299

Energy

It's sometimes easier to describe what energy does than what energy is. That's because, unlike matter, energy is not something you can see or touch. **Energy** is a property of matter, and all matter has it. Whenever a light bulb is lit, a turkey is roasted, an orchestra plays, a fan spins, a book falls off the shelf, or a fire burns, you can be sure that energy—in one form or another—made it happen.

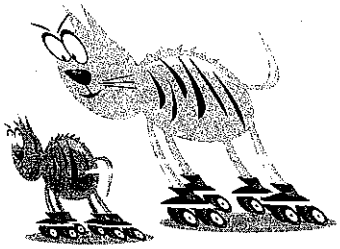
Forms of Energy

300

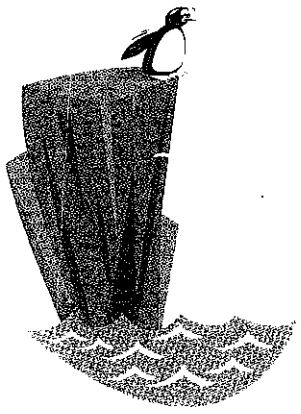
Energy comes in many different forms. While it can be transferred from one object or system to another, energy cannot be created or destroyed. This rule is known as the **law of conservation of energy.**

Like work, energy is measured in units called joules (J).

Mechanical energy is the energy an object has because of its motion or position. There are two kinds of mechanical energy: kinetic and potential. **Kinetic energy** is the energy an object has because it is moving. The greater the speed and the mass of the object, the greater its kinetic energy. **Potential energy** is energy an object has because of its position or shape. In the case of the penguin below, the higher up he is, the greater his potential energy.



The bigger cat has more kinetic energy than the smaller cat because he has more mass.



This penguin has potential energy because of his mass and his height above the water.

Other forms of energy include the following:

- **Thermal energy** (sometimes called heat energy) is the energy related to the temperature of a substance.
- **Light energy** is the energy carried by light and other kinds of electromagnetic waves.
- **Sound energy** is the energy carried by sound waves.
- **Electrical energy** is the energy produced by electric charges.
- **Chemical energy** is the energy stored in chemical bonds.
- **Nuclear energy** is the energy contained in the nuclei of atoms.

301 Thermal Energy
308 Light
312 Sound
315 The Law of Electric Charges
105 Animal Physiology
256 Atomic Structure

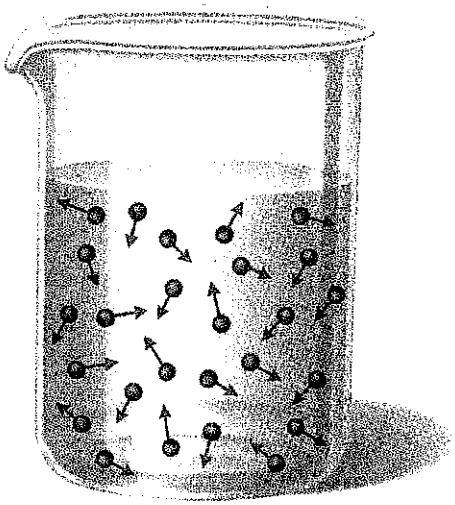
301

Thermal Energy

SEE ALSO
255 Atoms
261 Molecules
300 Forms of Energy

All matter is made of particles called atoms and molecules. These particles are in constant motion. They vibrate, rotate, or move from one place to another in a random manner. Some move faster than others. Since these particles are in motion, they have kinetic energy. Kinetic energy is the energy an object or substance has due to its motion.

Word Watch!
The prefix *therm-* means "heat."



Molecules of water have kinetic energy.

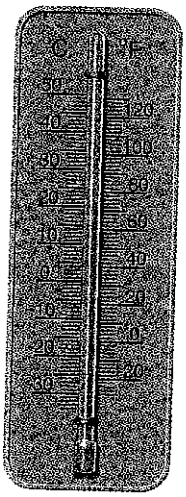
Thermal energy is the total amount of kinetic energy contained in all the particles of a substance. The greater the kinetic energy of the particles in the substance, the more thermal energy the substance has. But thermal energy also depends on the number of particles in a substance. The more particles a substance contains, the greater its thermal energy.

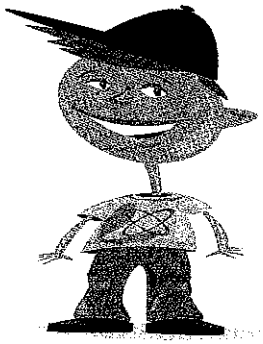
SEE ALSO
202 Ocean Water
302 Temperature versus Heat

Science Alert!
More thermal energy does not necessarily mean a higher temperature. For example, the ocean, because it is so massive, has far more thermal energy than a pot of boiling water.

