

Lecture Outline

Chapter 23: Electric Current

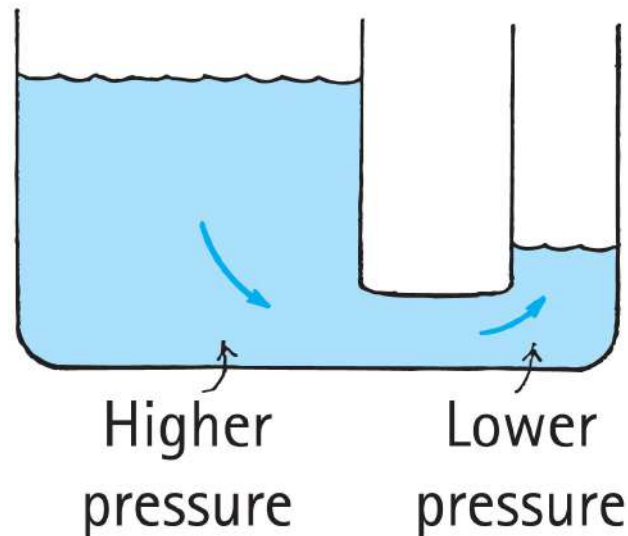


This lecture will help you understand:

- Flow of Charge
- Electric Current
- Voltage Sources
- Electrical Resistance
- Ohm's Law
- Direct Current and Alternating Current
- Speed and Source of Electrons in a Circuit
- Electric Power
- Compact Fluorescent Lamps (CFLs)
- Light-Emitting Diodes (LEDs)
- Electric Circuits

Flow of Charge

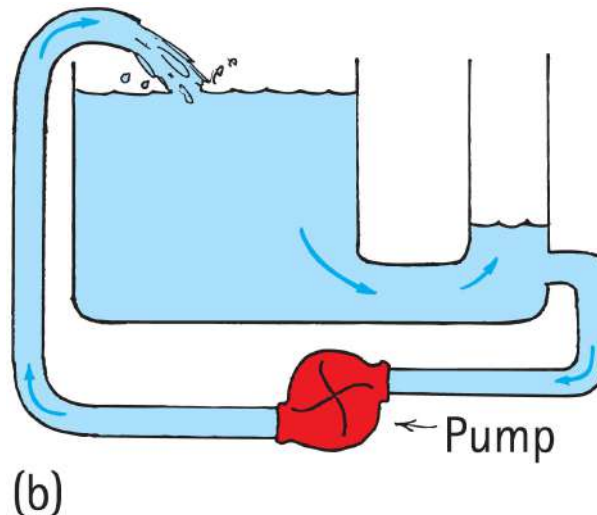
- When the ends of an electrical conductor are at different electric potentials—when there is a **potential difference**—charge flows from one end to the other.
 - Analogous to water flowing from higher pressure to lower pressure



(a)

Flow of Charge, Continued

- To attain a sustained flow of charge in a conductor, some arrangement must be provided to maintain a difference in potential while charge flows from one end to the other.
 - A continuous flow is possible if the difference in water levels—hence the difference in water pressures—is maintained with the use of a pump.



Electric Current

- Electric current
 - Flow of charged particles
 - In metal wires
 - Conduction electrons are charge carriers that are free to move throughout atomic lattice.
 - Protons are bound within the nuclei of atoms.
 - In fluids
 - Positive ions and electrons constitute electric charge flow.

Electric Current

CHECK YOUR NEIGHBOR

Which of these statements is true?

- A. Electric current is a flow of electric charge.
- B. Electric current is stored in batteries.
- C. Both A and B are true.
- D. Neither A nor B are true.

Electric Current

CHECK YOUR ANSWER

Which of these statements is true?

A. Electric current is a flow of electric charge.

Explanation:

Voltage, not current, is stored in batteries. The voltage will produce a current in a connecting circuit. The battery moves electrons already in the wire, but not necessarily those in the battery.

Electric Current, Continued

- Rate of electric flow
 - Measured in ampere (1 coulomb of charge per second).
 - Speed of electrons (drift speed) through a wire is slow because of continuous bumping of electrons in wire.
 - Charge flows *through* a circuit; voltage is established *across* a circuit.

