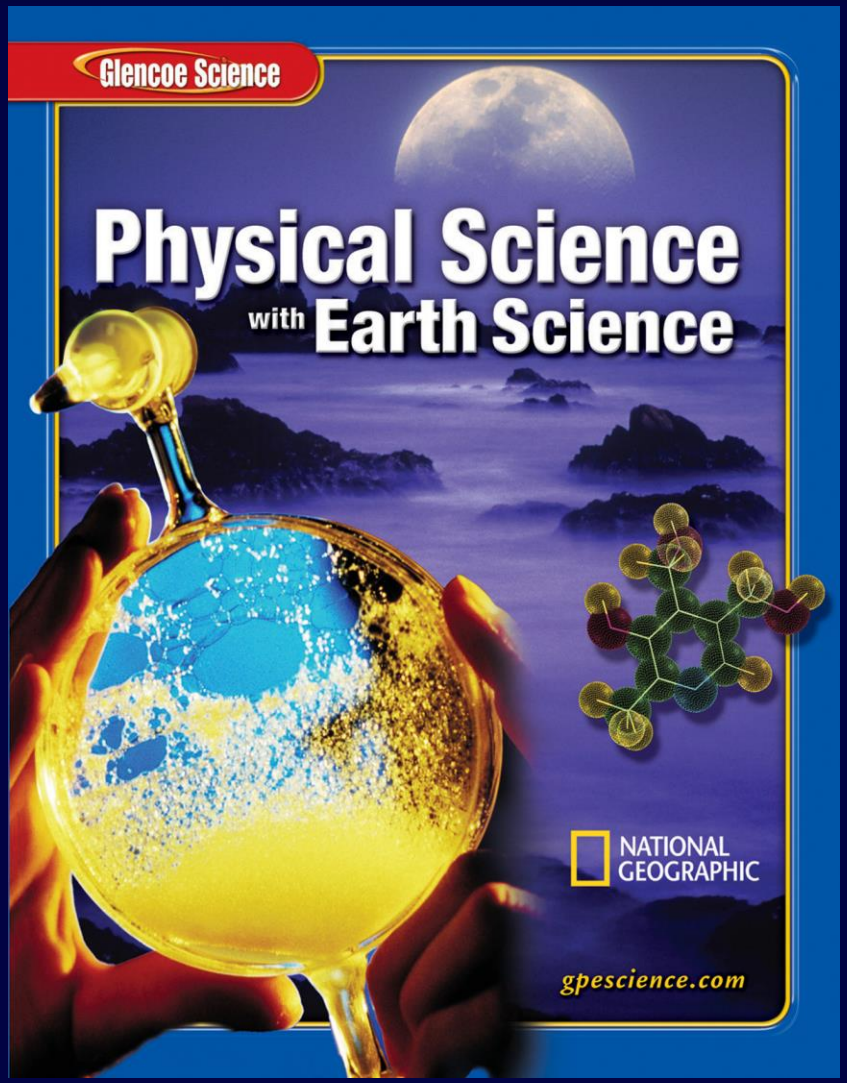
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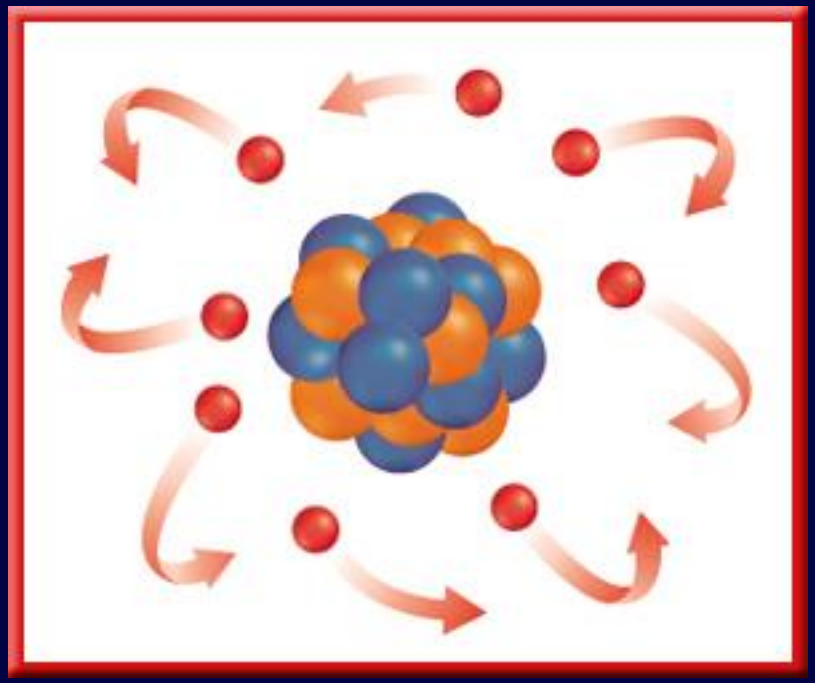
Chapter: Electricity

1

Positive and Negative Charge

- Atoms contain particles called protons, neutrons, and electrons.



- Protons and electrons have electric charge, and neutrons have no electric charge.

1

Positive and Negative Charge

- Protons have positive electric charge and electrons have negative electric charge.
- The amount of positive charge on a proton equals the amount of negative charge on an electron.

1

Positive and Negative Charge

- An atom contains equal numbers of protons and electrons, so the positive and negative charges cancel out and an atom has no net electric charge.

- Objects with no net charge are said to be electrically neutral.

1

Transferring Charge

- Compared to the electrons in carpet atoms, electrons are bound more tightly to the atoms in the soles of your shoes.

- When you walk on the carpet, electrons are transferred from the carpet to the soles of your shoes.

1

Transferring Charge

- The soles of your shoes have an excess of electrons and become negatively charged.
- The carpet has lost electrons and has an excess of positive charge.

- The accumulation of excess electric charge on an object is called **static electricity**.

1

Conservation of Charge

- According to the **law of conservation of charge**, charge can be transferred from object to object, but it cannot be created or destroyed.

- Whenever an object becomes charged, electric charges have moved from one place to another.

1

Charges Exert Forces

- Unlike charges attract each other, and like charges repel each other.

Opposite charges attract

Like charges repel

- The force between electric charges also depends on the distance between charges. The force decreases as the charges get farther apart.