Temperature versus Heat

When you think of temperature, you probably think "hot" or "cold." To scientists, **temperature** is a measure of the *average* kinetic energy of the particles in a substance. The more kinetic energy the particles have, the higher the temperature of the substance. Unlike thermal energy, however, temperature is not affected by the number of particles the substance contains.





Two common units of temperature are degrees Celsius (°C) and degrees Fahrenheit (°F).

A thermometer is a device used to measure temperature.

SEE ALSO
072 Taking Temperature Readings

Did You Know?

An object may feel hot or cold, but you can't tell its temperature just by touching it. That's because your skin can only detect *differences* in temperature, not temperature itself. For example, if your hands are very cold, even a cool object will feel warm.

So if thermal energy is the total kinetic energy of a substance, and temperature is the average kinetic energy of a substance, what is heat? **Heat** is the transfer of thermal energy between substances that are at different temperatures. The energy is always transferred from the warmer substance (the one with the higher temperature) to the cooler substance (the one with the lower temperature). Three methods of heat transfer are conduction, convection, and radiation.

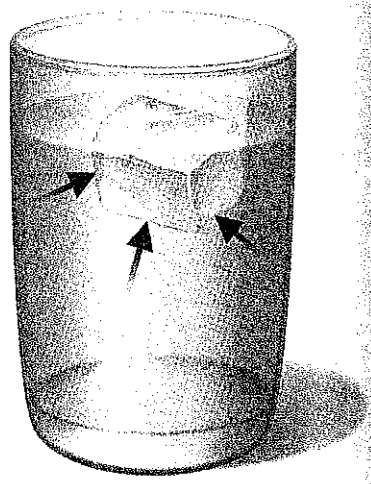
SEE ALSO
303 Equalization of Temperatures
304 Methods of Heat Transfer

303

Equalization of Temperatures

Whenever two objects come in contact with each other, heat will transfer (flow) from the object with the higher temperature to the object with the lower temperature. The heat will continue to flow until the temperature of the two objects has equalized, or reached the same temperature.

For example, suppose you place an ice cube in a glass of water. Because the water is warmer than the ice, heat flows from the water to the ice until the two reach the same temperature. Heat does not flow from the ice to the water.



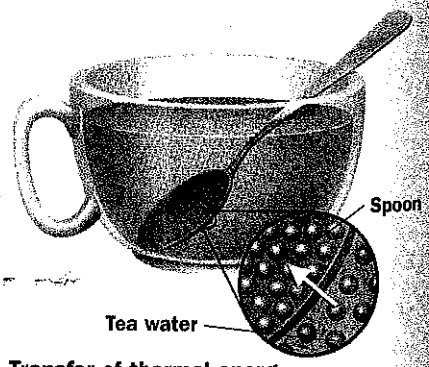
Heat flows from the warmer substance to the cooler substance.

304

Methods of Heat Transfer

There are three methods of heat transfer: conduction, convection, and radiation.

Conduction is the transfer of heat from a warmer substance to a cooler substance through direct contact. When two substances come into contact, their particles collide. The energy from the faster-moving particles is transferred to the slower-moving particles, until the particles in both substances are moving at the same speed and their temperature has equalized. Conduction is what causes the handle of a spoon placed in a cup of hot tea to warm up.



Transfer of thermal energy by conduction

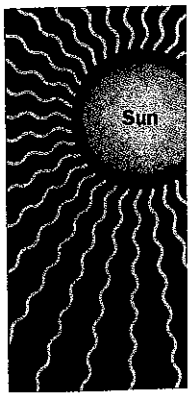
SEE ALSO
317 Current Electricity

Did You Know?

A conductor is a substance that conducts thermal energy (and other forms of energy) well. Metals tend to be better heat conductors than other solids.

Convection is tl
fluid through c
a pot of cold w
water at the bot
becomes less d
out and become
the warm water
water above it,
displaces the c
in turn, sinks. T
that results is c
The convection
energy through

Radiation is th
conduction and
of particles, rac
Earth through t

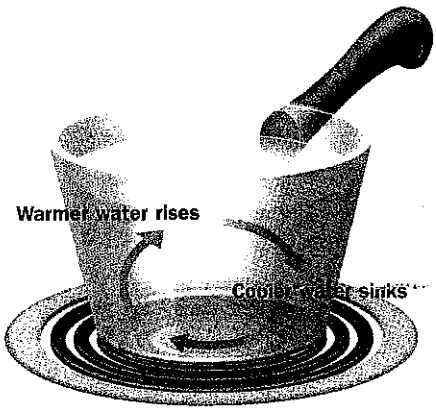


Transfer of energ

Waves

One way that e
oscillation (a b
from one place
tion.) Some wa
matter. Waves
Other waves, l
travel through
can travel thro

