

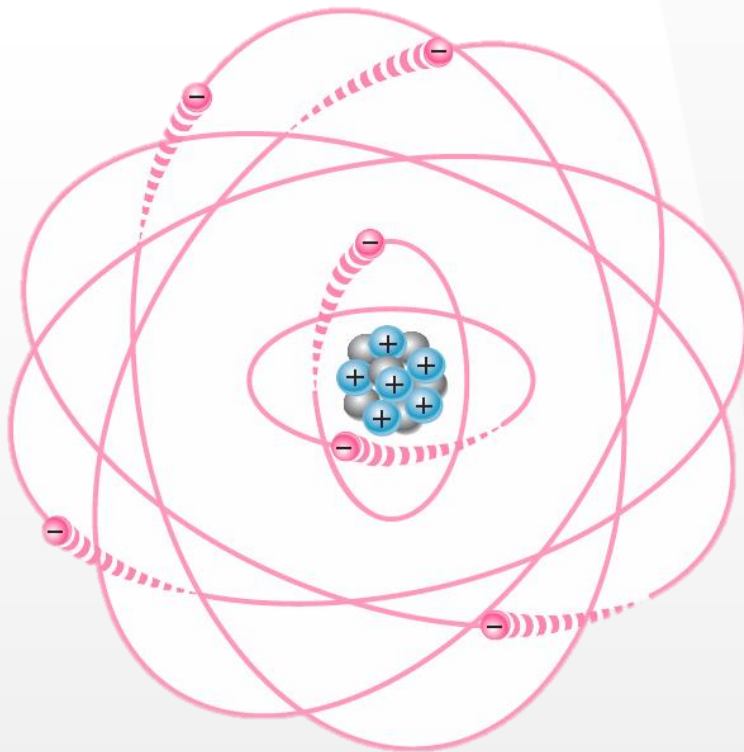
Chapter 2: Voltage, Current, and Resistance

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http://faculty.uml.edu/JeanFrancois_Millithaler/FunElec/Spring2017

