Chapter 20: Electricity

20.1 Electric Charge and Static Electricity

Electric Charge

Electric charge is a property that causes subatomic particles such as protons and electrons to attract or repel each other.

- Protons have a positive charge.
- Electrons have a negative charge.

Electric Charge

In an atom, a cloud of negatively charged electrons surrounds the positively charged nucleus. The atom is neutral because it has equal numbers of positive and negative charges.

- If an atom gains electrons, it becomes a negatively charged ion.
- If an atom loses electrons, it becomes a positively charged ion.

Electric Charge

The SI unit of electric charge is the coulomb (C).

- It takes about 6.24×10^{18} electrons to produce a single coulomb.

Electric Forces

The force of attraction or repulsion between electrically charged objects is **electric force.**

- The electric force between two objects is directly proportional to the net charge on each object.
- The electric force is inversely proportional to the square of the distance between the objects.

Electric Forces

Doubling the net charge on one object doubles the electric force.

Doubling the distance between the objects decreases the electric force to one fourth the original force.

Inside an atom, electric forces are much stronger than gravitational forces.

Electric Fields

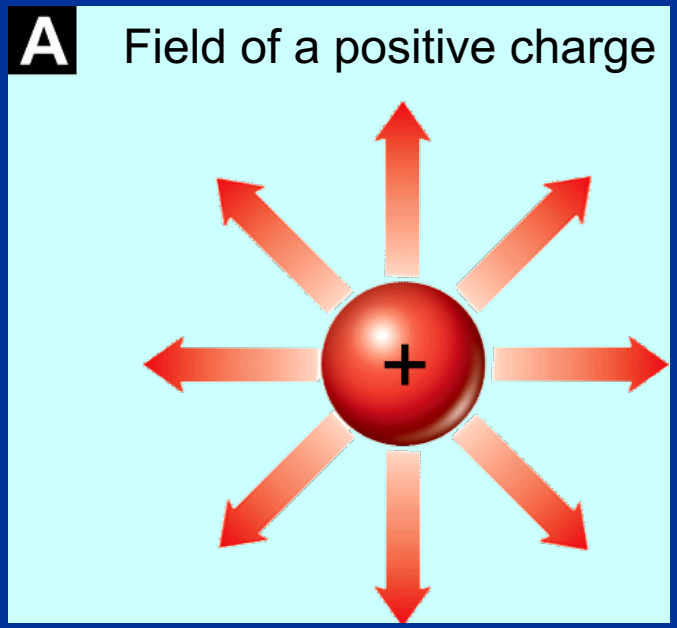
The effect an electric charge has on other charges in the space around it is the charge's **electric field.**

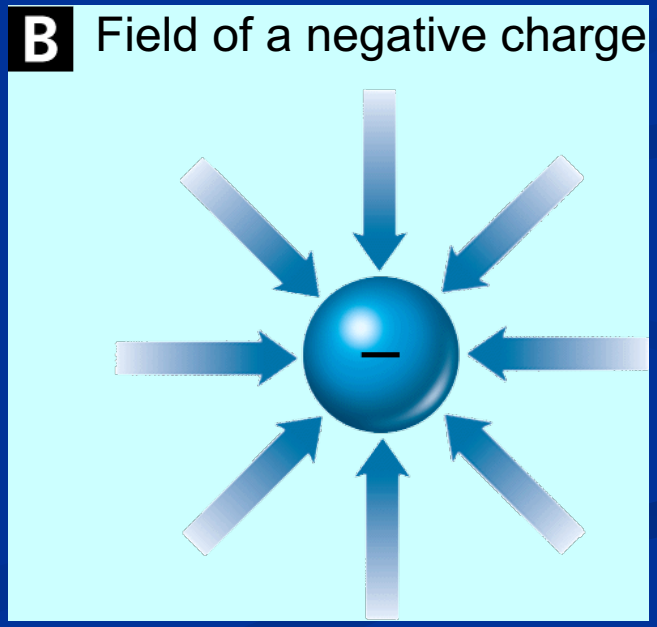
- An electric field exerts forces on any charged object placed in the field.
- The force depends on the net charge on the object and on the strength and direction of the field at the object's position.
- The direction of each field line shows the direction of the force on a positive charge.