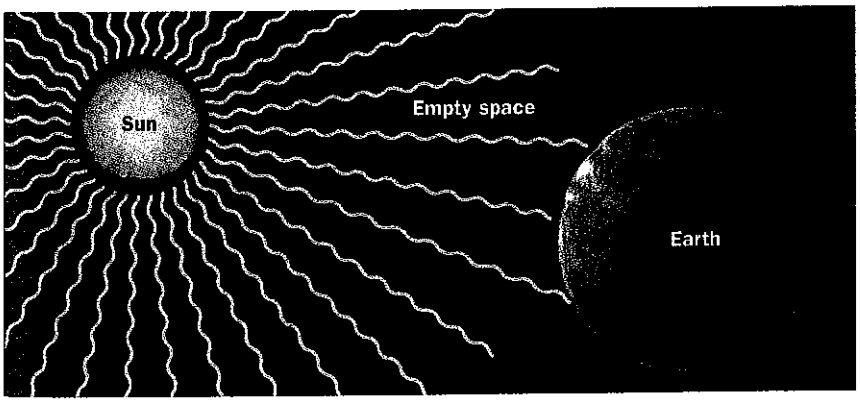
Convection is the transfer of heat in a fluid through currents. Suppose you place a pot of cold water on a hot stove. As the water at the bottom of the pot heats up, it becomes less dense (its particles spread out and become less compact). Because the warm water is less dense than the cold water above it, the warm water rises and displaces the cold water. The cold water, in turn, sinks. The movement of water that results is called a **convection current.** The convection current transfers thermal energy throughout the water in the pot.



Transfer of thermal energy by convection

Radiation is the transfer of energy as electromagnetic waves. Unlike conduction and convection, which involve the collision or movement of particles, radiation can occur through empty space. The sun heats Earth through the process of radiation.

SEE ALSO
309 Electromagnetic Spectrum
305 Waves



Transfer of energy by radiation

Waves

305

One way that energy is transported is through waves. A **wave** is an oscillation (a back-and-forth or up-and-down motion) that travels from one place to another with a certain velocity (speed and direction.) Some waves, like sound waves and water waves, travel through matter. Waves that travel through matter are called **mechanical waves.** Other waves, like visible light, microwaves, X-rays, and radio waves, travel through empty space (as well as through matter). Waves that can travel through empty space are called **electromagnetic waves.**

SEE ALSO
308 Light
312 Sound
186 Earthquakes

CHAPTER 11

ENERGY – FORCES – MOTION

- ***THE PHYSICAL SETTING: KEY IDEA 4***
  Energy exists in many forms, and when these forms change energy is conserved.
- ***THE PHYSICAL SETTING: KEY IDEA 5***
  Energy and matter interact through forces that result in changes in motion.

Forms of Energy

Energy is the ability to do work. Energy explains why an object is at rest or in motion. Energy is needed for matter to move.

Energy can be measured, but it is invisible. We can only observe the effects of energy. We see a tree swaying because of energy in the atmosphere, we cannot see the energy. There are many forms of energy.

FORM OF ENERGY	SOURCE	EXAMPLES
Mechanical	moving parts	muscles, machines, wind, rivers, waves
Chemical	molecules, compounds, elements	fossil fuels, food, batteries
Solar	energy from the Sun	heat, light, and ultraviolet radiation
Electrical	movement of electrons	lightning, electric current
Heat (thermal)	movement of the particles in a substance	heat lamp, fire, infrared radiation
Nuclear	atomic nuclei	uranium fuel
Geothermal	heat from inside Earth	hot springs, geysers
Sound	vibration of matter	thunder, piano, guitar
Light	waves of energy bundles called photons	Sun, light bulb

Review Questions

1. The major source of energy for Earth is the _____.
2. Oil and coal are forms of _____ energy.
3. The result of atoms splitting apart is _____ energy.
4. Energy from the inside of Earth is _____ energy.
5. The vibration of matter is _____ energy.
6. The movement of air molecules causes _____ energy.
7. The Sun gives off heat, light, and _____ radiation.
8. An infrared lamp gives off _____ energy.

Energy Transformations

Most activities in everyday life involve one form of energy being **transformed** (changed) into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. When you exercise, you transform chemical energy from digested food to mechanical energy in your muscles. In chemical reactions, energy is transferred into or out of the chemical reaction. This may involve the transfer of light, electricity, or mechanical motion.

During energy transformations, heat is always produced. Some transformations produce a large amount of heat, others very little. When you walk, your feet produce heat as they rub against the ground. A lamp transforms electrical energy to light energy, but heat is also produced so the lamp gets hot. During energy transformations energy is not created or destroyed, it only changes form. This is the *Law of Conservation of Energy.*

Review Questions

9. Most activities involve one form of energy being _____ to another form.
10. When energy transformations occur _____ energy is always produced.
11. The *Law of Conservation of Energy* states that energy cannot be created or _____.
12. Complete the chart for energy transformations that occur in different devices.

