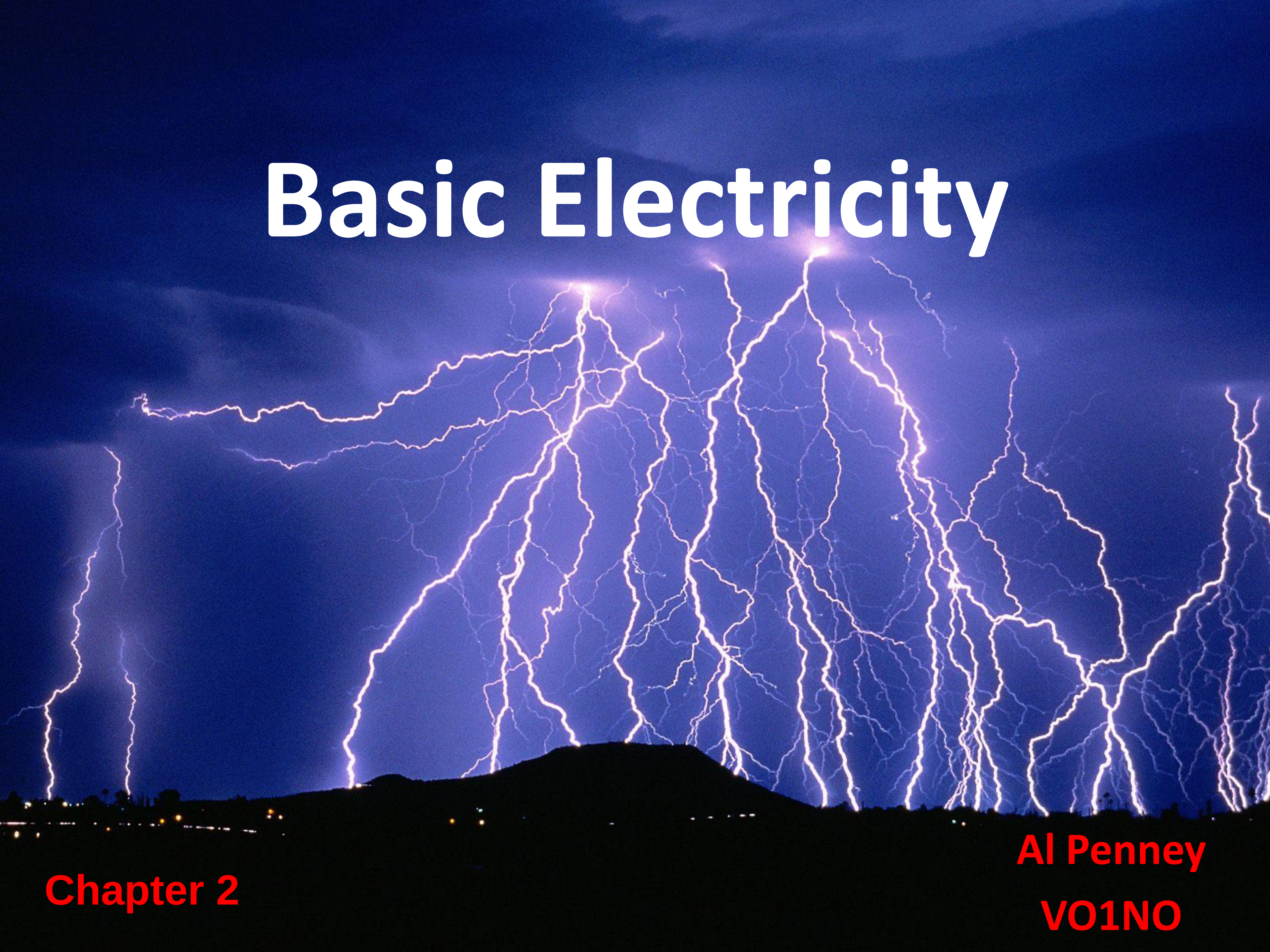
Basic Electricity



Chapter 2

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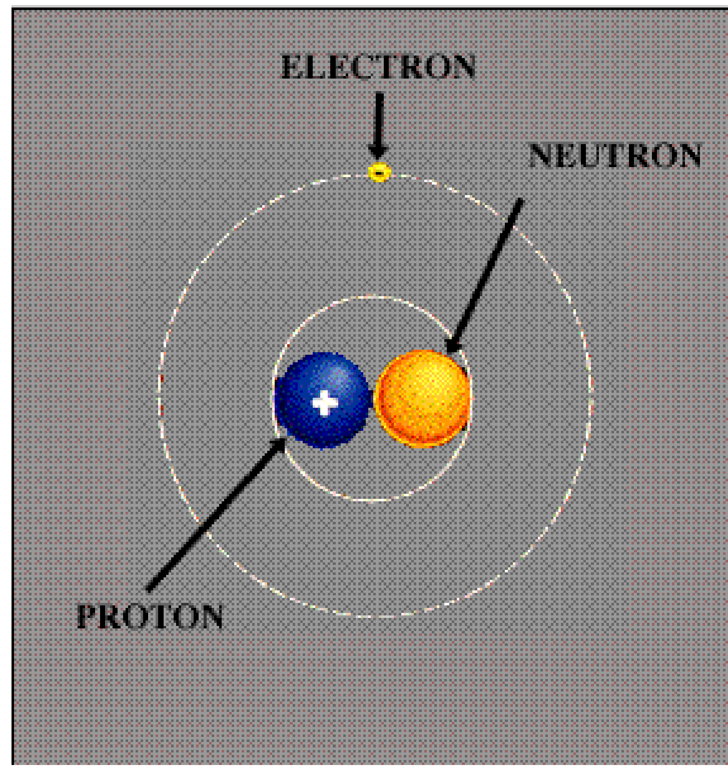
The Structure of Matter

- All matter is composed of Atoms.
- Atoms consist of:
  - Neutrons;
  - Protons; and
  - Electrons
- Over 100 different atoms.
- These are called Elements.



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Periodic Table of the Elements

1 1IA 11A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.0079																	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305											13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Series															
Lanthanide Series	57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetals | Nonmetals | Halogens | Noble Gas | Lanthanides | Actinides

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Atoms

- Electrostatic Attraction holds the negative electrons in place around the positive protons.
- Electrostatic Repulsion causes like-charged particles to repel each other.
- Strong Nuclear Force holds the Protons and Neutrons together in the nucleus.
- Atoms can:
  - Lose electrons, becoming positively charged; or
  - Gain electrons, becoming negatively charged.

