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

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

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.

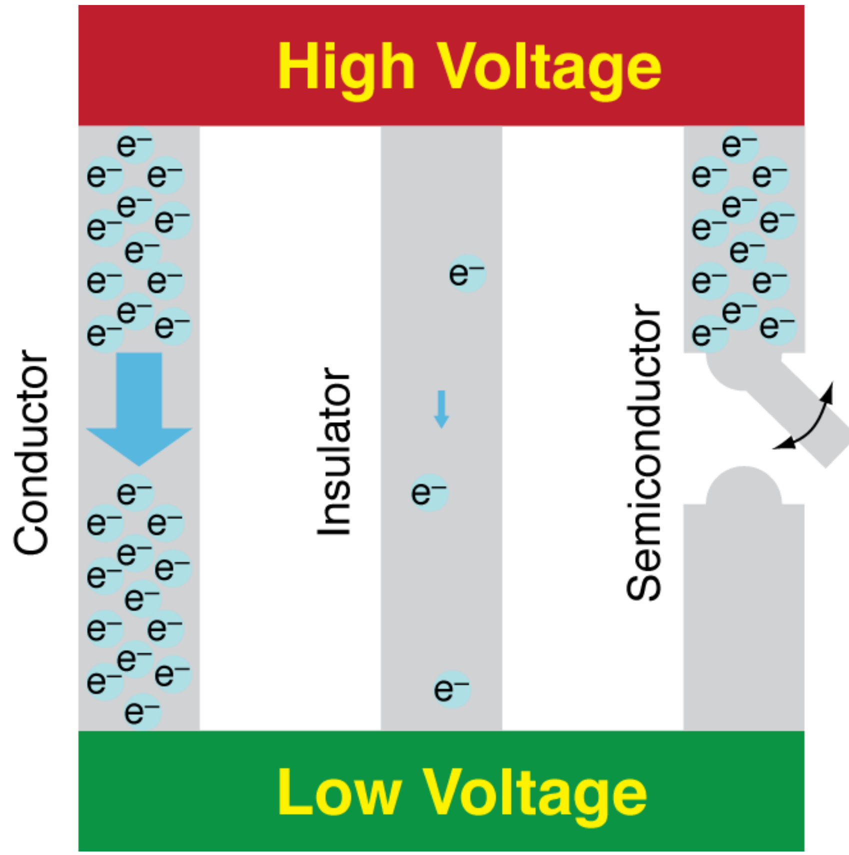
Definition

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.

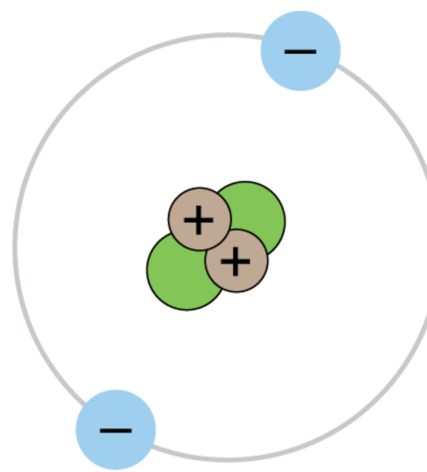
Simplified Functional Differences



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

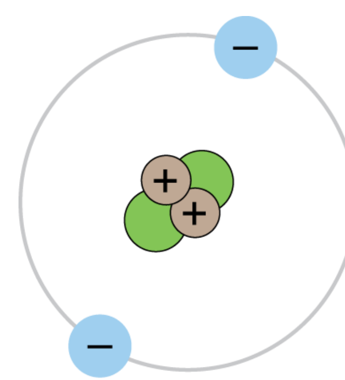
Elements

- 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 OF THE ELEMENTS

http://www.periodni.com

GROUP NUMBERS IUPAC RECOMMENDATION (1985) — 13; GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986) — IIIA

ATOMIC NUMBER	5
RELATIVE ATOMIC MASS (1)	10.811
SYMBOL	B
ELEMENT NAME	BORON

PERIOD \ GROUP	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 **H** HYDROGEN																	2 4.0026 **He** HELIUM
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.007 **N** NITROGEN	8 15.999 **O** OXYGEN	9 18.998 **F** FLUORINE	10 20.180 **Ne** NEON
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.974 **P** PHOSPHORUS	16 32.065 **S** SULPHUR	17 35.453 **Cl** CHLORINE	18 39.948 **Ar** ARGON
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.38 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.922 **As** ARSENIC	34 78.96 **Se** SELENIUM	35 79.904 **Br** BROMINE	36 83.798 **Kr** KRYPTON
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.96 **Mo** MOLYBDENUM	43 (98) **Tc** TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.76 **Sb** ANTIMONY	52 127.60 **Te** TELLURIUM	53 126.90 **I** IODINE	54 131.29 **Xe** XENON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 **La-Lu** **Lanthanide**	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.98 **Bi** BISMUTH	84 (209) **Po** POLONIUM	85 (210) **At** ASTATINE	86 (222) **Rn** RADON
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 **Ac-Lr** **Actinide**	104 (267) **Rf** RUTHERFORDIUM	105 (268) **Db** DUBNIUM	106 (271) **Sg** SEABORGIUM	107 (272) **Bh** BOHRIUM	108 (277) **Hs** HASSIUM	109 (276) **Mt** MEITNERIUM	110 (281) **Ds** DARMSTADTIUM	111 (280) **Rg** ROENTGENIUM	112 (285) **Cn** COPERNICIUM						

LANTHANIDE

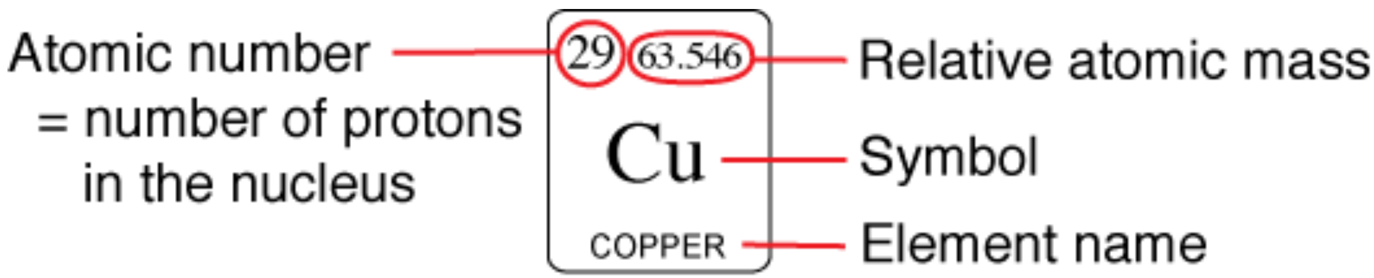
57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) **Pm** PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.26 **Er** ERBIUM	69 168.93 **Tm** THULIUM	70 173.05 **Yb** YTTERBIUM	71 174.97 **Lu** LUTETIUM