Device	Starting Energy	Changes to...
Battery	**a.**	Electrical energy
Clothes dryer	Electrical energy	**b.**
Car engine	Chemical energy	**c.**
Fireplace	**d.**	Heat Energy
Fan	Electrical energy	**e.**
Drum	**f.**	Sound energy

Kinetic and Potential Energy

All forms of energy exist as kinetic or potential energy. **Kinetic energy** is the energy of a moving object. A speeding car and a rolling ball both have kinetic energy. **Potential energy** is found in a resting object in the form of stored energy. A parked car has potential energy, a moving car has kinetic energy. A battery has potential chemical energy. A waterfall has kinetic mechanical energy.

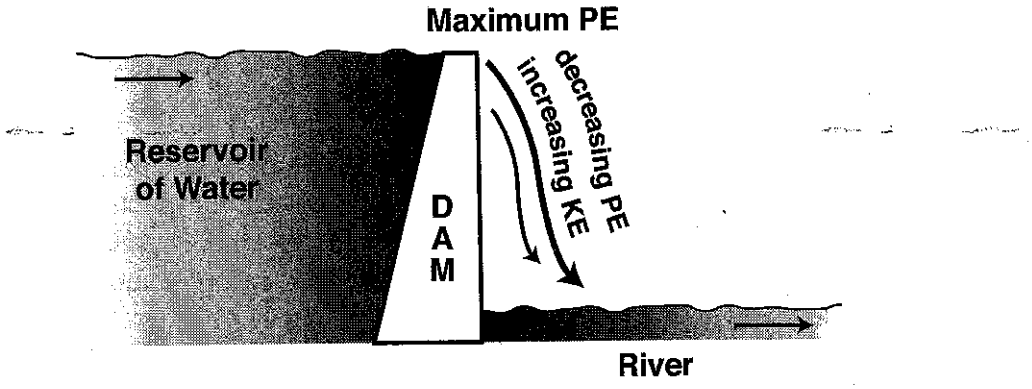


FIGURE 1. POWER DAM

The potential energy an object has is often a result of its position. The higher up an object is, the more potential energy it has. Water at the top of a power dam has potential energy equivalent to the height. When the water is allowed to fall through the dam the potential energy is converted to kinetic energy.

Review Questions

13. The wind has _____ mechanical energy.

14. A battery has _____ chemical energy.

15. At the top of a roller coaster, the car has the most _____ energy.

16. As a skier goes down a hill, potential energy will _____.

Forces

A **force** is a pull or a push that affects an object. A force can cause movement, stop movement, or change the speed and direction of movement. The amount of force applied is measured with a **spring scale**. The metric unit of force is the newton (N).

There are many types of forces. Electric force is caused by the electric attraction between positive and negative charges. This holds matter together and causes static cling on clothing.

CHAPTER REVIEW

1. What type of energy does a moving river have?
   (1) chemical (2) mechanical (3) electrical (4) thermal

2. Which type of energy is contained in a tank of gasoline?
   (1) chemical (2) mechanical (3) electrical (4) thermal

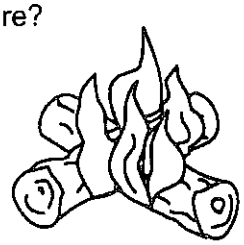
3. Thermal pollution refers to the harmful addition of what type of energy to the water and air?
   (1) heat
   (2) ultraviolet radiation
   (3) nuclear
   (4) electrical

4. The heat energy in magma beneath Earth's surface is classified as:
   (1) nuclear (2) solar (3) mechanical (4) geothermal

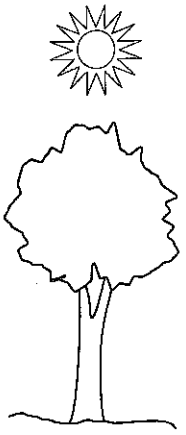
5. Which of the following is a force?
   (1) gravity (2) temperature (3) heat (4) sound

6. What is the energy transformation that occurs in a ceiling fan?
   (1) electrical to chemical
   (2) electrical to mechanical
   (3) mechanical to electrical
   (4) mechanical to thermal

7. What energy transformation is occurring in a campfire?
   (1) chemical to thermal
   (2) chemical to mechanical and thermal
   (3) chemical to light and thermal
   (4) thermal to light



8. What energy transformation occurs in a green plant on a sunny day?



   (1) light energy to mechanical energy
   (2) light energy to chemical energy
   (3) chemical energy to light energy
   (4) chemical energy to mechanical energy

