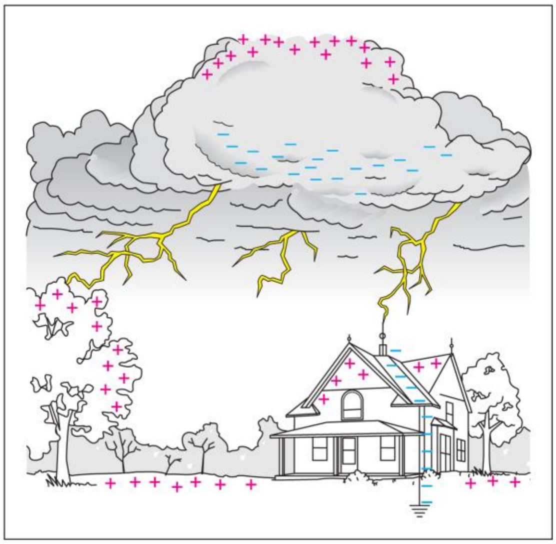


Conceptual Physical Science
6th Edition

Chapter 8:
STATIC AND CURRENT ELECTRICITY

1

Chapter 8:
STATIC AND CURRENT ELECTRICITY

Chapter 8:
Read: All
Homework: Four problems from the following *set:*
4, 6, 10, 12, 16, 18, 20, 22, 24, 26, 30, 36, 38, 48, 50, 52, 54, 56, 66, 68, 70, 74, 78, 80, 88, 90, 92, 94, 96, 98, 100, 102 & 106.
Due: 10-11-18

2

This lecture will help you understand:

- Electric Charge
- Coulomb's Law
- Electric Field
- Voltage Sources
- Electric Potential
- Electric Current
- Electrical Resistance
- Ohm's Law
- Electric Circuits
- Electric Power

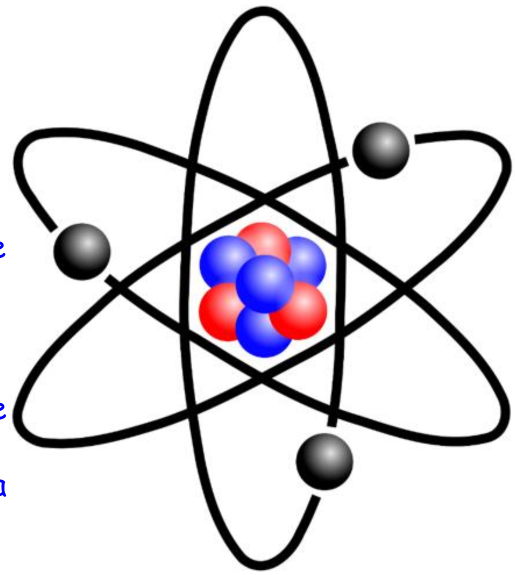
3

Electric and magnetic fields interact and can produce forces.

4

The atom contains:

- ***Electrons*** – found outside the nucleus; negatively charged
- ***Protons*** – found in the nucleus; positive charge equal in magnitude to the electron's negative charge
- ***Neutrons*** – found in the nucleus; no charge; virtually same mass as a proton



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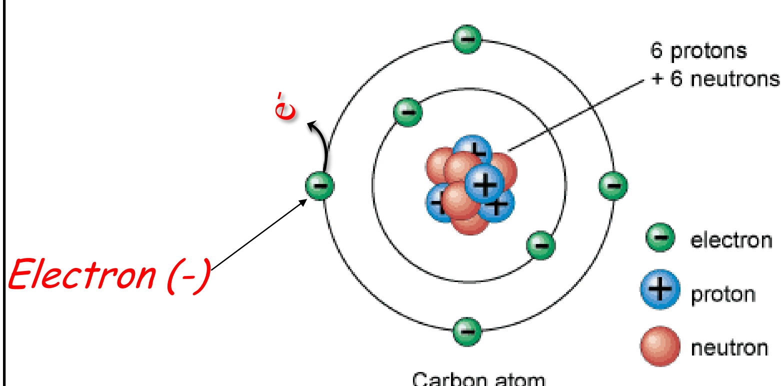
What is electricity?