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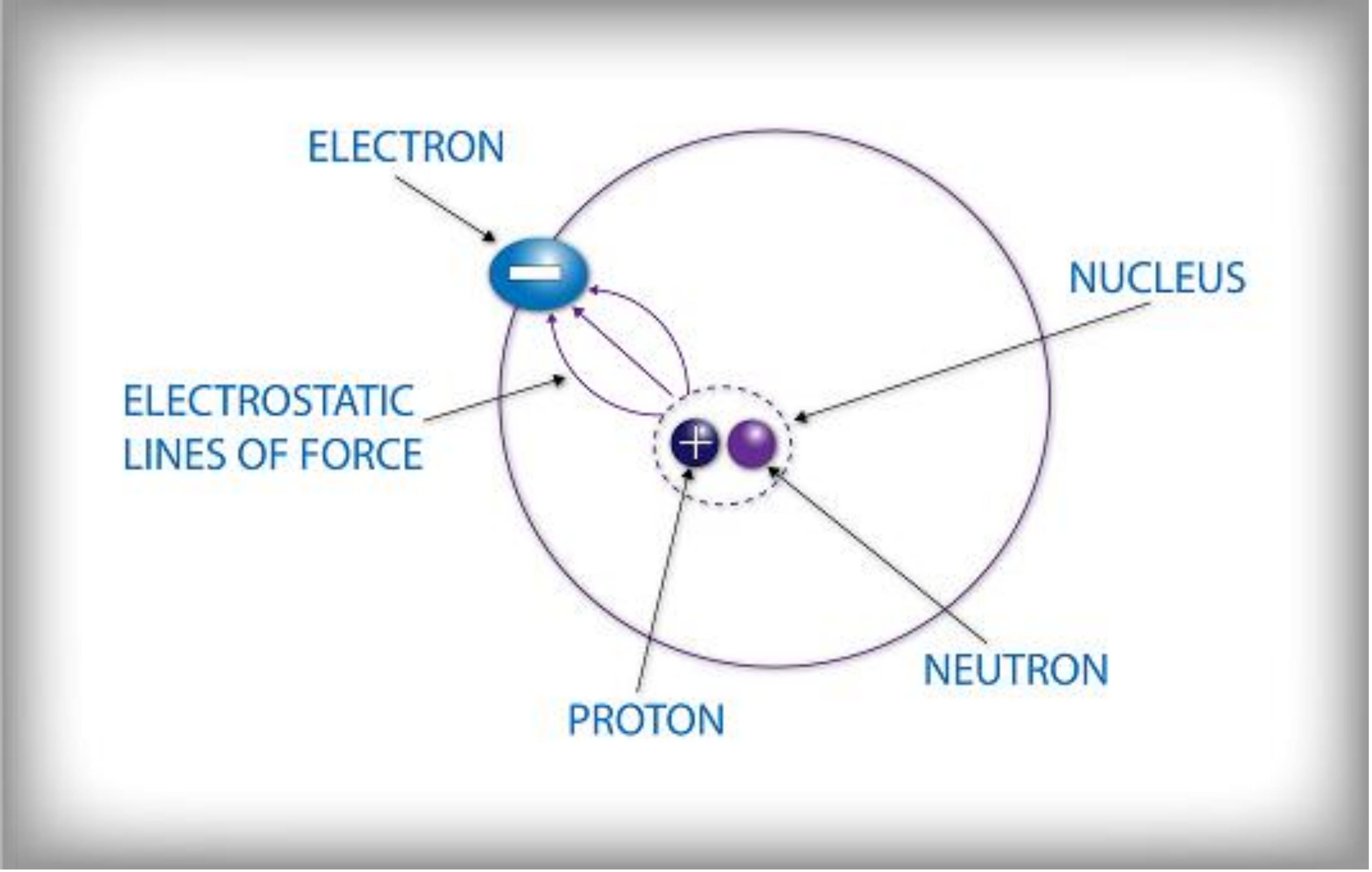