Atom

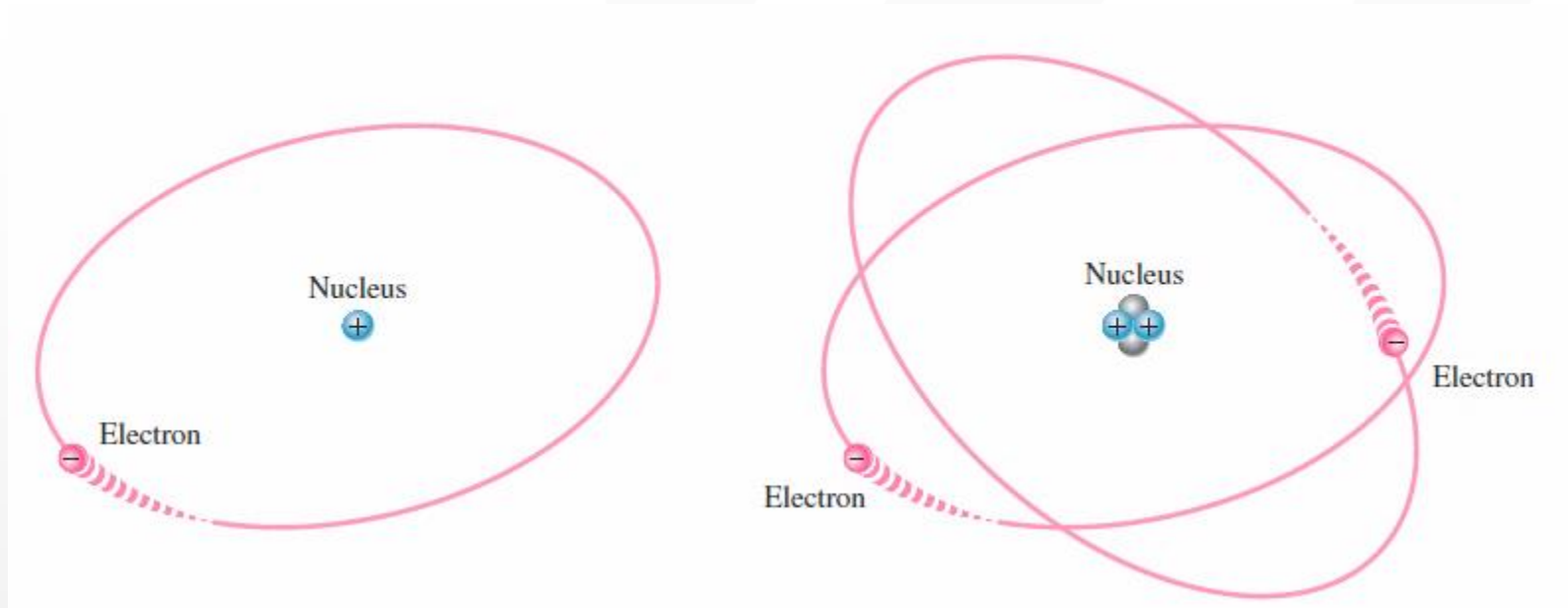
Visualization of atomic structure



— Electron + Proton ● Neutron

- ▶ **Nucleus:** positively charged (protons and neutrons)
- ▶ **Electrons:** negatively charged
- ▶ Atomic number = number of protons
- ▶ # electrons = # protons

Atoms

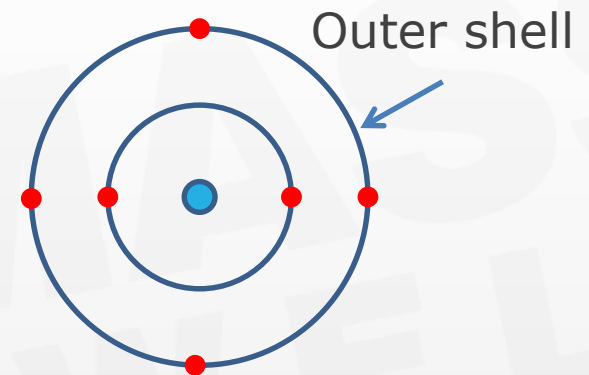


Hydrogen atom

Helium atom

Shells

- ▶ Electrons are orbiting at different energy levels
- ▶ They are called shells
- ▶ They allow a fixed number of electrons ($2N^2$)
 - Shell 1 allows $2 \times 1^2 = 2 e^-$
 - Shell 2 allows $2 \times 2^2 = 8 e^-$
 - Shell 3 allows $2 \times 3^2 = 18 e^-$
 - Next is more complicated ...



- ▶ Electrons in the outer shell (valence shell) are involved in chemical reactions and they account for electrical and thermal conductivity in metals

Mendeleïv Table

Dimitri Ivanovitch Mendeleïv, Russian scientist, 1834-1907

1 1.0079 H HYDROGÈNE	2 4.0026 He HÉLIUM																
3 6.941 Li LITHIUM	4 9.0122 Be BÉRYLLIUM																
11 22.990 Na SODIUM	12 24.305 Mg MAGNÉSIIUM																
19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANE	23 50.942 V VANADIUM	24 51.996 Cr CHROME	25 54.938 Mn MANGANÈSE	26 55.845 Fe FER	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu CUIVRE	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SÉLÈNIUM	35 79.904 Br BROME	36 83.80 Kr KRYPTON
37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOMIUM	42 95.94 Mo MOLYBDÈNE	43 (98) Tc TECHNÉTIUM	44 101.07 Ru RUTHÉNIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag ARGENT	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn ÉTAIN	51 121.76 Sb ANTIMOINE	52 127.60 Te TELLURE	53 126.90 I IODE	54 131.29 Xe XÉNON
55 132.91 Cs CÉSIIUM	56 137.33 Ba BARYUM	57-71 La-Lu Lanthanides	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALE	74 183.84 W TUNGSTÈNE	75 186.21 Re RHÉNIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINE	79 196.97 Au OR	80 200.59 Hg MERCURE	81 204.38 Tl THALLIUM	82 207.2 Pb PLOMB	83 208.98 Bi BISMUTH	84 (209) Po POLONAIIUM	85 (210) At ASTATE	86 (222) Rn RADON
87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinides	104 (261) Rf RUTHÉRFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNIUM	111 (272) Uuu UNUNNIUM	112 (285) Uub UNUNBIUM	114 (289) Uuq UNUNQUADIUM					

ANTHANIDES														
57 138.91	58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.04	71 174.97
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
LANTHANE	CÉRIUM	PRASEODYME	NÉODYME	PROMETHIUM	SAMARIUM	EUROPIUM	GADOLINIUM	TERBIUM	DYSPROSIUM	HOLMIUM	ERBIUM	THULIUM	YTTÉRIUM	LUTETIUM
ACTINIDES														
89 (227)	90 232.04	91 231.04	92 238.03	93 (237)	94 (244)	95 (243)	96 (247)	97 (247)	98 (251)	99 (252)	100 (257)	101 (258)	102 (259)	103 (262)
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
ACTINIUM	THORIUM	PROTACTINIUM	URANIUM	NEPTUNIUM	PLUTONIUM	AMÉRICIUM	CURIUM	BERKÉLIUM	CALIFORNIUM	EINSTEINIUM	FERMIUM	MENDELÉVIUM	NOBÉLIUM	LAWRENCIUM