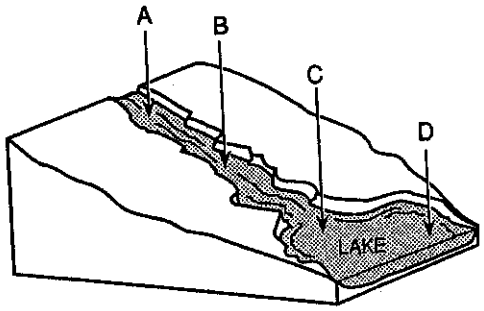
9. What energy transformation occurs when you rub your hands together?
(1) mechanical energy to heat energy
(2) mechanical energy to chemical energy
(3) chemical energy to heat energy
(4) heat energy to mechanical energy

10. Stored energy is
(1) friction
(2) potential energy
(3) kinetic energy
(4) gravitational energy

11. Which of the following groups all have kinetic energy?
(1) falling rock, rolling ball, burning log
(2) piece of coal, falling rock, rolling ball
(3) piece of coal, parked car, battery
(4) battery, falling rock, rolling ball

12. On a windy day a spinning windmill has
(1) potential mechanical energy
(2) kinetic mechanical energy
(3) kinetic thermal energy
(4) potential thermal energy

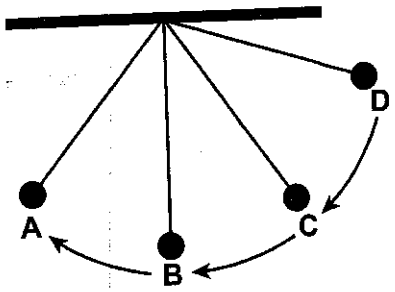
13. The diagram below shows the side view of a stream moving down a hill. At which position will the water in the stream have the most potential energy?



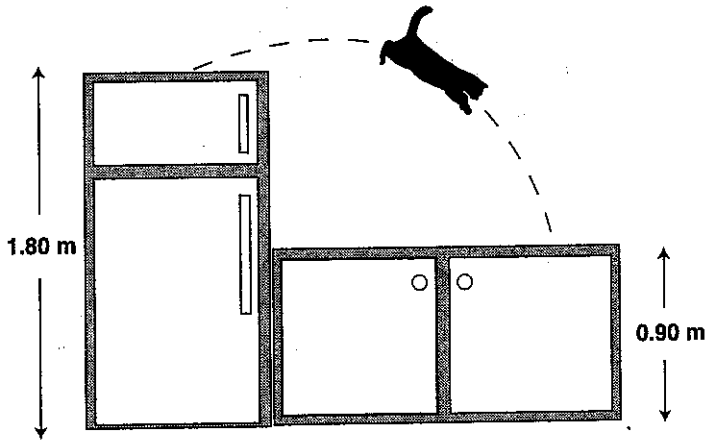
(1) A (2) B (3) C (4) D

14. The diagram shows a swinging pendulum. At which point does the pendulum have the most kinetic energy?

(1) A
(2) B
(3) C
(4) D



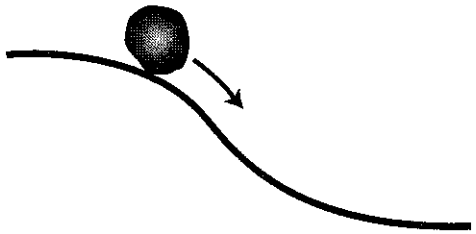
15. The diagram shows a kitten jumping from the top of the refrigerator to the kitchen counter.



Compared to the kitten's potential energy at the top of the refrigerator, its potential energy on the counter is:

(1) less (2) more (3) the same

16. Which energy transformation occurs as a rock rolls down a mountain?



(1) The rock's potential and kinetic energy decreases
(2) The rock's potential energy decreases and kinetic energy increases
(3) The rock's potential energy increases and kinetic energy decreases
(4) The rock's potential and kinetic energy increases

17. Which force causes avalanches and landslides?

(1) gravity (2) magnetic (3) electrical (4) friction

18. Which force causes a ball rolling down the street to slow down?

(1) gravity (2) magnetic (3) electrical (4) friction

Heat Energy

Another form of electromagnetic energy is infrared radiation, also known as **heat.** Matter is made up of tiny particles. These particles are always in motion. Heat or thermal energy makes the particles of matter move faster. The particles move faster and further apart as heat is added. Most substances **expand** when heated. When heat energy is removed from a material, the particles will move slower and closer together. Most materials will **contract** when cooled. Water is the exception, it expands as it cools and changes to ice.