Electric Fields

A. The electric field around a positive charge points outward.

B. The electric field around a negative charge points inward.





Static Electricity and Charging

Static electricity is the study of the behavior of electric charges.

According to the **law of conservation of charge**, the total charge in an isolated system is constant. When there is a charge transfer, the total charge is the same before and after the transfer occurs.

Charging by Friction

Rubbing a balloon on your hair causes charging by friction.

- Electrons move from your hair to the balloon because atoms in rubber have a greater attraction for electrons than atoms in hair.
- The balloon picks up a net negative charge.
- Your hair loses electrons and becomes positively charged.

Charging by Contact

A Van de Graaff generator builds a charge on a metal sphere. Touching the sphere transfers charge by contact.

The sphere is still charged, but its net charge is reduced.

Charging by Induction

Walking on a carpet builds a negative charge on your body. The negative charge in your hand repels electrons in a metal doorknob.

The doorknob is still neutral, but charge has moved within it. This is **induction**, a transfer of charge without contact between materials.

Static Discharge

Static discharge occurs when a pathway through which charges can move forms suddenly.

Static Discharge

Lightning is a more dramatic discharge.

- Charge can build up in a storm cloud from friction between moving air masses.
- Negative charge in the lower part of the cloud induces a positive charge in the ground below the cloud.
- As the charge in the cloud increases, the force of attraction between charges in the cloud and charges in the ground increases.
- Eventually the air becomes charged, forming a pathway for electrons to travel from the cloud to the ground.

Assessment Questions

1. Which of the following would double the electric force between two charged objects?
   a. doubling the mass of the objects
   b. doubling the net charge of both objects
   c. doubling the net charge of one of the objects
   d. cutting the distance between the objects in half

Assessment Questions

2. The attractive or repulsive effect an electric charge has on other charges in the space around it is the charge's
   a. electric force.
   b. electric field.
   c. static electricity.
   d. static discharge.

Assessment Questions

3. An object becomes charged by induction when there is a
   a. transfer of electrons, as the object rubs against another object.
   b. transfer of charge, as it contacts another charged object.
   c. transfer of charge by motion of electrons within the object.
   d. a sudden movement of electric charge from another object.

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20.2 Electric Current and Ohm's Law

Electric Current

The continuous flow of electric charge is an **electric current.**

- Charge flows only in one direction in **direct current** (DC). A flashlight and most other battery-operated devices use direct current.
- **Alternating current** (AC) is a flow of electric charge that regularly reverses its direction.

Electric Current

The SI unit of electric current is the ampere (A), or amp, which equals 1 coulomb per second.

Even though electrons flow in an electric current, scientists define current as the direction in which positive charges would flow.

Conductors and Insulators

An **electrical conductor** is a material through which charge can flow easily.

An **electrical insulator** is a material through which charge cannot flow easily.

Resistance

Resistance is opposition to the flow of charges in a material.

- As electrons move through a conducting wire, they collide with electrons and ions. These collisions convert some kinetic energy into thermal energy, and the current is reduced.
- The SI unit of resistance is the ohm.

Resistance

Resistance is greater in a longer wire because the charges travel farther. As temperature increases, a metal's resistance increases because electrons collide more often.

A **superconductor** is a material that has almost zero resistance when it is cooled to low temperatures.

Potential Difference

Electric charges flow from a higher to a lower potential energy.

- **Potential difference** is the difference in electrical potential energy between two places in an electric field.
- Potential difference is measured in joules per coulomb, or volts. Because it is measured in volts, potential difference is also called **voltage.**

Voltage Sources

A source of voltage does work to increase the potential energy of electric charges. Three common voltage sources are batteries, solar cells, and generators.

A battery is a device that converts chemical energy to electrical energy.

Ohm's Law

According to **Ohm's law,** the voltage (V) in a circuit equals the product of the current (I) and the resistance (R).

Ohm's Law

$$V = I \times R \text{ or } I = \frac{V}{R}$$

When the current is in amperes, and the resistance is in ohms, the voltage is in volts.

Ohm's Law

What is the voltage if the resistance is 3 ohms and the current is 3 amps?

