Assessment Anchors and Eligible Content: S8.C.2.1.1, S8.C.2.1.3

Review 12

Energy and Its Transformations

Energy is all around you. When you wake up in the morning, your body needs energy to get out of bed. As you turn on the lights in your bedroom, you use energy to flip the light switch, and the lightbulb provides you with light energy. When you eat breakfast, you are consuming food as a source of energy. After breakfast, you step outside and feel the warmth from the Sun (solar energy) and hear the song of a bird (sound energy) in the trees.

It is clear that energy is everywhere, but what exactly *is* energy? Can it be measured? How have humans harnessed energy to help us with our everyday needs? In this review, you will learn answers to these questions and more.

Above: A field of wind turbines under the Sun. Several wind farms have been built in Pennsylvania in recent years.

Words to Know

- chemical energy
- conduction
- conservation of energy
- convection
- electrical energy
- energy
- heat energy
- joule
- kinetic energy
- mechanical energy
- nonrenewable resource
- nuclear energy
- potential energy
- radiation
- renewable resource
- solar energy
- sound energy
- work

Defining Energy

Scientists say that **energy** is the ability to make a force that moves matter. In other words, energy is the capacity to do work. **Work** is done when a force is applied to matter, and the matter moves in the direction that the force acts. The unit for both energy and work is the Newton-meter (N-m), which scientists have named the **joule** (J). One joule of work is done when 1 N of force moves an object 1 m. When you lift an apple from a table to your mouth, you are doing about 1 J of work.

Types of Energy

Energy comes in many forms. Several important types are listed below. Keep in mind that there are other types of energy not listed here.

- **Chemical energy:** Energy stored in the bonds between atoms in molecules. When chemical bonds are made or broken, energy is absorbed or released. For example, when a leaf uses sunlight to bind carbon dioxide and water molecules into a sugar molecule, it is storing energy in chemical bonds within that sugar molecule.
- **Electrical energy:** Energy produced when electrons flow through materials or jump from one place to another. The light and heat in a lamp results from electrical energy; so does a bolt of lightning in the sky.
- **Heat energy:** Scientists define the heat of a substance as the average kinetic energy (energy of motion) of all the particles in that substance. A glass of warm water has more heat energy than an equal-sized glass of cold water because the molecules of the warm water are, on average, moving faster than the molecules of the cold water.
- **Mechanical energy:** This type of energy consists of two types of energy: kinetic energy, or energy of motion; and gravitational potential energy, or the energy that an object has due to its position above the Earth's surface. You will learn more about kinetic and gravitational potential energy later in this review.
- **Nuclear energy:** Energy associated with the nucleus of an atom. Nuclear energy is released when the nucleus of an atom splits or when the nuclei of two atoms fuse.
- **Solar energy:** Solar energy comes from the Sun and includes visible light and infrared energy. Solar energy is an electromagnetic wave, so it can travel through a vacuum, which is the complete absence of matter.
- **Sound energy:** Sound energy is a vibration that moves through solids, liquids, and gases. Sound travels most quickly through a solid and most slowly through a gas. Unlike solar energy, sound energy needs a medium (some kind of matter through which to travel).

Of the types of energy listed above, which type is commonly transported through metal wires?

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Energy Transformations

Energy can be transformed from one form to another. Suppose that you run down the street one afternoon. Some of the chemical energy from food you ate earlier in the day is released and converted into kinetic energy that makes your muscles move your bones. When your feet hit the pavement, some of your kinetic energy turns into sound energy. And, whether you're running down the street or reading a book, your body is always turning some of the chemical energy from food into heat energy to keep you warm.

Turn back to the first page of this review. Name one energy transformation that is taking place in the photograph on that page.

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Describe three energy transformations that occur when a car engine burns gasoline.

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Although energy can be transformed from one form to another, it can never be created or destroyed. This principle is called the law of **conservation of energy**. No energy transformation is perfectly efficient, however. During an energy transformation, some energy is always converted into heat energy that does no useful work. When gasoline burns in a car, for example, only about 40% of the chemical energy in the gasoline is actually transformed into the kinetic energy of the car. The rest of the energy that is released when gasoline is burned is turned into heat energy that does no useful work.

Kinetic and Potential Energy

Let's look more closely at mechanical energy. Mechanical energy consists of two components. The first is **kinetic energy**, or the energy of an object in motion. Any object in motion has kinetic energy. A school bus driving down the street, a bird flying, a penny dropping from your pocket, and a baseball sailing through the air—all of these objects have kinetic energy because they are in motion. The amount of kinetic energy of an object depends on two factors: its speed and its mass. If two objects have the same mass but move at different speeds, then the object that moves quickly has more kinetic energy than the object that moves slowly. If two objects move at the same speed but have different masses, the heavier object has the greater amount of kinetic energy.

A feather and a bowling ball dropped on the Moon would hit the ground at the same time. Which item would have more kinetic energy? Explain your answer.

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The second component of mechanical energy is potential energy. **Potential energy** is stored energy, or energy of position. Potential energy increases as you push an object away from something that is pulling on it. Have you ever been downhill sledding? In the case of the sled, trudging up the hill increases the distance between you and the center of the Earth. When you stop doing work and hop back on the sled, gravity begins to convert the potential energy into kinetic energy.