Electric Current, Continued-1

- Alternating current
 - Electrons oscillate to and fro around fixed positions.
 - Movement is produced by a generator or an alternator that switches the signs of charge periodically.
 - Commercial ac circuits are used in most residential circuits throughout the world and can be stepped up to high voltage for transmission over great distances with small heat losses, or stepped down where energy is consumed.

Voltage Sources

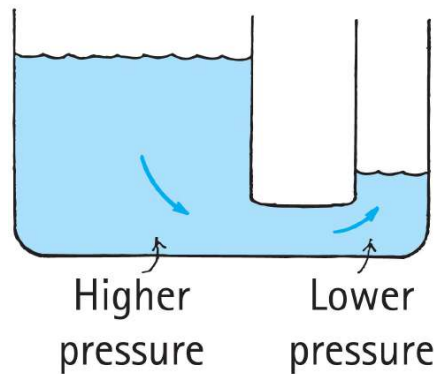
- Conductor
 - Any material having free charged particles that easily flow through it when an electric force acts on them

Voltage Sources, Continued

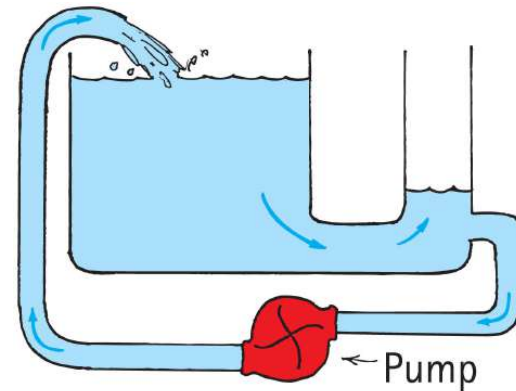
- Electric potential difference
 - Difference in potential between two points
 - Charges in conductor flow from higher potential to lower potential.
 - Flow of charge persists until both ends of conductor reach the same potential.
 - Maintained for continuous flow by pumping device.

Voltage Sources, Continued-1

- Electric potential difference (continued)
 - Example: Water from a higher reservoir to a lower one—flow continues until no difference



(a)

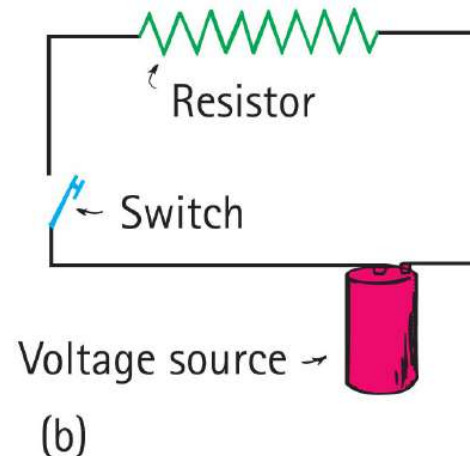
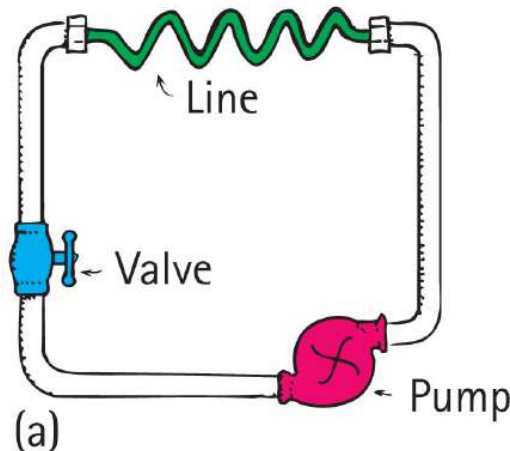


(b)

- No flow of charge occurs when potential difference is zero.

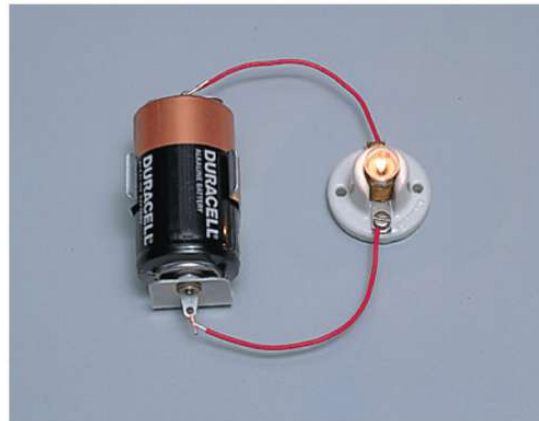
Voltage Sources, Continued-2

- Electric potential difference (continued)
 - A battery or generator can maintain a steady flow of charge.
 - Work is done in pulling negative charges apart from positive ones.
 - Electromagnetic induction at the generator terminals provides the electrical pressure to move electrons through the circuit.