•Everything is made of atoms which contain POSITIVE particles called PROTONS and NEGATIVE particles called ELECTRONS.



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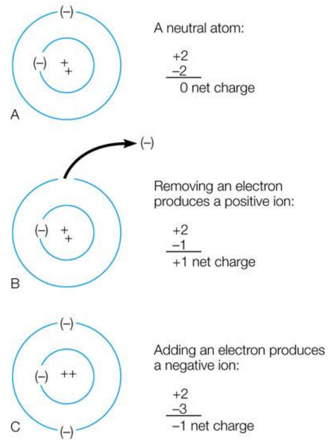
Electric Charge



- Charges in matter
  - Inseparable property of certain particles
  - Electrons: negative electric charge
  - Protons: positive electric charge
- Charge interaction
  - Electric force
  - "Like charges repel; unlike charges attract"
- Ions: non-zero net charge from loss/gain of electrons

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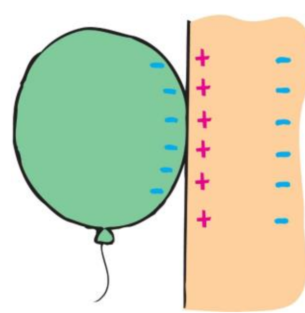
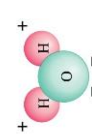
Polarization/ Induced Charge

Charge polarization

- Why a charged rubber balloon sticks to a wall.

  The charged balloon induces polarization of molecules or atoms in the wall. Negative charges on balloon pull positive sides of molecules near it. Hence a slightly positive induced surface charge on the wall.
  The balloon sticks.





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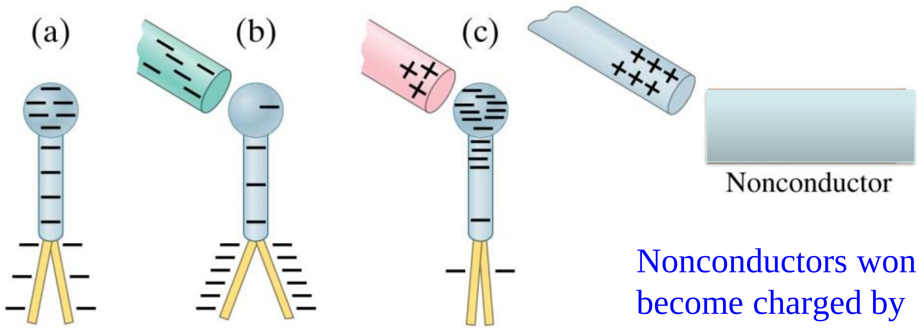
Induced Charge; Polarizing



Nonconductors won't become charged by conduction or induction.

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Electric Charge

Conservation of Charge

- In any charging process, no electrons are created or destroyed.
- Electrons are simply transferred from one material to another.

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Which of these particles has an electrical charge?

A) Proton.

B) Electron.

C) Ion.

D) All of the above.

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Which is the predominant carrier of charge in copper wire?

A) Proton.

B) Electron.

C) Ion.

D) All of the above.

12

If a neutral atom has 22 protons in its nucleus, the number of surrounding electrons is

A) less than 22.

B) 22.

C) more than 22.

D) sometimes all of the above in a neutral atom.

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When we say charge is conserved, we mean that charge can

A) be saved, like money in a bank.

B) only be transferred from one place to another.

C) take equivalent forms.

D) be created or destroyed, as in nuclear reactions.

