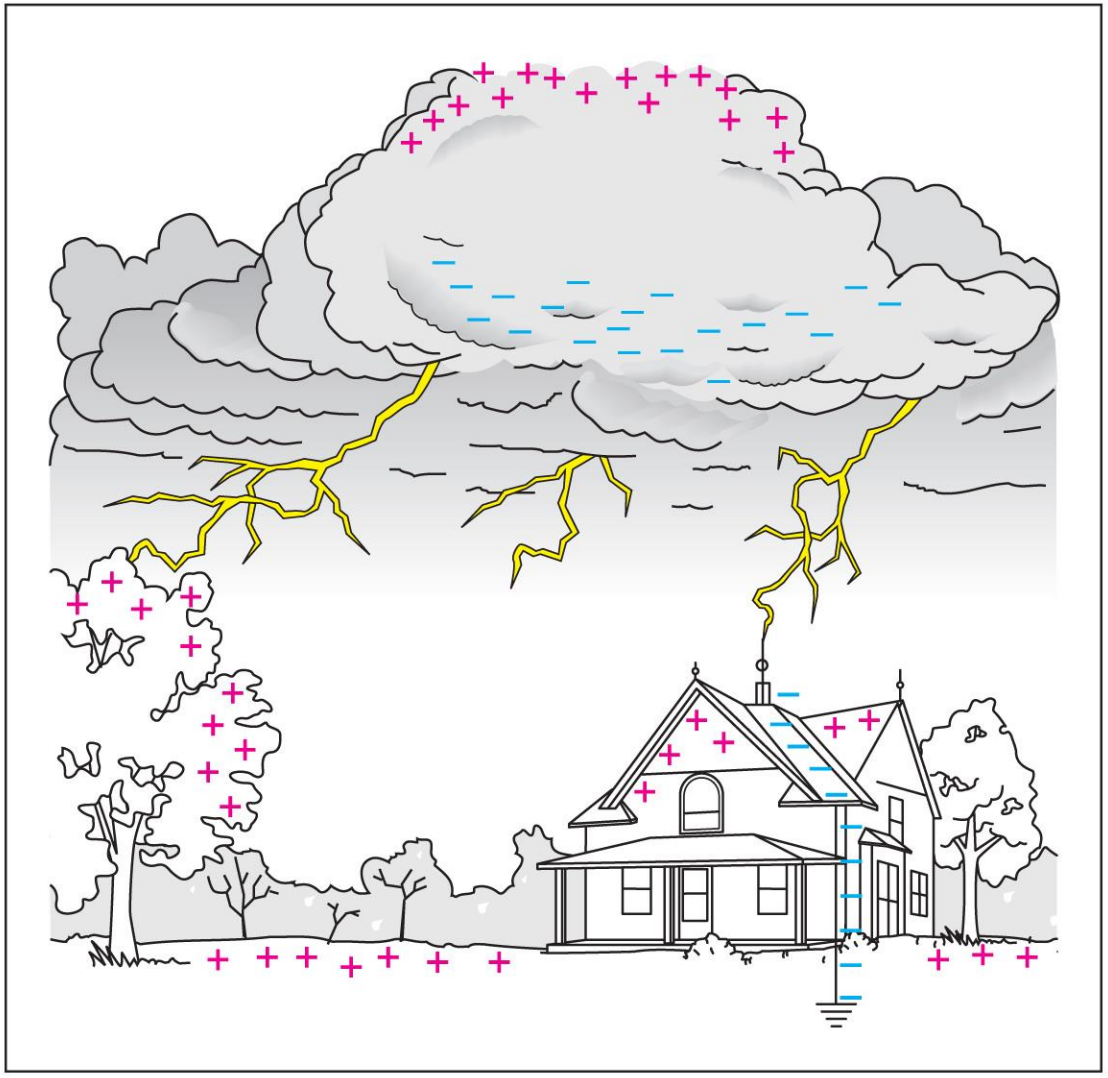


Chapter 20

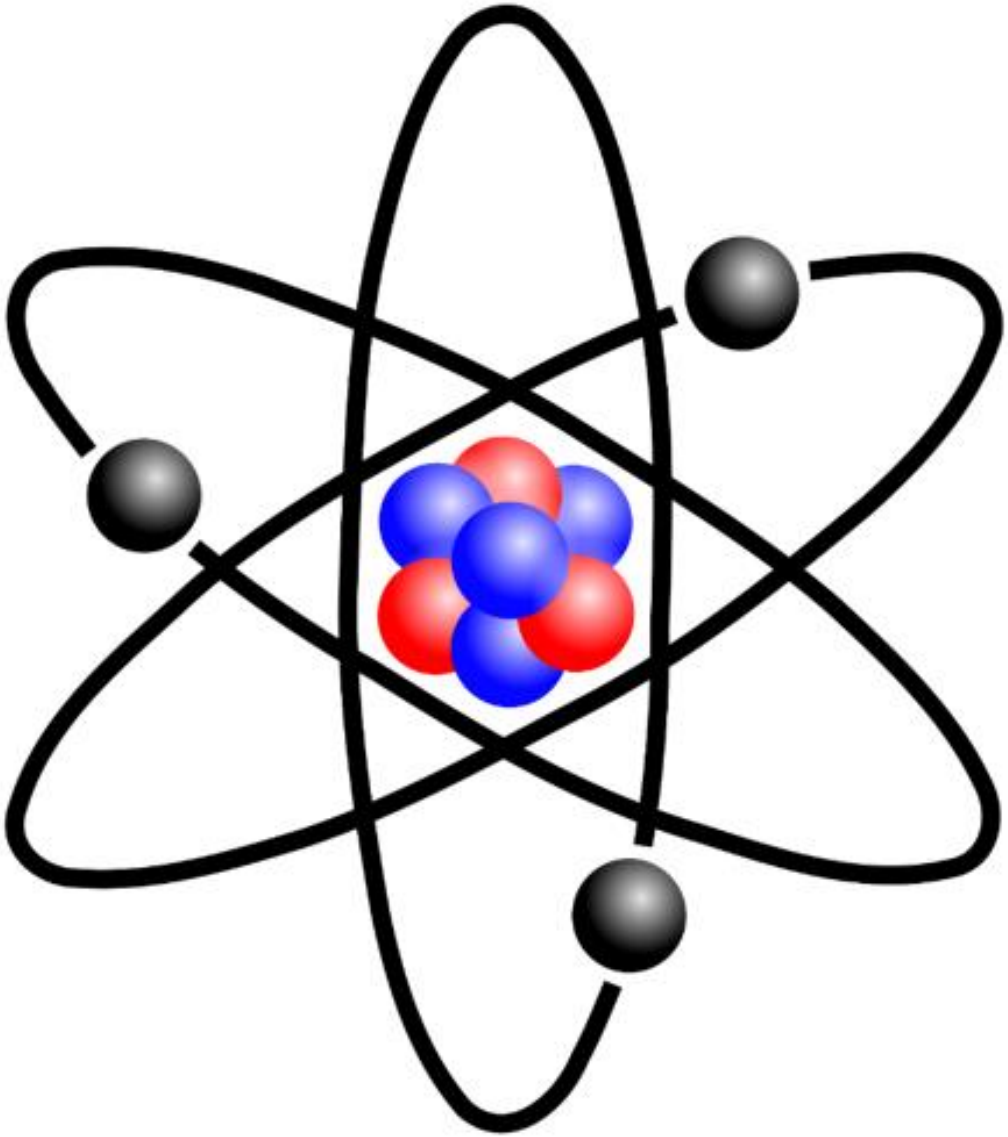
Ohm's law and circuits

This lecture will help you understand:

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

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



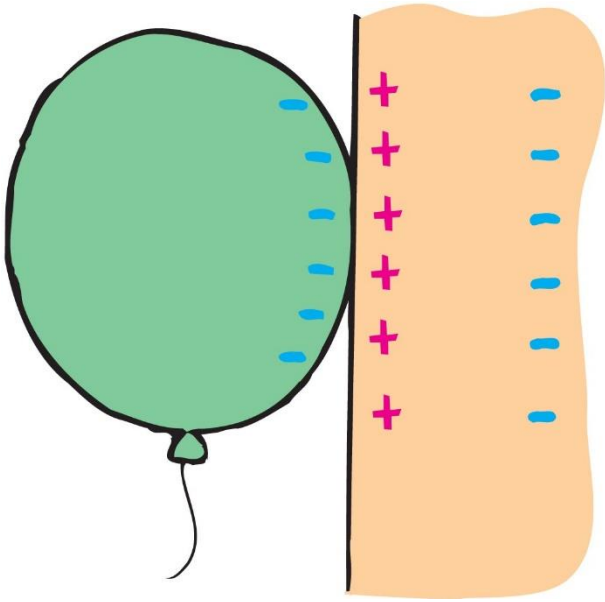
Polarization/ Induced Charge

