

Conservation of Energy

6-5 The student will demonstrate an understanding of the law of conservation of energy and the properties of energy and work. (Physical Science)

6-5.1 Identify the sources and properties of heat, solar, chemical, mechanical, and electrical energy.

Taxonomy level: 1.1-B Remember Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concepts of sources of heat and how heat moves by conduction in 3rd grade (3-4.3 and 3-4.4). In 4th grade (4-5), students demonstrated an understanding of the properties of light and electricity. In 5th grade, students have been introduced the concept of matter being composed of very small particles (5-4.1) that can form new substances when they are mixed (5-4.7) and to the concepts of motion and position (5-5.2). Students will further develop the concept of energy traveling in waves in 8th grade (8-6.8).

It is essential for students to know that energy can be in many different forms. Students should know sources and properties of the following forms of energy:

Heat energy

- Heat energy is the transfer of thermal energy (energy that is associated with the motion of the particles of a substance).
- Remember that all matter is made up of particles too small to be seen (5th grade).
- As heat energy is added to a substance, the temperature goes up indicating that the particles are moving faster. The faster the particles move, the higher the temperature.
- Material (wood, candle wax) that is burning, the Sun, and electricity are sources of heat energy.

Solar energy

- *Solar energy* is the energy from the Sun, which provides heat and light energy for Earth.
- *Solar cells* can be used to convert solar energy to electrical energy.
- Green plants use solar energy during photosynthesis (6-2.7) to produce sugar, which contains stored *chemical energy*.
- Most of the energy that we use on Earth originally came from the Sun.

Chemical energy

- *Chemical energy* is energy stored in particles of matter.
- Chemical energy can be released, for example in batteries or sugar/food, when these particles react to form new substances.

Electrical energy

- *Electrical energy* is the energy flowing in an electric circuit.
- Sources of electrical energy include: stored chemical energy in batteries; solar energy in solar cells; fuels or hydroelectric energy in generators.

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Mechanical energy

- *Mechanical energy* is the energy due to the motion (kinetic) and position (potential) of an object. When objects are set in motion or are in a position where they can be set in motion, they have mechanical energy.
 - *Mechanical Potential energy: Potential energy* is stored energy. Mechanical potential energy is related to the position of an object. A stretched rubber band has potential energy. Water behind a dam has potential energy because it can fall down the dam.
 - *Mechanical Kinetic energy: Kinetic energy* is the energy an object has due to its motion. Mechanical kinetic energy increases as an object moves faster. A moving car has kinetic energy. If the car moves faster, it has more kinetic energy.

NOTE TO TEACHER: Other types of energy can also be classified as potential and kinetic, but 6th grade students are only responsible for kinetic and potential mechanical energy.

It is not essential for students to know the terms *chemical reactions* or *changes* for chemical energy. They also do not need to know about electrons associated with electrical energy. The concept of nuclear energy will be addressed in high school.

Assessment Guidelines:

The objective of this indicator is to *identify* the sources and properties of heat, solar, chemical, mechanical, and electrical energy; therefore, the primary focus of assessment should be to retrieve from memory sources and properties of the forms of energy listed. However, appropriate assessments should also require students to *recognize* forms of energy by their sources.

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6-5.2 Explain how energy can be transformed from one form to another (including the two types of mechanical energy, potential and kinetic, as well as chemical and electrical energy) in accordance with the law of conservation of energy.

Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/Future knowledge: In 4th grade (4-5.5), students explained how electricity could be transformed into other forms of energy (including light, heat, and sound). Students will further develop these concepts in high school Physical Science (PS-6.1).

It is essential for students to know that the *Law of Conservation of Energy* states that energy cannot be created or destroyed. It may be transformed from one form into another, but the total amount of energy never changes. Energy can be changed from one form to another as follows:

Mechanical energy transformations

The mechanical energy that an object has may be kinetic energy or potential energy or some combination of the two. Energy transformations can occur between the two types of mechanical energy.

Examples of potential ↔ kinetic mechanical transformations might include:

- When water is behind a dam, it has potential energy. The potential energy of the water changes to kinetic energy in the movement of the water as it flows over the dam.
- When a rubber band is stretched, kinetic energy is transformed into potential energy.
- When a stretched rubber band is released its potential energy is transformed into kinetic energy as the rubber band moves.
- When a book is lifted to a shelf, kinetic energy is transformed into potential energy.
- If the book falls off the shelf the potential energy is transformed to kinetic energy.

It is essential for students to understand situations when potential energy is greater and when kinetic energy is greater.