1

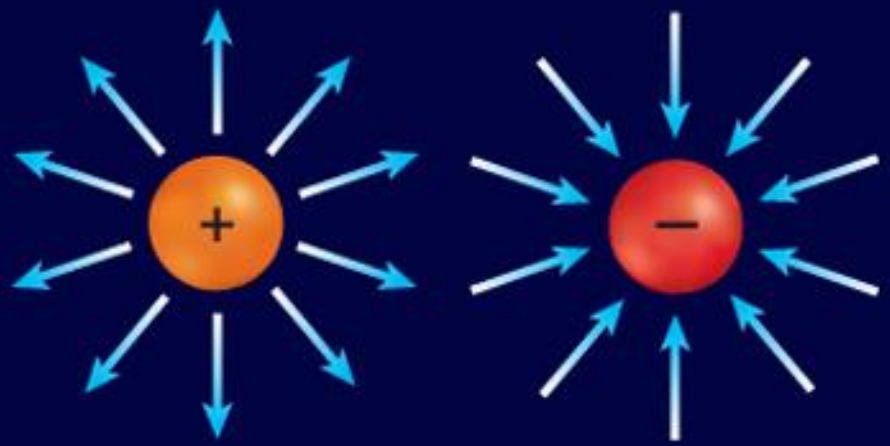
Charges Exert Forces

- The force between any two objects that are electrically charged decreases as the objects get farther apart.
- This force also depends on the amount of charge on each object.
- As the amount of charge on either object increases, the electrical force also increases.

1

Electric Fields

- An electric field surrounds every electric charge and exerts the force that causes other electric charges to be attracted or repelled.
- Any charge that is placed in an electric field will be pushed or pulled by the field.



1

Comparing Electric and Gravitational Forces

- The force of gravity between you and Earth seems to be strong. Yet, compared with electric forces, the force of gravity is much weaker.

1

Comparing Electric and Gravitational Forces

- The chemical bonds that form between atoms in molecules also are due to the electric forces between the atoms.
- These electric forces are much larger than the gravitational forces between the atoms.

1

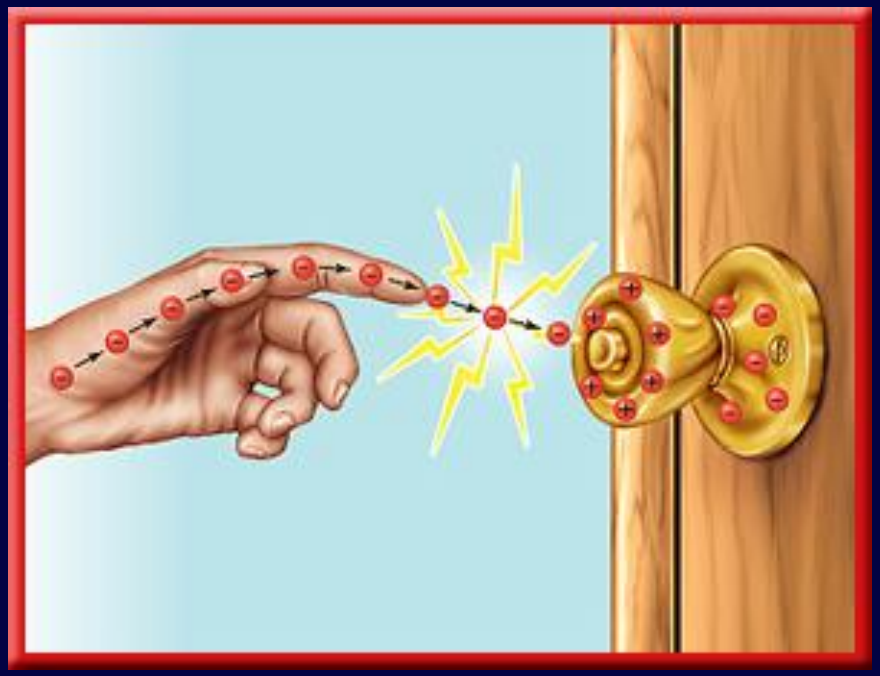
Comparing Electric and Gravitational Forces

- The electric forces between the objects around you are much less than the gravitational forces between them.
- Most objects that you see are nearly electrically neutral and have almost no net electric charge.
- As a result, there is usually no noticeable electric force between these objects.

1

Conductors and Insulators

- If you reach for a metal doorknob after walking across a carpet, you might see a spark.



- The spark is caused by electrons moving from your hand to the doorknob.

1

Conductors

- A material in which electrons are able to move easily is a **conductor**.
- The best electrical conductors are metals.
- The atoms in metals have electrons that are able to move easily through the material.

1

Insulators

- A material in which electrons are not able to move easily is an **insulator**.
- Electrons are held tightly to atoms in insulators.
- Most plastics are insulators.
- The plastic coating around electric wires prevents a dangerous electric shock when you touch the wire.

1

Charging Objects

- Rubbing two materials together can result in a transfer of electrons.
- Then one material is left with a positive charge and the other with an equal amount of negative charge.
- The process of transferring charge by touching or rubbing is called **charging by contact**.

1

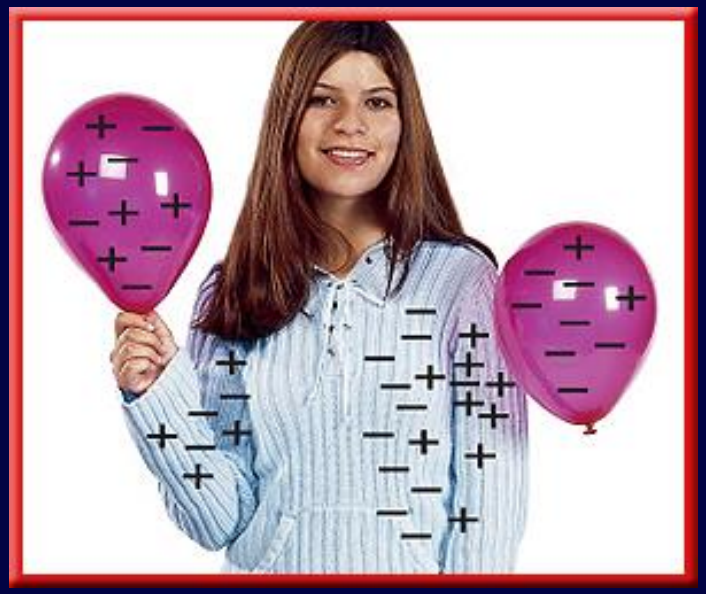
Charging at a Distance

- Because electrical forces act at a distance, charged objects brought near a neutral object will cause electrons to rearrange their positions on the neutral object.