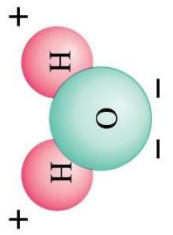
Charge polarization

- Why a charged rubber balloon sticks to a wall.

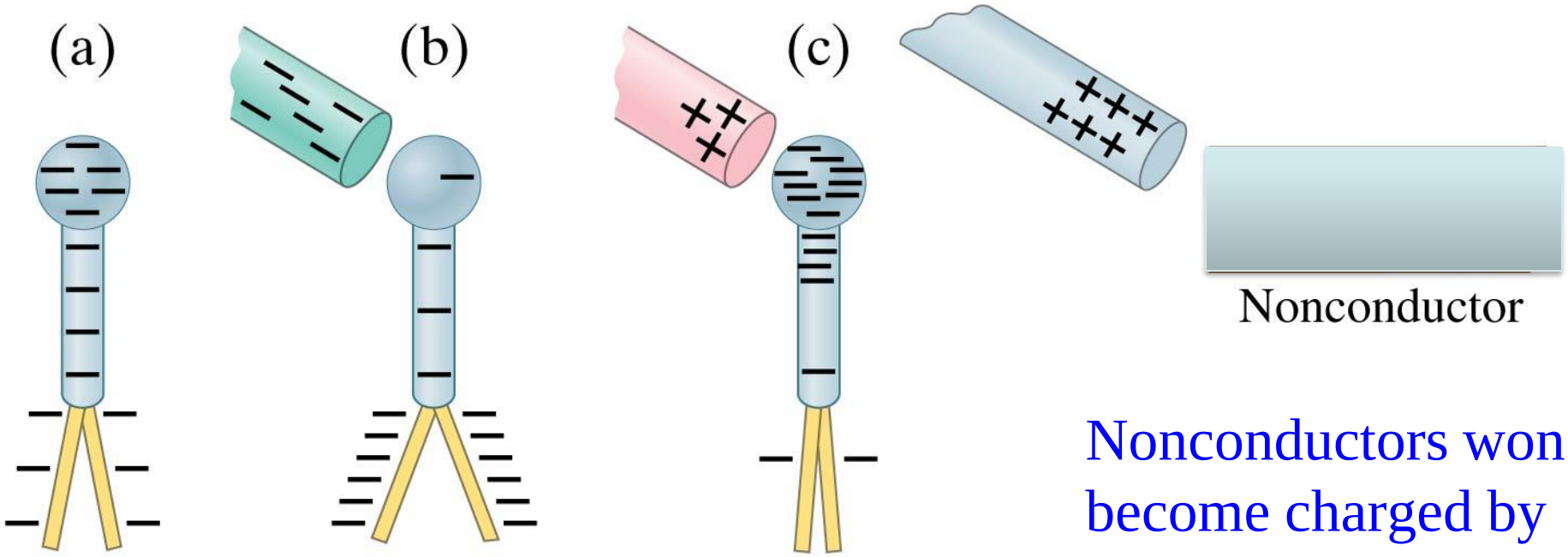
  The charged balloon induces polarization of molecules or atoms in the wall. Negative charges on balloon pull positive sides of molecules near it. Hence a slightly positive induced surface charge on the wall.

