Energy Transformations

Concept Sheet
Energy Transformations

PS.6: The student will investigate and understand states and forms of energy and how energy is transferred and transformed.

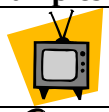
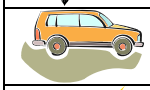
1. **Energy** is the ability to do work (apply a force through a distance). The many forms of energy include **mechanical (including sound)**, **electrical**, **thermal**, **light (radiant), chemical**, and **nuclear**.

   - **Kinetic energy** is the energy of a moving object. The amount of kinetic energy depends on the mass and velocity of the moving object. *Examples: An apple falling from a tree, wind, and a bird flying to its nest.*
   - **Potential energy** is the stored energy of an object based on its position. *Examples: A rock at the top of a hill has potential energy based on its position.*

   The chemical energy in fossil fuels is also a form of potential energy. Coal, oil, gasoline, and natural gas have potential energy because of their chemical composition.

2. Energy can change from one type to another. This is called an **energy conversion** or **energy transformation**.
   - The *Law of Conservation of Energy* states that energy can change form, but it cannot be created or destroyed. Therefore, the total amount of energy stays the same.
   - In energy transformations, some energy is always lost to the environment as thermal energy.

Examples of energy transformations and their uses:

	A television changes electrical energy into sound and light energy.
	A toaster changes electrical energy into thermal energy and light.
	A car changes chemical energy from fuel into thermal energy and mechanical energy.
	A flashlight changes chemical energy from batteries into light energy.
	When you speak into your telephone, sound energy from your voice is changed into electrical energy. The electrical energy is then converted back into sound energy on another phone, allowing someone to hear you.
	Light energy is converted into electrical energy using solar panels.
	Campfires convert chemical energy stored in wood into thermal energy, which is useful for cooking food and staying warm.
	Nuclear energy generates a tremendous amount of thermal energy, which can be converted into electrical energy in a nuclear power plant.

PS.7: The student will investigate and understand temperature scales, heat, and heat transfer.

3. **Thermal energy** is the total kinetic energy of a substance's atoms and molecules. Atoms and molecules are constantly in motion. When thermal energy causes particles to move faster and farther apart, the result is a **phase change** (or change of state). *During a phase change, the thermal energy is being used to break bonds between molecules. Even though thermal energy continues to be absorbed, the temperature does not rise.*

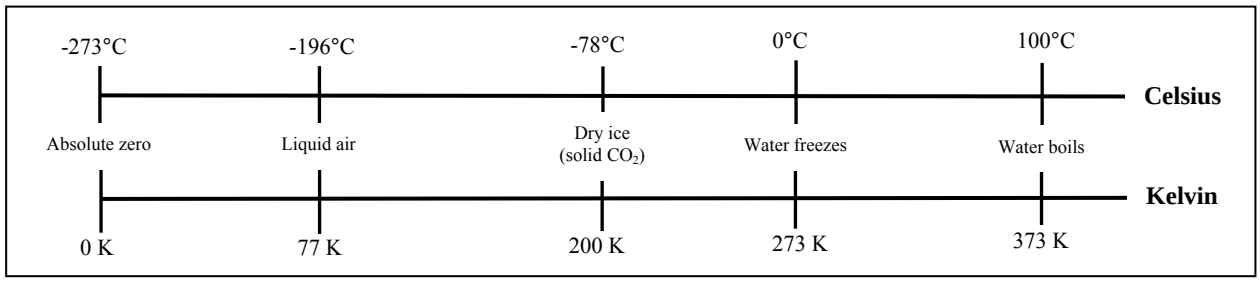
   Heat is the transfer of thermal energy from a substance of higher temperature to a substance of lower temperature.

   - **Vaporization** (boiling and evaporation) is a change from a liquid state to a gas.
   - **Condensation** is a change from gas to liquid.
   - **Freezing** is a change from liquid to solid.
   - **Melting** is a change from solid to liquid.

   Temperature is a measure of the **average** kinetic energy of the atoms and molecules in a substance.
   - The temperature at which liquids change to solids is their **freezing** point (water: 0 ºC).
   - The temperature at which solids change to liquids is their **melting** point (water: 0 ºC).
   - The temperature at which liquids change to gases is their **boiling** point (water: 100 ºC).
   - The temperature at which gases change to liquids is their **condensation** point (water: 100 ºC).
   - A temperature of **absolute zero** (-273 °C/0 K) is a theoretical point at which molecules stop moving.

Celsius and Kelvin Temperature Scale



Note: the Kelvin temperature scale does not use the degree (º) symbol.