Atoms are looking for the most stable configuration

Atoms can become ions

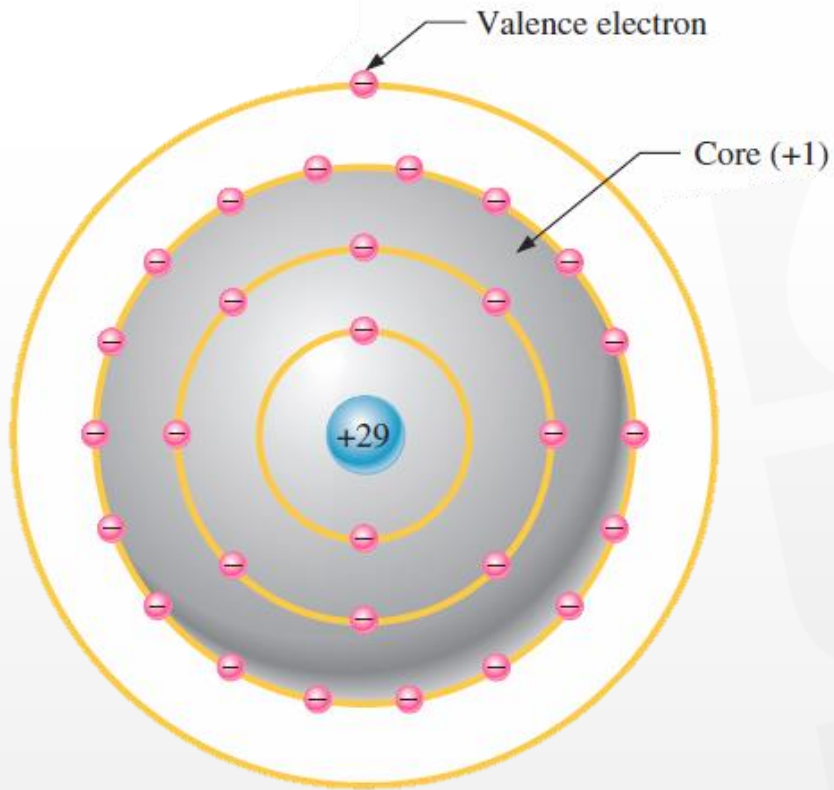
Ex: $\text{H} \rightarrow \text{H}^+$

Conductors

Semiconductors

Insulators

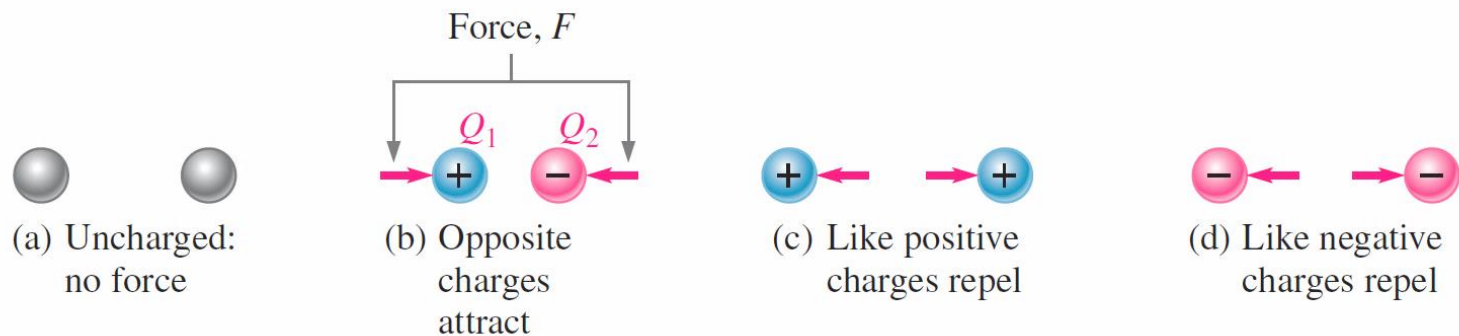
Copper atom



- ▶ Inner shell = Core
- ▶ Outer shell: 1 e^-
- ▶ With energy this e^- can move freely
- ▶ Copper = excellent conductor

Electrical charge

- ▶ There is a force (F) between electrical charges.