  The balloon sticks.





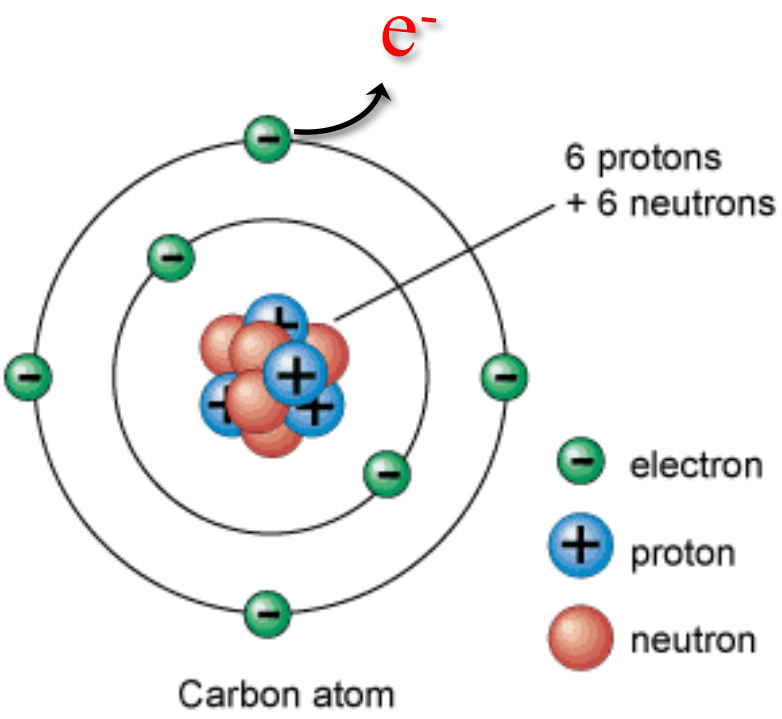
Induced Charge; Polarizing

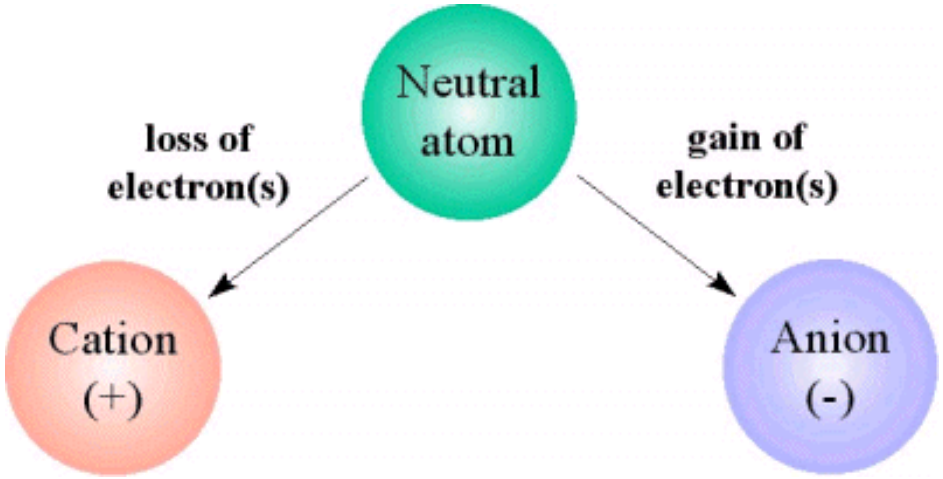


Nonconductors won't become charged by conduction or induction.

What is electricity?

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





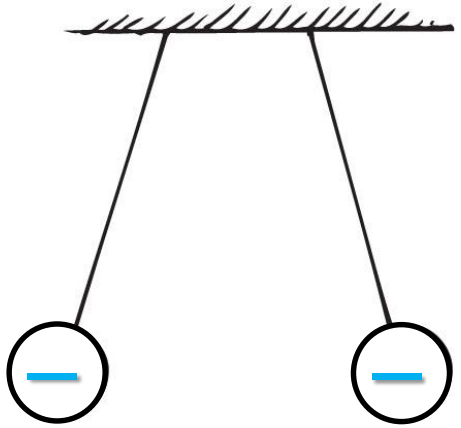
Electric Charge

Conservation of Charge

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

Electric Force and Charge

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

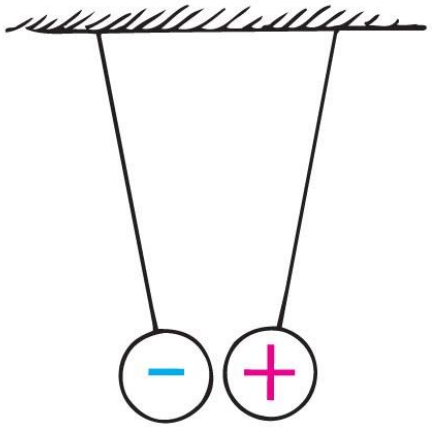


like signs of charge — force is repulsion

Fundamental rule for electricity:

