

Table of Contents

4 **Unit 1: Energy and Motion**

Chapter 4: Energy

4.1: The Nature of Energy

4.2: Conservation of Energy

The Nature of Energy

4.1 **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.
- Every change that occurs—large or small—involves energy.

The Nature of Energy


4.1 **Change Requires Energy**

- When something is able to change its environment or itself, it has energy. Energy is the ability to cause change.
- Anything that causes change must have energy.

The Nature of Energy

4.1 **Change Requires 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.



The Nature of Energy


4.1 **Different Forms of Energy**

- Energy has several different forms—electrical, chemical, radiant, and thermal.
- Is the chemical energy stored in food the same as the energy that comes from the Sun or the energy stored in gasoline?

The Nature of Energy

4.1 **Different Forms of Energy**

- 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.



CHAPTER RESOURCES

END

The Nature of Energy

4.1 **An Energy Analogy**

- 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.

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **An Energy Analogy**

- 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.

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Kinetic Energy**

- 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

kinetic energy (in joules) = mass (in kg) × [time (in m/s)]²

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

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Kinetic Energy**

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

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Potential Energy**

- Even motionless objects can have energy. This energy is stored in the object.
- A hanging apple in a tree has stored energy.




CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Potential Energy**

- 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.




CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Potential Energy**

- If it falls, that stored energy of position is converted to energy of motion.



CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Elastic Potential Energy**

- 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?

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Elastic 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.

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Chemical Potential 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**.

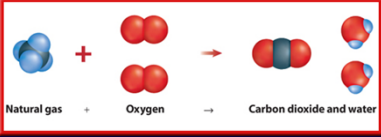
CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Chemical Potential Energy**

- Energy is stored in the bonds that hold the carbon and hydrogen atoms together and is released when the gas is burned.
- In this chemical reaction, chemical potential energy is released.



Natural gas + Oxygen → Carbon dioxide and water

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **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.

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Gravitational Potential Energy**

- 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.

CHAPTER RESOURCES

END

The Nature of Energy

4.1 **Changing GPE**

- 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.

CHAPTER RESOURCES

END

Section Check

4.1

Question 1

Energy is the ability to cause _____.

- A. change
- B. heat
- C. motion
- D. work

CHAPTER RESOURCES

END

Section Check

4.1

Answer

The answer is A. Energy is the ability to cause change and has several different forms.

CHAPTER RESOURCES

END

Section Check

4.1

Question 2

What are the four different forms of energy?

Answer

The four different forms of energy are electrical, chemical, radiant and thermal.

CHAPTER RESOURCES

END

Section Check

4.1

Question 3

The kinetic energy of an object depends on _____.

- A. the object's mass and speed
- B. the object's mass
- C. the object's speed
- D. the acceleration of the object

CHAPTER RESOURCES

Section Check

4.1

Answer

The answer is A. Kinetic energy depends on both the mass and speed of the moving object.

CHAPTER RESOURCES

Conservation of Energy

4.2

Changing Forms of Energy

- More likely to think of energy as race cars roar past or as your body uses energy from food to help it move, or as the Sun warms your skin on a summer day.
- These situations involve energy changing from one form to another form.

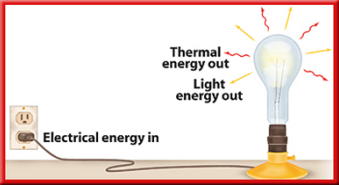
CHAPTER RESOURCES

Conservation of Energy

4.2

Transforming Electrical Energy

- Lightbulbs transform electrical energy into light so you can see.
- The warmth you feel around the bulb is evidence that some of that electrical energy is transformed into thermal energy.



CHAPTER RESOURCES

Conservation of Energy

4.2

Transforming Chemical Energy

- Fuel stores energy in the form of chemical potential energy.
- The engine transforms the chemical potential energy stored in gasoline molecules into the kinetic energy of a moving car or bus.

CHAPTER RESOURCES

Conservation of Energy

4.2

Transforming Chemical Energy

- Several energy conversions occur in this process.
- In a car, a spark plug fires, initiating the conversion of chemical potential energy into thermal energy.




CHAPTER RESOURCES

Conservation of Energy

4.2 Transforming Chemical Energy

- As the hot gases expand, thermal energy is converted into kinetic energy.



Gases expand


CHAPTER RESOURCES

END

Conservation of Energy

4.2 Transforming Chemical Energy

- Some energy transformations are less obvious because they do not result in visible motion, sound, heat, or light.
- Every green plant you see converts light energy from the Sun into energy stored in chemical bonds in the plant.



CHAPTER RESOURCES

END

Conservation of Energy

4.2 Conversions Between Kinetic and Potential Energy

- You have experienced many situations that involve conversions between potential and kinetic energy.
- To understand the energy conversions that occur, it is helpful to identify the mechanical energy of a system.