Mechanical energy transformations may involve other kinds of energy. Examples might include:

- When the book in the example above hits the floor the kinetic energy is transformed into other forms of energy such as sound and heat.
- The water that runs over the dam might be used to power an electric generator and thus the mechanical energy associated with the water can be transformed into electrical energy.
- The water was behind the dam because the energy from the sun evaporated water and deposited it at a higher elevation so that it could flow down hill thus solar energy was transformed to potential mechanical energy.

Transformations may occur between any of the various types of energy but the energy itself is always around in some form. It is never lost. Examples might include:

- Green plants transform the Sun's energy into food which is a form of stored chemical energy.
- Animals use chemical energy from food to move. The chemical energy in the food is transformed to mechanical energy.

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- Carbon-based fuels are all derived from the bodies of plants and/or animals. When carbon-based fuels (wood, natural gas, petroleum, or coal) are burned, the chemical energy which is transformed to heat energy.
- The heat energy from fuels can be transformed to electrical energy at a power plant.
- In an electric circuit the electrical energy can be transformed into many different types of energy such as mechanical, sound, light, and heat. (See Indicator 6-5.4)
- All of the energy from the electric circuit eventually changes to another form, much of it heat energy. The energy from all of these transformations still exists. The total amount of energy is conserved.

It is not essential for students to know the formulas for potential energy and kinetic energy. Students do not need to know the chemical equation for photosynthesis.

Assessment Guidelines:

The objective of this indicator is to *explain* how energy can be transformed from one form to another in accordance to the law of conservation of energy; therefore, the primary focus of assessment should be to construct a cause-and-effect model of how energy transformations follow the Law of Conservation of Energy. However, appropriate assessments should require students to; *interpret* diagrams or illustrations related to energy transformations; or *summarize* energy transformations and how the Law of Conservation of Energy applies.

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6-5.3 Explain how magnetism and electricity are interrelated by using descriptions, models, and diagrams of electromagnets, generators, and simple electrical motors.

Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/Future knowledge: In 4th grade (4-5.9), students summarized the properties of magnets and electromagnets (including polarity, attraction/repulsion, and strength). Students have not been introduced the concept of generators and simple electrical motors in previous grade levels. Students will further develop the concepts of electromagnets, generators, and simple electrical motors in high school physical science (PS-6-11).

It is essential for students to know that *magnetism* is the force of attraction or repulsion of magnetic materials.

- Surrounding a magnet is a *magnetic field* that applies a force, a push or pull, without actually touching an object.
- An electric current flowing through a wire wrapped around an iron core forms a *magnet*.
- A coil of wire spinning around a magnet or a magnet spinning around a coil of wire can form an *electric current*.

Examples of how magnetism and electricity are interrelated can be demonstrated by the following devices:

Electromagnets

- An *electromagnet* is formed when a wire in an electric circuit is wrapped around an iron core producing a magnetic field.
- The magnet that results loses its *magnetism* if the electric current stops flowing.

Generators

- A *generator* produces an electric current when a coil of wire wrapped around an iron core is rotated near a magnet.
- Generators at power plants produce electric energy for our homes.
- A generator contains coils of wire that are stationary, and rotating magnets are rotated by turbines. Turbines are huge wheels that rotate when pushed by water, wind, or steam.
- Thus mechanical energy is changed to electrical energy by a generator. Smaller generators may be powered by gasoline.

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Simple electric motors

- An electric motor changes electrical energy to mechanical energy.
- It contains an electromagnet that rotates between the poles of a magnet.
- The coil of the electromagnet is connected to a battery or other source of electric current.
- When an electric current flows through the wire in the electromagnet, a magnetic field is produced in the coil.
- Like poles of the magnets repel and unlike poles of the magnets attract.
- This causes the coil to rotate and thus changes electrical energy to mechanical energy.
- This rotating coil of wire can be attached to a shaft and a blade in an electric fan.

It is not essential for students to know components of generators or motors, the difference between AC and DC generators, or the function of a transformer. Understanding of how a magnetic field is produced is also not essential.

Assessment Guidelines:

The objective of this indicator is to *explain* how electricity and magnetism are interrelated by using descriptions, models and diagrams of electromagnets, generators, and simple electrical motors; therefore, the primary focus of assessment should be to construct a cause-and-effect model of how electricity and magnetism are interrelated. However, appropriate assessments should also require students to *interpret* diagrams of electromagnets, generators, or electric motors showing how electricity and magnetism are interrelated; *summarize* information about how electricity and magnetism are interrelated using diagrams, models, and descriptions of devices; *compare* devices based on how they interrelate electricity and magnetism; or *recognize* devices based on their functions.