Voltage Sources, Continued-3

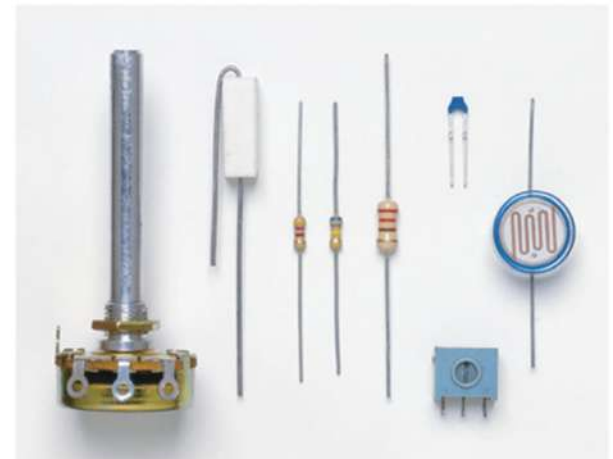
- Electric potential difference
 - In chemical batteries
 - Work by chemical disintegration of zinc or lead in acid.
 - Energy stored in chemical bonds is converted to electric potential energy.



Electric Resistance

- Current in a circuit is dependent on
 - voltage.
 - electrical resistance in ohms.
- Resistors
 - circuit elements that regulate current inside electrical devices

Resistors. The symbol of resistance in an electric circuit is 

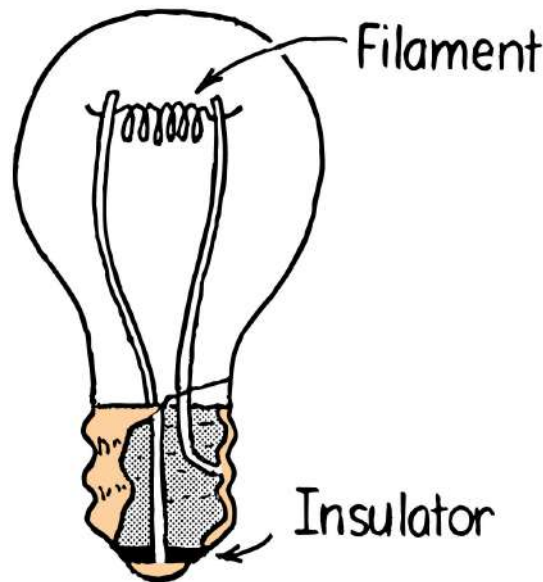


Electric Resistance, Continued

- Factors affecting electrical resistance:
 - Inversely proportional to cross-sectional area
 - thin wires, more resistance than thick wires
 - Directly proportional to length
 - doubling the length, doubles the resistance
 - Material
 - rubber—much more resistance than copper of the same size

Electric Resistance, Continued-1

- Factors affecting electrical resistance (continued)
 - Temperature
 - the higher the temperature, the more the resistance



Electric Resistance, Continued-2

- Semiconductors
 - Refers to materials that can alternate between being conductors and insulators
 - Example:
 - germanium
 - silicon

Electric Resistance, Continued-3

- Superconductors
 - Materials with zero electrical resistance to the flow of charge.
 - Flow of charge is without generation of heat.
- High-temperature superconductors
 - Refers to ceramic materials that can carry much current at a low voltage.

Ohm's Law

- Ohm's law
 - Relationship between voltage, current, and resistance
 - States that the current in a circuit varies in direct proportion to the potential difference, or voltage, and inversely with the resistance

Ohm's Law, Continued

- Ohm's law (continued)
 - In equation form: $\text{Current} = \frac{\text{voltage}}{\text{resistance}}$
 - Example:
 - For a constant resistance, current will be twice as much for twice the voltage.
 - For twice the resistance and twice the voltage, current will be unchanged.
- Resistors
 - Circuit elements that regulate current inside electrical devices.

Ohm's Law

CHECK YOUR NEIGHBOR

When you double the voltage in a simple electric circuit, you double the

- A. current.
- B. resistance.
- C. Both A and B.
- D. Neither A nor B.