4. **Thermal energy** can be **transferred** from warmer to colder particles in three ways:
   1. **Conduction** is the heating of an object from direct contact between a heat source and the object. An example is a pan getting hot from the stove.
   2. **Convection** is heating of an object through the movement of a fluid (a gas or liquid). Examples are the thermal currents in the ocean or in the atmosphere.
   3. **Radiation** is the heating of an object by radiant energy traveling through space by electromagnetic waves. An example is the thermal energy coming to the Earth from the Sun through infrared waves.

Some applications of thermal energy transfer include: heat engines (cars, lawn mowers), thermostats, refrigerators, and heat pumps.

PS.8: The student will investigate and understand characteristics of sound and the technological applications of sound waves.

5. A **wave** is a disturbance that transfers energy through matter or space. **Sound** is a form of mechanical energy produced by vibrations. It travels in longitudinal (compression) waves and moves much slower than the speed of light. In longitudinal waves, matter vibrates in the same direction as the waves are traveling.

   Sound waves require a medium (solid, liquid, or gas) through which to travel. Longitudinal waves cause molecules of a medium to vibrate "back and forth" in the same direction that the wave is traveling. The speed of sound depends on the type of medium (how dense) it is passing through and the temperature of the medium.

Sound Wave

Sound waves are used in sonar, medical ultrasonography imaging, and ultrasonic cleaners.

Doctors use sonography machines to "see" inside a person's body. The machine emits high frequency sound waves (inaudible by the human ear) which are reflected off of hard objects in the body. A computer interprets the data and creates an image of the area being studied. Sonograms are often used to monitor the development of unborn babies. Doctors also use sonography to see internal organs which helps them make a medical diagnosis.

All waves exhibit certain characteristics: **wavelength**, **frequency**, and **amplitude**.

- The **amplitude** (maximum distance particles move from rest) of a sound wave determines the intensity or loudness of the sound.
- The **frequency** of a wave is the number of waves per second.
- **Wavelength** is the distance between two consecutive compressions or rarefactions and determines the pitch of a sound.

There is an inverse relationship between frequency and wavelength: *As wavelength increases, frequency decreases.*

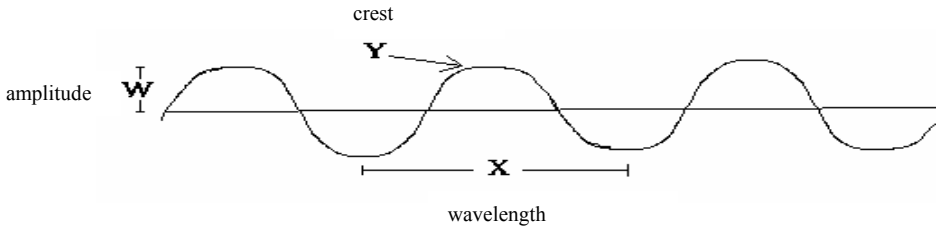
Interference occurs when waves overlap. For example, sound waves that combine in phase create a new wave pattern with higher amplitude (a louder sound). Waves that combine out of phase can cancel each other out. Noise canceling headphones are an example of interference.

Resonance occurs when an object vibrates near a second object with the same frequency, causing the second object to vibrate as well.

PS.9 The student will investigate and understand the nature and technological applications of light.

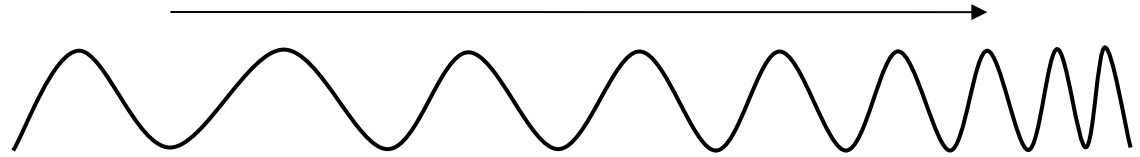
6. **Light** has properties of both waves and particles. The **particle theory** states that light energy is made up tiny packets of energy called **photons**. The **wave theory** describes light as form of radiant energy that moves in transverse waves which are waves that move particles up and down perpendicular to the direction of the wave.

Transverse Wave



Visible light is a part of the **electromagnetic spectrum**. The electromagnetic spectrum is an arrangement (model) of electromagnetic waves in order of their wavelengths and frequencies.

Decreasing Wavelength, Increasing Frequency



Radio waves Infrared Visible Ultraviolet X-Rays Gamma Rays

- Radio waves have the lowest energy (longest wavelength, lowest frequency).
- Gamma rays have the highest energy (shortest wavelength, highest frequency).
- Visible light makes up only a very small portion of the electromagnetic spectrum.
- All types of electromagnetic radiation travel at the speed of light, but have different wavelengths.
- Electromagnetic radiation does not need a medium through which to travel. For this reason, this form of energy is able to move from stars far away in the universe to reach the Earth.