1

Charging at a Distance

- The balloon on the left is neutral. The balloon on the right is negatively charged. It produces a positively charged area on the sleeve by repelling electrons.



- The rearrangement of electrons on a neutral object caused by a nearby charged object is called **charging by induction**.

1

Lightning

- Lightning is a large static discharge.
- A static discharge is a transfer of charge between two objects because of a buildup of static electricity.
- A thundercloud is a mighty generator of static electricity. As air masses move and swirl in the cloud, areas of positive and negative charge build up.

1

Lightning

- Eventually, enough charge builds up to cause a static discharge between the cloud and the ground.
- As the electric charges move through the air, they collide with atoms and molecules. These collisions cause the atoms and molecules in air to emit light.

1

Thunder

- Lightning also generates powerful sound waves.
- The electrical energy in a lightning bolt rips electrons off atoms in the atmosphere and produces great amounts of heat.
- The heat causes air in the bolt's path to expand rapidly, producing sound waves that you hear as thunder.

1

Grounding

- A discharge can occur any time that charge builds up in one area.
- Providing a path for charge to reach Earth prevents any charge from building up.
- Earth is a large, neutral object that is also a conductor of charge.

1

Grounding

- Any object connected to Earth by a good conductor will transfer any excess electric charge to Earth.

- Connecting an object to Earth with a conductor is called grounding.

1

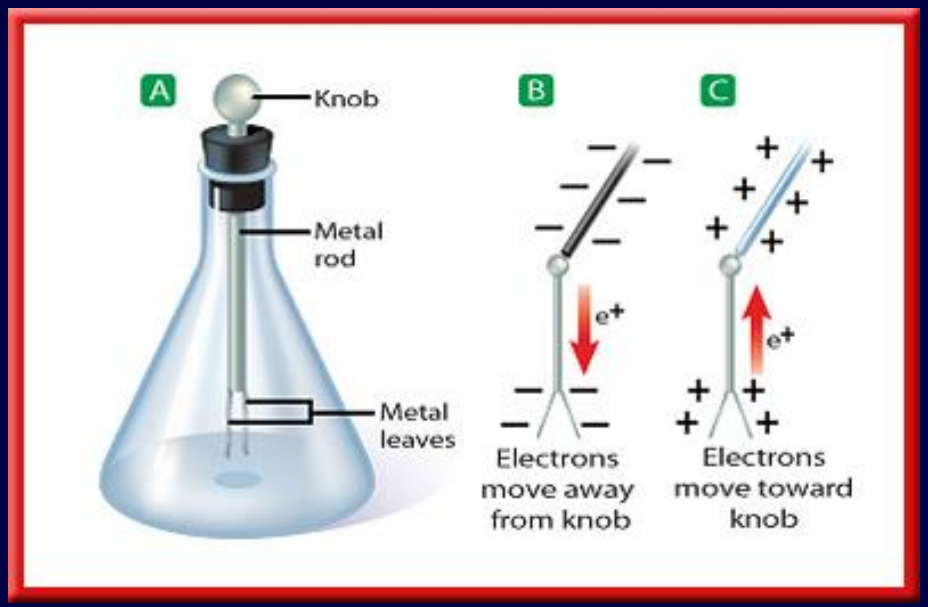
Detecting Electric Charge

- The presence of electric charges can be detected by an electroscope.
- One kind of electroscope is made of two thin, metal leaves attached to a metal rod with a knob at the top.
- The leaves are allowed to hang freely from the metal rod.

1

Detecting Electric Charge

- When the device is not charged, the leaves hang straight down.
- Notice the position of the leaves on the electroscope when they are A uncharged, B negatively charged, and C positively charged.



1

Question 1

The law of conservation of charge states that _____.

Answer

Charge can be transferred from object to object, but it cannot be created or destroyed.

1

Question 2

Which of the following is the best conductor of electricity?

A. copper
B. rubber
C. wood
D. water

1

Answer

The answer is A. The best electrical conductors are metals.

1

Question 3

The accumulation of excess electric charge on an object is called _____.

A. lightning
B. static electricity
C. static discharge
D. thunder

1

Answer

The answer is B. Lightning is a large static discharge that emits light.

2

Current and Voltage Difference

- The net movement of electric charges in a single direction is an **electric current**.

- In a metal wire, or any material, electrons are in constant motion in all directions. As a result, there is no net movement of electrons in one direction.

2

Current and Voltage Difference

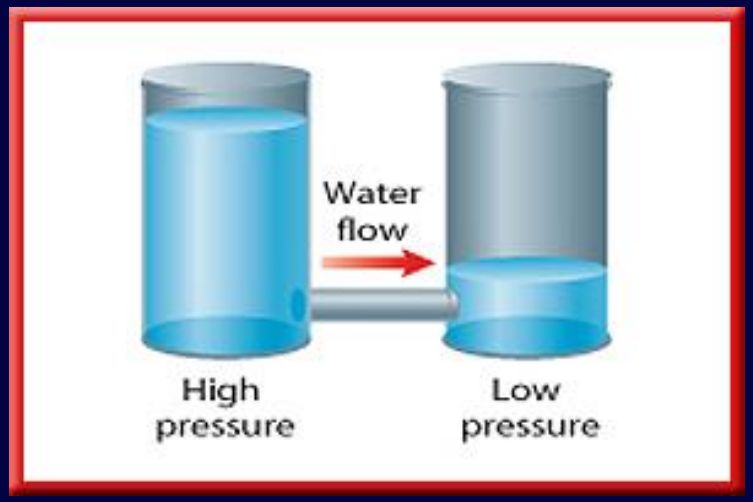
- When an electric current flows in the wire, electrons continue their random movement, but they also drift in the direction that the current flows.

- Electric current is measured in amperes.