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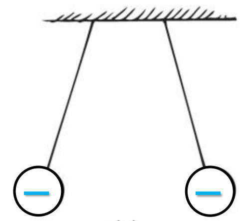
Electric Force and Charge

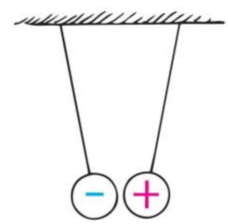
Electric force:
a fundamental force of nature can attract some objects (opposite charge) and repel others (same charge)



like signs of charge — force is repulsion

Fundamental rule for electricity:

Like charges repel;
unlike charges attract.



unlike signs of charge — force is attraction

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Electric Charge

- Unit of charge = coulomb (C)
  - Equivalent to charge of 6.24×10^{18} electrons!
  - Metric unit of charge
- Electron charge
  - Fundamental charge
  - Smallest seen in nature
  - Quantity of charge and the number of electrons

Quantity of charge — Electron charge

$$q = ne$$

Number of electrons

$$e = \frac{q}{n} = \frac{1.00\ coulomb}{6.24 \times 10^{18} electron}$$

$$= 1.60 \times 10^{-19} \frac{coulomb}{electron}$$

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Electrostatic Forces

Force

Product of two charges

$$F = k\frac{q_1 q_2}{d^2}$$

Distance between charges, squared!

$$k = 9.00 \times 10^{9}\frac{N \cdot m^2}{C^2}$$

$$G = 6.67 \times 10^{-11} N \cdot m \cdot kg^{-2}$$

$$F = \frac{G m_1 m_2}{d^2}$$

Coulomb's law

- Relationship giving force between two charges
- Similar to Newton's law of gravitation
- k versus G implies weaker gravity

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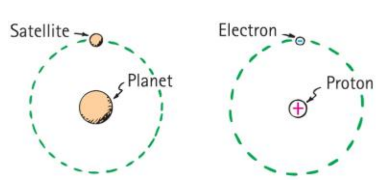
Coulomb's Law

Differences and similarities between gravitational and electrical forces:

- Gravity only attracts. Electricity can both attract and repel.
- Both forces can act between things that are not in contact with each other.
- Both forces act in a straight-line direction between masses or charges.
- A force field surrounds both: Gravitational field for mass and electric field for charge.



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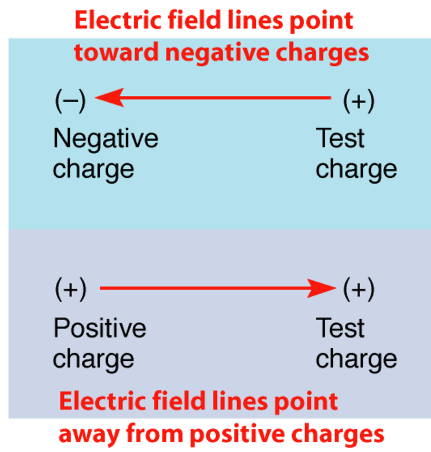
Force Fields

How do forces act through space?

- Charges surrounded by electric fields (vector fields/directional)
- Fields and charges inseparable
- Fields act on other charges
  - Direction of fields = motion of positive test charge in the field
  - Visualized with lines of force
- Same ideas apply to gravity and magnetism



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Force Fields

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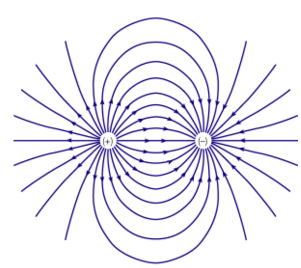
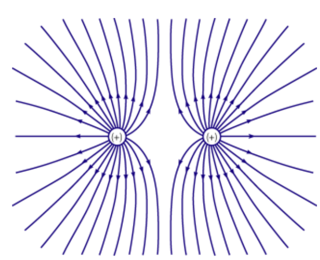