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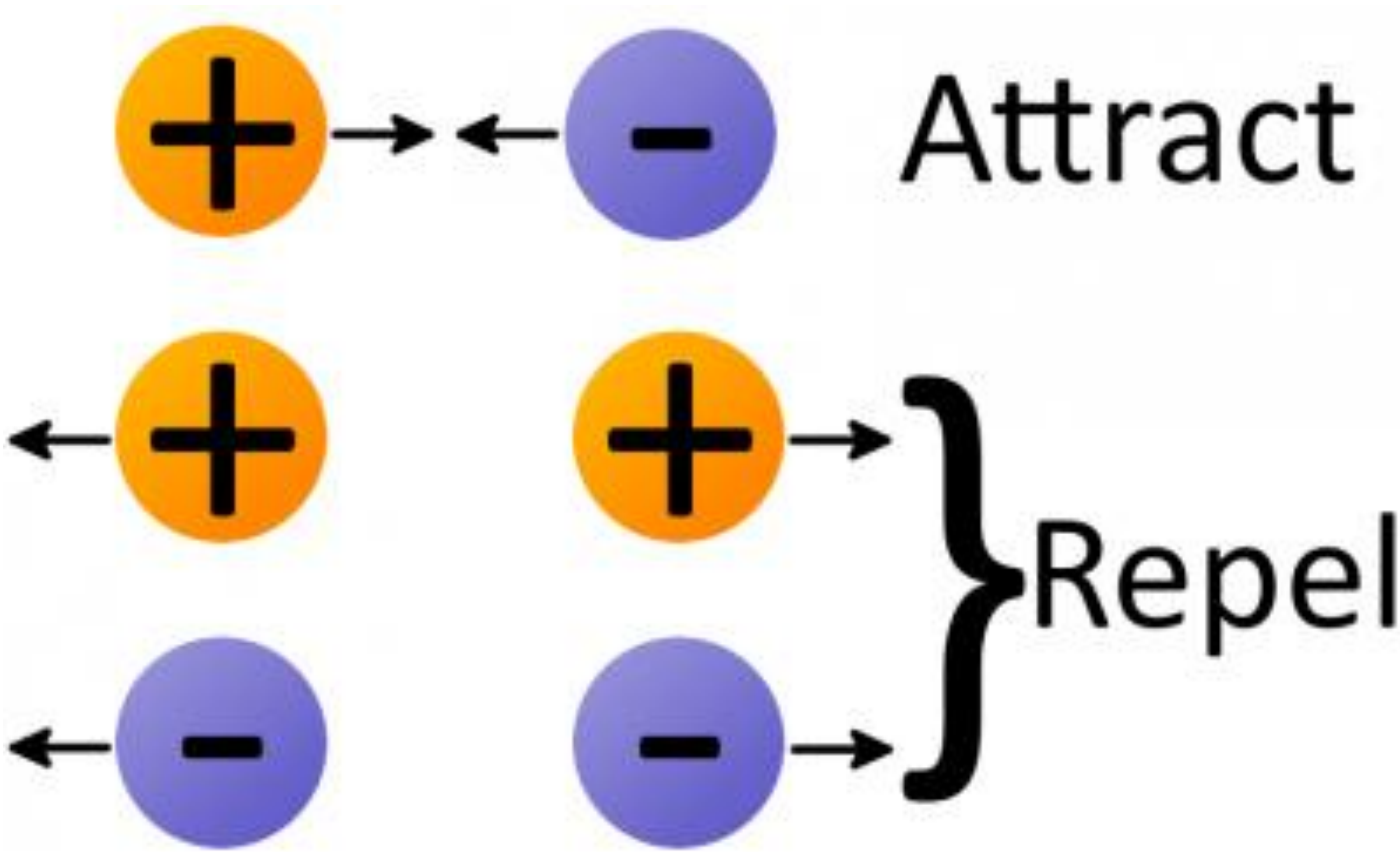

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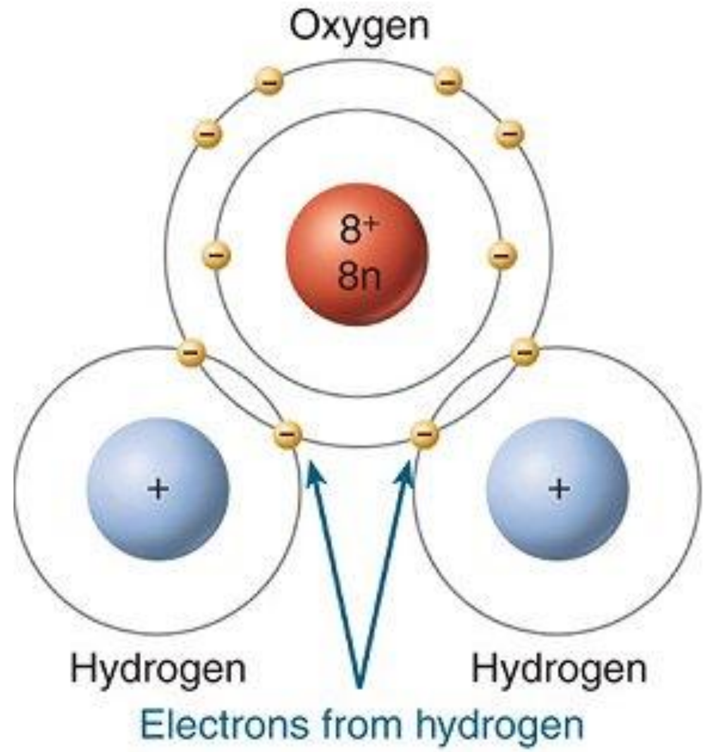
Molecules

- Electrically neutral group of two or more atoms.
- Held together by chemical bonds.