If you do work to push or pull something away from gravity, you are giving it gravitational potential energy (GPE). A can on a shelf, an apple on a tree, or a sled at the top of a hill all have GPE. There are other types of pulls besides gravity, of course. An important type of pull is elasticity. If you pull back a slingshot, for example, you are putting elastic potential energy (EPE) into the system.

Why do you think that the potential energy of a car parked on a hill is not completely changed into kinetic energy when the car rolls down the hill? (Hint: Remember that no energy transformation is 100% efficient.)

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Solar Energy

Much of the energy on the Earth can be traced back to the Sun. Let's look at an example of this. You turn on the television, which converts the electrical energy in the wires into sound and pictures. But where did the electrical energy come from? Your power company might burn coal or oil to generate the electrical energy that they sell you. When the fuel burns, it creates lots of heat energy that is used to create steam. The steam is made of fast moving water molecules with lots of kinetic energy. The steam turns a turbine, which then turns a device that generates electricity. The oil or coal that begins this process is ancient, organic material made of dead plants and animals that heat and pressure have transformed into hydrocarbon compounds. The energy stored in these compounds is similar to the energy stored in plants and animals that are still alive; all of this energy comes from the Sun!

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Give another example of a series of energy transformations that can be traced back to the Sun.

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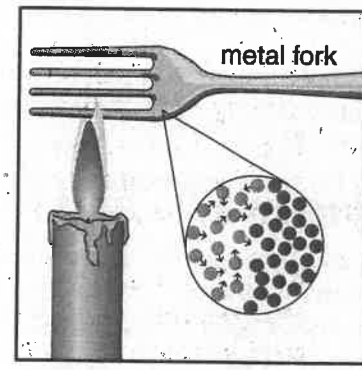
Heat Energy and Its Movement

Heat energy is the average energy of motion of all the particles of a substance. One property of heat energy is that it naturally flows from areas of higher to lower temperature. There are three common ways in which heat energy flows within substances or from one substance to another.

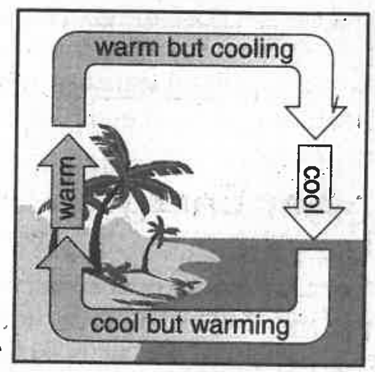
In **conduction**, heat energy transfers when particles with greater kinetic energy collide with less-energetic particles. For example, a metal fork held over a candle flame will heat up first at one end, while the other end of the fork remains cool. However, the high-energy particles at the hot end of the fork immediately start colliding with low-energy particles closer to the handle. This transfers kinetic energy to the low-energy particles, which then collide with even lower-energy particles further up the handle. Given sufficient time, enough heat energy moves into the fork to increase the kinetic energy of all of the particles, not just those directly over the flame. (Hold the fork long enough, and the particles in the fork will start donating their kinetic energy to your fingers. Ouch!)

Conduction



In **convection**, heat energy transfers through the movement of a substance. An example of convection occurs on a sunny day near the ocean. Land heats up more quickly than water, so the air over the land warms, becomes less dense, and rises. This pulls in cooler air from over the water, which then heats up and rises. A cycle is set up in which the warmed air then moves over the water, cools, becomes more dense, and falls to the surface of the ocean. This cooled air is then pulled back in to the land, and the cycle continues.

Convection



Land not only heats up more quickly than water, it also cools down more quickly than water. Predict what happens to the land-ocean convection cycle at night.

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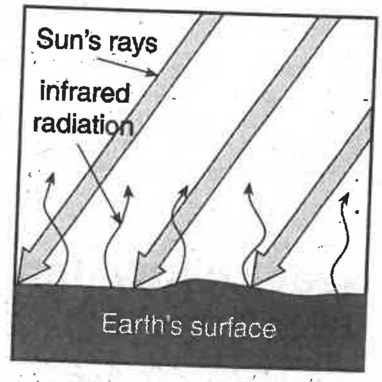
In **radiation**, electromagnetic waves interact with particles in matter and increase their kinetic energy. The Sun's rays are electromagnetic waves that heat the Earth's surface. The Earth's surface then releases its heat energy to the atmosphere in the form of infrared radiation. Radiation differs from conduction and convection in that no direct physical contact is necessary to transfer the heat energy. (This is a good thing, in the case of the Sun.)

Radiation



When a candlewick burns, the flame heats the air, and the wax softens and melts. Discuss how a burning candle demonstrates two ways that heat energy flows.

Renewable and Nonrenewable Energy Sources

In modern society, many sources of energy—chemical, solar, nuclear—are converted into electrical energy. This is because electrical energy can be easily sent through wires to power our businesses, factories, stores, and homes. Modern society requires a large supply of energy resources to produce so much electricity. But energy resources are not endless. Resources that nature cannot replace within a human life span are called **nonrenewable resources**. For example, fossil fuels such as coal, oil, and natural gas took millions of years for nature to create from the remains of dead organisms. Once such resources are used up, they are gone forever—at least as far as human civilization is concerned.