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6-5.4 Illustrate energy transformations (including the production of light, sound, heat, and mechanical motion) in electrical circuits.

Taxonomy level: 2.2-B Understand Conceptual Knowledge

Previous/Future knowledge: In 4th grade, students explained how electricity could be transformed into other forms of energy (including light, heat, and sound) (4-5.5). They also summarized the functions of the components of complete circuits (including wire, switch, battery, and light bulb) (4-5.6) and illustrated the path of electric currents in series and parallel circuits (4-5.7). Students have not been introduced to the term “mechanical motion” in previous grade levels. Students will further develop the concept of energy transformations in high school Physical Science (PS-6.1).

It is essential for students to know that *electrical energy* can be transformed to light, sound, heat, and mechanical motion in an electric circuit.

- An electric circuit contains a source of electrical energy, a conductor of the electrical energy (wire) connected to the energy source, and a device that uses and transforms the electrical energy.
- All these components must be connected in a complete, unbroken path in order for energy transformations to occur.

The electrical energy in circuits may come from many sources including:

- The electrical energy in a battery comes from stored chemical energy.
- The electrical energy in a solar cell comes from light energy from the sun.
- The electrical energy in outlets may come from chemical energy (burning fuels) which powers a generator in a power plant.

Electrical energy can be transformed to other forms of energy in a circuit.

Light

- Electrical energy can be transformed into light energy in an electric circuit if a light bulb is added to the circuit.
- The transformation in this case might be that chemical energy in a battery is transformed into electrical energy in the circuit which is transformed into light and heat energy in the light bulb.

Sound

- Electrical energy can be transformed into sound energy in an electric circuit if a bell, buzzer, radio, or TV is added to the circuit.
- The transformation in this case might be that chemical energy in a battery is transformed into electrical energy in the circuit which is transformed into sound energy by the buzzer.

Heat

- Electrical energy can be transformed into heat energy in an electric circuit if a toaster, stove, or heater is added to the circuit.

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- The transformation in this case might be that chemical energy from the fuel at the power plant is transformed into heat energy which is transformed into mechanical energy to turn a generator.
- The generator transforms the mechanical energy into electrical energy.
- Then the electrical energy in the circuit is transformed into heat energy in the heater.

Mechanical motion

- Electrical energy can be transformed into the energy of mechanical motion if a fan or motor is added to the circuit.
- Transformation in this case might be that chemical energy in a battery is transformed into electrical energy in the circuit which is transformed into the energy of mechanical motion by the fan or motor.

A generator in a circuit can change mechanical motion into electrical energy. The transformation in this case might be that chemical energy from the fuel at a power plant is transformed into heat energy which is transformed into mechanical energy to turn a generator. The generator transforms the mechanical energy into electrical energy. This is the source of energy in electric outlets.

It is not essential for students to know the mechanisms of energy transformation, only that energy transformations do occur. Students do not need to compare series and parallel circuits, know how to calculate power, or use Ohm's Law.

Assessment Guidelines:

The objective of this indicator is to *illustrate* energy transformations in electric circuits; therefore, the primary focus of assessment should be to give illustrations or use illustrations to show the concept of energy transformations (including the production of light, sound, heat, and mechanical motion) in electric circuits. However, appropriate assessments should also require students to *recall* that energy transformations can only occur when an electrical circuit is complete; *recognize* devices used to transfer electrical energy to another form of energy in an electrical circuit; or *infer* the types of energy transformations that would occur with specific devices.

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6-5.5 Illustrate the directional transfer of heat energy through convection, radiation, and conduction.

Taxonomy level: 2.2-B Understand Conceptual Knowledge

Previous/Future knowledge: In 3rd grade (3-4.3), students explained how heat moves easily from one object to another through direct contact in some materials (called conductors) and not so easily through other materials (called insulators). Students have not been introduced to the concepts of radiation or convection. Students will further develop the concept of thermal energy in high school Physical Science (PS-6.1).

It is essential for students to know energy transfer as heat can occur in three ways:

Conduction

- Conduction involves objects in direct contact.
- The transfer of energy as heat occurs between particles as they collide within a substance or between two objects in contact.
- All materials do not conduct heat energy equally well.
- Poor conductors of heat are called insulators.
- The energy transfers from an area of higher temperature to an area of lower temperature.
- For example, if a plastic spoon and a metal spoon are placed into a hot liquid, the handle of the metal spoon will get hot quicker than the handle of the plastic spoon because the heat is conducted through the metal spoon better than through the plastic spoon.