- ▶ The force is directly proportional to charge.
- ▶ The force is inversely proportional to square of distance.

Coulomb: the unit of charge

Charles Augustin Coulomb, French scientist, 1736-1806

- ▶ One **coulomb** is the total charge possessed by $6.25 \times 10^{18} e^-$
- ▶ Charge of a single $e^- = 1.6 \times 10^{-19} \text{ C}$
- ▶ Total charge $Q = \frac{\text{number of } e^-}{6.25 \times 10^{18} e^-/\text{C}}$

Voltage

Alessandro Volta, Italian scientist, 1745-1827

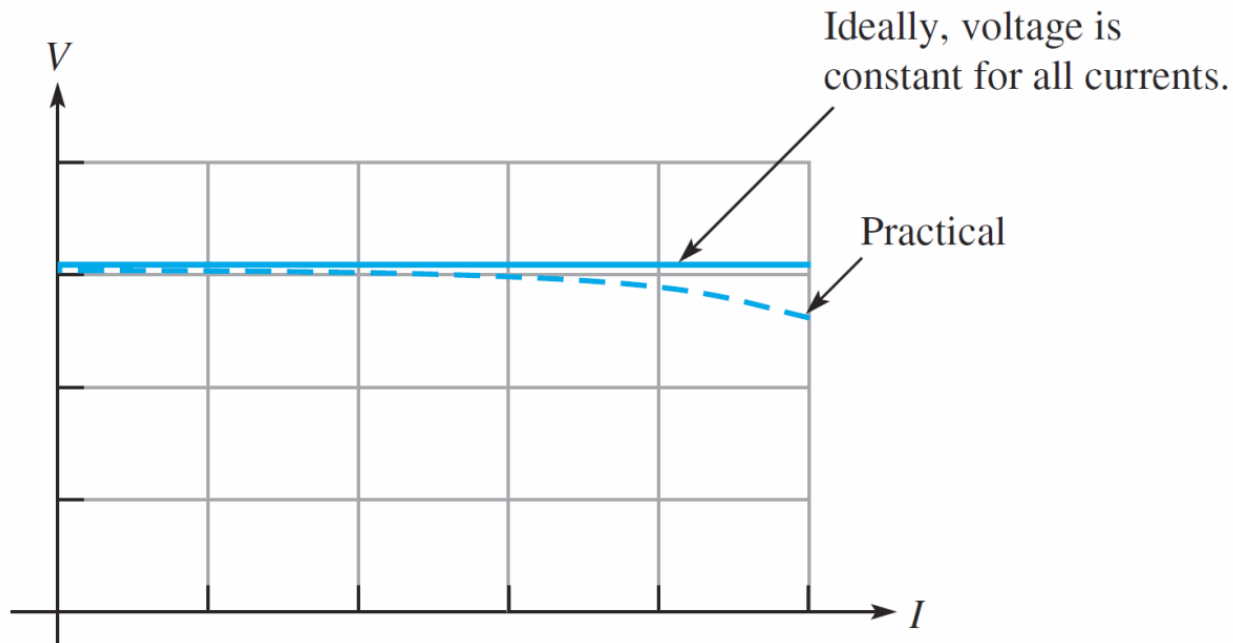
- ▶ Voltage = energy per unit of charge

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

- ▶ V is voltage in volts, W is energy in joules (J), and Q is charge in coulombs (C).
- ▶ One volt is the potential difference (voltage) between two points when one joule of energy is used to move one coulomb of charge from one point to the other.

Voltage

- ▶ Ideal voltage source can provide a constant voltage
- ▶ Doesn't exist but can be closely approximated in practice