All waves travel in a straight line, but their pathway can be changed in the following ways:

1. As a light wave passes through a dense medium (like water or a lens) a change in the speed of the wave can cause the light to be **refracted** (or bent). When sunlight passes through raindrops or a prism, the light is refracted, and you see a rainbow.
2. All types of waves can bounce off or be **reflected** from objects, such as light rays reflecting off of mirrors, or sound reflecting off a wall (an echo).
3. **Diffraction** occurs when waves curve or bend around an object. This can occur with any type of wave – sound or light.

PS.11: The student will investigate and understand basic principles of electricity and magnetism.

7. There is a relationship between electricity and magnetism:
Electricity can generate magnetic fields and magnetic fields can generate electricity.

One very important property of electricity is that a current-carrying wire is surrounded by a magnetic field. This can be easily observed by moving a compass (small magnet) near the surface of a current-carrying wire. The moving compass needle clearly indicates the presence of a magnetic field surrounding the wire.

Electromagnets

When a current-carrying wire is wrapped around a magnetic metal, such as iron, the magnetic field which surrounds the wire creates an **electromagnet**. Electromagnets are temporary magnets and lose their magnetic properties when the current is removed.

Electromagnetic induction

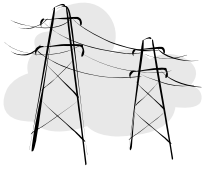
- When a magnetic field is passed near a wire that is a good conductor of electricity, an electric current can be "induced" in the wire in a process called electromagnetic induction. It is believed that the magnetic field exerts a force upon the electrons in the wire, thus causing the flow of electrons (current).
- Mechanical energy from wind, moving water, or steam is used to move powerful magnets through coils of wire to cause electromagnetic induction to occur. This is how electrical generators create electricity (wind turbines, hydroelectric dams, nuclear power plants, etc.).

Motors and Generators

When magnetic fields interact (ex: opposite poles attract), movement (mechanical motion) can occur

- A **motor** uses electricity to create an electromagnet inside the motor. The magnetic field surrounding the electromagnet interacts with the magnetic field of a permanent magnet inside the motor. The interacting magnetic fields alternately attract and repel to create mechanical motion.
- A **generator** uses the energy from wind, moving water, or steam to move a permanent magnet inside a coil of wire. This creates electricity through electromagnetic induction.

8. **Electricity** is a form of energy produced by moving electrons. Electricity can be "**static**" (not moving) or moving through **electrical conductors** (**electric current**). Moving electrons transmit electrical energy from one point to another.
   - In static electricity, energy cannot be used to do useful work. In current electricity, however, the energy of moving electrons can be used to do work in devices such as motors, heaters, light bulbs, etc.



Electric current is defined as a continuous flow of electrons through a wire. In **direct current**, electrons flow in the same direction while in **alternating current** electrons reverse their direction regularly. Electrical energy consumption is measured in **kilowatts**.

Electric current flows in circuits.
- A **series circuit** is a circuit in which there is only one path for electrons to flow.
- If there are several paths in a circuit, it is a **parallel circuit**.

In an electrical circuit, the number of electrons that are moving past a given point each second is called the **amperage** or the **current**, and it is measured in **amps**.

The "pressure" pushing the electrons along is called the **voltage** and is measured in **volts**. Voltage is the "push" needed to move the electrons. Voltage is caused by a potential difference between two conductors. For this reason, no current flows through a battery with electrodes made of the same metal. When different metals are used, however, current flows due to a potential difference between the two metals.

Resistance is the property of matter that affects the flow of electricity. Some matter has more resistance than other matter. If there is more resistance, there is less flow of current.
- It is often useful to use the analogy of water flowing from a water tank to understand the relationship between voltage, current, and resistance. For example, a hose connected to an open water tank will release water in a steady stream due to the pressure on the water from the atmosphere. In this analogy, atmospheric pressure represents voltage, the rate of water flow represents current, and the diameter of the hose represents resistance.
- Increasing voltage in a circuit will increase the current in the circuit. Increasing the resistance, however, will impede the flow of electrons and will reduce the current in the circuit.

Electric motors, such as those in power tools, blenders, and washing machines, convert electrical energy into mechanical energy through the interaction of magnetic fields.

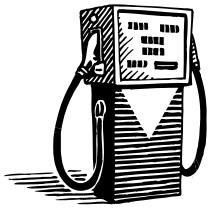
Static electricity is a buildup of an electrical charge due to friction. Friction causes electrons to transfer from one object to another.