ACTINIDE

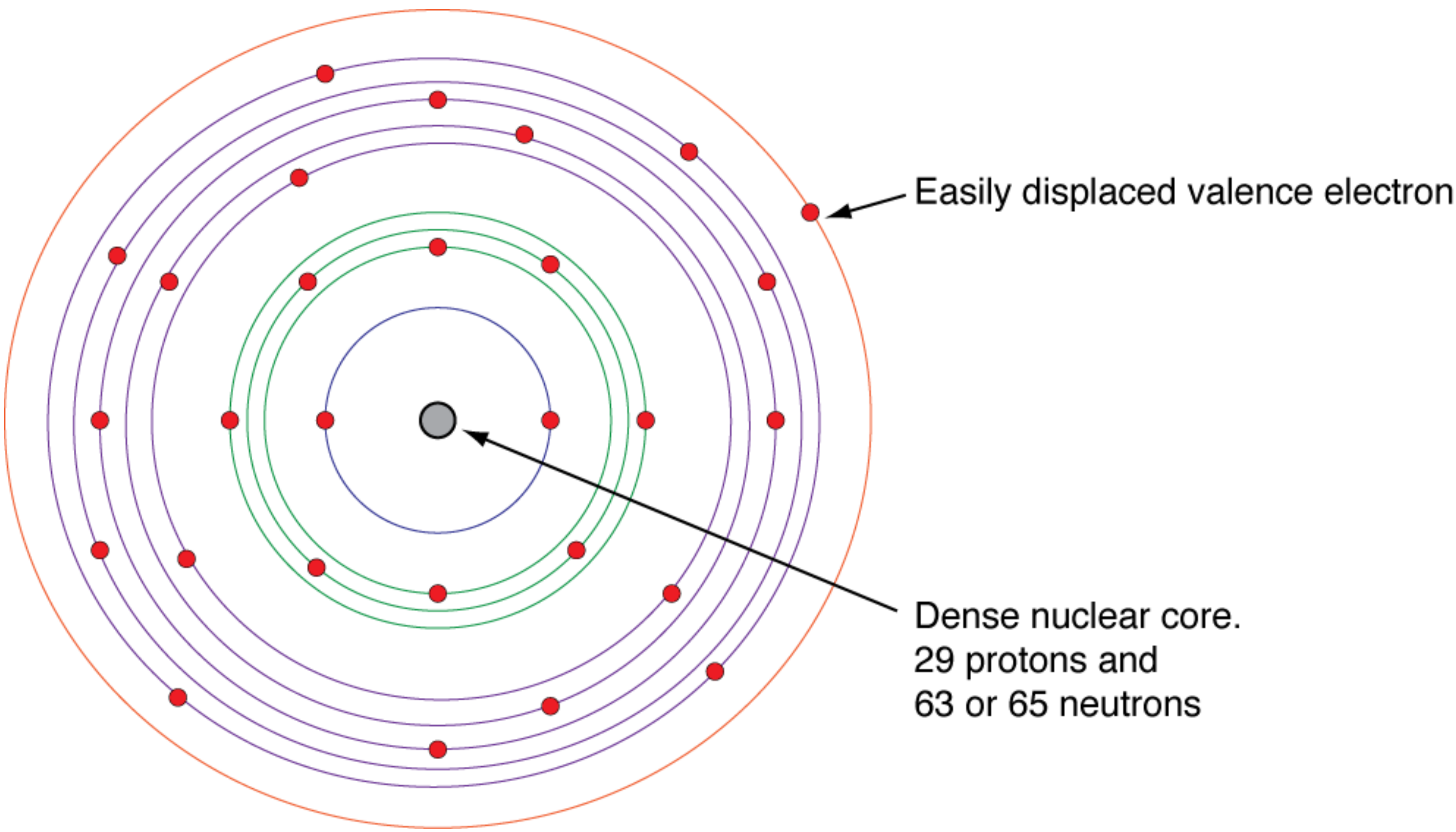
89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) **Np** NEPTUNIUM	94 (244) **Pu** PLUTONIUM	95 (243) **Am** AMERICIUM	96 (247) **Cm** CURIUM	97 (247) **Bk** BERKELIUM	98 (251) **Cf** CALIFORNIUM	99 (252) **Es** EINSTEINIUM	100 (257) **Fm** FERMIUM	101 (258) **Md** MENDELEVIUM	102 (259) **No** NOBELIUM	103 (262) **Lr** LAWRENCIUM

(1) Pure Appl. Chem., **81**, No. 11, 2131-2156 (2009)
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element. However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