(a) Electron shells in a water molecule

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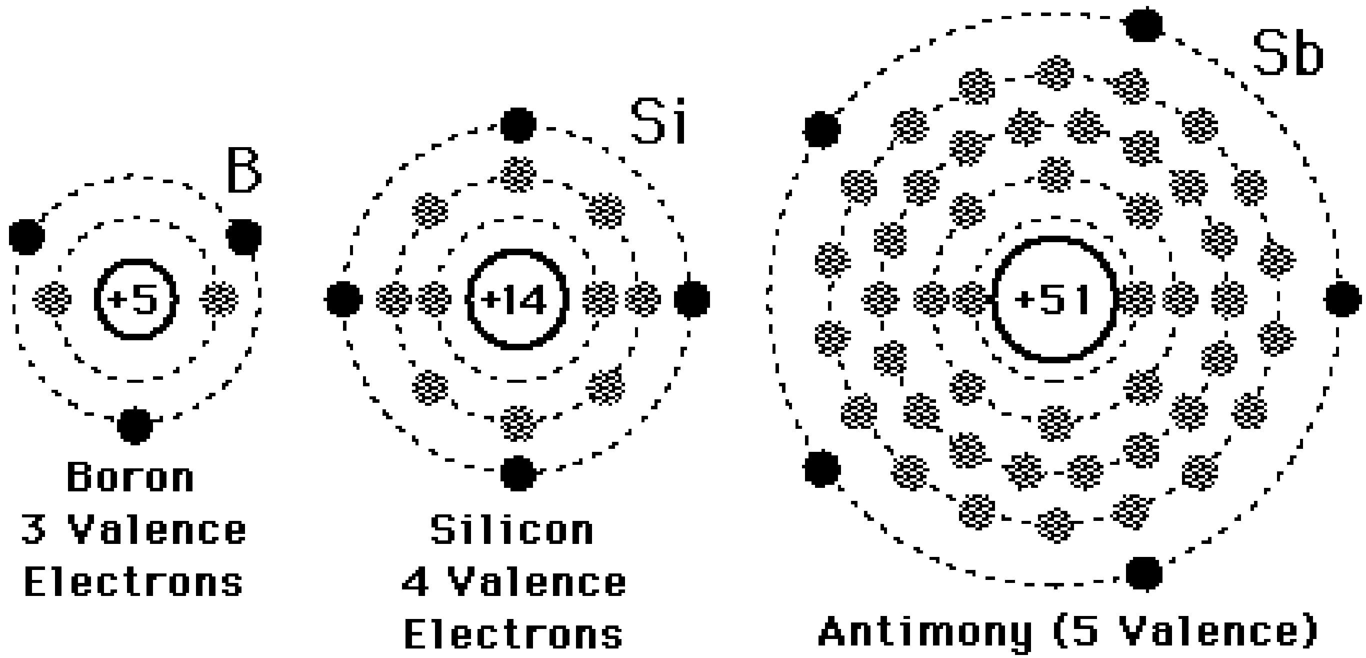
Valence Electrons