Electric field lines around plus and minus charges



Electric field lines around two positive charges

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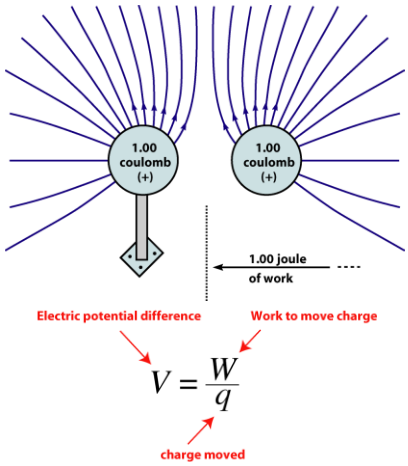
Electric Potential



$$V = \frac{W}{q}$$

- Scalar field associated with potential energy
- Unit = volt (V)
- Related to work involved in positioning charges
- Potential difference important in producing forces and moving charges
- Analogous to moving masses in gravitational fields

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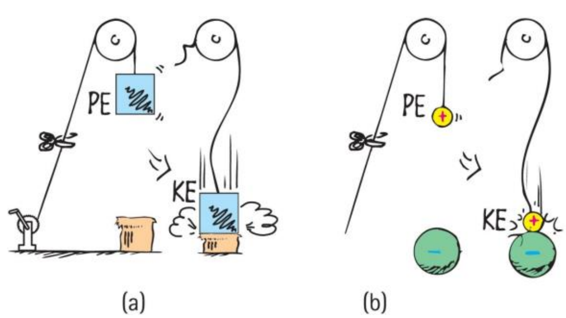
Electric Potential Energy

Electric potential energy

- Energy possessed by a charged particle due to its location in an electric field.



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Electric Potential Energy

Electric Potential Energy

Batteries and generators pull negative charges away from positive ones, doing work to overcome electrical attraction

The amount of work depends on number of charges and separation distance

Work done by a battery or generator is then available to a circuit as electrical PE

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Electric Potential

Electric potential:

- electric potential energy per charge
- energy that a source provides to each unit of charge

$$\text{Electric potential} = \frac{\text{electric potential energy}}{\text{charge}}$$

Electric potential and voltage are one and the same.

Unit of measurement is the *volt*.

$$1\ \text{volt} = \frac{1\ \text{joule}}{\text{coulomb}}$$

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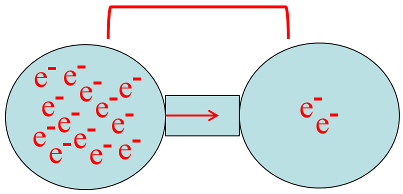
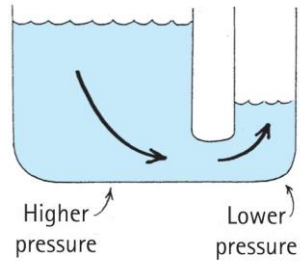
Electric Potential

Electric potential, Voltage, ***V (volts)***



Conductor

Flow of electrons= current, *I (Amps)*



Resistance, *R (Ohms)*

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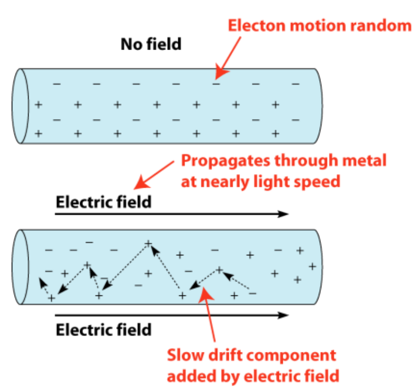
Current Mechanisms

Liquids and gases

- Both positive and negative charges move, in opposite directions

Metals

- Delocalized electrons free to move throughout metal
- Electric field moves through at nearly light speed



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Conductors and Insulators
CHECK YOUR NEIGHBOR

When you buy a water pipe in a hardware store, the water isn't included. When you buy copper wire, electrons

A. must be supplied by you, just as water must be supplied for a water pipe.
B. are already in the wire.
C. may fall out, which is why wires are insulated.
D. None of the above.