Ohm's Law

CHECK YOUR ANSWER

When you double the voltage in a simple electric circuit, you double the

A. current.

Explanation:

This is a straightforward application of Ohm's law.

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

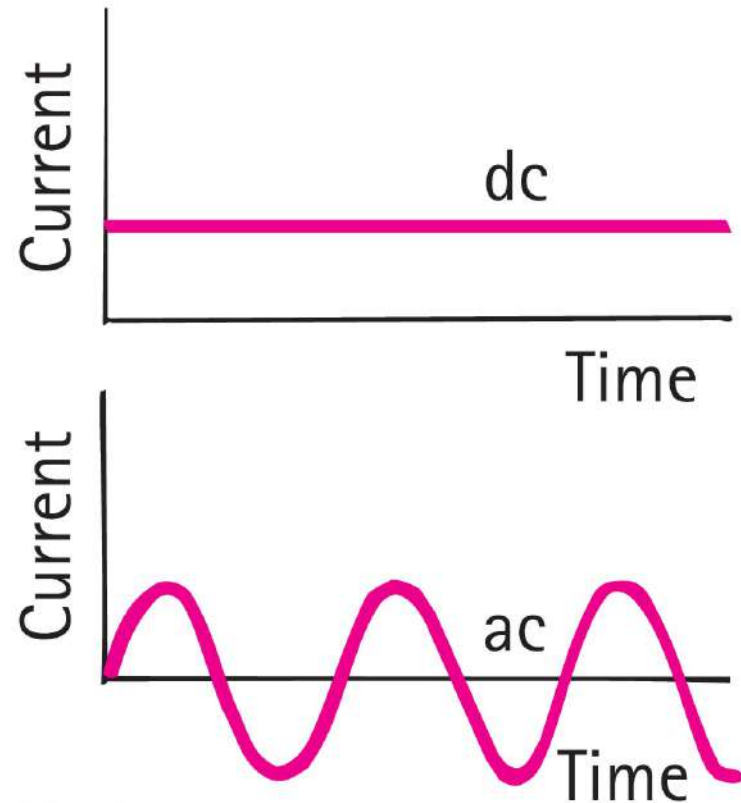
Ohm's Law, Continued-1

- Electric shock
 - Damaging effects of shock result from current passing through the body.
 - Electric potential difference between one part of your body and another part depends on body condition and resistance, which can range from 100 ohms to 500,000 ohms.



Direct and Alternating Current

- Direct current (dc)
 - Flows in one direction only.
 - Electrons always move from the negative terminal toward the positive terminal.
- Alternating Current (ac)
 - Electrons in the circuit are moved first in one direction and then in the opposite direction, alternating to and fro about fixed positions.
 - This is accomplished by alternating the polarity of voltage at the generator or other voltage source.

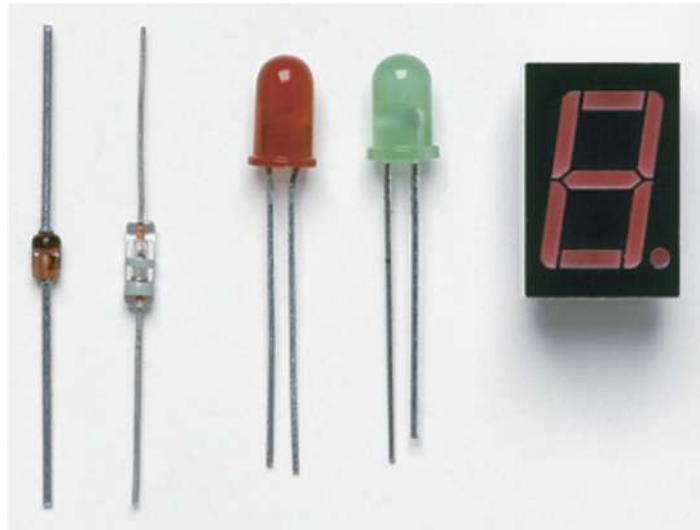


Direct and Alternating Current, Continued

- Commercial electricity in North America
 - Alternating current (ac)
 - 60 cycles per second
 - Voltage is 120 V
- Power transmission is more efficient at higher voltages.
 - Europe adopted 220 V as its standard.
 - U.S. continued with 120 V because so much equipment was already installed.