A belt moving inside a Van De Graf generator creates static electricity, causing a person's hair to become charged and stand on end!

6.2:	**The student will understand the basic sources of energy, their origins, transformations, and uses.**

9. Most of the sources of energy on Earth come from the Sun. Energy sources include:
   - **Non-renewable resources,** such as fossil fuels (coal, petroleum (oil), natural gas, and nuclear energy

Oil well

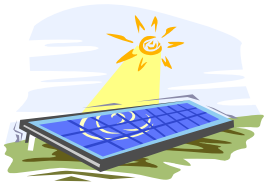


Gasoline

Natural gas

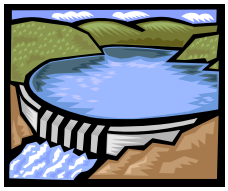
Coal

   - **Renewable resources**, such as solar, tidal, hydroelectric, wind, geothermal (heat energy from Earth's interior), and wood.



Solar energy

Wind energy



Hydroelectric energy

Energy from wood

About Fossil Fuels:

Millions of years ago, fossil fuels formed from the remains of plants and animals. Fossil fuels are rich in carbon and hydrogen and store energy from the sun from the ancient past. Once the fossil fuels are used up, they cannot be renewed, because they take a very long time to form.

The energy stored in fossil fuels is *potential energy* until the energy is released. Fossil fuels are highly combustible and, therefore, have the potential to do work.

Our industrial society is very dependent on fossil fuels, a non-renewable resource, as a major source of energy for transportation and manufacturing.

Energy Transformations

Name _____ Class _____ Date _____

Read each question and choose the best answer or complete the required task.

___1. What temperature is absolute zero?

A. -273 °C
B. 0 °C
C. -273 K
D. 0 °F

___2. Which of the following actions does **not** describe potential energy being changed into kinetic energy?

A. Releasing a stretched rubber band.
B. A child sliding down a slide.
C. A spring being compressed.
D. An apple falling from a tree.

___3. When the electrons move back and forth reversing their direction regularly, the current is called ___

A. direct current.
B. series current.
C. electric charge.
D. alternating current.

___4. An electric current in a wire coil produces ___

A. another current.
B. a magnetic field.
C. a generator.
D. a source of voltage.

___5. Which is **not** a renewable fuel source?

A. Geothermal
B. Wood
C. Coal
D. Solar

___6. The behavior of light energy is explained by two theories because light has properties of ***both*** ___ and ___ (***Choose two***)

A. longitudinal waves.
B. transverse waves.
C. particles.
D. water droplets.

___7. According to the Law of Conservation of Energy, when energy changes from one form to another form, the total energy of that system ___

A. increases.
B. decreases.
C. alternates.
D. remains the same.

___8. When an object's temperature ***increases***, its particles have ___

A. stopped moving.
B. gained kinetic energy.
C. lost kinetic energy.
D. stopped hitting other particles.

___9. What type of energy transfer explains Earth receiving energy from the Sun?

A. Radiation
B. Conduction
C. Convection
D. Condensation

___10. What type of energy transfer explains a warm ocean current moving through cold water?

A. Radiation
B. Conduction
C. Convection
D. Condensation

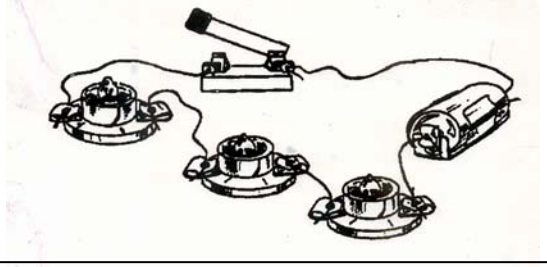
Refer to the following diagrams for questions 11 and 12.

11. Label each diagram with the type of circuit.

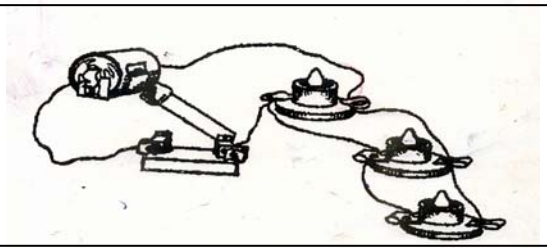
A. _____ Circuit

B. _____ Circuit

A.



B.