2

Voltage Difference

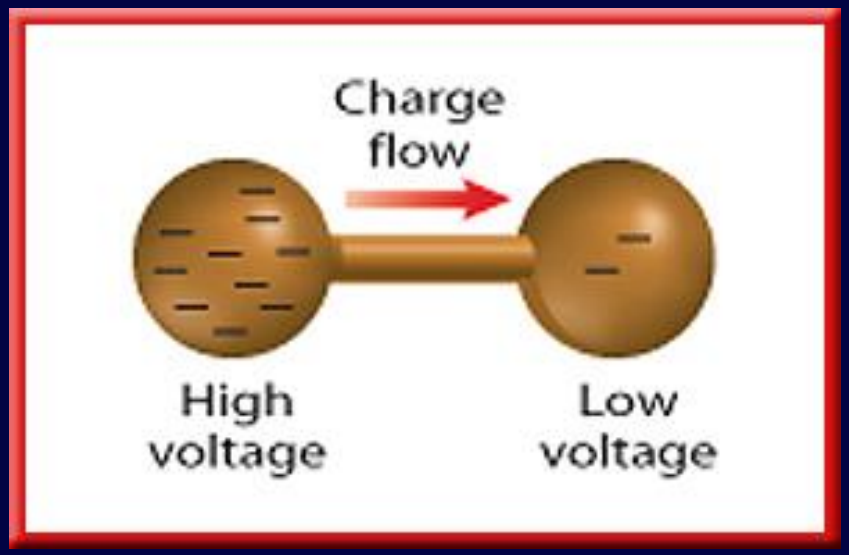
- In some ways, the electric force that causes charges to flow is similar to the force acting on the water in a pipe.
- Water flows from higher pressure to lower pressure.



2

Voltage Difference

- In a similar way, electric charge flows from higher voltage to lower voltage.

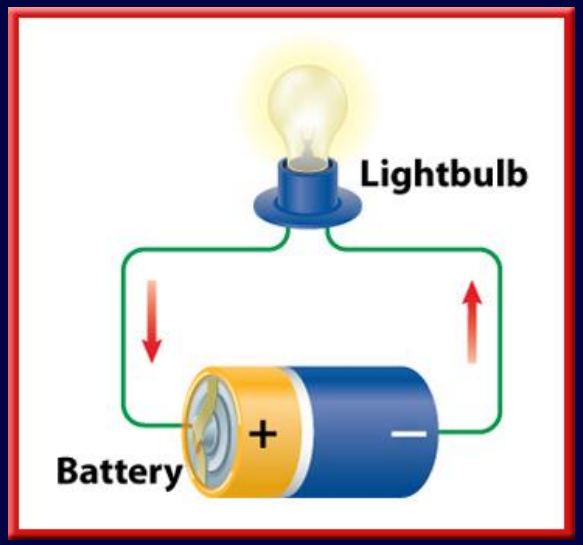


- A **voltage difference** is related to the force that causes electric charges to flow. Voltage difference is measured in volts.

2

Electric Circuits

- This figure shows an electric current doing work by lighting a lightbulb.
- A closed path that electric current follows is a **circuit**.



- If the circuit is broken by removing the battery, or the lightbulb, or one of the wires, current will not flow.

2

Batteries

- To keep an electric current continually flowing in the electric circuit a voltage difference needs to be maintained in the circuit.
- A battery can provide the voltage difference that is needed to keep current flowing in a circuit.
- Current flows as long as there is a closed path that connects one battery terminal to the other battery terminal.

2

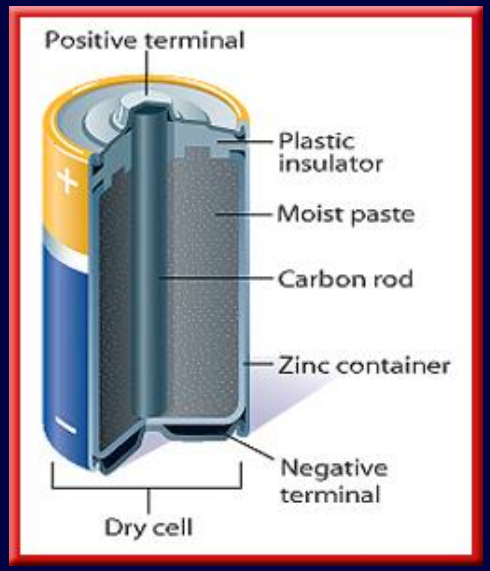
Dry-Cell Batteries

- A cell consists of two electrodes surrounded by a material called an electrolyte.
- The electrolyte enables charges to move from one electrode to the other.

2

Dry-Cell Batteries

- One electrode is the carbon rod, and the other is the zinc container.
- The electrolyte is a moist paste containing several chemicals.

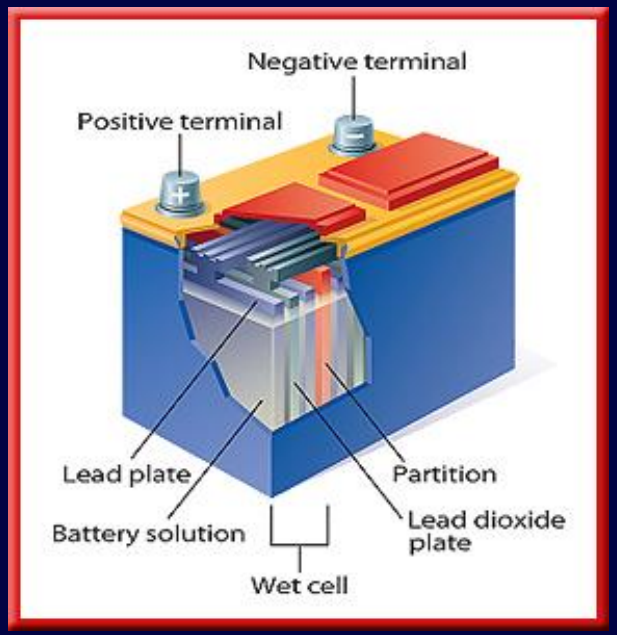


- The cell is called a dry cell because the electrolyte is a moist paste, and not a liquid solution.

2

Wet-Cell Batteries

- A wet cell contains two connected plates made of different metals or metallic compounds in a conducting solution.



- A wet-cell battery contains several wet cells connected together.