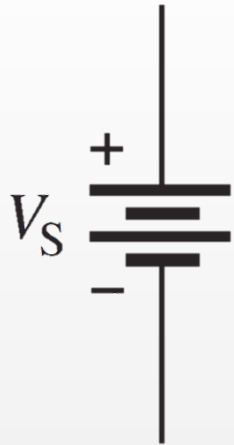


Voltage source graph

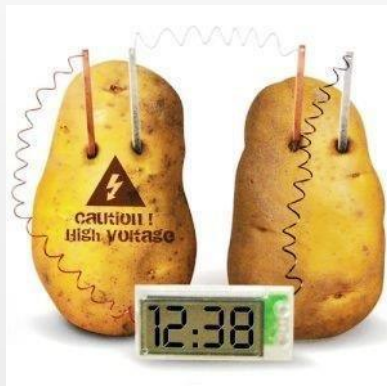
Voltage

Batteries and Sources

- ▶ Voltage is responsible for establishing current

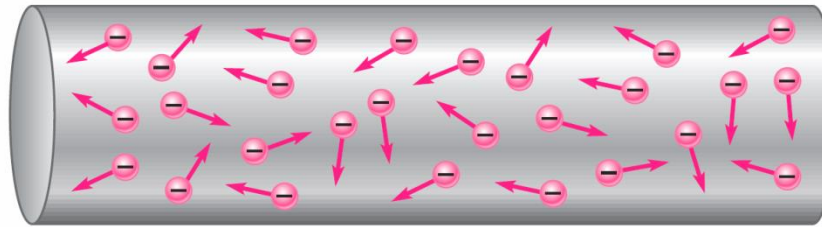


Symbol for
dc voltage
sources

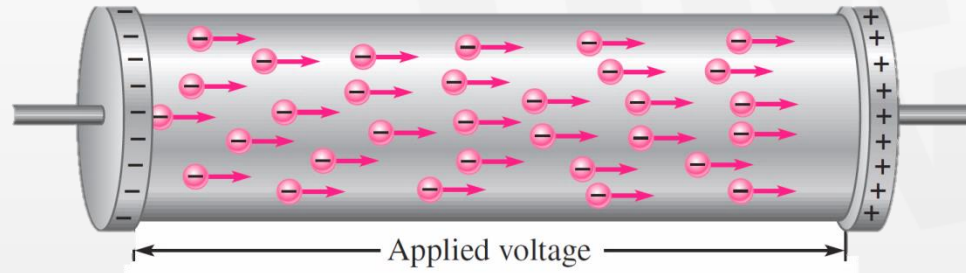


Current

André Marie Ampère, French scientist, 1775-1836



- ▶ Random motion of free electrons in a material



- ▶ Electrons flow from negative to positive when a voltage is applied across a conductive material

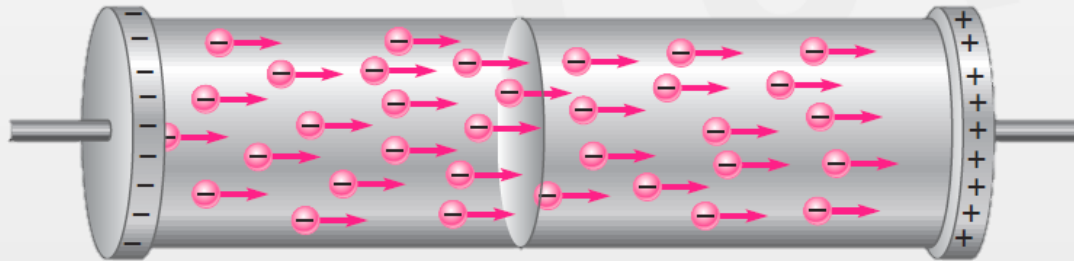
Current

Ampere: the unit of current

- ▶ Electrical current is the rate of flow of charge

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

- ▶ I is current in amperes (A), Q is the charge of the electrons in coulombs (C), and t is time in seconds (s)
- ▶ One **ampere** (1 A) is the amount of current that exists when a number of electrons having a total charge of one coulomb (1 C) move through a given cross-sectional area in one second (1 s).