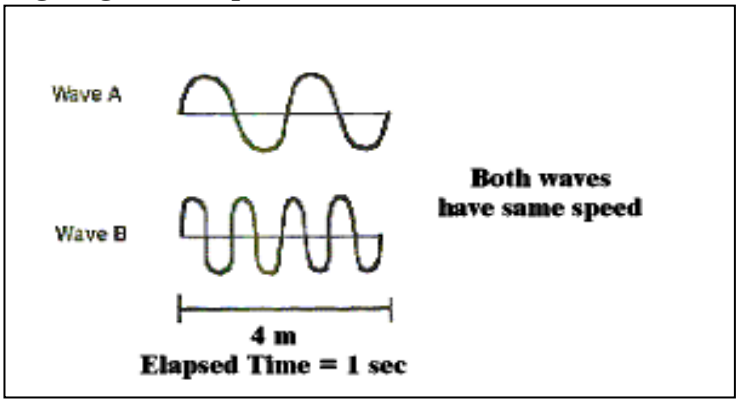


12. If the switch is closed and all three bulbs in each circuit are lit, what would happen to the other two bulbs in each circuit if one were unscrewed?

(Answer question in the spaces to the right for <u>both</u> circuits.)

Circuit A:
Circuit B:

Refer to the following diagram for questions 13 and 14.



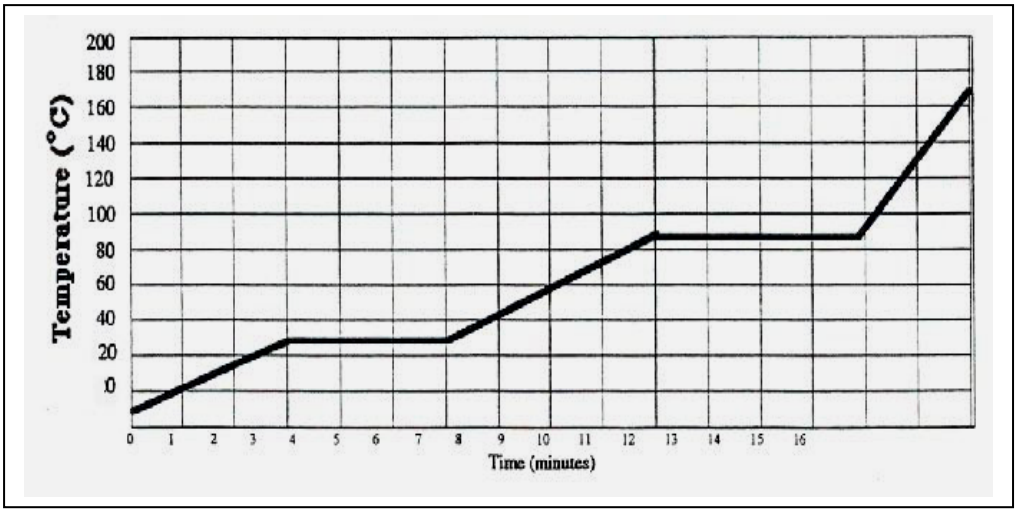
___13. What is the wavelength of wave A?

A. 1 m
B. 2 m
C. 3 m
D. 4 m

___14. At a given velocity, as the frequency increases, the wavelength ___

A. increases.
B. decreases.
C. remains the same.
D. cannot be predicted.

Refer to the following graph for questions 15 and 16.



___15. The melting point of this substance is approximately ___

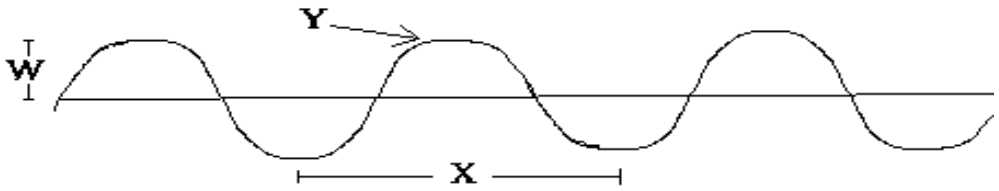
A. 170 °C
B. 85 °C
C. 30 °C
D. 10 °C

___16. Which of the following statements is true?

A. The freezing point and the melting point are identical.
B. The freezing point and the boiling point are identical.
C. The substance will become a gas at the melting point.
D. The freezing point, melting point, and boiling point are always different temperatures.

___17. Fill in the letter of the following parts of this transverse wave.

A. Amplitude_____ B. Wavelength_____ C. Crest _____



___18. For a sound to get louder, what ***must*** increase?

A. Amplitude
B. Wavelength
C. Frequency
D. Vibration

___19. Which waves have the ***lowest*** energy (longest wavelength, lowest frequency)?

A. Infrared
B. X-rays
C. Visible
D. Radio