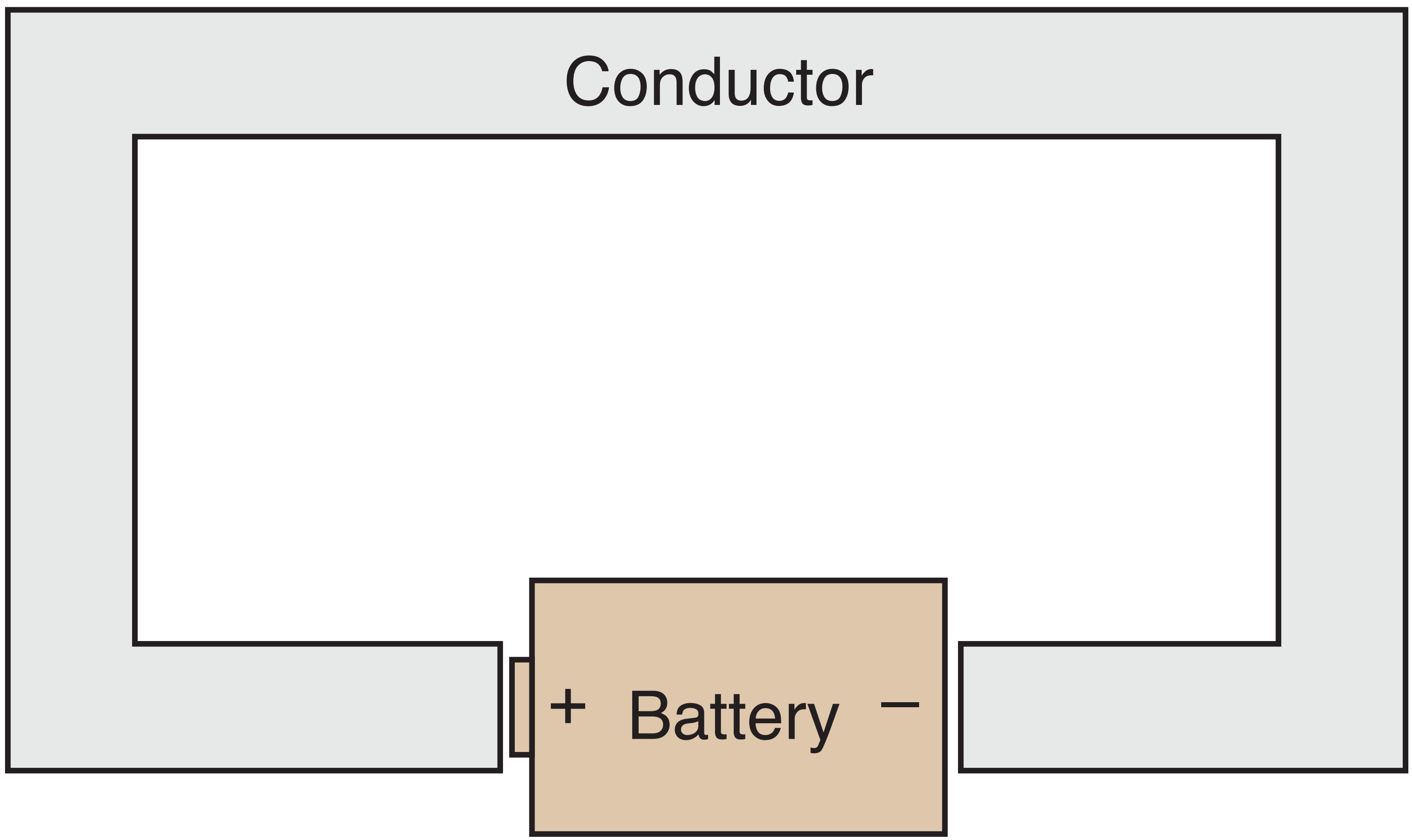
Periodic Table: Copper



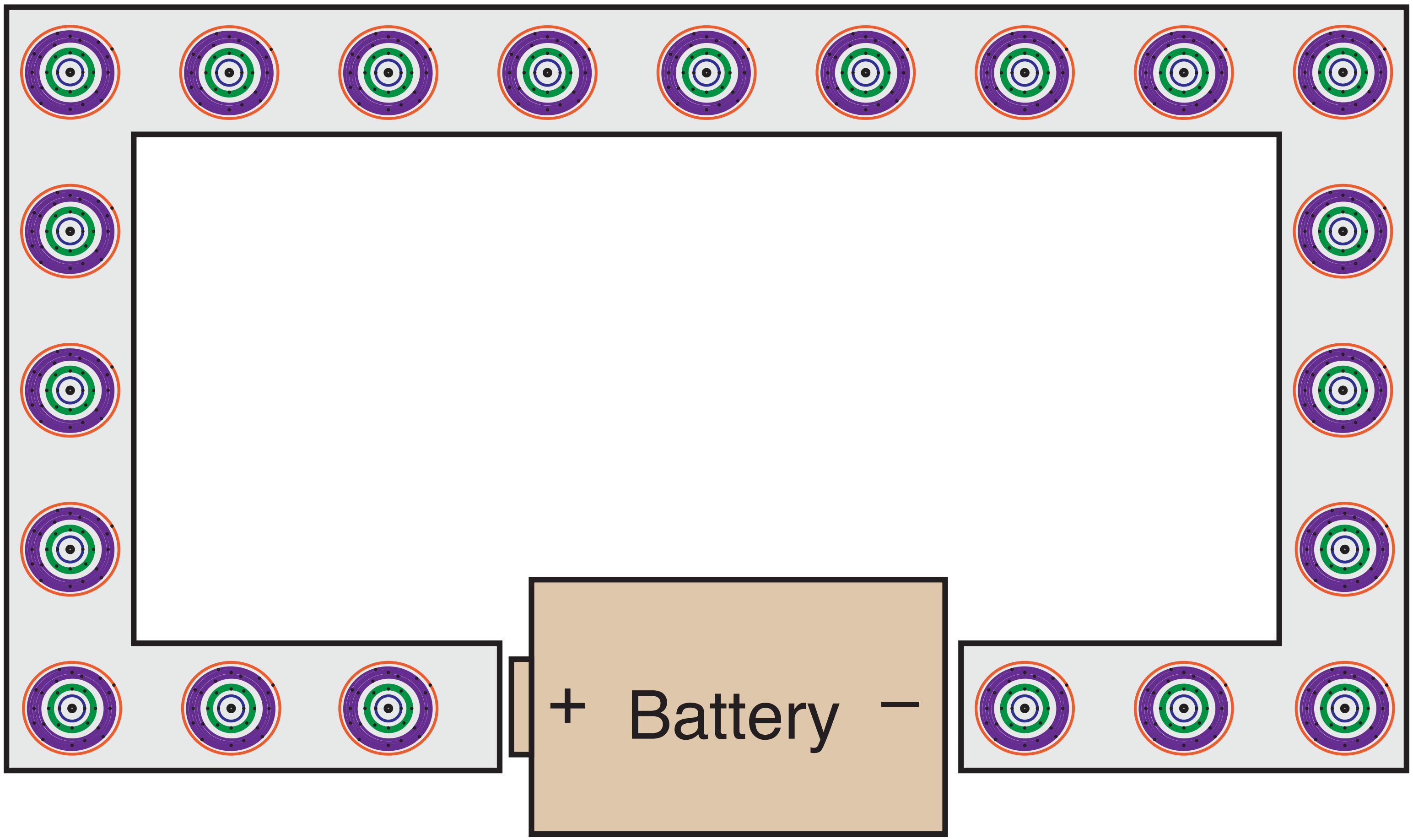
Bohr Model of the atom (Cu)