Resistance Example

- The headlights of a typical car are powered by a 12 V battery. What is the resistance of the headlights if they draw 3.0 A of current when turned on?

Resistance Practice

1. Find resistance if a portable lantern uses 24 V power supply and draws a current of 0.8 A
2. If the current is 0.5 A and the resistance is 12 Ω, what is the voltage?

Resistance Practice

I (amps)	V (volts)	R (ohms)
	12	75
15	240	
5.5		20
	6	25
5	110	

Assessment Questions

1. Which of the following materials is a good conductor of electric current?

   a. wood

   b. glass

   c. air

   d. iron

Assessment Questions

2. If a piece of wire has a certain resistance, which wire made of the same material will have a lower resistance?
   a. a hotter wire
   b. a thicker wire
   c. a longer wire
   d. a thinner wire

Assessment Questions

3. What does the voltage between two points in an electric field represent?
   a. the total kinetic energy
   b. the difference in mechanical energy
   c. the difference in potential energy
   d. the electrical energy

Assessment Questions

4. A 9-volt battery drives an electric current through a circuit with 4-ohm resistance. What is the electric current running through the circuit?
   a. 0.44 A
   b. 2.25 A
   c. 5 A
   d. 36 A

Assessment Questions

5. The two types of electric current are direct current and indirect current.

True
False

Chapter 20 Electricity

20.3 Electric Circuits

Circuit Diagrams

An **electric circuit** is a complete path through which charge can flow.

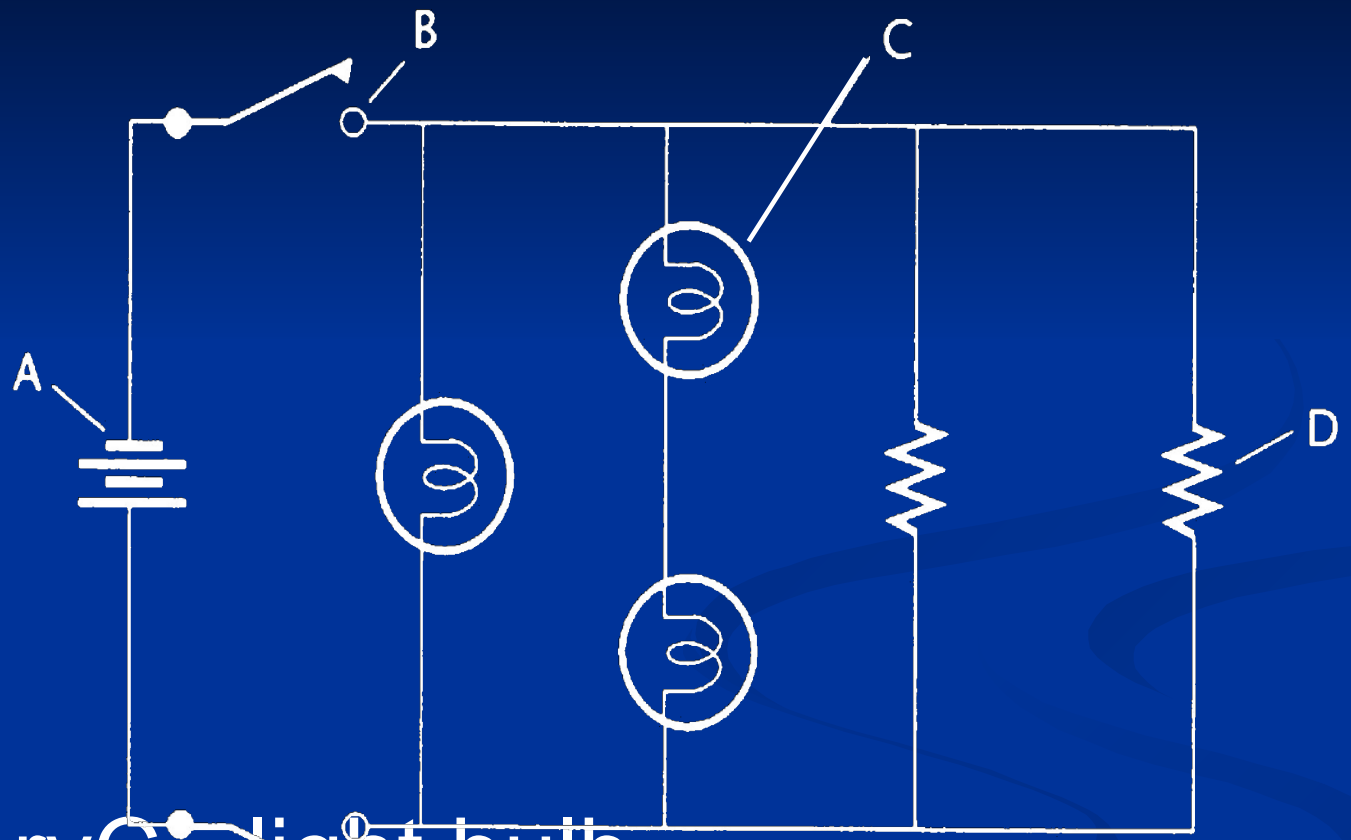
- A circuit diagram shows one or more complete paths in which charge can flow.
- Arrows show the direction of current, from positive to negative. The direction of current is defined as the direction in which positive charges would flow, but electrons flow in the opposite direction.