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Charge, Current & Time

- Electric current is given the symbol **I**
- Electric current is the movement of negative charges (electrons) in a Circuit
- Current is the amount of charge flowing per second and is given the unit
  - Amps (A)

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More Current Details

Electric current

Quantity of charge

$$I = \frac{q}{t}$$

time

- Current = charge per unit time
- Units = ampere, amp (A)
- Direct current (DC)
  - Charges move in one direction
  - Electronic devices, batteries, solar cells
- Alternating current (AC)
  - Charge motion oscillatory
  - No net current flow

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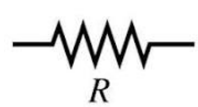
Resistors

- Resistors the flow of electric current. They have a property called which is measured in

The symbol for a resistor is 

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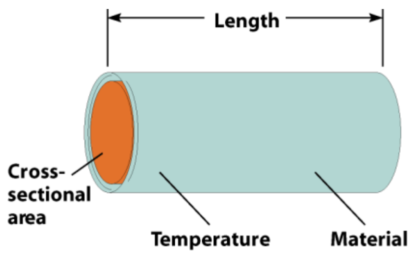
More on Resistance



- Resistance factors
  - Type of material
  - Length
  - Cross-sectional area
  - Temperature
- Superconductors
  - Negligible resistance at very low temperatures

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Resistors

Standard resistors are manufactured for use in electric circuits; they are color-coded to indicate their value and precision.

The resistance of a wire is directly proportional to its length and inversely proportional to its cross-sectional area:

$$R = \rho \frac{\ell}{A}$$

The constant ρ, the resistivity, is characteristic of the material.

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Electrical Conductors and Insulators

- Electrical conductors
  - Electrons are free to move throughout material
  - Added charge dissipates
  - Examples: metals
- Electrical insulators
  - Electron motions restricted
  - Added charge tends to remain on object
  - Examples: glass, wood, diamond (carbon)
- Semiconductors
  - Conduct/insulate depending on circumstances
  - Applications: computer chips, solar cells, ...

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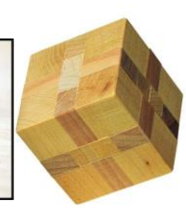
What is a conductor?

Good conductors allow electrons to move through them easily. Insulators do not allow electrons to move easily.

What is an insulator?



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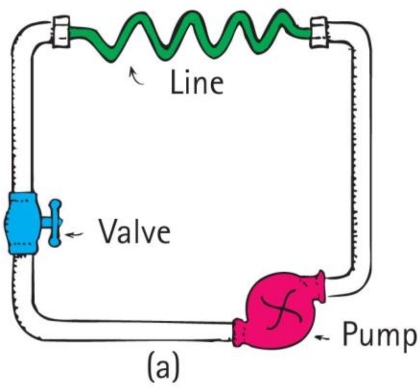
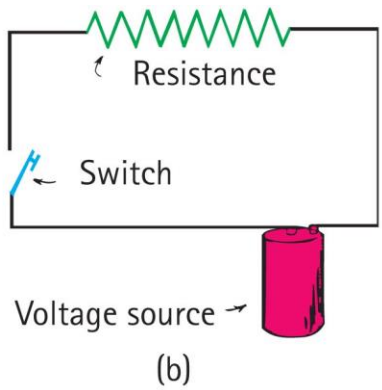
Voltage Sources

Electric potential difference (continued)

- Water and electric circuits compared





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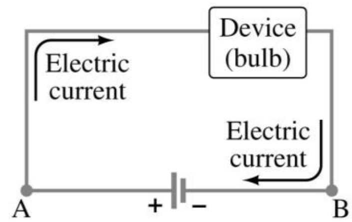
Electric Circuits

Electric circuits:

any closed path along which electrons can flow

for continuous flow — no gaps (such as an open electric switch)