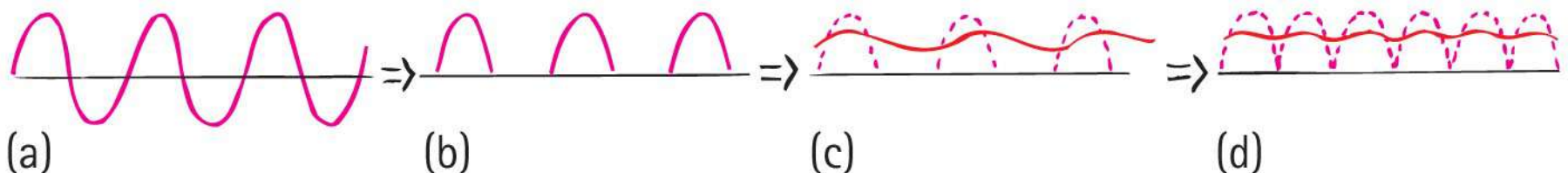
Direct and Alternating Current, Continued-1

- Converting from ac to dc
 - Household current is ac, but current in laptop is dc.
 - The converter uses a *diode*, a tiny electronic device that acts as a one-way valve to allow electron flow in one direction only.



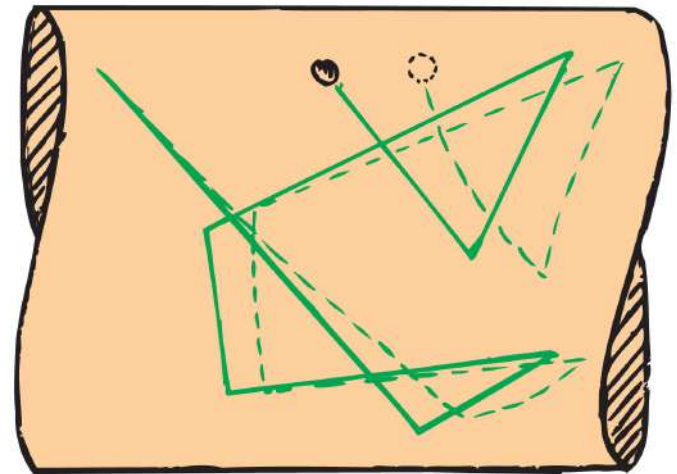
Direct and Alternating Current, Continued-2

- Converting from ac to dc
 - a. When input to a diode is ac, output is pulsating dc.
 - b. Slow charging and discharging of a capacitor provides continuous and smoother current.
 - c. A pair of diodes is used, so there are no gaps in current output. The pair of diodes reverses the polarity of alternate half-cycles instead of eliminating them.



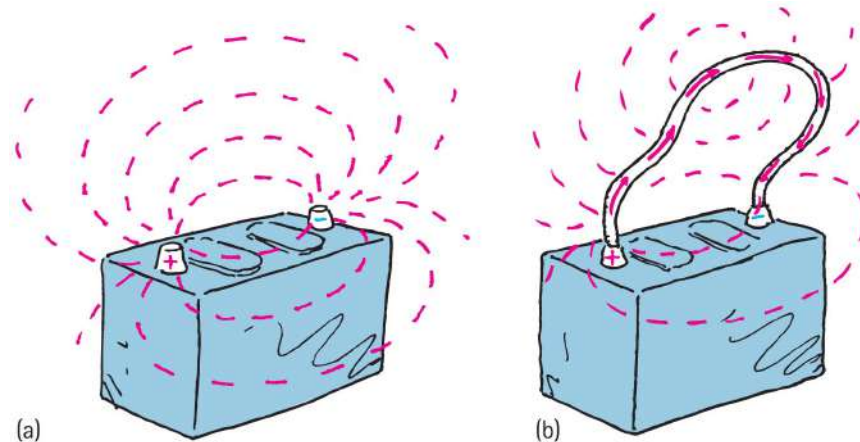
Speed and Source of Electrons in a Circuit

- When we flip the light switch on a wall and the circuit, an electric field is established inside the conductor.
 - The electrons continue their random motions while simultaneously being nudged by the electric field.
 - Current is established through the wires at nearly the speed of light.
 - It is *not* the electrons that move at this speed.
 - It is the electric field that can travel through a circuit at nearly the speed of light.