Circuit Diagrams

Switches show places where the circuit can be opened.

- If a switch is open, the circuit is not a complete loop, and current stops. This is called an open circuit.
- If the switch is closed, the circuit is complete, and charge can flow. This is called a closed circuit.

Circuit Components



A - batteryC - light bulb

B - switchD - resistor

Series Circuits

In a **series circuit**, charge has only one path through which it can flow.

- If one bulb burns out in a series circuit, it becomes an open circuit.
- The bulbs in a circuit are a source of resistance. Adding bulbs to a series circuit increases the resistance. The current decreases, and each bulb shines less brightly.

Parallel Circuits

A **parallel circuit** is an electric circuit with two or more paths through which charges can flow.

- If one bulb in a parallel circuit burns out, charge still flows along the other path, and the other bulb stays lit.
- In a home, electric circuits are wired in parallel so they can operate independently.

Power and Energy Calculations

The rate at which electrical energy is converted to another form of energy is **electric power.** Recall that power is the rate of doing work.

The unit of electric power is the joule per second, or watt (W). Power often is measured in thousands of watts, or kilowatts (kW).

Electrical Energy

$$E = P \times t$$

Math Skills

Calculating Electric Power

An electric oven is connected to a 240-volt line, and it uses 34 amps of current. What is the power used by the oven?

Power and Energy Calculations

1. A clothes dryer uses about 27 amps of current from a 240-volt line. How much power does it use?

Answer:

Power and Energy Calculations

2. A camcorder has a power rating of 2.3 watts. If the output voltage from its battery is 7.2 volts, what current does it use?

Answer:

Power and Energy Calculations

3. A power tool uses about 12 amps of current and has a power rating of 1440 watts. What voltage does the tool require?

Answer:

- 4.When a hairdryer is plugged into a 120 V outlet, it has 9.1 A current in it. What is the power rating?

Electric Power Practice

1. A heater requires 29 A of 120 V current, find power
2. A TV has a power rating of 320 W, how much current is there across 120 V?

Power and Energy Calculations

An appliance's power rating lets you know how much power it uses under normal conditions.

Find the electrical energy used by an appliance by multiplying power by time.

Electrical Energy

$$E = P \times t$$

Electrical Safety

Home Safety

A **fuse** prevents current overload in a circuit. A wire in the center of the fuse melts if too much current passes through it.

A **circuit breaker** is a switch that opens when current in a circuit is too high. The circuit breaker must be reset before the circuit can be used again.

Electrical Safety

Insulation also prevents short circuits.

A three-prong plug can prevent shocks caused by short circuits. If a short circuit develops, the current takes an easier path to ground through the grounding wire.

The transfer of excess charge through a conductor to Earth is called **grounding.**

Electrical Safety

A ground-fault circuit interrupter (GFCI) is an electrical safety outlet. It monitors current flowing to and from an outlet or appliance.