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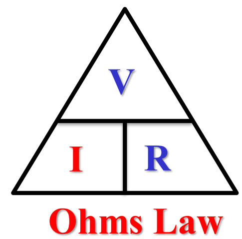
Ohm's Law

Ohm's Law

relationship between current, voltage, and resistance

Current in a circuit varies in direct proportion to the potential difference (voltage) and inversely with the resistance:

$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \quad \text{or} \quad I = \frac{V}{R}$$



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Questions

The flow of charge is defined as

A. potential difference.
B. power.
C. energy.
D. current.

If a potential difference of 12.0 V is required to produce a current of 3.0 A in a wire, the resistance of the wire is

A. 4.0 Ω.
B. 36 Ω.
C. 0.25 Ω.
D. 3.0 Ω.

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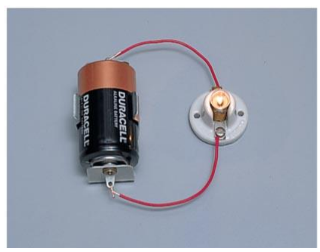
Electric Circuits

Electric circuits:

any closed path along which electrons can flow

for continuous flow — no gaps (such as an open electric switch)



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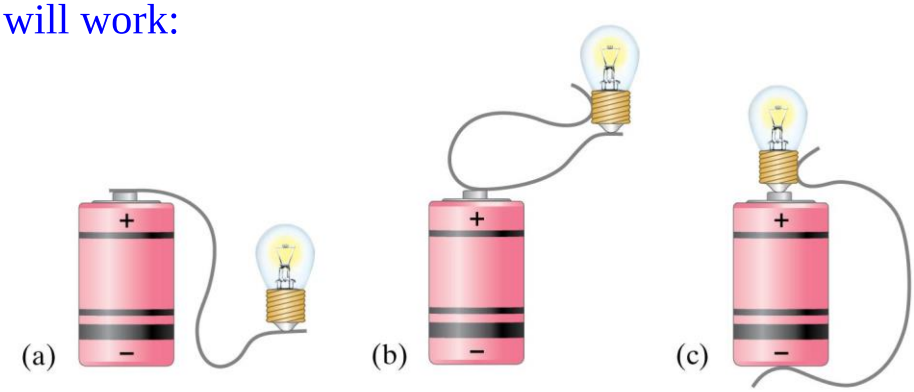
Electric Current

In order for current to flow, there must be a path from one battery terminal, through the circuit, and back to the other battery terminal. Only one of these circuits will work:



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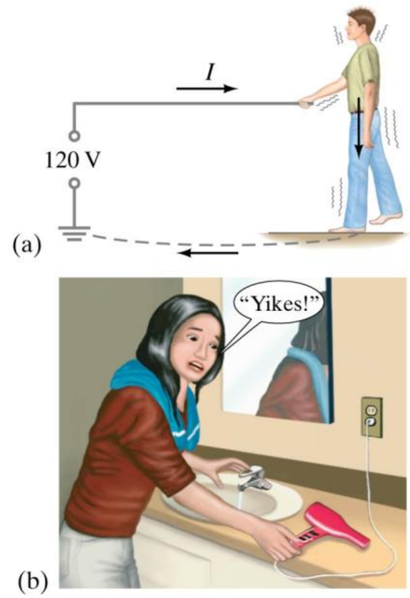
Electric Hazards

A person receiving a shock has become part of a complete circuit.