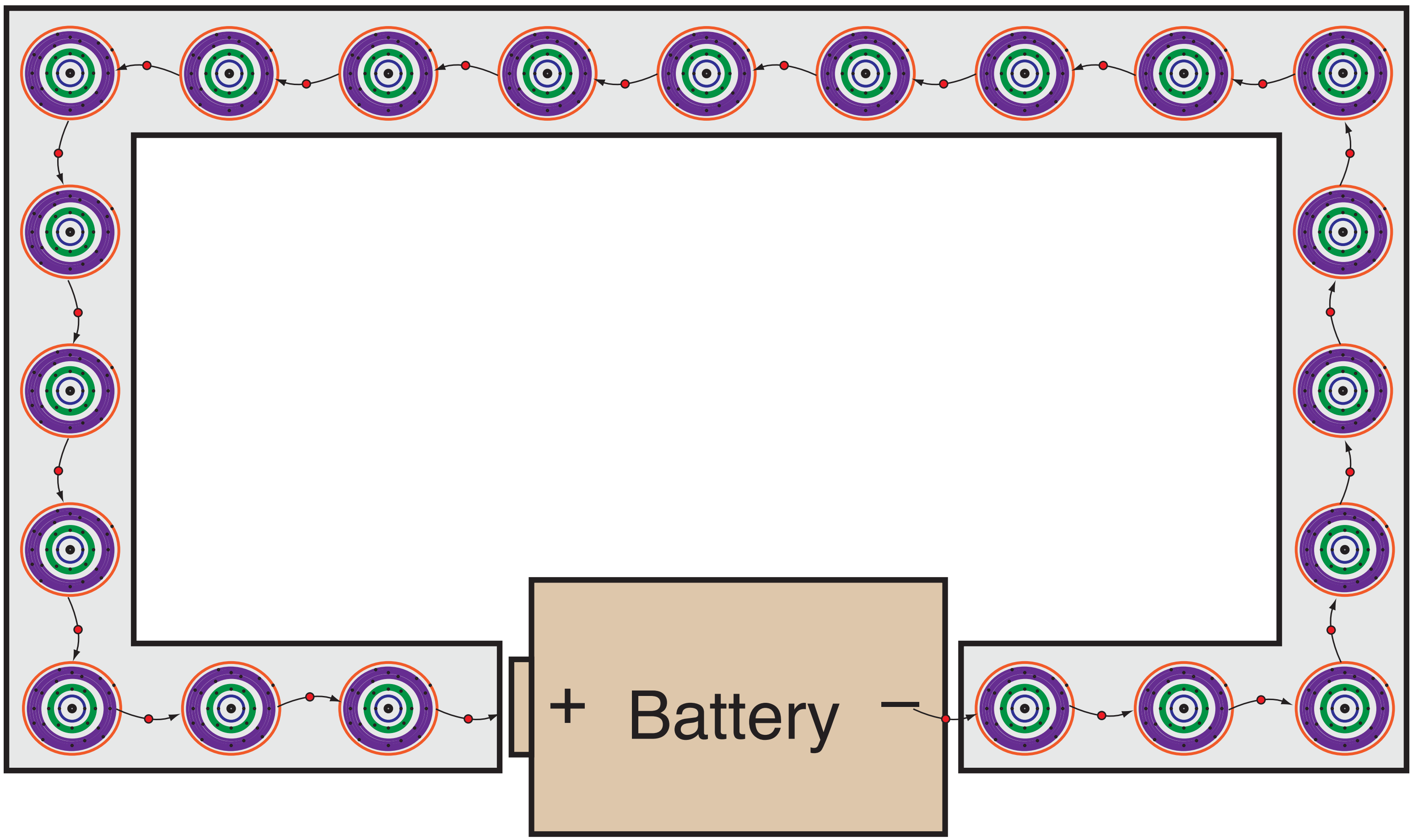
Electrical current in a trivial circuit



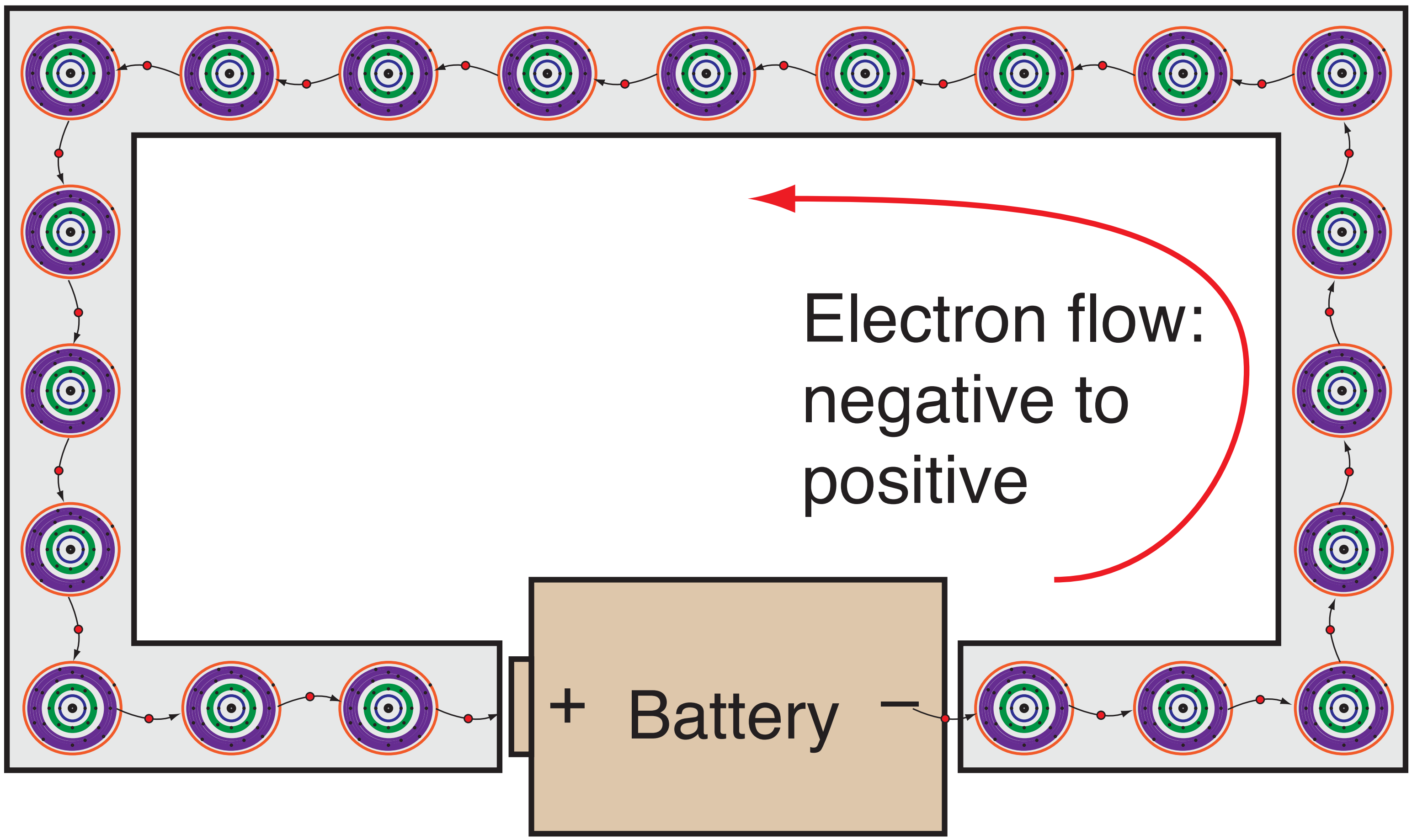
Electrical current: atomic model



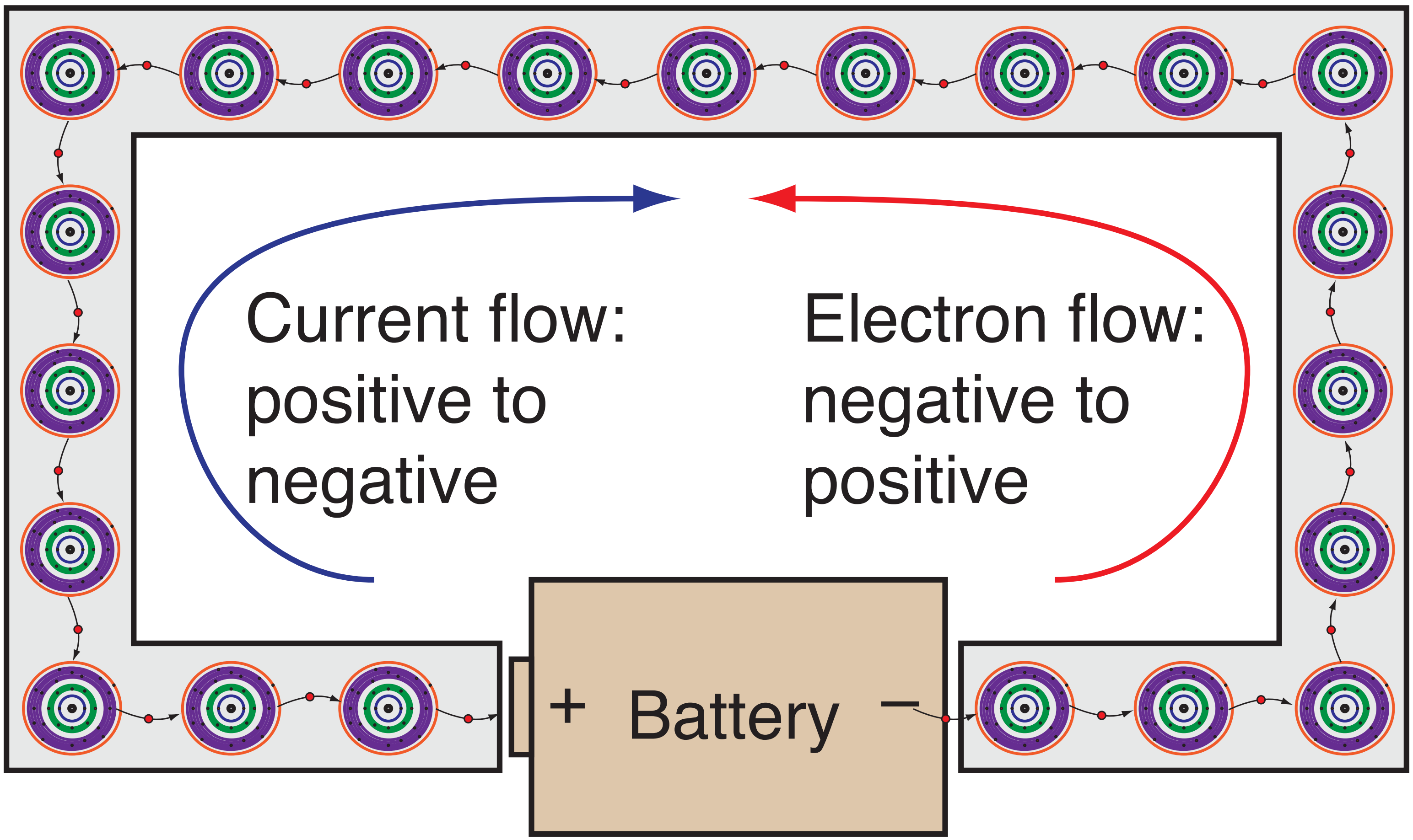
Electrical Current: electron flow



Electrical Current: electron flow

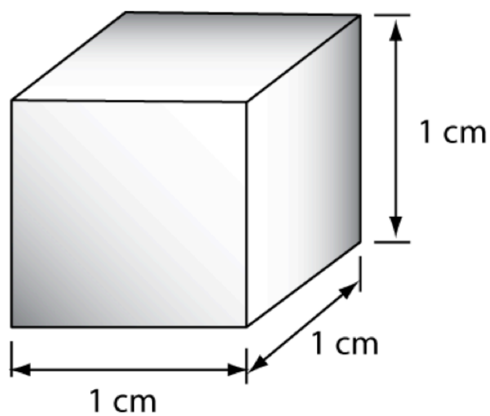


Electrical Current: current convention



How many electrons?

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



Useful data:

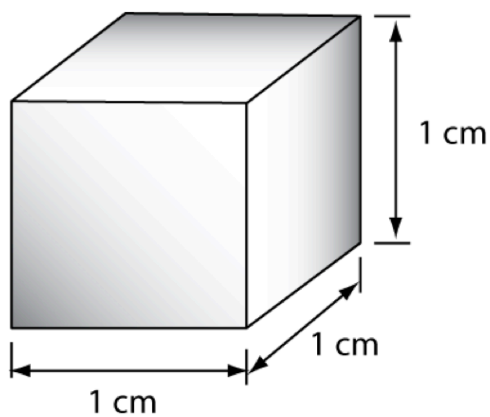