If these two currents are not equal, it means current is escaping.

The GFCI opens the circuit to prevent serious electric shocks.

Assessment Questions

1. A number of light bulbs are connected to an energy source in a series circuit. What will happen to the other bulbs if one of the bulbs burns out?
   a. Nothing will happen.
   b. They will be brighter.
   c. They will be dimmer.
   d. They will turn off.

Assessment Questions

2. A pair of 15-watt computer speakers are connected to a 12-volt power supply. What is the electric current running through the speakers?
   a. 0.8 A
   b. 1.25 A
   c. 12.5 A
   d. 180 A

Assessment Questions

3. A ground-fault circuit interrupter is a switch that opens to prevent overheating when the current in a circuit is too high.

   True
   False

Chapter 20 Electricity

20.4 Electronic Devices

Electronic Signals

The science of using electric current to process or transmit information is **electronics.**

- Information is carried by an **electronic signal,** patterns in the controlled flow of electrons through a circuit.

Electronic Signals

Analog Signals

An **analog signal** is a smoothly varying signal produced by continuously changing the voltage or current in a circuit.

Information is encoded in the strength or frequency of the analog signal.

Digital Signals

A **digital signal** encodes information as a string of 1's and 0's.

When the current is off, it represents a "0." When the current is on, it represents a "1."

Vacuum Tubes

A vacuum tube was used to control electron flow in early electronic devices.

Vacuum tubes have many useful features, but some types burn out frequently and need to be replaced. They are also much too large for use in small electronic devices.

Vacuum Tubes

One useful type of vacuum tube is a cathode-ray tube (CRT).

- Three metal plates in the CRT emit electron beams.
- The electrons strike a glass surface on the other end of the tube.
- The glass is coated with phosphors that glow red, green, or blue in response to the electron beams.

Semiconductors

A **semiconductor** is a crystalline solid that conducts current only under certain conditions.

- Most semiconductors are made with silicon or germanium. In pure form, these elements are poor conductors.

Semiconductors

- A p-type semiconductor can be made by adding a trace amount of boron to silicon. Spaces called holes occur at each boron atom. The holes are positively charged.
- An n-type semiconductor can be made by adding phosphorus to silicon. Phosphorus atoms provide weakly bound electrons that can flow.

Diodes

A **diode** is a solid-state component that combines an n-type and p-type semiconductor.

- When a voltage is applied across a diode, electrons flow from the n-type to the p-type semiconductor.
- There is no current if voltage is applied in the opposite direction.
- A diode can change alternating current to direct current.

Transistors

A **transistor** is a solid-state component with three layers of semiconductors.

- A small current flowing through its center layer changes its resistance.
- A transistor can be a switch–the small current can turn another current on or off.
- A transistor can be an amplifier–a small voltage applied to one side produces a large voltage on the other side.

Integrated Circuits

An **integrated circuit** is a thin slice of silicon that contains many solid-state components. Integrated circuits are sometimes called chips or microchips.

Communications Technology

A **computer** is a programmable device that can store and process information.

A mobile phone contains many solid-state components.

- Transistors amplify the phone's incoming signal.
- Capacitors store electric charge.
- Diodes maintain proper voltage levels in the circuits.

Assessment Questions

1. What is the function of a transistor in an electronic device?
   a. allows current flow in one direction but not the other
   b. stores electrical charges until they are needed
   c. acts as a current switch or amplifier
   d. converts analog signals into digital signals

Assessment Questions

2. What is the structure of a diode?
   a. a combination of an n-type semiconductor and a p-type semiconductor
   b. a combination of two n-type semiconductors
   c. an n-type semiconductor layer between two p-type semiconductors
   d. any combination of three semiconductors

Assessment Questions

3. Why are devices using integrated circuits smaller than comparable devices that do not use solid-state components?
   a. Many components can be built on a single silicon microchip.
   b. Solid-state devices do not need as many circuit components.
   c. Each vacuum tube is replaced by one microchip that is much smaller.
   d. Solid-state devices are smaller because they don’t need to hold as much electricity.

Assessment Questions

1. In electronic devices, a digital signal conveys information by converting it into a string of 1’s and 0’s.

   True
   False

2.