Resources that nature can replace quickly are called **renewable resources**. Solar, wind, hydroelectric, and geothermal plants are all examples of facilities that use renewable resources to produce energy.

- A solar energy plant transforms the energy from sunlight either directly into electricity or into heat that produces steam that turns a turbine.
- A wind farm is a vast field of wind turbines, as in the photo on page 141. The wind causes the blades to move, which causes the turbine to generate electricity.
- The most common form of hydroelectric energy plant is a dam. A dam uses the kinetic energy of moving water to turn a turbine, which generates electricity.
- Geothermal plants are built in areas where the rock layer just below the Earth's surface is especially hot. These hot rocks turn liquid water into steam, which a geothermal plant then uses to turn a turbine for electricity.
- Biomass refers to plant or animal products that can be used to produce energy. Corn, for example, can be used to make ethanol, a substitute for gasoline. As another example, organic waste that decomposes in a landfill produces a gas called methane. Methane can be burned to produce heat.

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Why can't geothermal or hydroelectric plants be built just anywhere?

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Keys to Keep

- **Energy is the ability to perform work.**
- **Energy can be transformed but cannot be created or destroyed.**
- **The Sun is the source of much of the energy on the Earth.**
- **Mechanical energy includes kinetic energy and gravitational potential energy.**
- **Heat energy naturally flows from regions of higher to lower temperature.**
- **Renewable sources of energy are replenished quickly; nonrenewable sources are not.**

People in Science

One of the greatest inventors and thinkers of ancient times was the Greek mathematician Archimedes. He showed how levers could lift great weights, and he invented the compound pulley, with which he is said to have lifted a ship full of passengers. He is credited with inventing an irrigation system. He was a master of thinking up tools of war, including a catapult to hurl rocks and burning objects. He also solved problems for the king of his region. The king once suspected his goldsmith of cheating him by including other, lesser metals in a supposedly gold crown. He asked Archimedes to prove the trickery. Archimedes was having trouble with the problem, until one day he climbed out of the bathtub and noticed how the water level dropped. The tub was more full with him in it than after he climbed out. He made the connection between his body volume and the weight of water he displaced. As the story goes, the idea so excited him that he ran out onto the streets without bothering to dress, shouting "Eureka!" (I have found it!). He tested the crown using this idea of displacement and discovered the king had indeed been cheated. He also used this same idea to explain how objects float in liquid.

Archimedes
(Greece, around 287 B.C.–212 B.C.)

SCIENCE

1. Two metal blocks have temperatures of 30° C and 10° C. Both blocks are made of the same material. The hotter one is three times the size of the cooler one. Their temperatures are not affected by anything but each other. Once they have reached the same temperature, **about** what temperature will that be?

   A 10° C
   B 15° C
   C 25° C
   D 30° C

2. A pole vaulter runs with the pole, plants it in the ground, rises up in the air, and soars over the bar. Which of the following statements is **not** true about the energy transformations?

   A The place where the pole vaulter has the least potential energy is at the top of his vault.
   B As the pole vaulter plants the pole, part of the vaulter's kinetic energy is released in the form of heat.
   C The force of gravity is one cause of the changes in the pole vaulter's potential energy.
   D As the pole vaulter falls after he soars over the bar, he is gaining kinetic energy.

3. Which energy resource is nonrenewable?

   A natural gas
   B solar
   C wind
   D biomass

4. After a hot day, the temperature cools and John opens windows both upstairs and downstairs in his house. Cool air enters through the downstairs windows and hot air exits through the upstairs windows. What sort of heat transfer has occurred?

   A conduction
   B convection
   C radiation
   D reflection

5. What type of energy transformation occurs when you turn on a toaster?

   A light into heat
   B electrical into light and heat
   C nuclear into electrical
   D electrical into chemical

6. In Iceland, some power plants inject water deep into the Earth. There, the water heats up and turns into steam. The steam returns to the power plant, where it turns a turbine that makes power for lights, televisions, and so on. Which type of energy transformation occurs within these power plants?

A geothermal to electrical
B radiant to geothermal
C chemical to magnetic
D mechanical to geothermal

7. A car company designs two new types of engines. When the two engines use gasoline at the exact same rates, Engine 1 gets hotter than Engine 2. Which engine is more efficient, and why?

A Engine 1, because it produces more heat than Engine 2.
B Engine 2, because it uses less gasoline than Engine 1.
C Engine 1, because it uses less gasoline than Engine 2.
D Engine 2, because it produces less heat than Engine 1.

8. Corinne and Mischa were camping in the woods. Corinne used a match to light a campfire. As Mischa watched the flames dance, she marveled at how such a little amount of energy (the match flame) could create such a big amount of energy (the fire).

A. Describe one energy transformation taking place in this situation.

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B. Mischa's statement is incorrect. Identify the flaw and correct her statement.

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