Name ____________________ Class ______________ Date __________

Summary

20.1 Electric Charge and Static Electricity

Electric charge is a trait of protons and electrons. Protons have a positive electric charge. Electrons have a negative electric charge. An atom has a net, or overall, electric charge of zero. This is because an atom has equal numbers of protons and electrons. An atom can gain or lose electrons. If an atom gains electrons, it has a net negative charge. If an atom loses electrons, it has a net positive charge. The unit of electric charge is the coulomb (C).

Like charges repel, or push, each other. Unlike charges attract, or pull, each other. Electric force is the pushing and pulling between charged objects. The electric force between two objects depends on the net charge of each object and the distance between the objects.

An electric charge has an effect on other charges in the space around it. This effect is called an electric field. An electric field exerts forces on any charged object in the field. The strength of the electric field depends on the amount of charge that produces the field and the distance from the charge.

Static electricity is the study of the behavior of electric charges, including the transfer of charges. Charges can be transferred from one object to another. This can happen in three ways: friction, induction, and contact. When you walk across a carpet, electrons are transferred from the carpet to you. You become negatively charged. This happens because of friction. As you reach for a doorknob, your negatively charged hand repels electrons in the doorknob. The end of the doorknob near your hand becomes positively charged even before you touch it. This happens because of induction. When you actually touch the doorknob, electrons rush from your hand to the doorknob. This happens because of contact. The rush of electrons from your hand to the doorknob is called static discharge. Static discharge occurs when charges suddenly find a new pathway to follow. A lightning bolt is a huge static discharge between two clouds or between a cloud and the ground.

Although charges can be transferred, there is never any overall change in charge. This is the law of conservation of charge.

20.2 Electric Current and Ohm's Law

Electric current is a flow of electric charges. The unit of electric current is the ampere (A), which equals 1 coulomb per second. There are two types of electric current: direct current (DC) and alternating current (AC).

- Direct current always flows in the same direction. Direct current is used in flashlights and other devices that use batteries.
- Alternating current keeps changing direction. Alternating current is used in homes and schools.

An electrical conductor is a material through which charges can flow easily. Copper and silver are good electrical conductors because they have free electrons that can conduct charge. An electrical insulator is a material through which charges cannot flow easily. Wood and plastic are good electrical insulators.

As electrons flow through a wire, they collide with other electrons and with ions. This reduces the current. This opposition to the flow of charges is called resistance. The amount of resistance in a wire depends on how thick, long, and warm the wire is. A thicker wire has less resistance, because more charges can flow through it. A longer wire has more resistance, because charges must travel farther. A warmer wire also has more resistance. This is because the wire's electrons collide more often. A material that has almost no resistance at very low temperatures is called a superconductor.

For charges to flow in a wire, the wire must be part of a closed loop. The loop also must include a source of voltage, such as a battery. Voltage is a difference in electrical potential energy. A difference in electrical potential energy causes charges to flow spontaneously, or on their own. The charges flow from a negatively charged area to a positively charged area. In a battery, one terminal is positive and the other terminal is negative. Therefore, there is a difference in electrical potential between the terminals. In a circuit, charges flow from the negative terminal through the wire to the positive terminal.

Voltage, current, and resistance are related. Georg Ohm discovered this relationship. It is called Ohm's law. According to the law, voltage (V) equals current (I) times resistance (R):

$$V = I \times R$$

This equation can also be written as

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

This form of the equation shows that increasing voltage increases current. It also shows that increasing resistance decreases current.

20.3 Electric Circuits

An electric circuit is a complete path through which charges can flow. Wires in a house are joined in many connected circuits. An electrician uses circuit diagrams to keep track of all the circuits in a house. Circuit diagrams use symbols to represent the different parts of a circuit. There are symbols for the source of electrical energy and for the devices that use the energy. Circuit diagrams also show the paths through which charges can flow. In addition, switches show places where the circuit can be opened. If a switch is open, the circuit is not a complete loop, and current cannot flow. When the switch is closed, the circuit is complete, and current can flow.

There are two types of electric circuits: series circuits and parallel circuits.

- A series circuit has only one path through which current can flow. If a light bulb burns out in a series circuit, current stops flowing throughout the entire circuit.
- A parallel circuit has more than one path through which current can flow. If a light bulb burns out in a parallel circuit, current can flow through another path in the circuit.

Appliances change electrical energy to other forms of energy. For example, a toaster changes electrical energy to heat energy. Electric power is the speed at which an appliance changes electrical energy to another form of energy. Units of electric power are the watt (W) and kilowatt (kW). One kilowatt equals 1000 watts. You can calculate electric power (P) of an appliance by multiplying current (I) by voltage (V):

$$P = I \times V$$

You can also calculate the electrical energy used by an appliance. Electrical energy (E) equals power (P) multiplied by time (t):

$$E = P \times t$$

A common unit of electrical energy is the kilowatt-hour. For example, if a 6-kilowatt oven operates for 2 hours, it uses 12 kilowatt-hours of energy.

Electricity can be dangerous. It can kill people and start fires. Several things help make electrical energy safer to use. These include correct wiring, fuses, circuit breakers, insulation, and grounded plugs.

- Correct wiring can handle all the current a household needs without becoming overheated.
- Fuses and circuit breakers stop the current in a circuit if it becomes too high.
- Insulation around wires keeps the current safely inside the wires.
- Grounded plugs transfer excess current to the ground where it cannot do damage.

20.4 Electronic Devices

Electronics is the science of using electric currents to carry information. A current is encoded with a signal. It may be an analog signal or a digital signal. In an analog signal, the voltage changes continuously to code the information. In a digital signal, the current repeatedly goes on and off to code the information.

One way to control current in an electronic device is with a vacuum tube. One type of vacuum tube can increase or decrease voltage. It can also turn current on and off. Another type of vacuum tube is a cathode-ray tube. It turns electronic signals into images. Many computer monitors and televisions contain this type of vacuum tube. Vacuum tubes are too large to be used in small electronic devices.

Small electronic devices use semiconductors to control current. A semiconductor is a small piece of a solid that conducts current under certain conditions.There are two types of semiconductors: n-type and p-type. An n-type semiconductor contains weakly bound electrons that can flow. A p-type semiconductor contains positively charged holes that attract electrons. When n-type and p-type semiconductors are joined together, electrons in the n-type semiconductor are attracted to the positive holes in the p-type semiconductor. As electrons jump from hole to hole, it looks like a flow of positive charge because the locations of the holes change.

A semiconductor is an example of a solid-state component. Solid-state components are devices that use solids to control current. Most modern electronic devices have solid-state components. Three types of solid-state components are diodes, transistors, and integrated circuits.

- A diode is a solid-state component containing an n-type and a p-type semiconductor. A diode can change alternating current to direct current.
- A transistor is a solid-state component with three layers of semiconductors. A transistor can increase voltage.
- An integrated circuit consists of a thin slice of silicon. The silicon contains many solid-state components. Integrated circuits are sometimes called microchips. They are used in computers, cell phones, and pagers. Integrated circuits are tiny. They are very fast, because the current does not have far to travel.