Like charges repel;

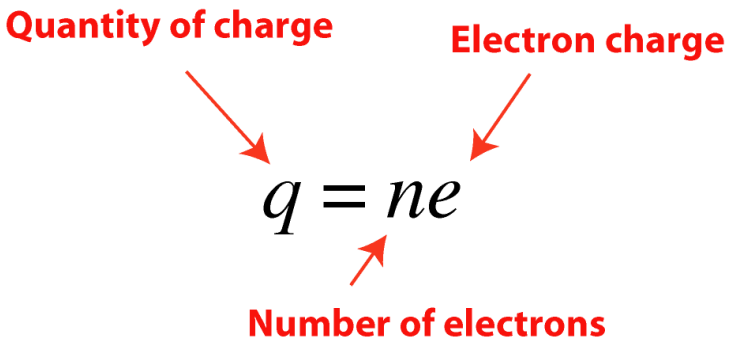
unlike charges attract.



unlike signs of charge — force is attraction

Electric Charge

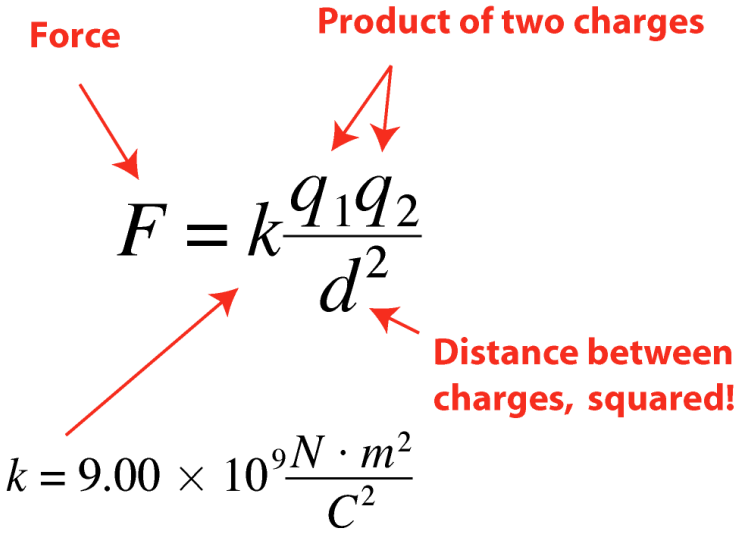
- Unit of charge = coulomb (C)
  - Equivalent to charge of 6.24×10^{18} electrons!
  - Metric unit of charge
- Electron charge
  - Fundamental charge
  - Smallest seen in nature
  - Quantity of charge and the number of electrons



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

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

Electrostatic Forces



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

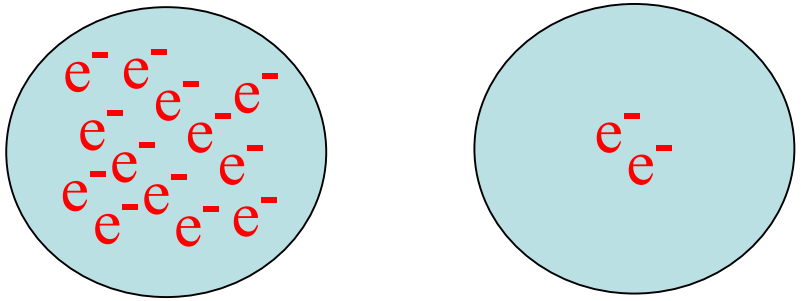
$$F = \frac{Gm_1 m_2}{d^2}$$

Coulomb's law

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

Electric Potential = voltage

Electric potential:



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

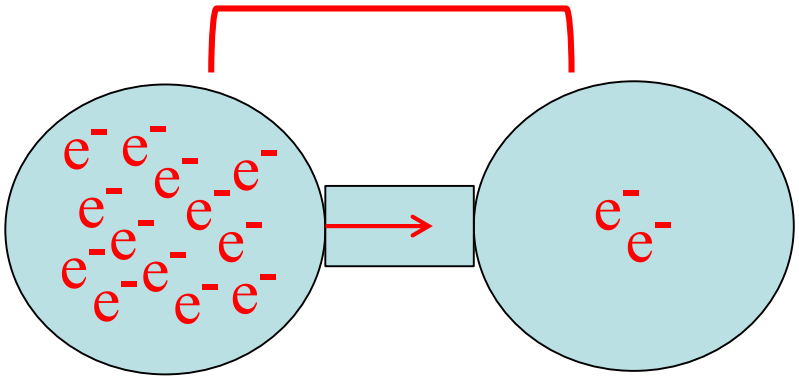
Electric potential and voltage are one and the same.

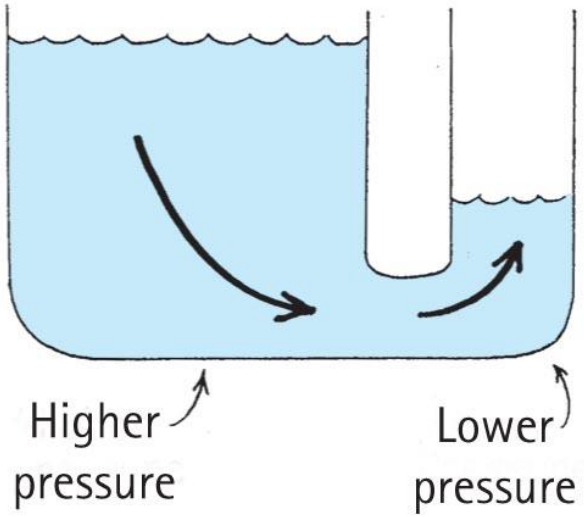
Unit of measurement is the *volt*.

