Basic Electricity

EAS 199A Lecture Notes

Learning Objectives

Successful completion of this module will enable students to

- Link the basic model of an atom to the flow of electricity
- Apply the definitions of Amp, Volt, Coulomb, Joule, Watt to unit conversions and basic problems involving current and voltage
- Apply Ohm's Law to simple DC circuits

Definition

Electricity is a form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current.

Concise Oxford English Dictionary, revised 10th edition

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Definition

Conductor:

A conductor is a material that readily allows the flow of electricity. A good conductor has a high numerical value of a *conductivity*, and a low numerical value of *resistance*.

Definition

Conductivity:

All materials have a measurable property called electrical conductivity that indicates the ability of the material to either allow or impede the flow of electrons. Materials that easily conduct electricity have a high conductivity.

Definition

Insulator:

An insulator is a material that tends to impede the flow of electricity. A resistor has a low numerical value of conductivity and high numerical value of resistance.

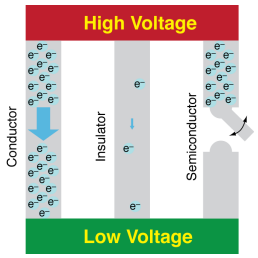
Definition

Semiconductor:

A semiconductor is a material with conductivity between that of a conductor and insulator.

The conductivity of a semiconductor can be changed by exposing it to an electrical field, light, mechanical pressure, or heat.

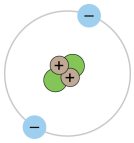
Simplified Functional Differences



Semiconductors can be used in devices that act like a switch.

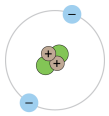
Elements

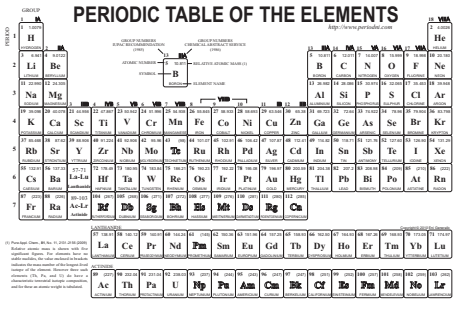
- Pure substances are made of elements.
- An element consists of atoms
- Atoms have a nucleus consisting of protons and neutrons
- Electrons move in shells around the nucleus



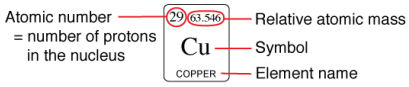
Elements

- Number of protons determines the element
- Number of electrons varies
  - State of electrical charge
  - Is the element in a chemical bond?
- Number of neutrons varies with *isotope*

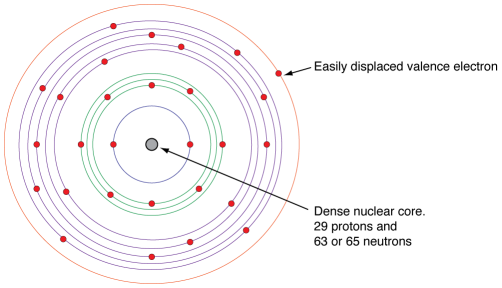




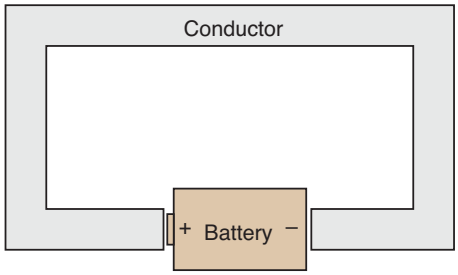
Periodic Table: Copper



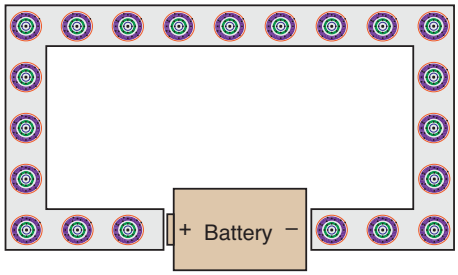
Bohr Model of the atom (Cu)



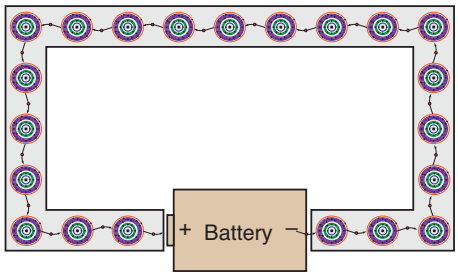
Electrical current in a trivial circuit



Electrical current: atomic model



Electrical Current: electron flow



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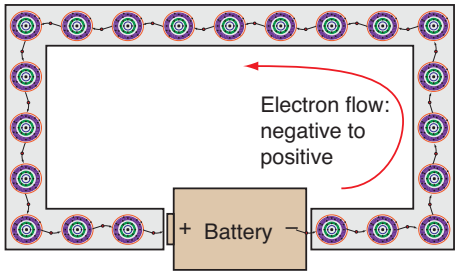
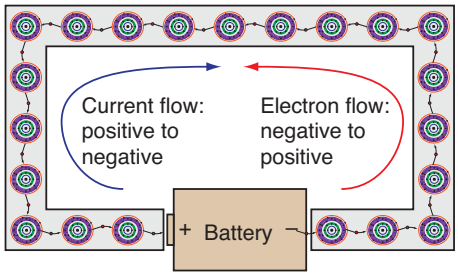
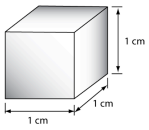


Electrical Current: current convention



How many electrons?