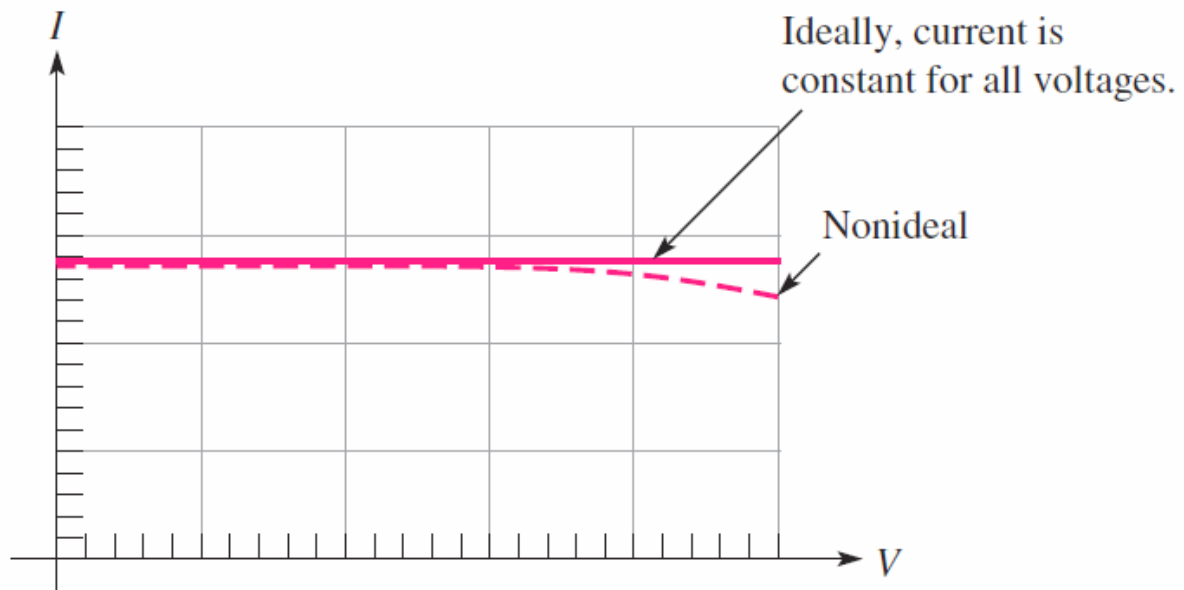


Current

- ▶ An ideal current source can provide a constant current in any load.
- ▶ Does not exist but can be approximated in practice



Symbol

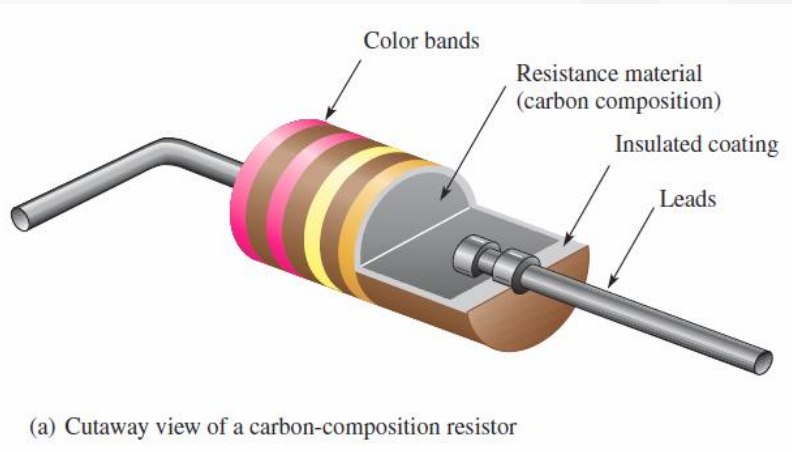


I-V characteristic

Resistance

Georg Simon Ohm, German scientist, 1787-1854

- ▶ **Resistance** is the opposition to current
- ▶ One **ohm** (1Ω) of resistance exists when there is one ampere (1 A) of current in a material with one volt (1 V) applied across the material



Conductance

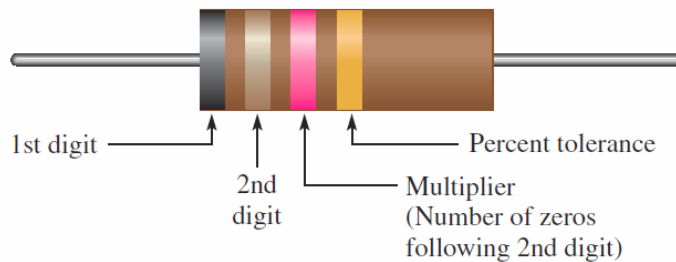
Ernst Werner von Siemens, Russian scientist, 1816-1892

- ▶ **Conductance** is the reciprocal of resistance

$$G = \frac{1}{R}$$

- ▶ The unit of conductance is the **siemens**, symbolized by **S**.