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

Electric Potential

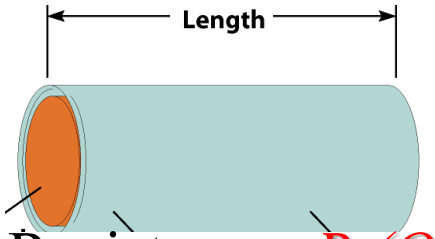
Electric potential,
Voltage, *V (volts)*





Conductor

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

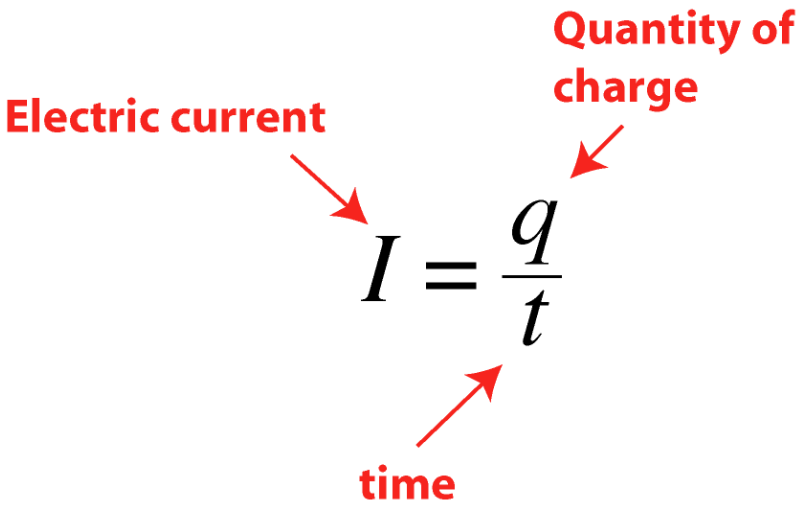


Resistance, *R (Ohms)*

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)

More Current Details



- 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

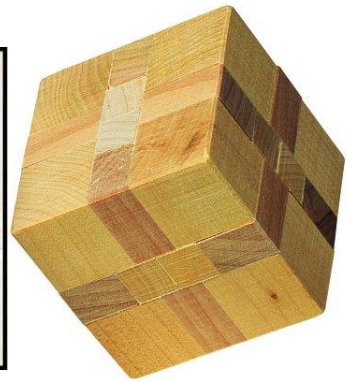
Electrical Conductors and Insulators

- 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, ...

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?

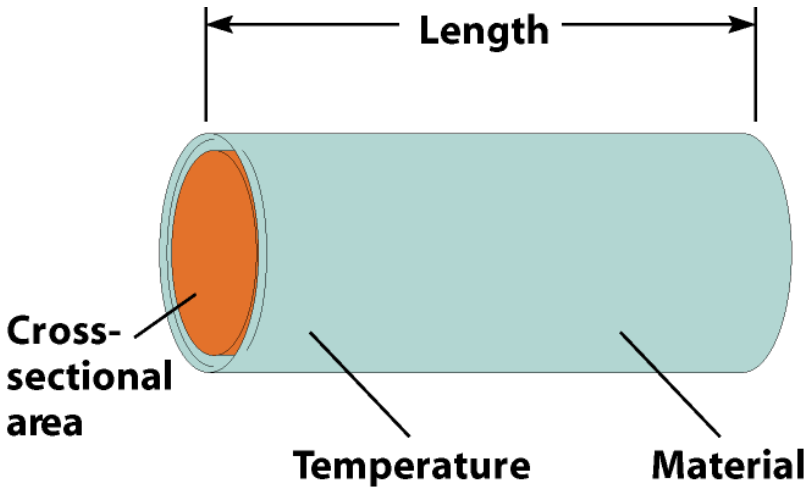


Resistors

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

The symbol for a resistor is

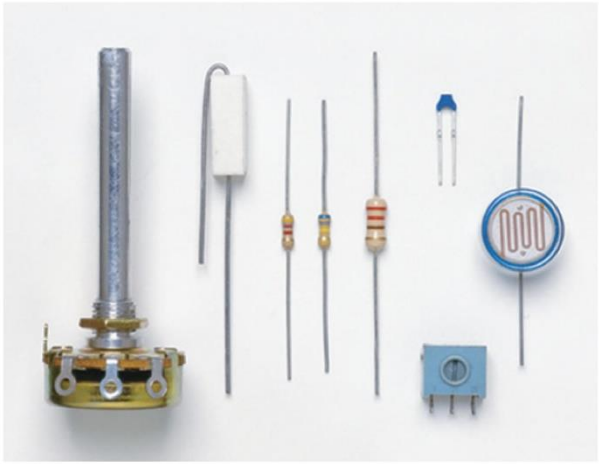
More on Resistance



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

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:

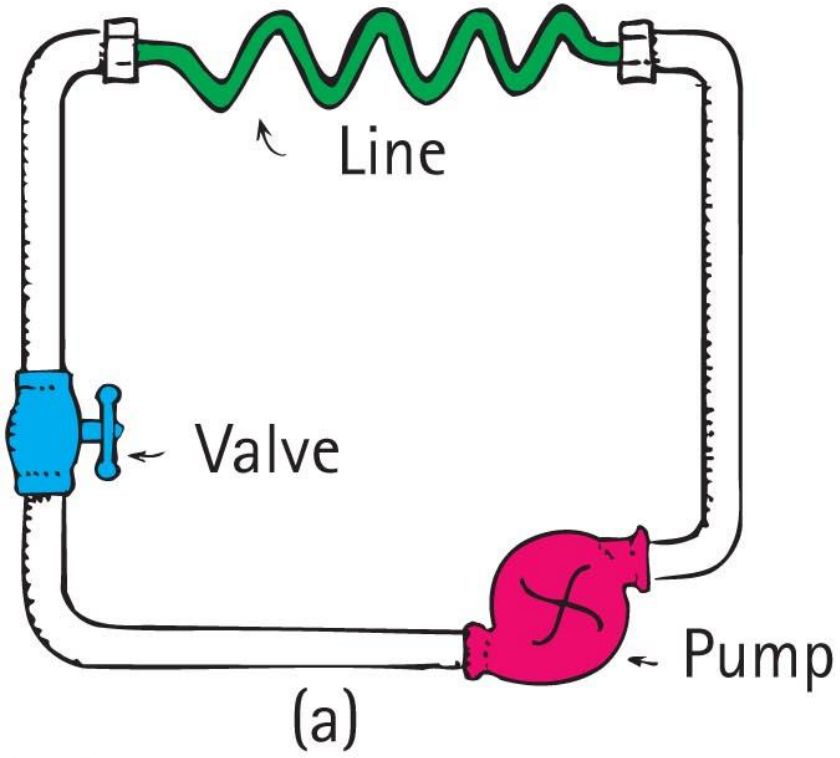
$$R = \rho \frac{\ell}{A}$$

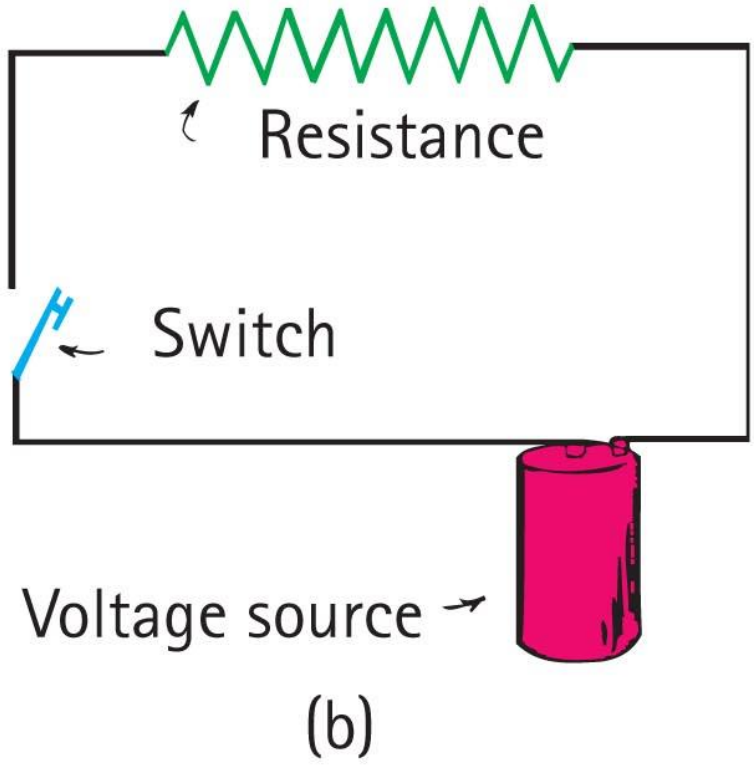
The constant ρ, the resistivity, is characteristic of the material.

Voltage Sources

Electric potential difference (continued)

- Water and electric circuits compared

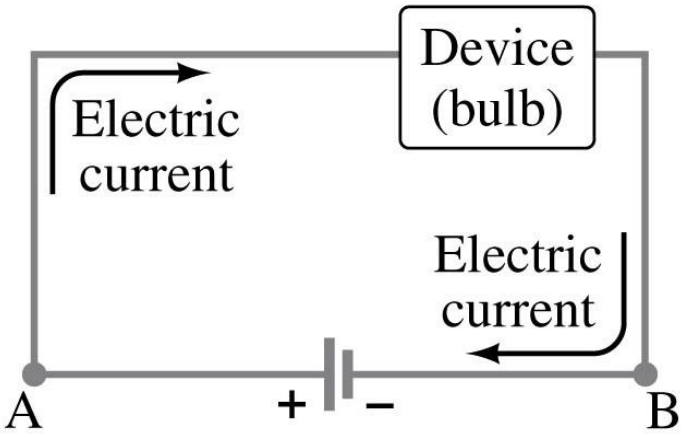




Electric Circuits

Electric circuits:

- any closed path along which electrons can flow
- for continuous flow — no gaps (such as an open electric switch)



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:

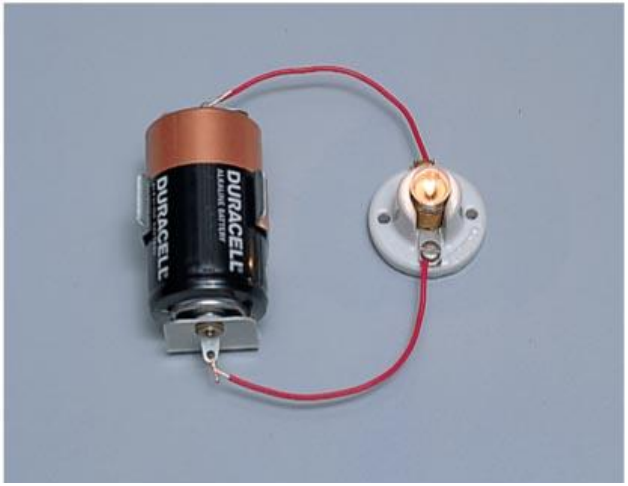
$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \quad \text{or} \quad I = \frac{V}{R}$$

Electric Circuits

Electric circuits:

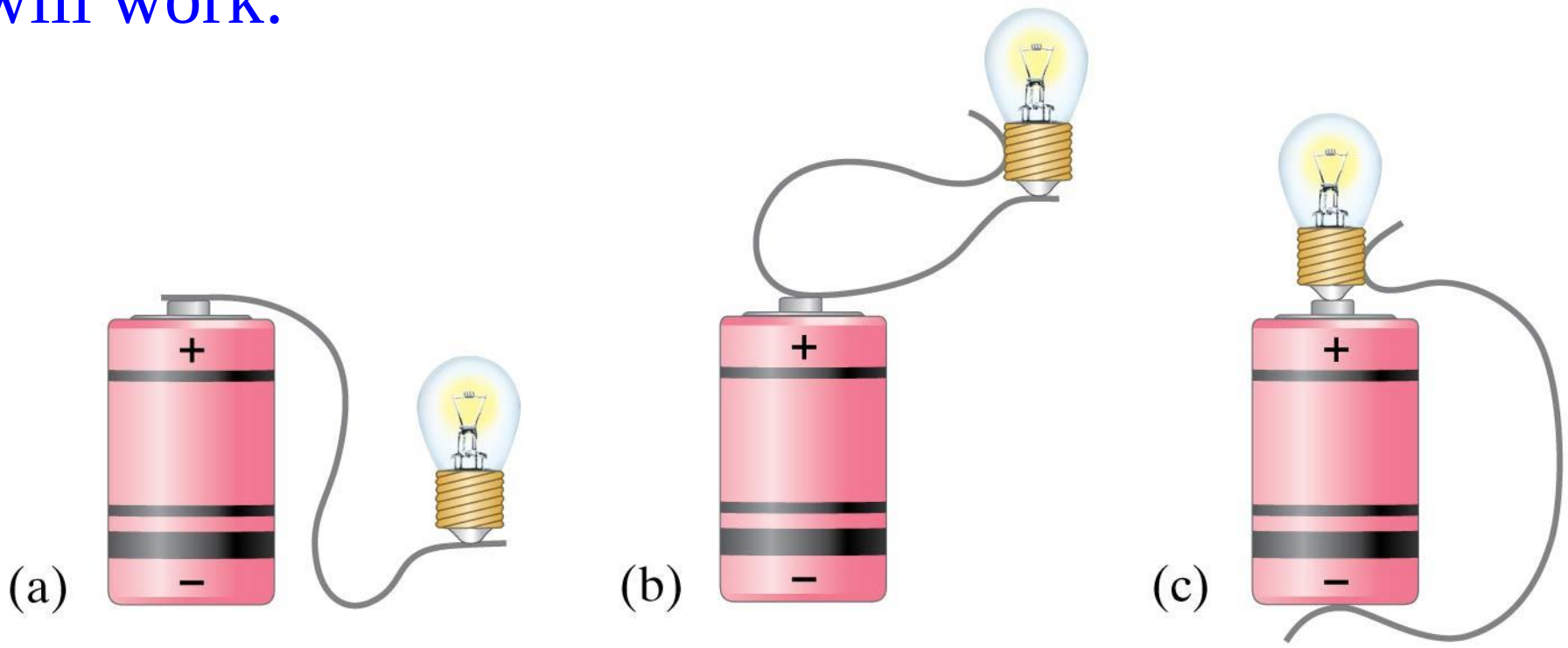
any closed path along which electrons can flow

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



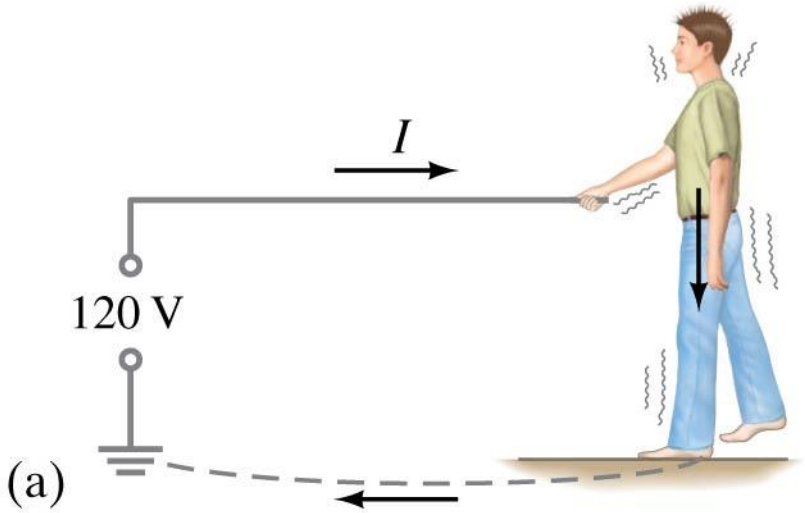
Electric Current

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:



Electric Hazards

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



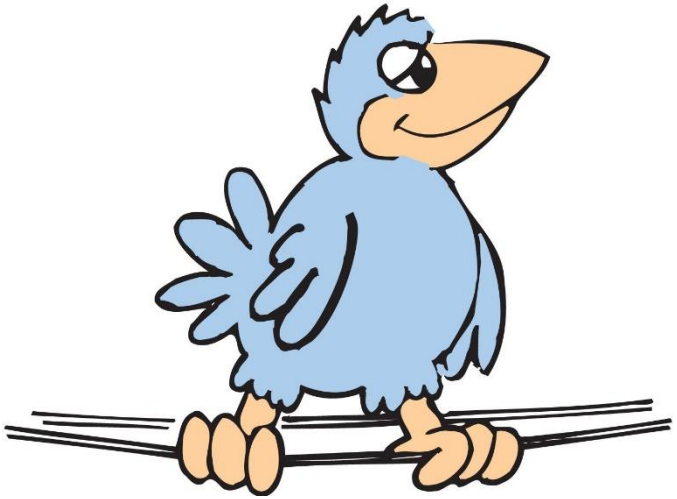
(a)