Example: How many valence electrons are in a 1cm cube of copper?



Useful data:
Atomic mass = 63.55 g/mol
Density of pure copper = 8.94 g/cm^3
Avogadro's number $N_A = 6.022 \times 10^{23}$ atoms/mol

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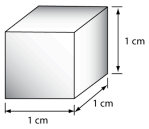

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Density of pure copper = 8.94 g/cm^3
Avogadro's number $N_A = 6.022 \times 10^{23}$ atoms/mol

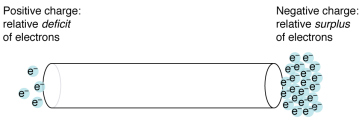
First compute the number of atoms, N

$$N = 1\,\text{cm}^3 \times 8.93\,\frac{\text{gm}}{\text{cm}^3} \times \frac{1\,\text{mol}}{63.55\,\text{g}} \times \frac{6.022 \times 10^{23}\,\text{atoms}}{\text{mol}} = 8.5 \times 10^{22}\,\text{atoms}$$

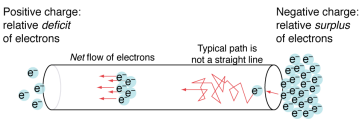
Since each copper atom has one valence electron, there are 8.5×10^{22} valence electrons in a 1 cm cube of copper.

Note: N is greater than the number of grains of sand on the earth. Compute the number of sand grains by assuming that 10 cm of sand covers all 200 million square miles of the earth's surface. Assume that each grain is 1 mm in diameter and are the packing efficiency is 68 percent.

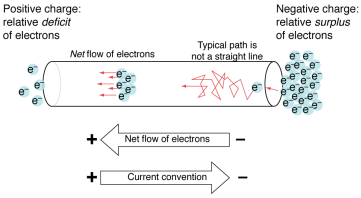
Electrical current: potential



Electrical current: electron flow



Electrical current: convention



Definition: Charge

Elementary charge

1 electron = 1.602×10^{-19} coulomb

Coulomb

1 coulomb= 6.24×10^{18} electrons

Definition: Current

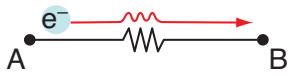
$$1\,\mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$$

$$1\ \mathrm{C} = 6.24 \times 10^{18}\,\mathrm{electrons}$$

Definition: Voltage

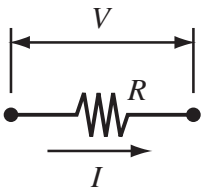
$$1\,\mathrm{V} = 1\frac{\mathrm{J}}{\mathrm{coulomb}}$$

Voltage and electrical work



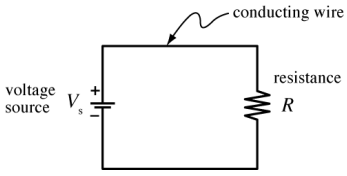
If the voltage between A and B is one volt, then one Joule of work is done when 6.28×10^{18} electrons move from A to B.

Ohm's Law



$V = IR$

Ohm's Law



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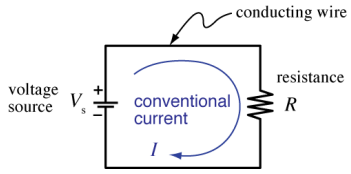

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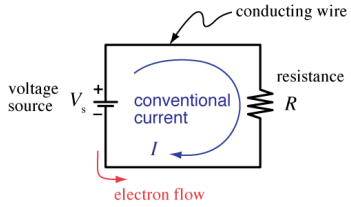

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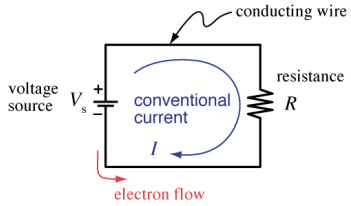

$$V = I \times R$$

voltage = current × resistance

volts = amps × ohms

Example: Current through a light bulb

A 1.5 volt AA battery is wired to a light bulb with a resistance of 30 Ω.

a. Sketch the components.

b. Draw the circuit.

c. Find the current flowing through the light bulb.

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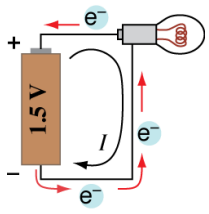

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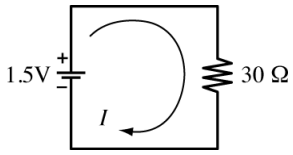

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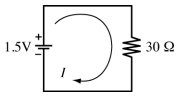

Apply Ohm's Law to the loop

$V = I R$

V and *R* and known, so solve for *I*

$I = V/R$

Substitute the known values and compute the value of *I*

$$I = \frac{1.5\,\text{V}}{30\,\Omega} = 0.05\,\text{A} = 50\,\text{mA}$$

where 1 A = 1000 mA.