Resistance color-code



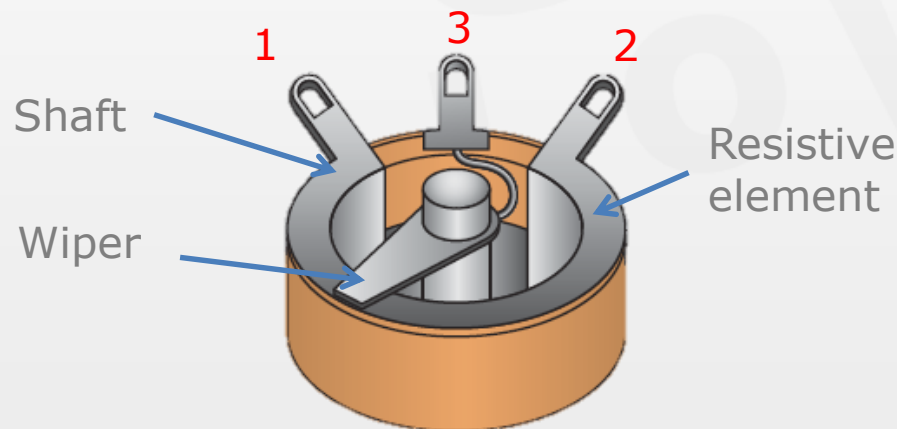
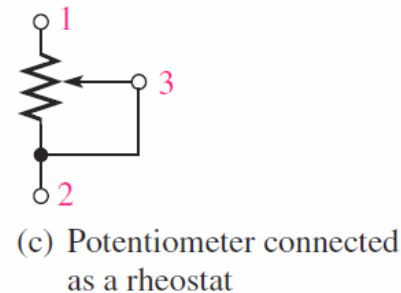
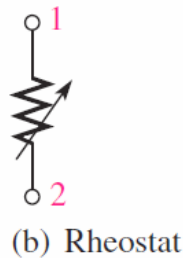
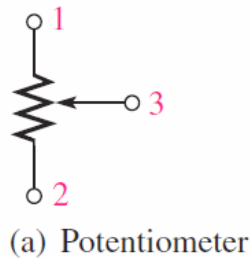
	Digit	Color
Resistance value, first three bands: First band—1st digit Second band—2nd digit *Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

Mnemonic phrase

Better Be Right Or Your Great Big Venture Goes West

Variable resistors

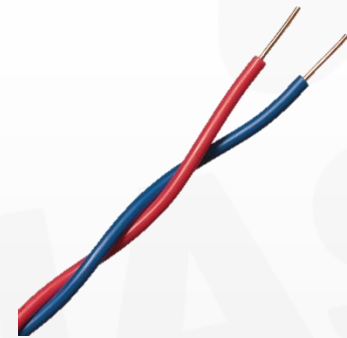
- Variable resistors include the potentiometer and rheostat. The center terminal of a variable resistor is connected to the wiper.



Wire resistance

- ▶ Resistance of wire is:

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

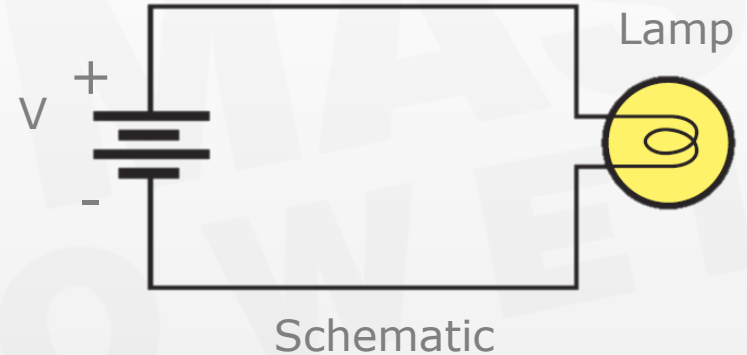
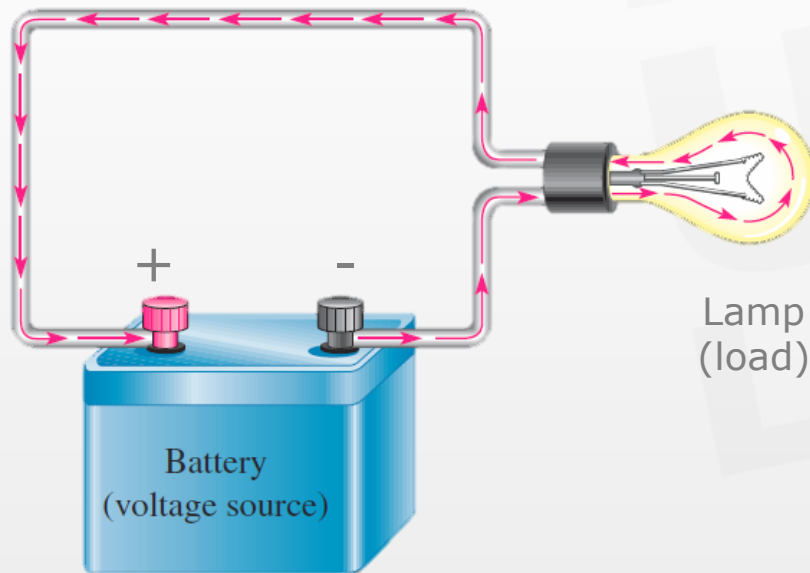