Speed and Source of Electrons in a Circuit, Continued

- If the voltage source is dc, like the battery, electric field lines are maintained in one direction in the conductor.
- Conduction electrons are accelerated by the field in a direction parallel to the field lines.
- Before they gain appreciable speed, they "bump into" the anchored metallic ions in their paths and transfer some of their kinetic energy to them.



(a)

(b)

Speed and Source of Electrons in a Circuit, Continued-1

- Misconceptions about electric current:
 - "Current is propagated through the conducting wires by electrons bumping into one another."
 - NOT true: Electrons that are free to move in a conductor are accelerated by the electric field impressed upon them.
 - True, they do bump into one another and other atoms, but this slows them down and offers resistance to their motion.
 - Electrons throughout the entire closed path of a circuit all react simultaneously to the electric field.

Speed and Source of Electrons in a Circuit, Continued-2

- Misconceptions about electric current:
 - "Electrical outlets in the walls of the homes are a source of electrons."
 - NOT true: The outlets in homes are ac. Electrons make no net migration through a wire in an ac circuit.
 - When you plug a lamp into an outlet, *energy* flows from the outlet into the lamp, not electrons. Energy is carried by the pulsating electric field and causes vibratory motion.
 - Electrical utility companies sell *energy*. You provide the electrons.

Electric Power

- Electric power
 - Rate at which electric energy is converted into another form
 - In equation form:
$$\text{Power} = \text{current} \times \text{voltage}$$
 - In units: watts

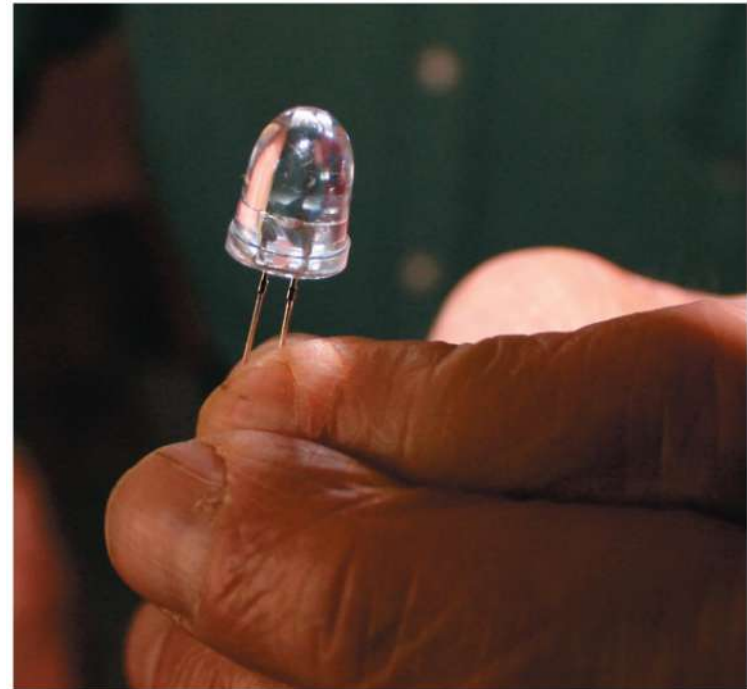
Compact Fluorescent Lamps (CFLs)

- Incandescent bulbs dissipate most of their energy in the form of heat, not light. So, they are not energy efficient.
- Fluorescent lamps, on the other hand, emit much less heat, which is why you can touch them without burning yourself.
- Compact fluorescent lamps (CFLs) are a type of fluorescent lamp that fits into a standard lightbulb socket.
- For the same wattage, CFLs emit much more light and much less heat than incandescent bulbs.