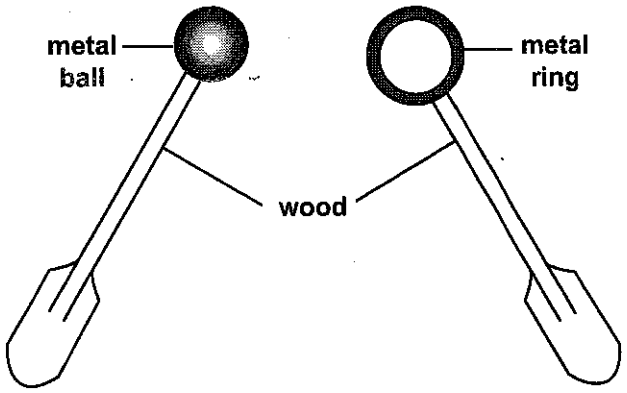


FIGURE 9. WHEN THE BALL IS COOL IT WILL PASS THROUGH THE RING. WHEN THE BALL IS HEATED, IT EXPANDS, AND WILL NOT FIT THROUGH THE RING.

Heat is a form of kinetic energy. Heat and temperature are not the same. **Temperature** indicates that heat energy is present. Heat affects the temperature of a substance. When heat is added, the temperature usually increases. When heat is removed, the temperature usually decreases. Heat moves in a predictable way. It flows from warm objects to cooler ones, until both reach the same temperature.

The unit of heat is the calorie. It takes one calorie of heat to raise the temperature of one gram of water by 1 degree Celsius. You may be familiar with food Calories. Food Calories are equal to 1000 calories.

Substances will heat faster or slower, depending on their color, texture, and type of material. Dark colors absorb energy faster than light colors. Black asphalt will heat faster than sand. Rough textures will absorb faster than smooth surfaces which reflect energy. Soil will heat faster than water.

Review Questions

26. Heat is a form of electromagnetic energy known as _____ radiation.

27. Most substances will _____ when heated.

28. When a material is cooled, the substance will usually _____.

29. When heat is removed, the temperature _____.

30. For each statement select the process that is occurring.

	Description	Reflection	Absorption
a.	A shiny, smooth surface		
b.	We see the Moon at night		
c.	A dark shirt becomes very warm		
d.	We see our face in a mirror		

Changes in the Phases of Matter

Matter can change state or phase when heat is absorbed or released. This is a physical change, there is no chemical change in the substance. When heat is added, molecules gain energy from the environment. As heat is added to water, the molecules move faster and further apart. They finally move fast enough to escape from their container as vapor. Energy is absorbed when a solid changes to a liquid (melting), or when a liquid changes to a gas (**evaporation**). When heat is removed, the particles of matter lose energy. Heat is removed when gases change to a liquid (**condensation**), or a liquid changes to a solid (**freezing**).

A substance's **freezing point** is the temperature at which its liquid form changes to a solid. Liquid water changes to ice at 32°F or 0°C. Every liquid has its own freezing point. Alcohol freezes at –117°C, and ocean water at –1°C. The melting point is the same as the freezing point. Melting will occur when heat is added, freezing will occur when heat is removed.

A substance's **boiling point** is the temperature when it evaporates, or changes from a liquid to a gas. Alcohol boils at 78°C; water boils at 100°C. Water vapor will condense at 100°C when heat is removed.

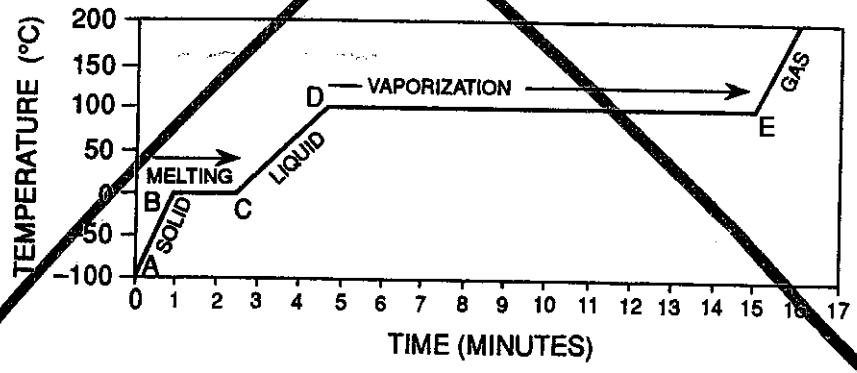


FIGURE 10. PHASE CHANGE

Methods of Energy Transfer

All types of energy can be transferred between locations, objects, or through matter in three ways: conduction, convection, and radiation. Energy is transferred through empty space by **radiation.** During radiation energy moves from one object to another without direct contact or matter in between. This is how electromagnetic radiation from the Sun reaches Earth.