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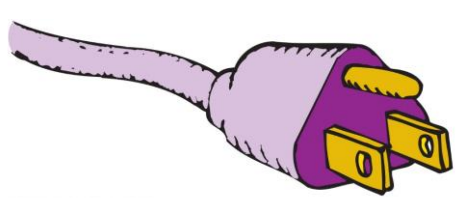
Ohm's Law

Prongs on electric plugs and sockets:

- two flat prongs for the current-carrying double wire, one part live and the other neutral
- third prong is longer and the first to be plugged into socket; path to ground prevents harm to user if there is an electrical defect in the appliance



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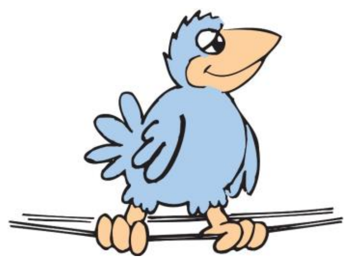
Ohm's Law

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



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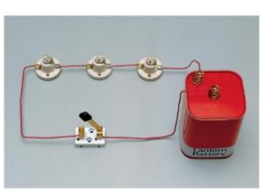
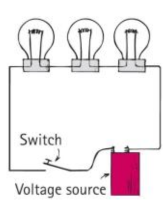
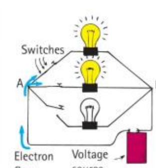
Electric Circuits

Devices connect to a circuit in one of two ways:

- Series
- Parallel







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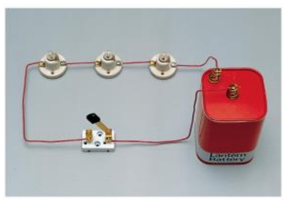
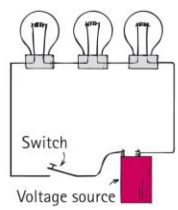
Electric Circuits

Series:

- A single-pathway circuit for electron flow
- A break anywhere in the path results in an open circuit; electron flow ceases
- Total resistance adds, more devices, less current





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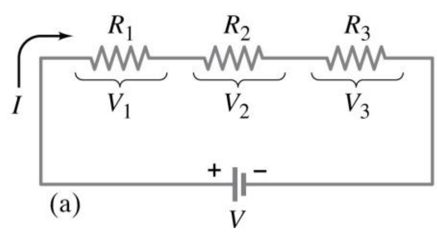
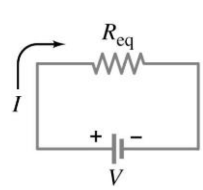
Resistors in Series and in Parallel

A series connection has a single path from the battery, through each circuit element in turn, then back to the battery.



From this we get the equivalent resistance (that single resistance that gives the same current in the circuit).



$$R_{eq} = R_1 + R_2 + R_3.$$

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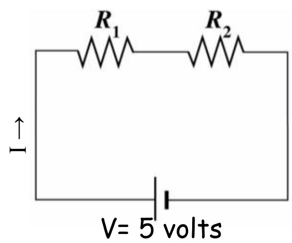
Circuits— example problems

A pair of 1-ohm resistors connected in series has a combined resistance of



What is the current?

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Cricuits— example problems

As more lamps are put into a series circuit, the overall current in the power source

A) increases.
B) decreases.
C) stays the same.

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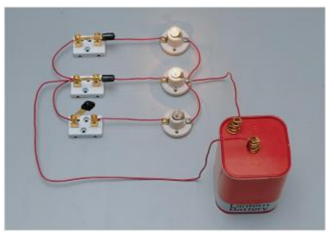
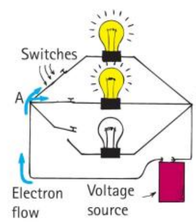
Electric Circuits

Parallel:

- A branched pathway is formed for the flow of electrons
- A break in any path doesn't interrupt flow in other paths
- A device in each branch operates independently of the others
- Total current in the branches add





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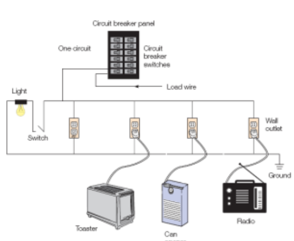
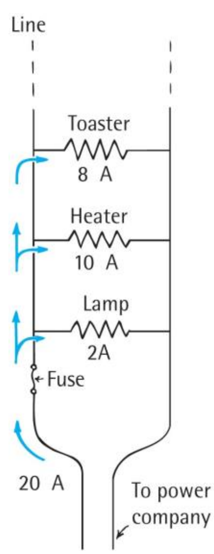
Electric Circuits

Parallel circuits and overloading

- Homes are wired in parallel. As more and more devices are connected, more current moves through the wires. Each device can carry a certain amount of current before overheating. Excessive current can result in a fire.





