	2	
Rubber	Floor	3	
Tennis	Box	1	

Conclude and Apply

1. **Calculate** the gravitational potential energy of each ball before dropping it.
2. **Calculate** the average bounce height for the three trials under each condition. Describe your observations.
3. **Compare** the bounce heights of the balls dropped on a cardboard box with the bounce heights of the ballls dropped on the floor. Hint: *Did you observe any movement of the box when the balls bounced?*
4. **Explain** why the balls bounced to different heights, using the concept of elastic potential energy.

Communicating Your Data

Meet with three other lab teams and compare average bounce heights for the tennis ball on the floor. Discuss why your results might differ. **For more help, refer to the Science Skill Handbook.**