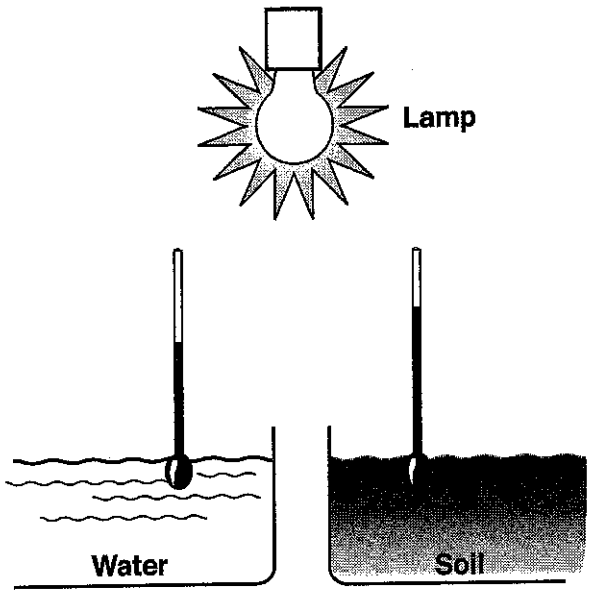


FIGURE 11. RADIATION

Conduction is the flow of energy through a solid by the collisions of its atoms or molecules. Energy is transferred by direct contact. The handle of a pot on the stove may get hot, even though the flame is not near it. Conductors are materials that allow energy to move through easily. This is why metal pots are used in cooking. Poor conductors are called insulators. They keep heat in and prevent heat from moving from place to place. This is why pot handles are often made of wood or plastic.

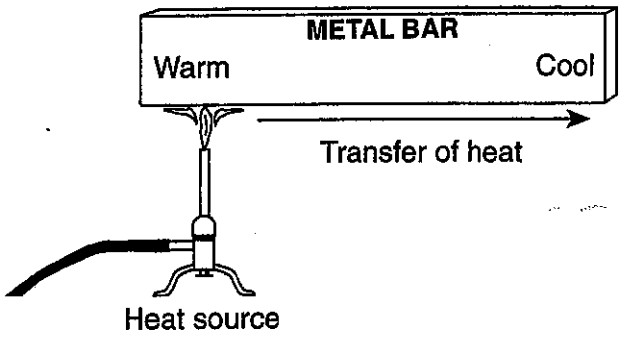


FIGURE 12. CONDUCTION

Convection is the flow of energy within a gas or a liquid. It is caused by density differences. Cold, dense air and water will sink causing the less dense, warm air or water to rise. This circulation of energy causes **convection currents**. This is why you are instructed to drop to the floor in a fire. The cooler air is at the bottom of the room.

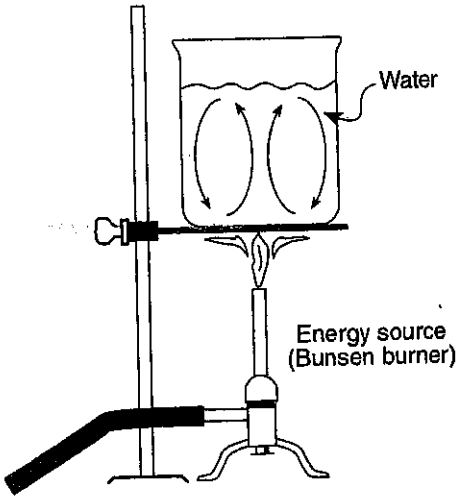


FIGURE 13. CONVECTION

Review Questions

37. Energy is transferred by direct contact during _____.

38. Hot air is _____ dense than cold air.

39. Heat circulates through the air in a classroom by _____.

40. Place an "**X**" in the column for the method of energy transfer described.

	Description	Radiation	Conduction	Convection
a.	Radio waves travel through space			
b.	Heat travels through a metal spoon			
c.	Electricity travels through an electric cord			
d.	Food is warmed in a microwave			
e.	Ocean water circulates by currents			
f.	Sunlight passes through a window			

10. A surface reflects 90 percent of the light that hits it. This surface is most likely:

(1) dark colored and rough textured
(2) dark colored and smooth textured
(3) light colored and smooth textured
(4) light colored and rough textured

11. Compared to a dull and rough surface, a shiny and smooth surface will most likely cause sunlight to be

(1) reflected (2) refracted (3) scattered (4) absorbed

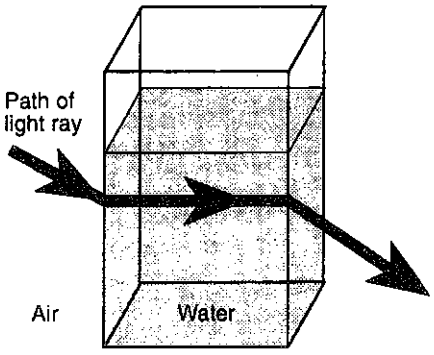
12. Changing the color of the roof of a house from light to dark would probably increase the amount of solar energy that is

(1) reflected (2) created (3) refracted (4) absorbed

13. On a sunny day changing your shirt from a light color to a dark color would make you feel

(1) cooler due to reflection
(2) cooler due to absorption
(3) warmer due to absorption
(4) warmer due to reflection

14. The diagram below shows the path of visible light as it travels from air through water. The light did not travel in a straight line because of



(1) reflection (2) refraction (3) diffraction (4) convection

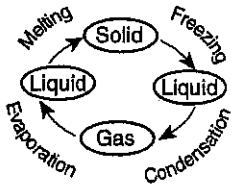
15. If you can not remove a metal cap from a glass jar, it might be helpful to place the cap under hot water. Which of the following supports this advice?