Atomic mass = 63.55 g/mol

Density of pure copper = 8.94 g/cm^3

Avogadro's number $N_A = 6.022 \times 10^{23}$ atoms/mol

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

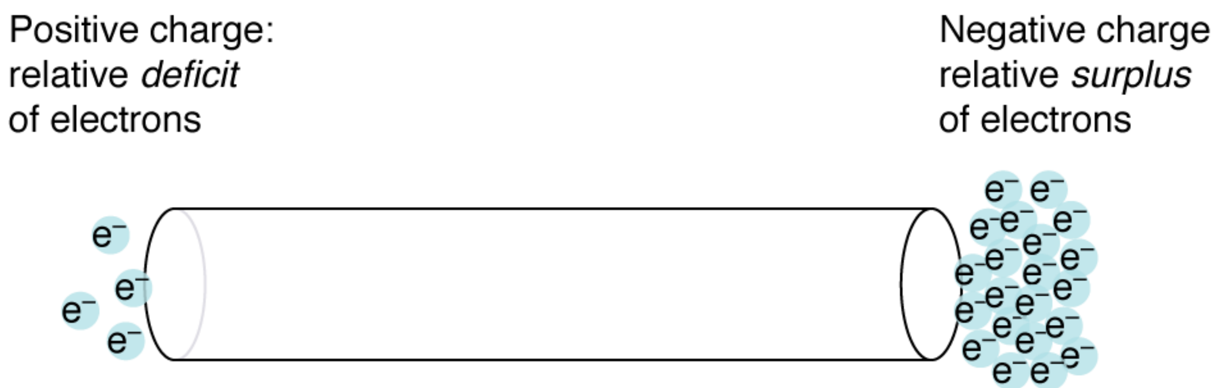
First compute the number of atoms, N

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

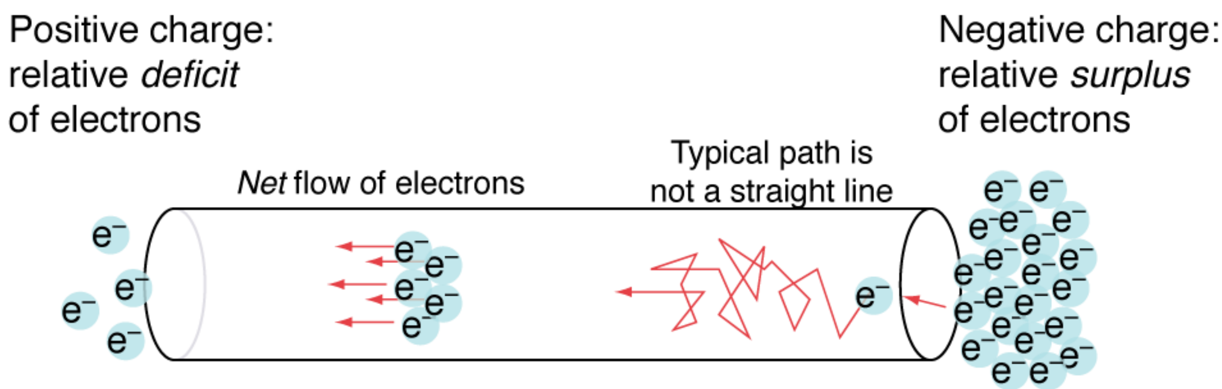
Since each copper atom has one valence electron, there are 8.5×10^{22} valence electrons in a 1 cm cube of copper.