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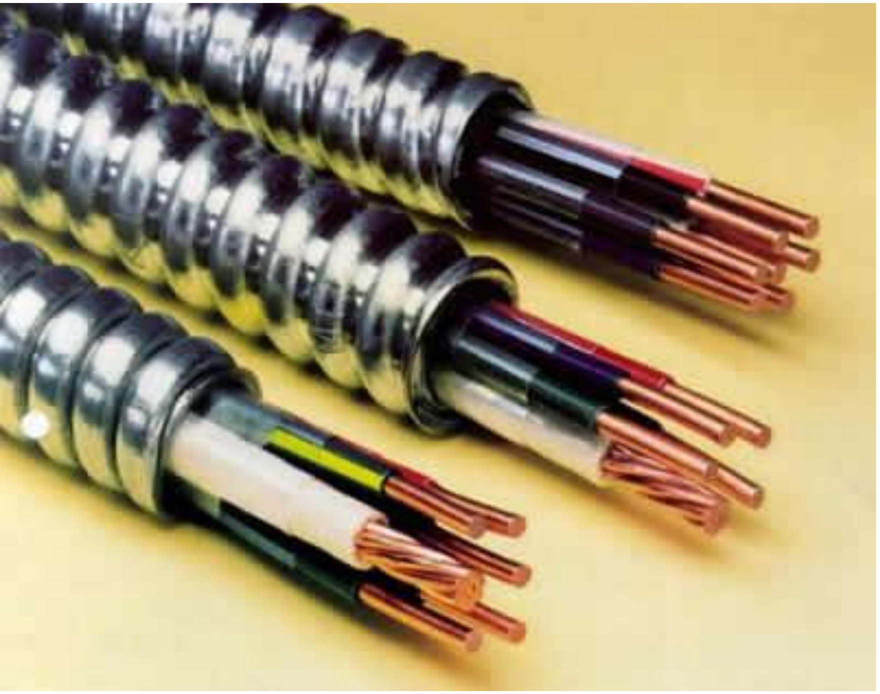
Conductors vs Insulators!



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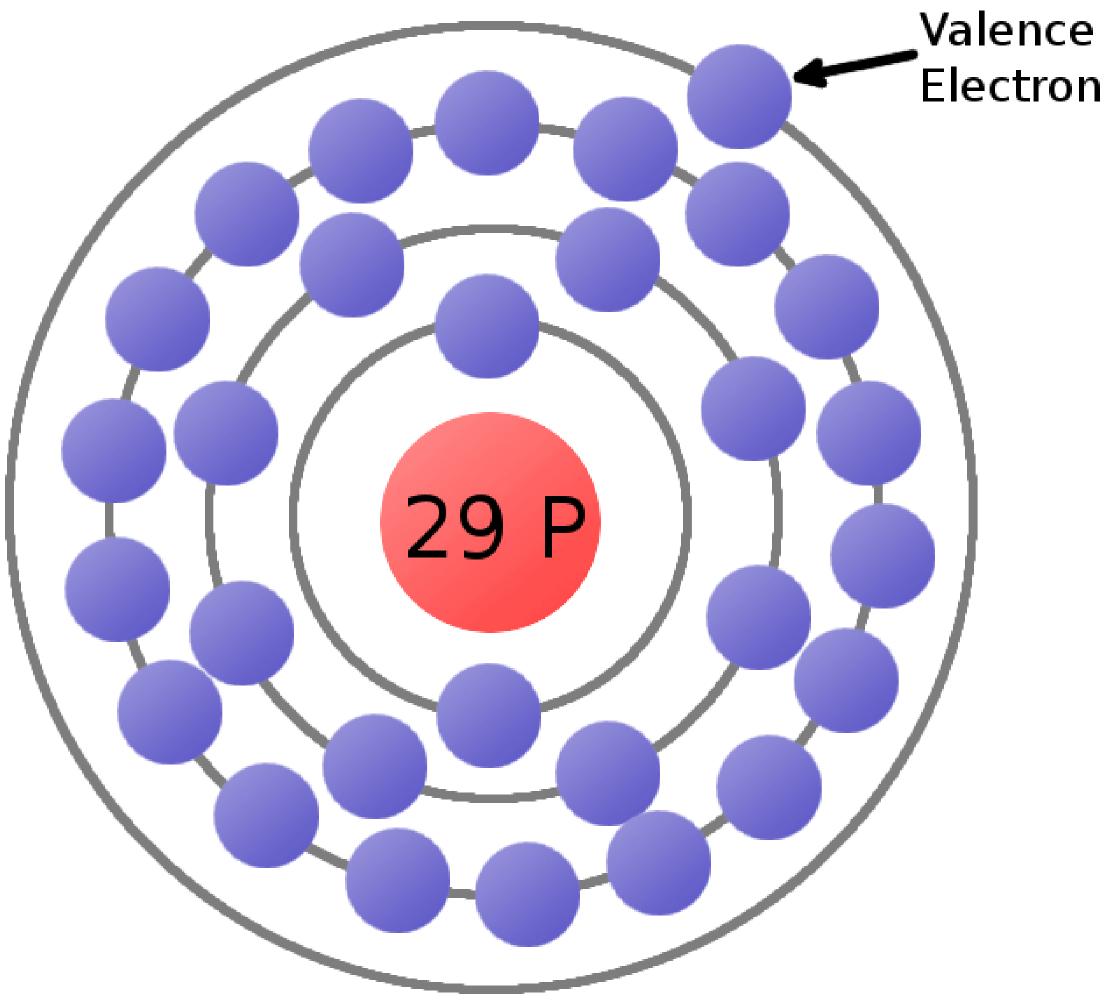
Conductors