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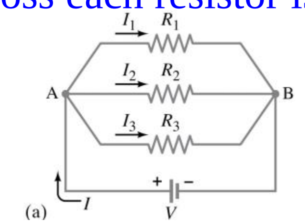
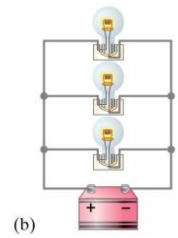
Resistors in Series and in Parallel

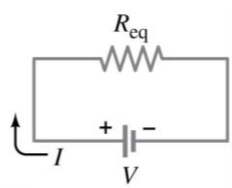
A parallel connection splits the current; the voltage across each resistor is the same:





This gives the reciprocal of the equivalent resistance:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$



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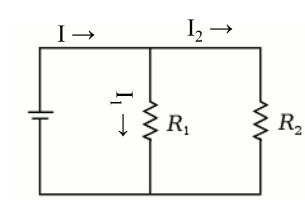
Circuits— example problems

A pair of 1-ohm resistors connected in parallel has a combined resistance of

V= 5 volts



What is the total current?

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Electricity— example problems

Compared to the resistance of two resistors connected in series, the same two resistors connected in parallel have

A) more resistance.
B) less resistance.
C) the same resistance.

As more lamps are put into a parallel circuit, the overall current in the power source

A) increases.
B) decreases.
C) remains the same.

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Electric Power

Electric power

- rate at which electric energy is converted into another form
- in equation form:

$$\textit{power} = \textit{current} \times \textit{voltage}$$

The unit of power is the watts, W

Example: 100-watt lamp draws 0.8 ampere

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Electricity— example problems

What is the resistance of a 120-W incandescent lamp connected to a 120-V power supply?

A) 1 ohm
B) 60 ohms
C) 100 ohms
D) 144 ohms
E) none of the above

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Electricity— example problems

A power line with a resistance of 2 ohms draws a current of 80 A. The power dissipated in the line is

A) 40 W.
B) 160 W.
C) 320 W.
D) 12,800 W.
E) none of the above

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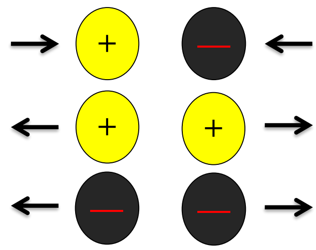
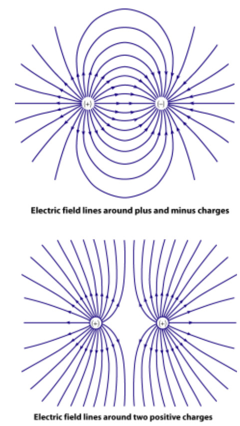
Summary





$$F = G\frac{m_1 m_2}{d^2}$$

Newton's Law Universal Gravity

$$F = k\frac{q_1 q_2}{d^2}$$

Coulomb's law

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Summary

- Electric Charge
  Electric Force

e^-

Like charges repel; unlike charges attract

- Coulomb's Law

$$F = k\frac{q_1 q_2}{d^2}$$

- Electric Potential (voltage)

$$1 \text{ volt} = \frac{1 \text{ joule}}{\text{coulomb}}$$

- Electric Current

$$I = \frac{Q}{t}$$

- Electrical Resistance

- Ohm's Law

$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \quad \text{or} \quad I = \frac{V}{R}$$

- Power

$$P = IV.$$

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