2

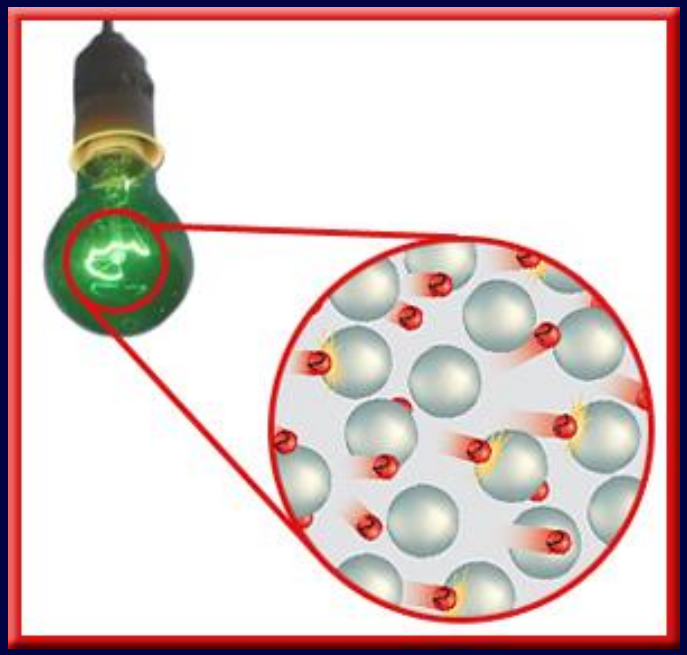
Lead-Acid Batteries

- Most car batteries are lead-acid batteries.
- A lead-acid battery contains a series of six wet cells made up of lead and lead dioxide plates in a sulfuric acid solution.
- The chemical reaction in each cell provides a voltage difference of about 2 V, giving a total voltage difference of 12 V.

2

Resistance

- As the electrons flow through the filament in a lightbulb, they bump into the metal atoms that make up the filament.

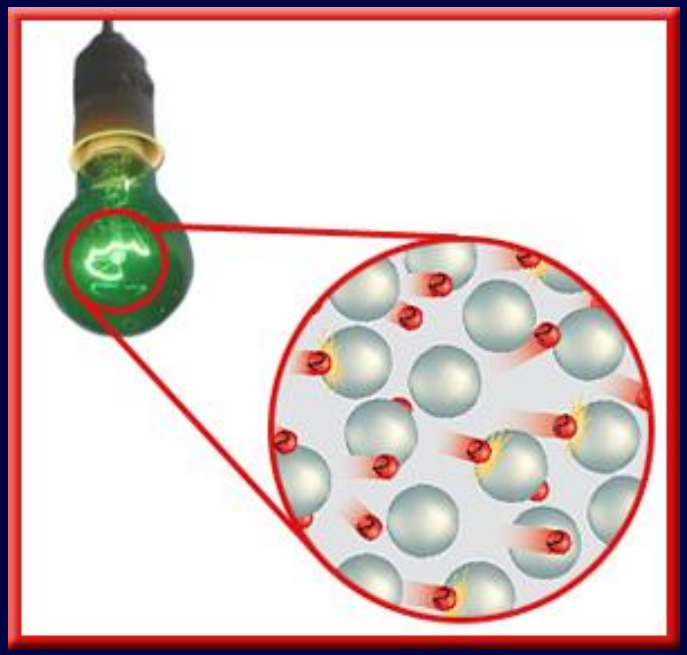


- In these collisions, some of the electrical energy of the electrons is converted into thermal energy.

2

Resistance

- Eventually, the metal filament becomes hot enough to glow, producing radiant energy that can light up a dark room.



2

Resisting the Flow of Current

- **Resistance** is the tendency for a material to oppose the flow of electrons, changing electrical energy into thermal energy and light.
- With the exception of some substances that become superconductors at low temperatures, all materials have some electrical resistance.
- Resistance is measured in ohms (Ω).

2

Temperature, Length, and Thickness

- The electric resistance of most materials usually increases as the temperature of the material increases.

- The resistance of an object such as a wire also depends on the length and diameter of the wire.

2

Temperature, Length, and Thickness

- The resistance of a wire, or any conductor, increases as the wire becomes longer.
- The resistance also increases as the wire becomes thinner.

2

The Current in a Simple Circuit

- A simple electric circuit contains a source of voltage difference, such as a battery, a device, such as a lightbulb, that has resistance, and conductors that connect the device to the battery terminals.

- When the wires are connected to the battery terminals, current flows in the closed path.

2

The Current in a Simple Circuit

- The voltage difference, current, and resistance in a circuit are related.
- If the voltage difference doesn't change, decreasing the resistance increases the current in the circuit.
- If the resistance doesn't change, increasing the voltage difference increases the current.

2

Ohm's Law

- According to **Ohm's law**, the current in a circuit equals the voltage difference divided by the resistance.
- If *I* stands for the electric current, Ohm's law can be written as the following equation.

Ohm's Law

$$\text{current (in amperes)} = \frac{\text{voltage difference (in volts)}}{\text{resistance (in ohms)}}$$

$$I = \frac{V}{R}$$

2

Ohm's Law

- Ohm's law provides a way to measure the resistance of objects and materials. First the equation below is written as:

$$R = \frac{V}{I}$$

- An object is connected to a source of voltage difference and the current flowing in the circuit is measured.
- The object's resistance then equals the voltage difference divided by the measured current.

2

Question 1

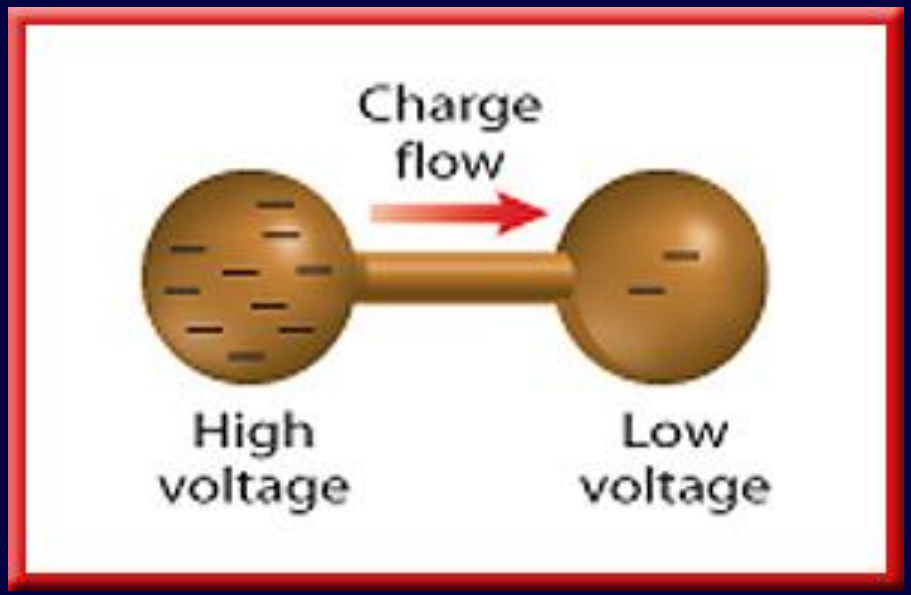
_____ is the net movement of electric charges in a single direction.