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.

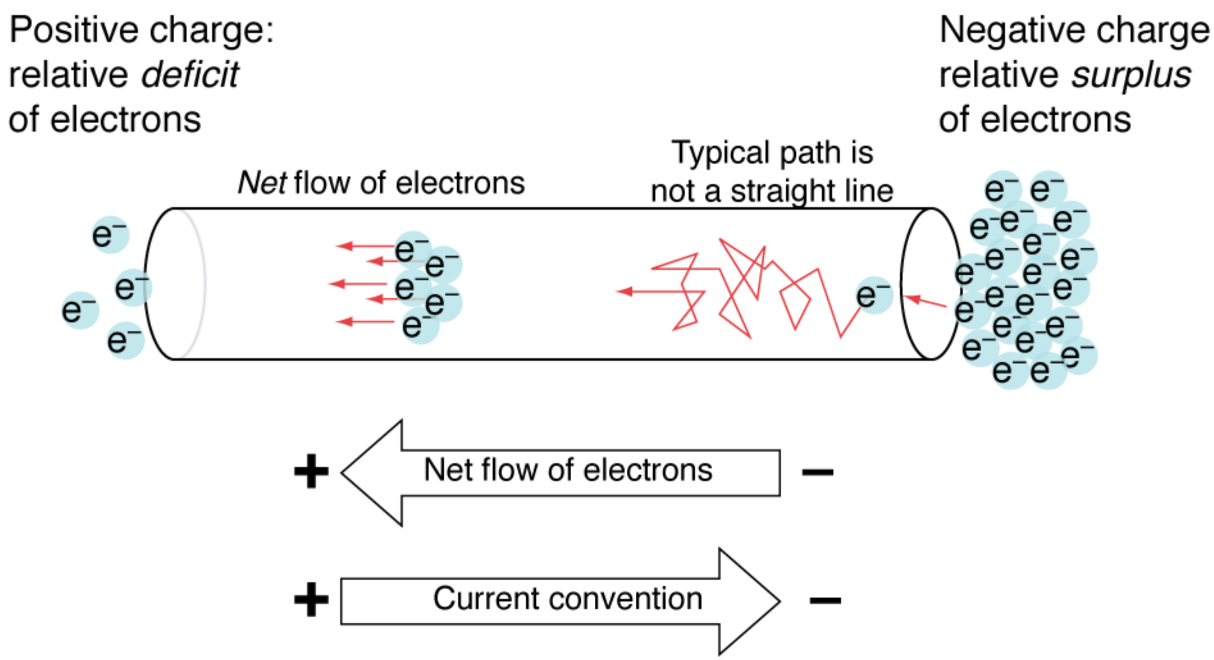
Electrical current: potential



Electrical current: electron flow



Electrical current: convention



Definition: Charge

Elementary charge

$$1 \text{ electron} = 1.602 \times 10^{-19} \text{ coulomb}$$

Coulomb

$$1 \text{ coulomb} = 6.24 \times 10^{18} \text{ electrons}$$

Definition: Current

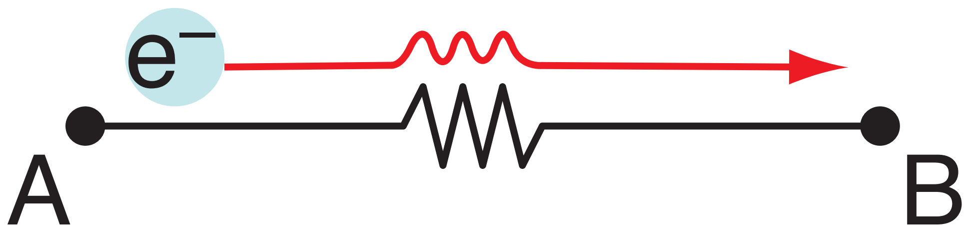
$$1\,\text{A} = 1\frac{\text{C}}{\text{s}}$$

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

Definition: Voltage

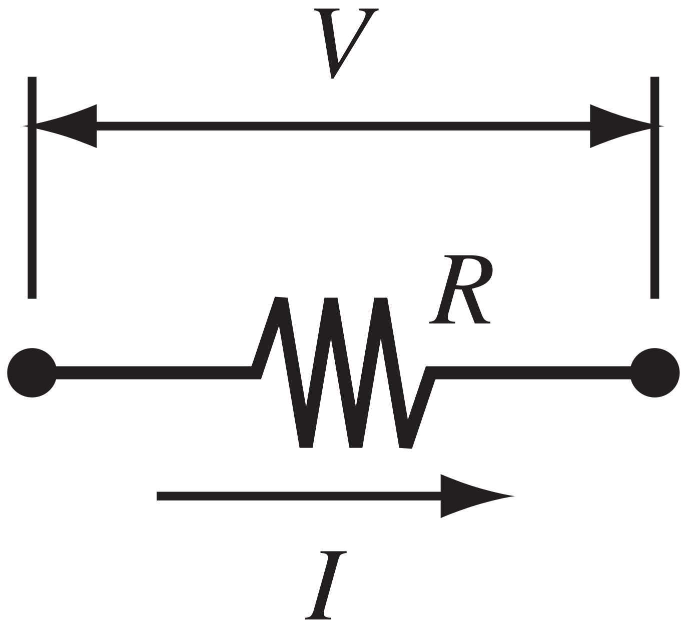
$$1\,\mathrm{V} = 1\,\frac{\mathrm{J}}{\mathrm{coulomb}}$$