- ▶ ρ is the resistivity in $\Omega \cdot \text{m}$, l the length in meter (m), and A is the cross sectional area in m^2

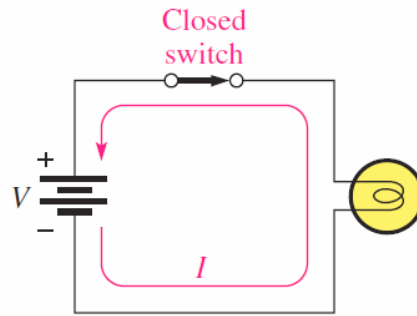
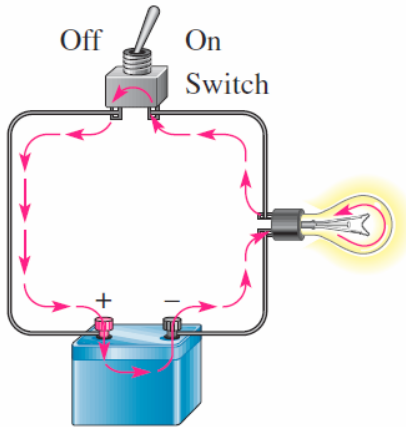
Circuits

Voltage source + Load + path for current

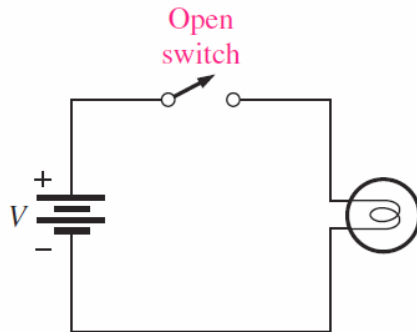
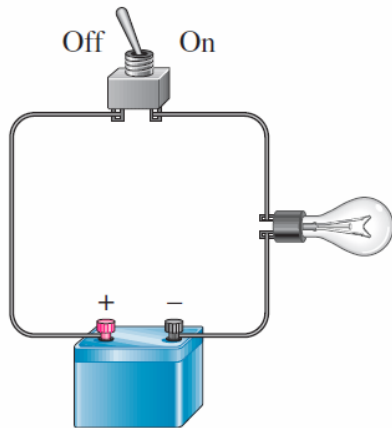
Wire conductor (current path)



Circuit and switch

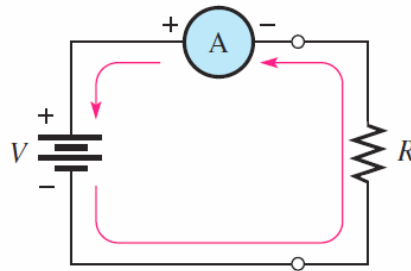
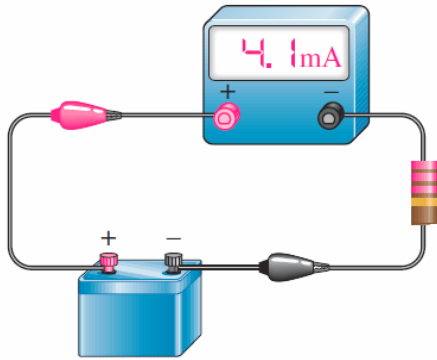


► Switch ON circuit is closed

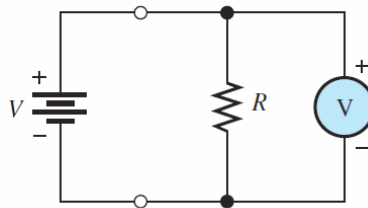
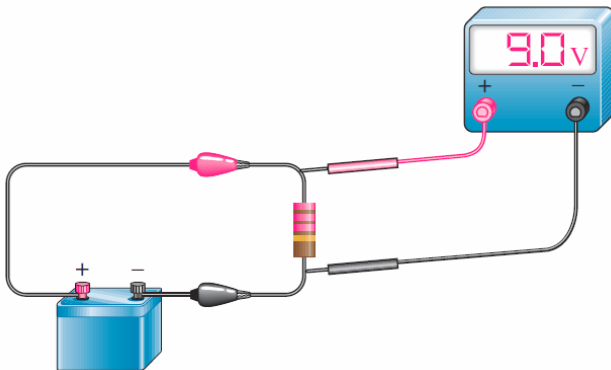


► Switch OFF circuit is open

Ammeter & Voltmeter



► Ammeter in series



► Voltmeter in parallel