A. An open circuit
B. Electric current
C. Proton flow
D. Voltage

2

Answer

The answer is B. Electric forces in a material cause electric current to flow.



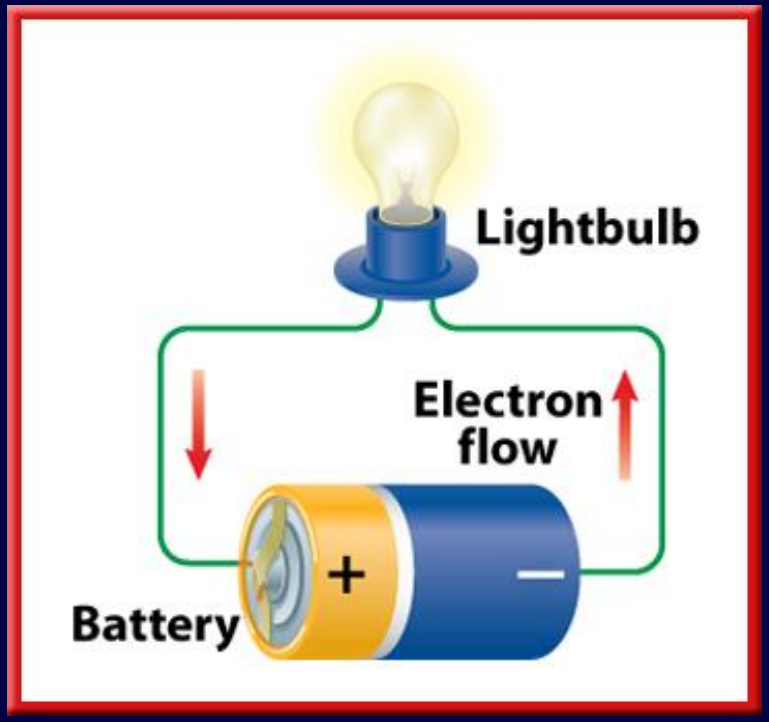
2

Question 2

What is a volt?

Answer

A volt is the unit of measurement for voltage difference, which is related to the force that causes electric charges to flow.



2

Question 3

What is the tendency for a material to oppose the flow of electrons called?

Answer

The tendency for a material to oppose the flow of electrons is called resistance, and is measured in ohms.

3

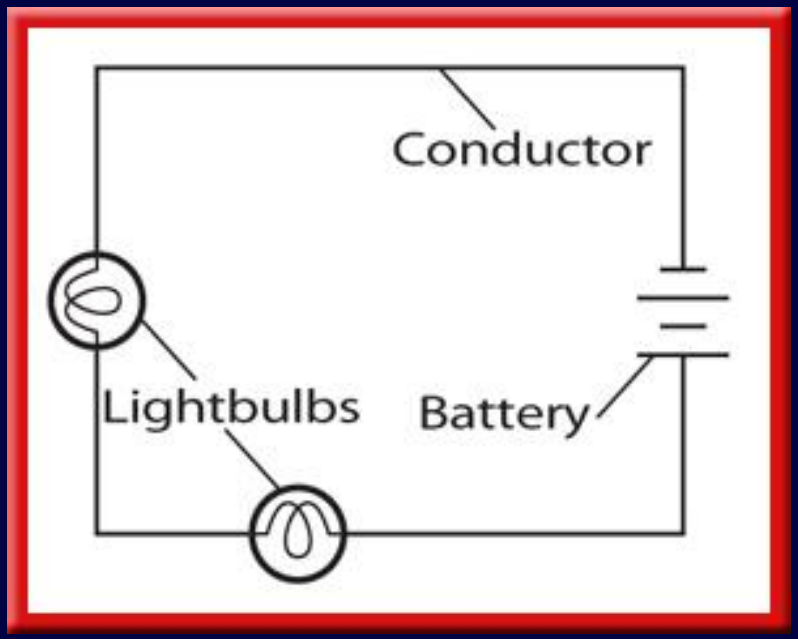
Series and Parallel Circuits

- Circuits usually include three components. One is a source of voltage difference that can be provided by a battery or an electrical outlet.
- Another is one or more devices that use electrical energy.
- Circuits also include conductors such as wires that connect the devices to the source of voltage difference to form a closed path.

3

Series Circuits

- One kind of circuit is called a series circuit.



- In a **series circuit**, the current has only one loop to flow through.
- Series circuits are used in flashlights and some holiday lights.

3

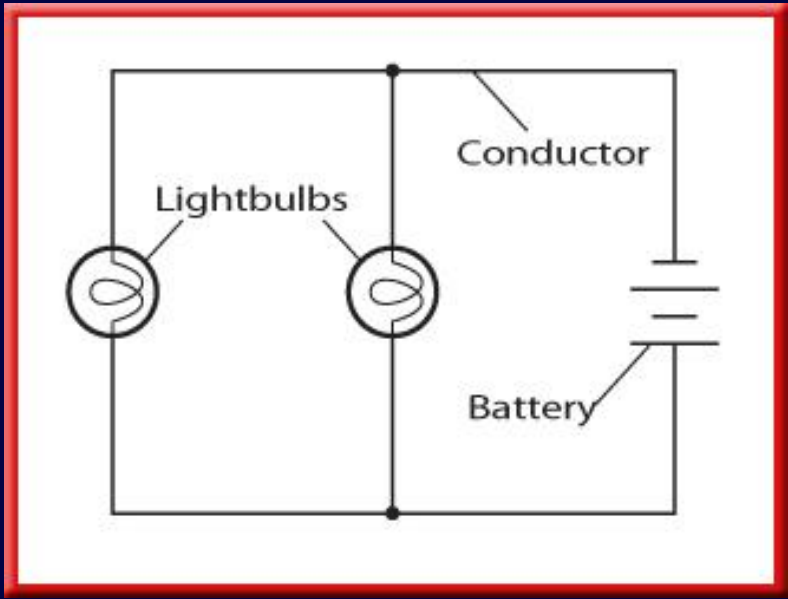
Open Circuit

- How can one faulty bulb cause a whole string of lights to go out?
- When any part of a series circuit is disconnected, no current flows through the circuit.
- This is called an open circuit. The burned-out bulb causes an open circuit in the string of lights.

3

Parallel Circuits

- Houses are wired with parallel circuits.
- **Parallel circuits** contain two or more branches for current to move through.