(1) Heating causes metal to contract faster than glass.
(2) Heating causes metal to expand faster than glass.
(3) Heating does not cause metals or glass to change.

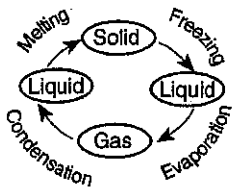
16. Complete the statement: Cooling is to contracting, as heating is to

(1) vibrating (2) expanding (3) shortening (4) boiling

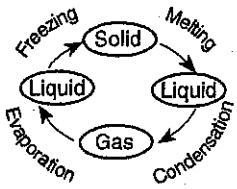
17. Which diagram correctly shows the processes that change the states of matter?



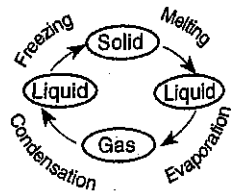
(1)



(2)



(3)



(4)

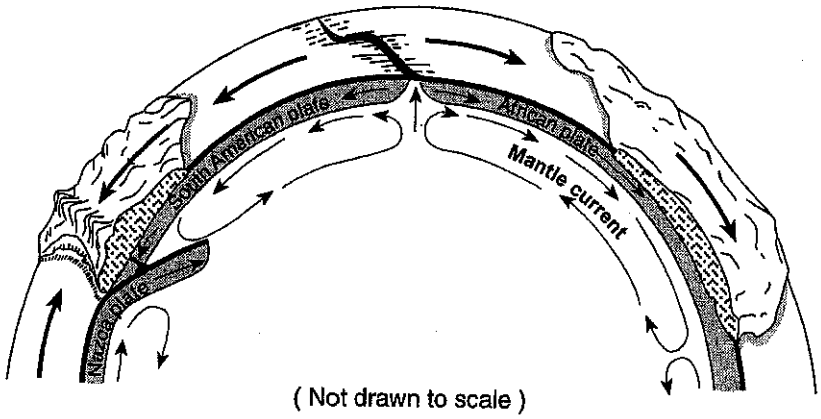
18. The change in phase from gas to liquid is called

(1) evaporation (2) condensation (3) precipitation (4) transpiration

19. Water releases energy when it changes phase from

(1) liquid to solid (2) solid to liquid (3) liquid to gas (4) solid to gas

20. The diagram below shows the movement of crustal plates. The arrows in the mantle indicate the flow of heat energy by:



(Not drawn to scale)

(1) conduction (2) convection (3) radiation (4) refraction

21. On a clear summer night the ground cools off by

(1) conduction (2) convection (3) radiation (4) refraction

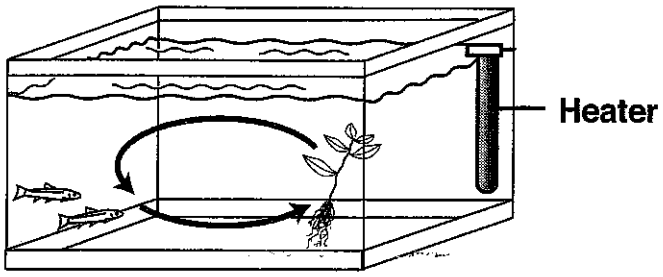
22. On Earth the movement of air by winds and currents is due to

(1) conduction (2) convection (3) radiation (4) refraction

23. Light from *Polaris*, the North Star, travels to Earth by

(1) conduction (2) convection (3) radiation (4) refraction

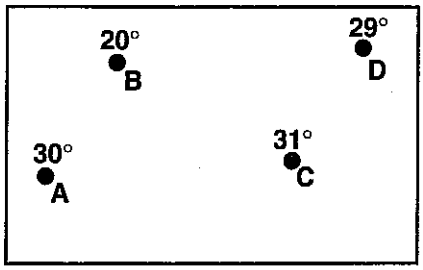
24. A piece of plant in a fish tank moved up and across the tank away from the water heater. When the plant reached the other side of the fish tank, it sank. What type of energy transfer does this movement show?



(1) convection (2) conduction (3) refraction (4) radiation

25. The map shows four locations with the temperature of each given in Celsius. Heat will flow from:

(1) A to B
(2) A to C
(3) B to D
(4) D to C



26. During a sunny afternoon it will become warmer because air molecules
(1) move faster (2) move slower (3) stop moving

27. Which action would help an air-conditioner use less energy on a hot, summer day?
(1) opening the curtains and blinds
(2) opening the windows
(3) turning on the lights and stove
(4) adding extra insulation in the walls and ceiling