CHAPTER RESOURCES

END

Conservation of Energy

4.2 Conversions Between Kinetic and Potential Energy

- Mechanical energy** is the total amount of potential and kinetic energy in a system and can be expressed by this equation.

$$\text{mechanical energy} = \text{potential energy} + \text{kinetic energy}$$


CHAPTER RESOURCES

END

Conservation of Energy

4.2 Falling Objects

- An apple on a tree has gravitational potential energy due to Earth pulling down on it.
- The instant the apple comes loose from the tree, it accelerates due to gravity.




CHAPTER RESOURCES

END

Conservation of Energy

4.2 Falling Objects

- As it falls, it loses height so its gravitational potential energy decreases.
- This potential energy is transformed into kinetic energy as the velocity of the apple increases.



CHAPTER RESOURCES

END

Conservation of Energy

4.2 Falling Objects

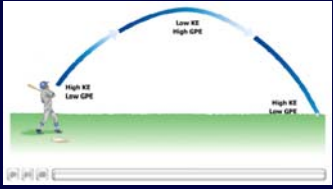
- If the potential energy is being converted into kinetic energy, then the mechanical energy of the apple doesn't change as it falls.
- The potential energy that the apple loses is gained back as kinetic energy.
- The form of energy changes, but the total amount of energy remains the same.

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Conservation of Energy

4.2 Energy Transformations in Projectile Motion

- Energy transformations also occur during projectile motion when an object moves in a curved path.

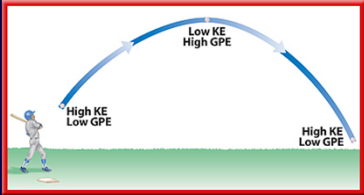


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Conservation of Energy

4.2 Energy Transformations in Projectile Motion

- However, the mechanical energy of the ball remains constant as it rises and falls.




? CHAPTER RESOURCES ⏪ 📄 ⏩ END

Conservation of Energy

4.2 Energy Transformations in a Swing

- When you ride on a swing part of the fun is the feeling of almost falling as you drop from the highest point to the lowest point of the swing's path.



? CHAPTER RESOURCES ⏪ 📄 ⏩ END

Conservation of Energy

4.2 Energy Transformations in a Swing

- The ride starts with a push that gets you moving, giving you kinetic energy.
- As the swing rises, you lose speed but gain height.
- In energy terms, kinetic energy changes to gravitational potential energy.

? CHAPTER RESOURCES ⏪ 📄 ⏩ END

Conservation of Energy

4.2 Energy Transformations in a Swing

- At the top of your path, potential energy is at its greatest.
- Then, as the swing accelerates downward, potential energy changes to kinetic energy.


? CHAPTER RESOURCES ⏪ 📄 ⏩ END

Conservation of Energy

4.2 The Law of Conservation of Energy

- Energy can change from one form to another, but the total amount of energy never changes.

Energy in = Energy out



Electrical energy = { Thermal energy
Kinetic energy
Sound energy


? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 The Law of Conservation of Energy

- Even when energy changes from from electrical to thermal and other energy forms as in the hair dryer shown energy is never destroyed.

Energy in = Energy out



Electrical energy = { Thermal energy
Kinetic energy
Sound energy

? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 The Law of Conservation of Energy

- This principle is recognized as a law of nature.
- The **law of conservation of energy** states that energy cannot be created or destroyed.

? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 Conserving Resources

- You might have heard about energy conservation or been asked to conserve energy.
- These ideas are related to reducing the demand for electricity and gasoline, which lowers the consumption of energy resources such as coal and fuel oil.

? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 Conserving Resources


- The law of conservation of energy, on the other hand, is a universal principle that describes what happens to energy as it is transferred from one object to another or as it is transformed.

? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 Is energy always conserved?

- While coasting along a flat road on a bicycle, you know that you will eventually stop if you don't pedal.
- If energy is conserved, why wouldn't your kinetic energy stay constant so that you would coast forever?




? CHAPTER RESOURCES < > END

Conservation of Energy

4.2 The Effect of Friction

- You know from experience that if you don't continue to pump a swing or be pushed by somebody else, your arcs will become lower and you eventually will stop swinging.



? CHAPTER RESOURCES END

Conservation of Energy

4.2 The Effect of Friction

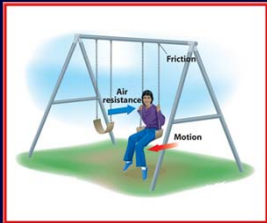
- In other words, the mechanical (kinetic and potential) energy of the swing seems to decrease, as if the energy were being destroyed. Is this a violation of the law of conservation of energy?

? CHAPTER RESOURCES END

Conservation of Energy

4.2 The Effect of Friction

- With every movement, the swing's ropes or chains rub on their hooks and air pushes on the rider.
- Friction and air resistance cause some of the mechanical energy of the swing to change to thermal energy.