Voltage and electrical work



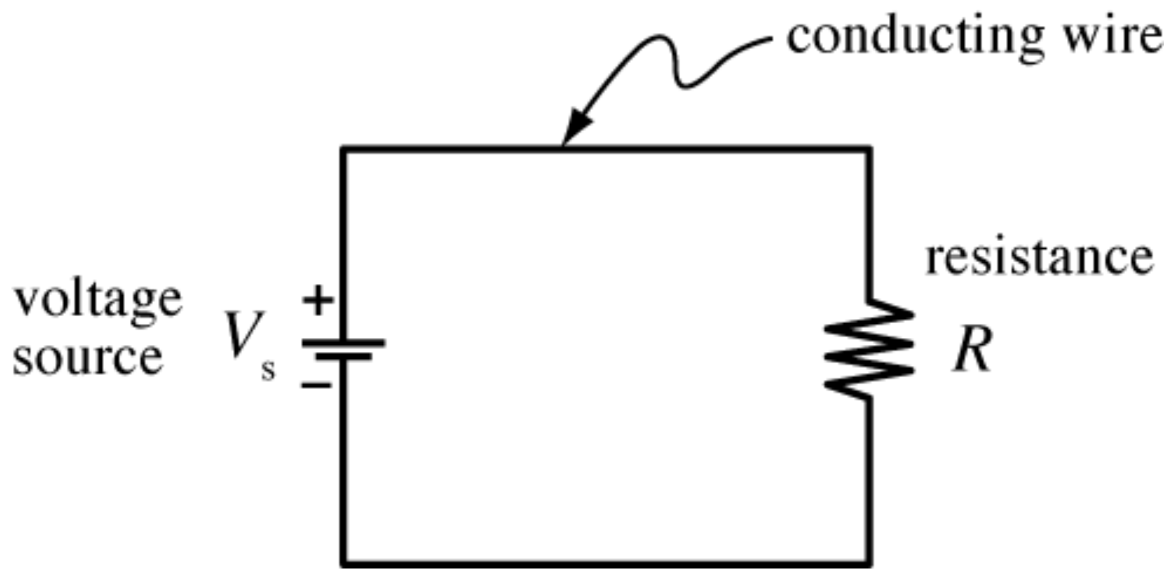
If the voltage between A and B is one volt, then one Joule of work is done when 6.28×10^{18} electrons move from A to B.