(b)

Ohm's Law

Electric shock

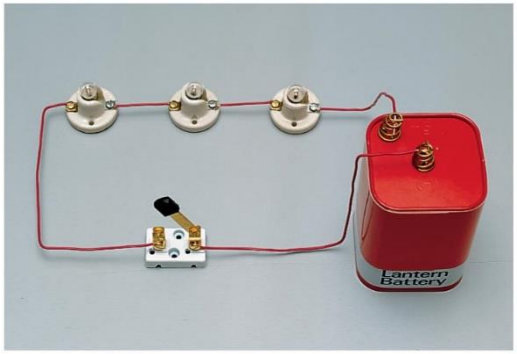
- damaging effects of shock result from current passing through the body
- electric potential difference between one part of your body and another part depends on body condition and resistance, which can range from 100 ohms to 500,000 ohms

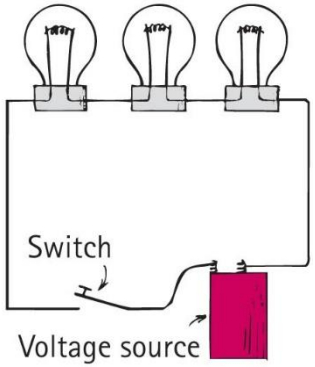


Electric Circuits

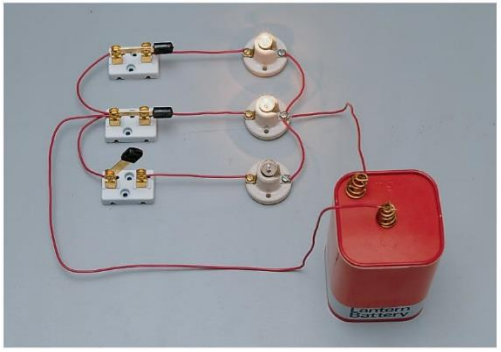
Devices connect to a circuit in one of two ways:

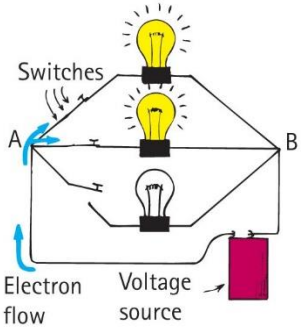
- Series





- Parallel

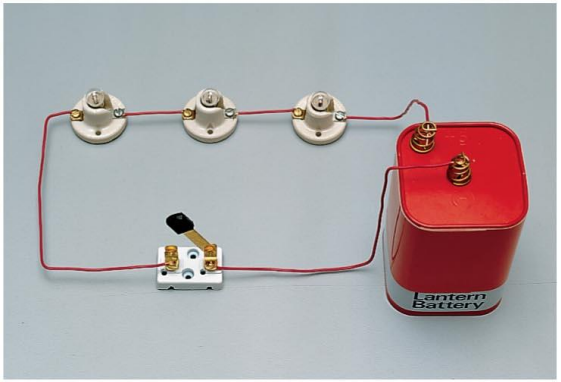


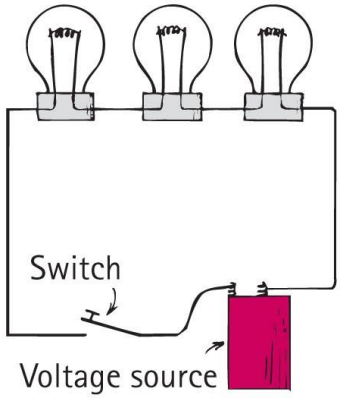


Electric Circuits

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

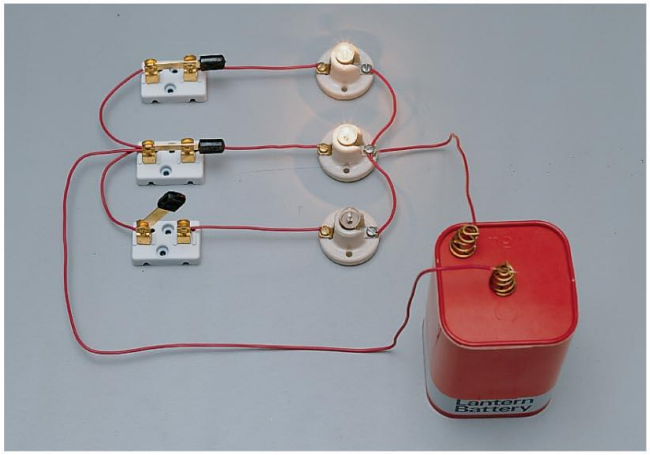


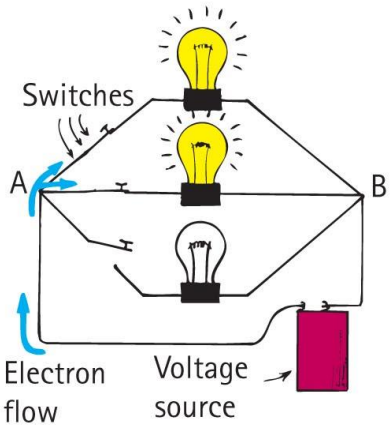


Electric Circuits

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





Electric Power

Electric power

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

$$power = current \times voltage$$

$$P = IV$$

The unit of power is the watts, W

Example: 100-watt lamp draws
0.8 ampere

Which of these particles has an electrical charge?

A) Proton.

B) Electron.

C) Ion.

D) All of the above.

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 are true.
D. Neither are true.

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.

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.

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

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

$$P = IV.$$