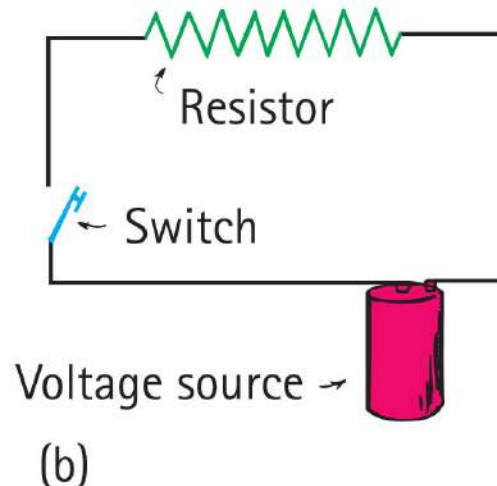
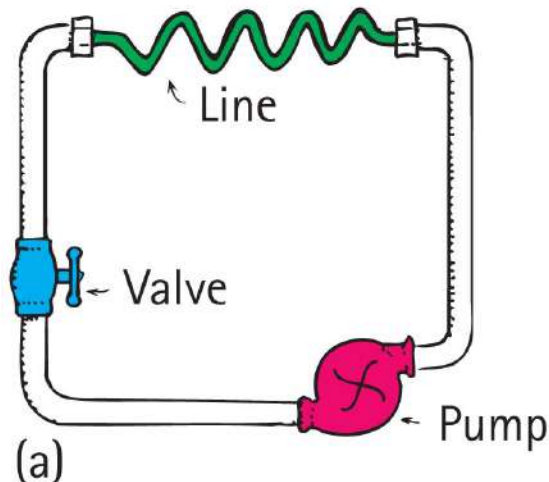
Light-Emitting Diodes (LEDs)

- Another light source even more long-lasting is the light-emitting diode (LED).
 - The most primitive being the little red lights that tell you whether your stereo is on or off
- Between CFLs and LEDs, common-use incandescent bulbs will soon be history.



Electric Circuits

- Circuits
 - Any path along which electrons can flow from the negative terminal to the positive terminal
 - Complete circuit allows continuous flow of electrons with no openings or gaps

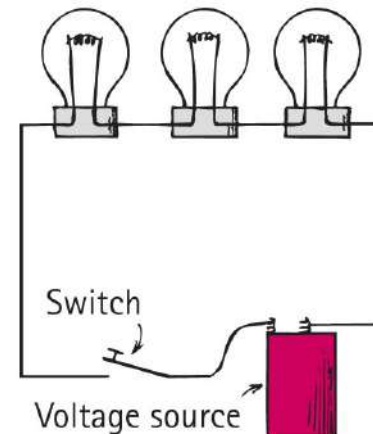
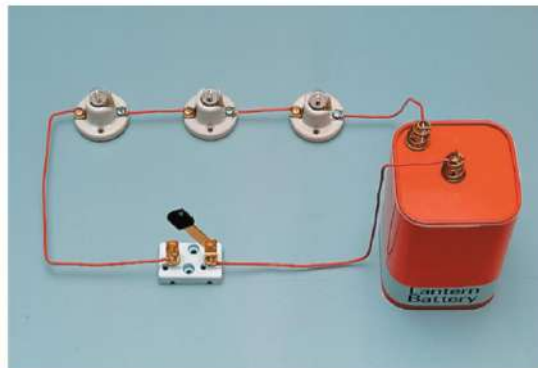


Electric Circuits, Continued

- Circuits
 - Connected in two common ways:
 - series
 - forms a single pathway for electron flow between the terminals of the battery, generator, or wall outlet
 - parallel
 - forms branches, each of which is a separate path for the flow of electrons

Electric Circuits, Continued-1

- Series circuits
 - Characteristics of series circuit
 1. Electric current through a single pathway.
 2. Total resistance to current is the sum of individual resistances.
 3. Current is equal to the voltage supplied by the source divided by the total resistance of the circuit.

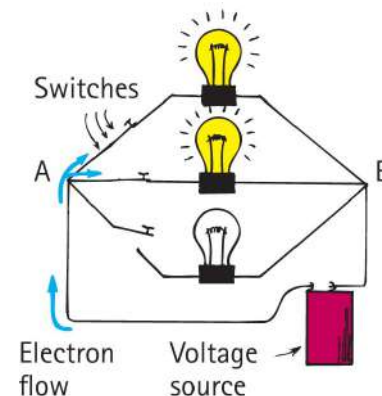
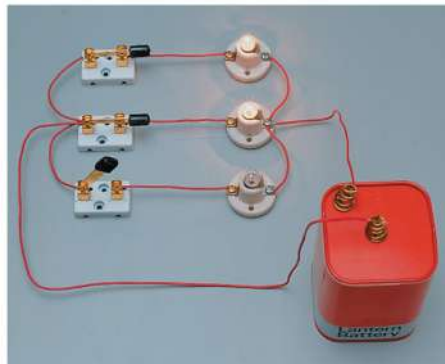


Electric Circuits, Continued-2

- Series circuits
 - Characteristics of series circuit (continued):
 4. The total voltage impressed across a series circuit divides among the individual electrical devices in the circuit so that the sum of the "voltage drops" across the resistance of each individual device is equal to the total voltage supplied by the source.
 5. The voltage drop across each device are proportional to its resistance.
 6. If one device fails, current in the entire circuit ceases.