Ohm's Law

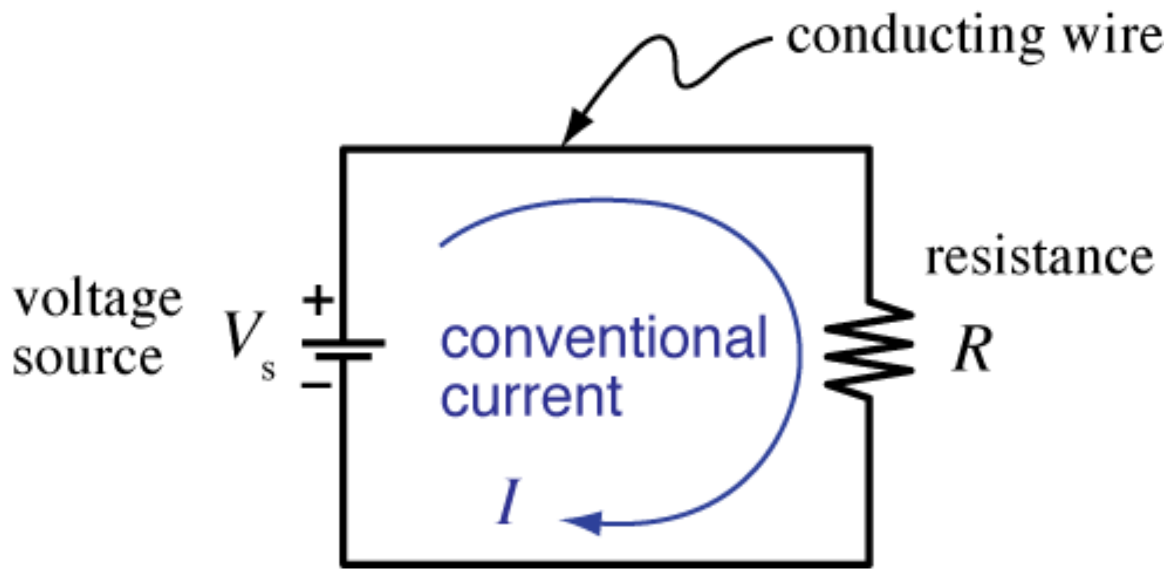


$$V = IR$$

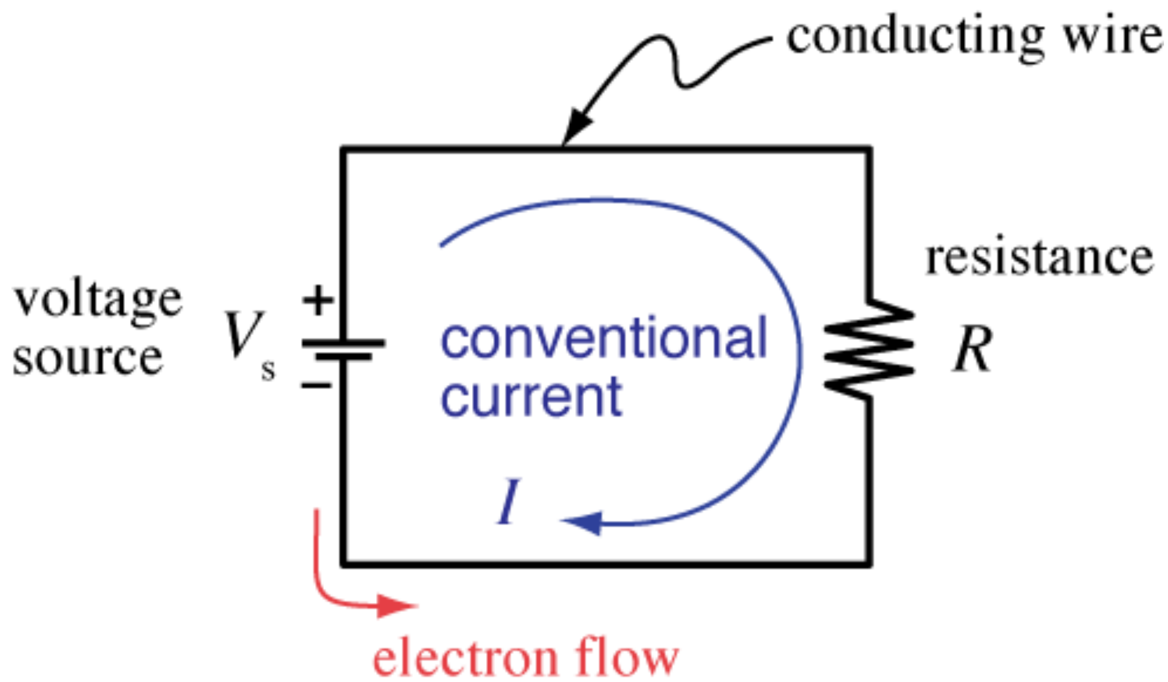
Ohm’s Law



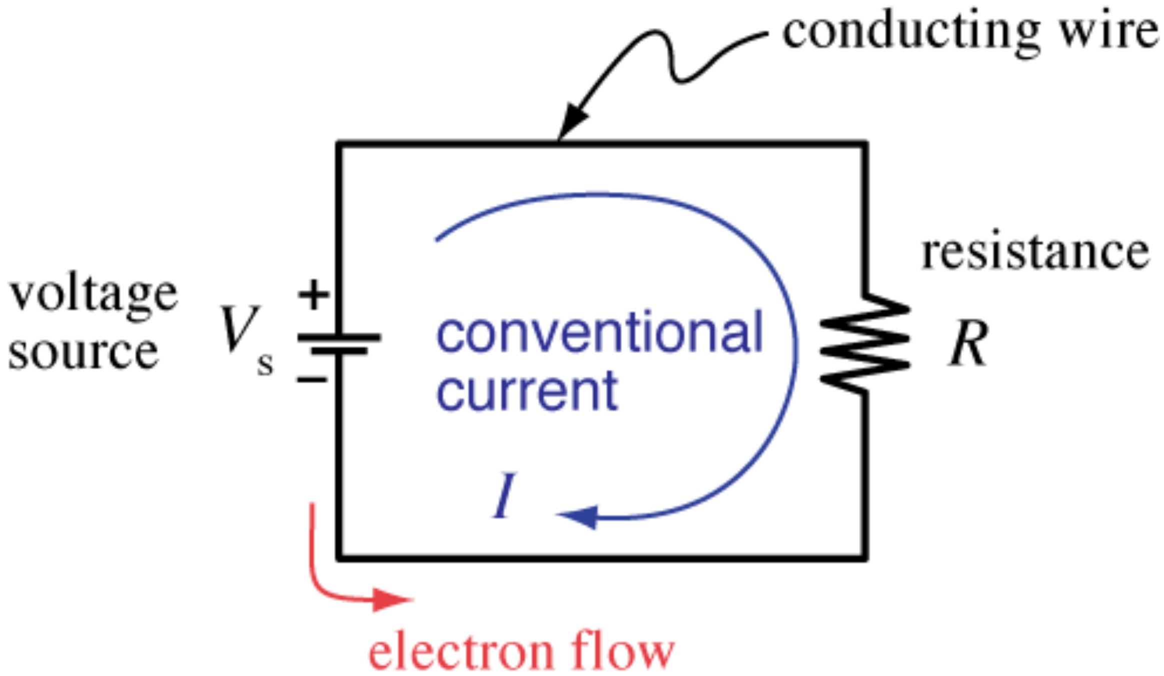
Ohm’s Law


conducting wire
resistance
voltage
source
V_s
+
−
conventional
current
R
I

Ohm's Law


conducting wire
resistance
voltage
source
V_s
+
−
conventional
current
I
R
electron flow

Ohm's Law



$$V = I \times R$$

$$\text{voltage} = \text{current} \times \text{resistance}$$

$$\text{volts} = \text{amps} \times \text{ohms}$$

Example: Current through a light bulb

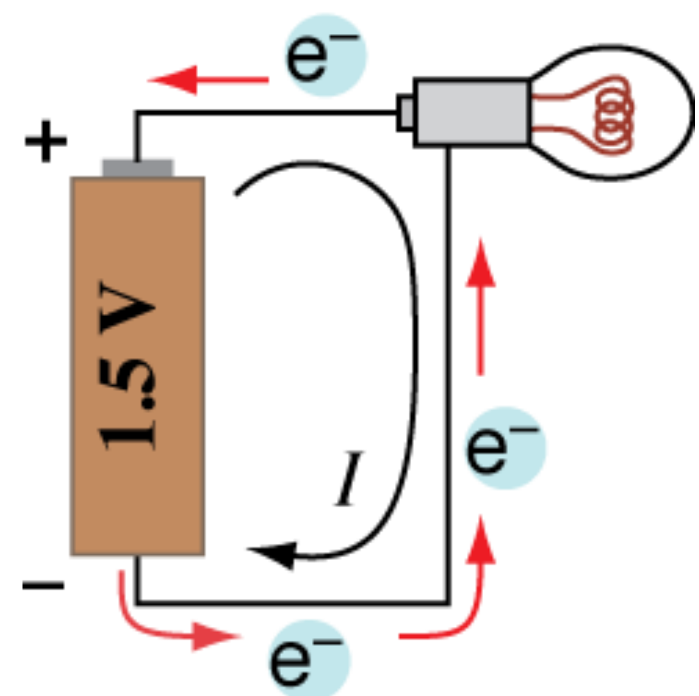
A 1.5 volt AA battery is wired to a light bulb with a resistance of 30 Ω.

a. Sketch the components.
b. Draw the circuit.
c. Find the current flowing through the light bulb.

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.

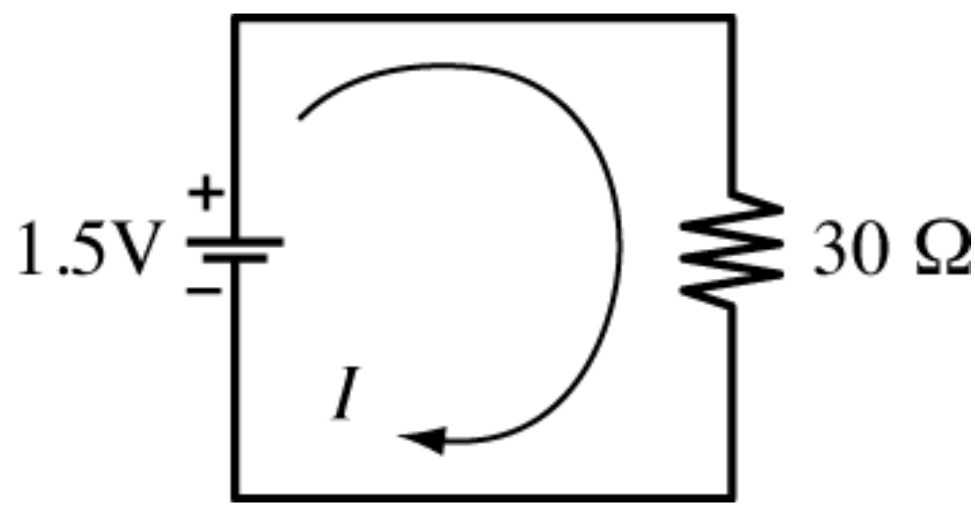


Example: Current through a light bulb

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

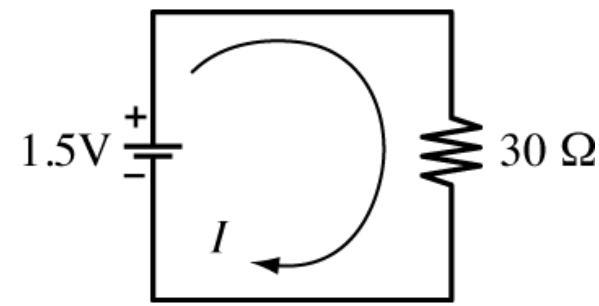
a. Sketch the components.

b. Draw the circuit.



Example: Current through a light bulb

c. Find the current flowing through the bulb



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.