Convection

- Convection is the transfer of energy as heat by movement of the heated substance itself, as currents in fluids (liquids and gases).
- In convection, particles with higher energy move from one location to another carrying their energy with them.
- Heat transfer occurs when particles with higher energy move from warmer to cooler parts of the fluid.
- Uneven heating can result in convection, both in the air and in water. This causes currents in the atmosphere (wind) and in bodies of water on earth which are important factors in weather and climate.

Radiation

- Radiation is the transfer of energy through space without particles of matter colliding or moving to transfer the energy.
- This radiated energy warms an object when it is absorbed.
- Radiant heat energy moves from an area of higher temperature to an area of cooler temperature.

It is not essential for students to know about areas of higher or lower density of fluids. They also do not need to know about electromagnetic waves being transferred in radiation.

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Assessment Guidelines:

The objective of this indicator is to *illustrate* the directional transfer of heat energy through conduction, convection, and radiation; therefore, the primary focus of assessment should be to give illustrations or use illustrations to show the concept of heat transfer through conduction, convection, or radiation. However, appropriate assessments should also require students to *recognize* the types of heat transfer based on descriptions of how particles behave; *classify* methods of heat transfer based on how particles behave; *infer* the direction of heat transfer; or *summarize* the direction of heat transfer in various types of heat transfer processes if given temperature differences.

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6-5.6 Recognize that energy is the ability to do work (force exerted over a distance).

Taxonomy level: 1.1-B Remember Conceptual Knowledge

Previous/Future knowledge: In 3rd grade (3-5.3), students explained how the motion of an object is affected by the strength of a push or pull and the mass of the object. In 5th grade, students illustrated the affects of force on motion (5-5.1) and explained how a change of force or a change in mass affects the motion of an object (5-5.6). Students have not been introduced to the concept of work in previous grades. They will further develop the concept of work in 9th grade Physical Science (PS-6.3).

It is essential for students to know that *energy* is a property that enables something to do work.

- *Work* means to (1) apply a force to an object over a distance, and (2) the object moves in response to the force.
- If something has the ability to cause a change in motion, it is has energy.
- Energy can cause work to be done, so when we see work done, we see evidence of energy.

An evidence of energy is when work is being done. For example:

- When a toy car at rest is pushed, work is done on the car if it moves. This work (or movement) is evidence of energy.
- When a fan is connected to an electric circuit, it moves, so work was done on the fan. This work (or movement) is evidence of energy.
- When an object is lifted, it moves, so work is done on the object. This work (or movement) is evidence of energy.

A *spring scale* is used to measure force. Force (including weight) is measured in SI units called *newtons* (N).

It is not essential for students to know how to calculate work using the formula of amount of force multiplied by the distance moved, or that work is measured in units of joules.

Assessment Guidelines:

The objective of this indicator is to *recognize* that energy is the ability to do work (force exerted over a distance); therefore, the primary focus of assessment should be to remember that work is force exerted over a distance. However, appropriate assessments should require students to *recall* that force is measured in newtons (N); *recognize* that energy can cause things to move; *identify* situations that show work; or *recall* that work is an evidence for energy.

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6-5.7 Explain how the design of simple machines (including levers, pulleys, and inclined planes) helps reduce the amount of force required to do work.

Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/Future knowledge: In 3rd grade (3-5.3), students explained how the motion of an object is affected by the strength of a push or pull and the mass of an object. In 5th grade, students illustrated the affects of force on motion (5-5.1) and explained how a change of force or a change in mass affects the motion of an object (5-5.6). Students have not been introduced to the concept of simple machines in previous grades. Students will further develop the concept of force in 8th grade (8-5.4) and quantitative relationships of work in high school Physical Science (PS-6.4).

It is essential for students to know that a *simple machine* is a device that helps reduce the amount of force required to do work. Work is done when a force (*effort force*) is applied over a distance.

- A simple machine allows the user to apply a smaller force over a larger distance to move an object.
- Simple machines can also change the direction of the force applied.
- If the distance over which the effort force is exerted is increased, the same amount of work can be done with a smaller effort force.
- This is the principle that simple machines use to reduce the amount of effort force needed to do work.