Electric Circuits, Continued-3

- Parallel circuits
 - Characteristics of parallel circuit:
 1. Voltage is the same across each device.
 2. The total current in the circuit divides among the parallel branches. The amount of current in each branch is inversely proportional to the resistance of the branch.
 3. The total current in the circuit equals the sum of the currents in its parallel branches.



Electric Circuits, Continued-4

- Parallel circuits
 - Characteristics of parallel circuit (continued):
 4. As the number of parallel branches is increased, the overall resistance of the circuit is decreased.
 5. A break in one path does not interrupt the flow of charge in the other paths.

Electric Circuits

CHECK YOUR NEIGHBOR

When two identical lamps in a circuit are connected in parallel, the total resistance is

- A. less than the resistance of either lamp.
- B. the same as the resistance of each lamp.
- C. less than the resistance of each lamp.
- D. None of the above.

Electric Circuits

CHECK YOUR ANSWER

When two identical lamps in a circuit are connected in parallel, the total resistance is

A. less than the resistance of either lamp.

Explanation:

Resistors in parallel are like extra lines at a checkout counter. More lines means less resistance, allowing for more flow.

Electric Circuits

CHECK YOUR NEIGHBOR, Continued

Consider a lamp powered by a battery. Charge flows

- A. out of the battery and into the lamp.
- B. from the negative terminal to the positive terminal.
- C. with a slight time delay after closing the switch.
- D. through both the battery and the lamp.



Electric Circuits

CHECK YOUR ANSWER, Continued

Consider a lamp powered by a battery. Charge flows

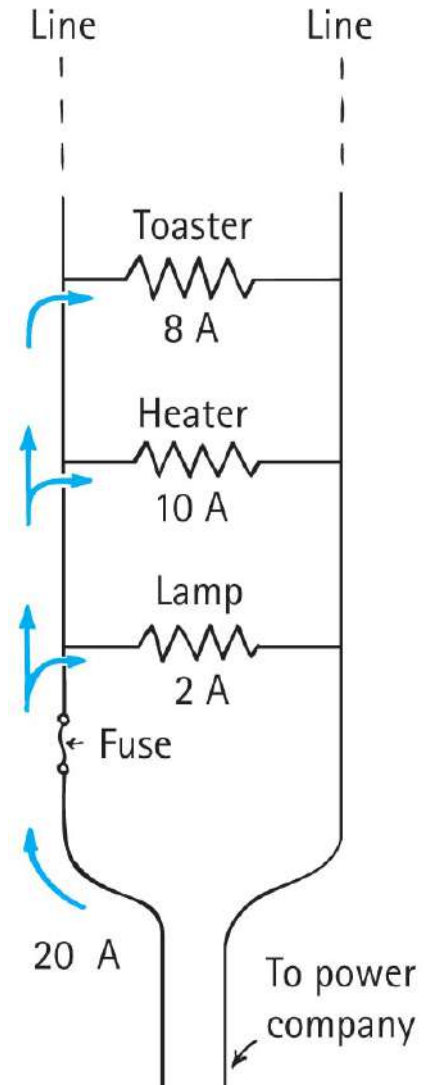
D. through both the battery and the lamp.

Explanation:

Remember, charge is already in all parts of the conducting circuit. The battery simply gets the charges moving. As much charge flows in the battery as outside. Therefore, charge flows *through* the entire circuit.

Electric Circuits, Continued-5

- Parallel circuits and overloading
 - Homes are wired in parallel. As more and more devices are connected to a circuit, more current moves through the wires. There is an amount of current each device can carry before it overheats. When the current is excessive, overheating can result in a fire.



Electric Circuits, Continued-6

- Parallel circuits and overloading (continued)
 - Also, the addition of excess devices in a parallel circuit increases the amount of current moving through the wires, producing an overload and overheating of the system, which can result in a fire.

Electric Circuits, Continued-7

- Safety fuses
 - Are wires that melt when the given current is exceeded
 - Are connected in series along the supply line to prevent overloading in circuits
 - Are replaced by circuit breakers in modern buildings
- Circuit breaker
 - Automatic switch that turns off when the current is excessive