? CHAPTER RESOURCES END

Conservation of Energy

4.2 The Effect of Friction

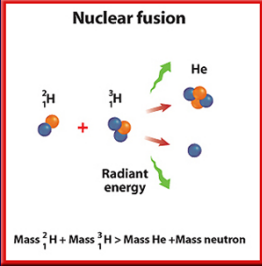
- With every pass of the swing, the temperature of the hooks and the air increases a little, so the mechanical energy of the swing is not destroyed.
- Rather, it is transformed into thermal energy.

? CHAPTER RESOURCES END

Conservation of Energy

4.2 Converting Mass into Energy

- A special kind of energy conversion—nuclear fusion—takes place in the Sun and other stars.
- During this process a small amount of mass is transformed into a tremendous amount of energy.

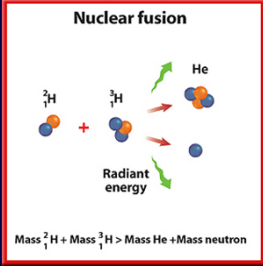


? CHAPTER RESOURCES END

Conservation of Energy

4.2 Converting Mass into Energy

- In the reaction shown here, the nuclei of the hydrogen isotopes deuterium and tritium undergo fusion.



? CHAPTER RESOURCES END

Conservation of Energy

4.2 Nuclear Fission

- In processes involving nuclear fission and fusion, the total amount of energy is still conserved if the energy content of the masses involved are included.

Mass U + Mass neutron = Mass Xe + Mass Sr + Mass neutrons

CHAPTER RESOURCES

END

Conservation of Energy

4.2 Nuclear Fission

- Then the total energy before the reaction is equal to the total energy after the reaction, as required by the law of conservation of energy.

Mass U + Mass neutron = Mass Xe + Mass Sr + Mass neutrons

CHAPTER RESOURCES

END

Conservation of Energy

4.2 The Human Body—Balancing the Energy Equation

- What forms of energy can you find in the human body?
- With your right hand, reach up and feel your left shoulder.
- With that simple action, stored potential energy within your body was converted to the kinetic energy of your moving arm.

CHAPTER RESOURCES

END

Conservation of Energy

4.2 The Human Body—Balancing the Energy Equation

- Some of the chemical potential energy stored in your body is used to maintain a nearly constant internal temperature.
- A portion of this energy also is converted to the excess heat that your body gives off to its surroundings.

CHAPTER RESOURCES

END

Conservation of Energy

4.2 Energy Conversions in Your Body

- Your body stores energy in the form of fat and other chemical compounds.
- This chemical potential energy is used to fuel the processes that keep you alive, such as making your heart beat and digesting the food you eat.

CHAPTER RESOURCES

END

Conservation of Energy

4.2 Energy Conversions in Your Body

- Your body also converts this energy to heat that is transferred to your surroundings, and you use this energy to make your body move.

Type of Activity	Calories Used in 1 h		
	Small	Medium	Large
Sleeping	48	56	64
Sitting	72	84	96
Eating	84	98	112
Standing	96	112	123
Walking	180	210	240
Playing tennis	380	420	460
Bicycling (fast)	500	600	700
Running	700	850	1,000v

CHAPTER RESOURCES

END

Conservation of Energy

4.2 **Food Energy**

- The food Calorie (C) is a unit used by nutritionists to measure how much energy you get from various foods—1 C is equivalent to about 4,184 J.
- Every gram of fat a person consumes can supply 9 C of energy.
- Carbohydrates and proteins each supply about 4 C of energy per gram.

CHAPTER RESOURCES

Reviewing Main Ideas

4.2 **Conservation of Energy**

- The total amount of kinetic energy and gravitational potential energy in a system is the mechanical energy of the system:

$$\text{mechanical energy} = KE + GPE$$
- The law of conservation of energy states that energy never can be created or destroyed. The total amount of energy in the universe is constant.

CHAPTER RESOURCES

Section Check

4.2 **Question 1**

Mechanical energy is the total amount of _____ in a system.

A. kinetic energy
 B. momentum
 C. potential energy
 D. potential and kinetic

CHAPTER RESOURCES

Section Check

4.2 **Answer**

The answer is D. Mechanical energy is the energy due to position and motion of all objects in a system.

CHAPTER RESOURCES

Section Check

4.2 **Question 2**

State the law of conservation of energy.

Answer

The law of conservation of energy states that energy cannot be created or destroyed.

CHAPTER RESOURCES

Section Check

4.2 **Question 3**

Friction converts _____ energy into _____ energy.

A. electrical, thermal
 B. mechanical, thermal
 C. thermal, electrical
 D. thermal, mechanical

CHAPTER RESOURCES

Section Check

4.2

Answer

The answer is B. Friction converts mechanical energy into thermal energy.

CHAPTER RESOURCES

END

Help

4

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