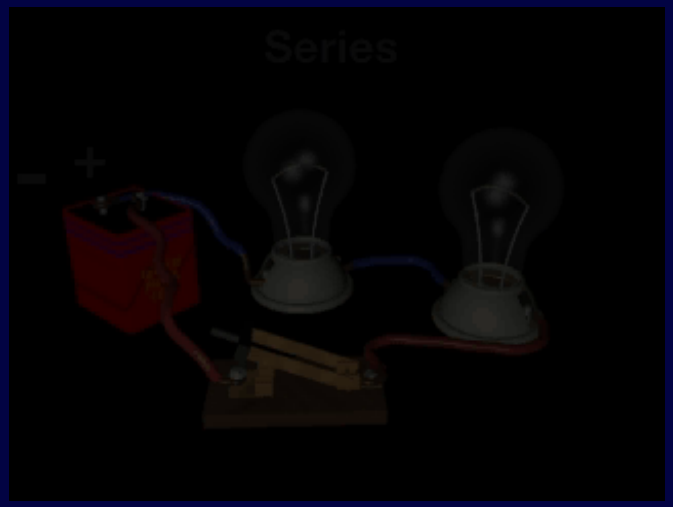


- The current can flow through both or either of the branches.

3

Parallel Circuits

- Parallel circuits have several advantages.
- When one branch of the circuit is opened, such as when you turn a light off, the current continues to flow through the other branches.



Click box to play movie.

3

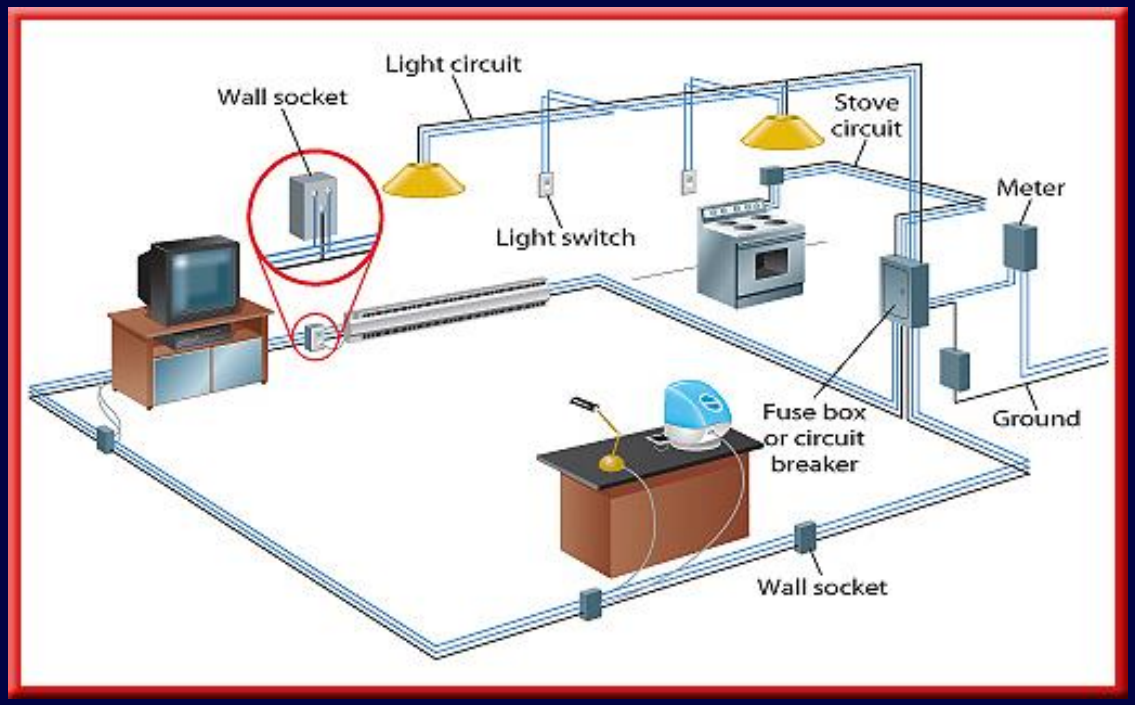
Household Circuits

- The wiring in a house must allow for the individual use of various appliances and fixtures.
- This wiring is mostly a combination of parallel circuits connected in an organized and logical network.

3

Household Circuits

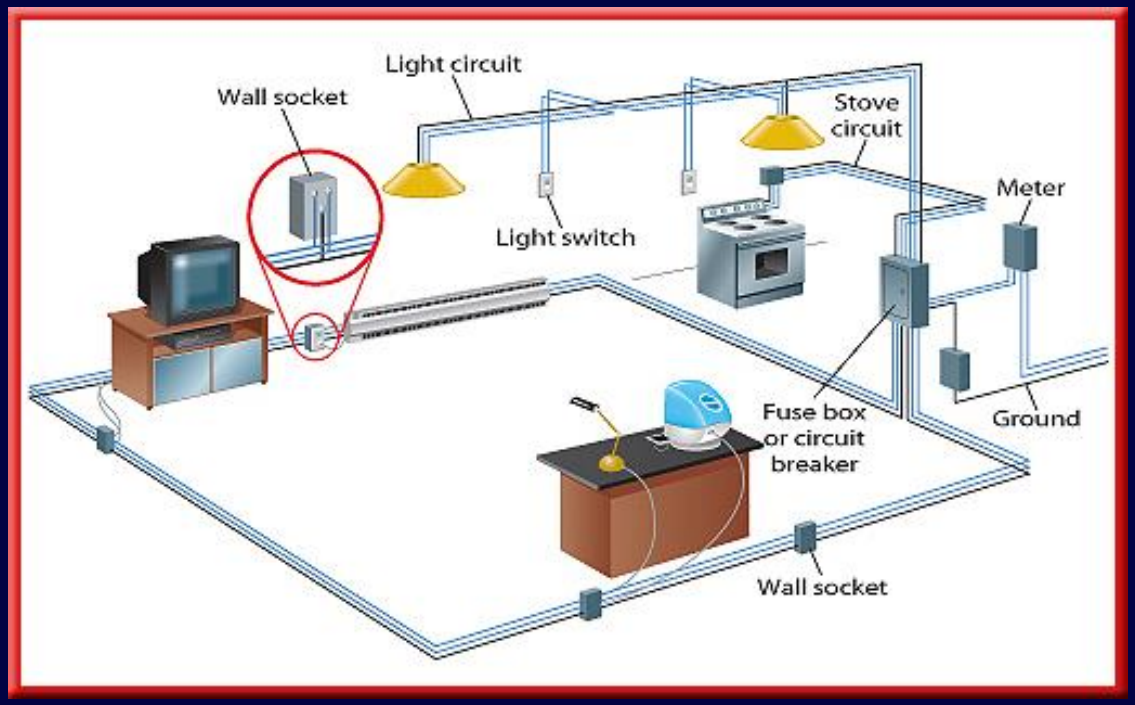
- The main switch and circuit breaker or fuse box serve as an electrical headquarters for your home.