The design of the simple machines can reduce the amount of force required to do work:

Lever

- A *lever* is a rigid bar or board that is free to move around a fixed point called a *fulcrum*.
- The fulcrum may be placed at different locations along the bar.
- A lever can be designed to reduce the amount of force required to lift a weight in two ways: (1) By increasing the distance from the fulcrum to the point where the effort force is applied, or (2) by decreasing the distance the weight is from the fulcrum.
- By increasing the distance the effort force moves relative to the distance the weight moves, a lever can reduce the effort force needed.

Pulley

- A *pulley* has a grooved wheel with a rope running along the groove.
- Pulleys can change the amount and/or the direction of the force applied (*effort force*).
- By arranging the pulleys in such a way as to increase the distance that the effort force moves relative to the distance the weight moves, a pulley can reduce the effort force needed.
- Movable pulleys are used to reduce the effort force.
- A single fixed pulley changes only the direction of the force (you pull down and the weight goes up.)

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Inclined plane

- An *inclined plane* is a sloping surface, like a ramp, that reduces the amount of force required to lift an object.
- An inclined plane can be designed to reduce the force needed to lift a weight in two ways: (1) increase the length of the ramp or (2) decrease the height of the ramp.
- By increasing the distance the effort force moves (length of the ramp) relative to the distance the weight is lifted (height of the ramp), an inclined plane can reduce the effort force needed.

It is not essential for students to know the classes of levers or how to calculate the mechanical advantage of simple machines.

Assessment Guidelines:

The objective of this indicator is to *explain* how the design of simple machines helps reduce the amount of force required to do work; therefore, the primary focus of assessment should be to construct a cause-and-effect model which shows how the design of simple machines (including levers, pulleys, and inclined planes) reduces the effort force or changes its direction. However, appropriate assessments should also require students to *recognize* that simple machines can be designed to reduce the force needed to move an object; *interpret* a diagram showing different designs of the same simple machine to determine which would reduce the amount of force the most based on their designs; or *summarize* the relationship between the design of the simple machine and the reduction in force required to move an object.

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6-5.8 Illustrate ways that simple machines exist in common tools and in complex machines.

Taxonomy level: 2.2-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of simple machines in previous grade levels.

It is essential for students to know how simple machines, such as levers, pulleys, inclined planes (ramps, wedges, screws) and wheel and axles are found in common tools and in complex (compound) machines. For example:

Levers

- Levers that have the fulcrum between where the effort force is applied and the weight is located can be found in tools, for example, scissors (two levers working together) and crowbar.
- Levers that have the fulcrum on the end and the effort is applied in the middle to lift a weight on the other end can be found in tools, for example, tweezers (two levers working together) or a broom.
- Levers that have the fulcrum on the end and the effort force are applied on the other end to lift a weight in the middle can be found in tools, for example, a wheelbarrow, or a bottle opener.

Pulleys

- Pulleys that are *fixed*, meaning that they are attached to a structure, can be found on the top of a flag pole and on window blinds.
- Pulleys that are *moveable*, meaning that they are not attached to a structure, can be found on construction cranes and as part of a block and tackle system.

Inclined planes

- Inclined planes with a sloping surface can be found as *ramps* on a truck or wheelchair ramp and stairs.
- Inclined planes that are *wedges*, one inclined plane or two back-to-back inclined planes that can move are found as knife blades or nails.
- Inclined planes that are wound around a post or cylinder are called *screws*. Screws can be found in bolts and jar lids.

Wheel and axles

- Wheel and axles consist of two circular objects: a central shaft, called an axle, inserted through the middle of a wheel.
- Wheel and axles can be found as door knobs, steering wheels, screwdrivers, gears, and bicycles wheels.

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Complex machines

Complex machines, also known as *compound machines*, consist of two or more simple machines. Examples may include:

- scissors consisting of two levers and two inclined planes (wedges);
- a fishing pole consisting of a lever, a wheel and axle and a pulley;
- a bicycle consists of levers (handlebars and handbrakes), wheel and axles (gears, wheels, and pedals), and a number of screws.

It is not essential for students to know which classes of levers are in common tools or complex machines.

Assessment Guidelines:

The objective of this indicator is to *illustrate* ways that simple machines exist in common tools and in complex machines; therefore the primary focus of assessment should be to simple machines that are part of simple tools and of complex machines using pictures, diagrams, or word descriptions. However, appropriate assessments should also require students to *identify* the types of simple machines that are found in common tools and in complex machines; *interpret* a diagram of common tools or complex machines to identify the simple machines present; *exemplify* common tools that are simple machines; or *exemplify* the use of simple machines in everyday life.