3

Household Circuits

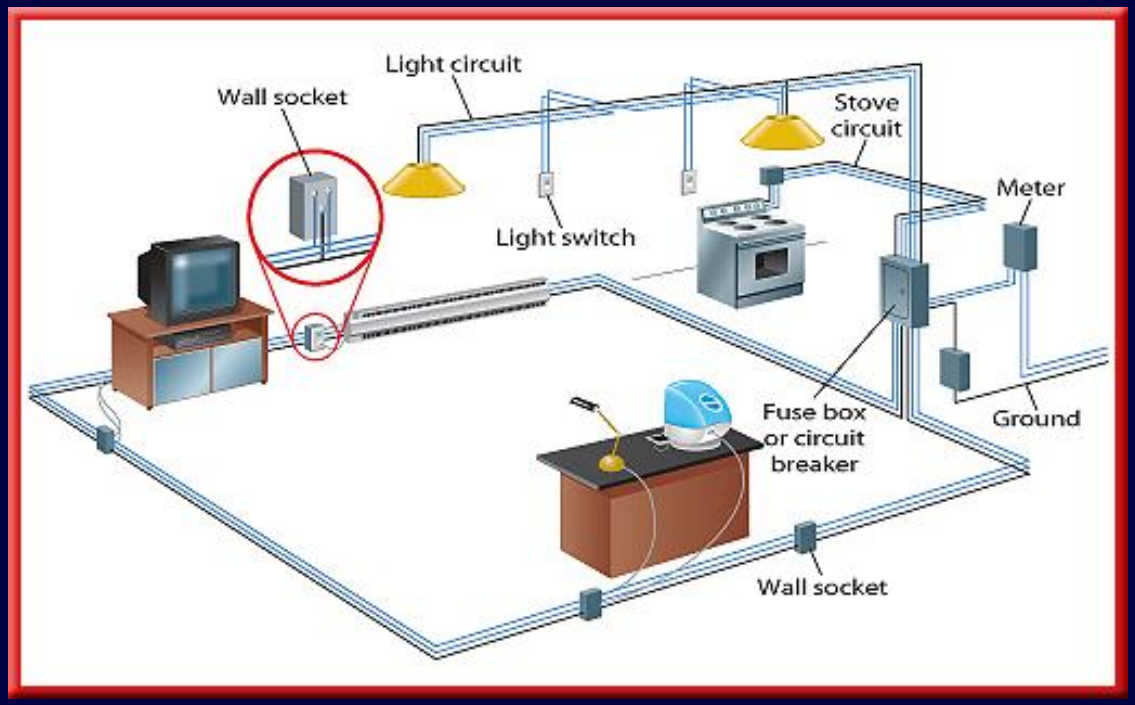
- Parallel circuits branch out from the breaker or fuse box to wall sockets, major appliances, and lights.



3

Household Circuits

- To protect against overheating of the wires, all household circuits contain either a fuse or a circuit breaker.



3

Fuses

- An electrical fuse contains a small piece of metal that melts if the current becomes too high.

- When it melts, it causes a break in the circuit, stopping the flow of current through the overloaded circuit.

3

Fuses

- To enable current to flow again in the circuit, you must replace the blown fuse with a new one.

- Too many appliances in use at the same time is the most likely cause for the overheating of the circuit.

3

Circuit Breaker

- A circuit breaker contains a piece of metal that bends when the current in it is so large that it gets hot.
- The bending causes a switch to flip and open the circuit, stopping the flow of current.
- Circuit breakers usually can be reset by pushing the switch to its “on” position.

3

Electric Power

- The reason that electricity is so useful is that electrical energy is converted easily to other types of energy.

- The rate at which electrical energy is converted to another form of energy is the **electric power**.

3

Calculating Electric Power

- Electric power can be calculated from the following equation.

Electric Power Equation

electric power (in watts) = **current** (in amperes) × **voltage difference** (in volts)

$$P = IV$$

- The unit for power is the watt (W). Because the watt is a small unit of power, electric power is often expressed in kilowatts (kW).
- One kilowatt equals 1,000 watts.

3

Electrical Energy

- Electric companies charge by the amount of electrical energy used, rather than by the electric power used.
- Electrical energy usually is measured in units of kilowatt hours (kWh) and can be calculated from this equation:

Electric Energy Equation

electric energy (in kWh) = **electric power** (in kW) × **time** (in hours)

$$E = PT$$

3

The Cost of Using Electrical Energy

- The cost of using the appliance can be computed by multiplying the electrical energy used by the amount the power company charges for each kWh.
- For example, if a 100-W lightbulb is left on for 5 h, the amount of electrical energy used is:

$$E = Pt = (0.1\ \text{kW})\ (5\ \text{h}) = 0.5\ \text{kWh}$$

3

The Cost of Using Electrical Energy

Power and Energy Used by Home Appliances

Appliance	Time of Usage (h/day)	Power Rating (W)	Energy Usage (kWh/day)
Hair dryer	0.25	1,000	0.25
Microwave oven	0.5	700	0.35
Stereo	2.5	100	0.27
Range (oven)	1	2,600	2.60
Refrigerator/freezer (15 ft^3, frostless)	10	615	6.15
Television (color)	3.25	200	0.80
100-W lightbulb	6	100	0.60
40-W fluorescent lightbulb	1	40	0.04

- The cost of using some household appliances is given in this table, where the cost per kWh is assumed to be $0.09/kWh.

3

Question 1

What is an open circuit?

Answer

An open circuit is a series circuit in which one part is disconnected. This prevents current from flowing through the circuit.

3

Question 2

The rate at which electrical energy is converted to another form of energy is called _____.

A. electrical fuse
B. electrical switching
C. electric power
D. thermal energy

3

Answer

The answer is C. Electric power is the rate of energy conversion and is measured in watts.

3

Question 3

Which of the following equations is used to calculate electric power?

A. $P = IV$
B. $P = I/V$
C. $P = V/I$
D. $P = AV$

3

Answer

The answer is A. Electric power is equal to the current, *I*, multiplied by the voltage difference, *V*.

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End of Chapter Summary File