- Relatively easy to dislodge outer valence electron, allowing electric current to flow easily.
- Most metals are good conductors.
- Best conductors are:
  - Silver
  - Copper
  - Aluminum
- Gold is actually not a great conductor, but won’t corrode.

Copper Atom



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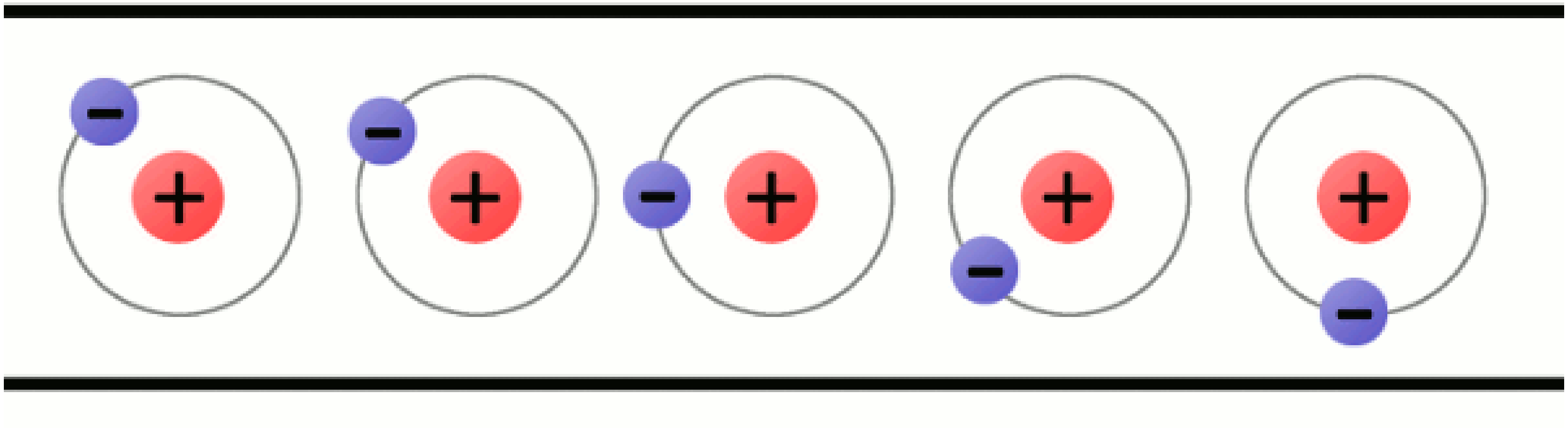
Electric Current



Electric current is the flow of electrons through a conductor.

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Insulators

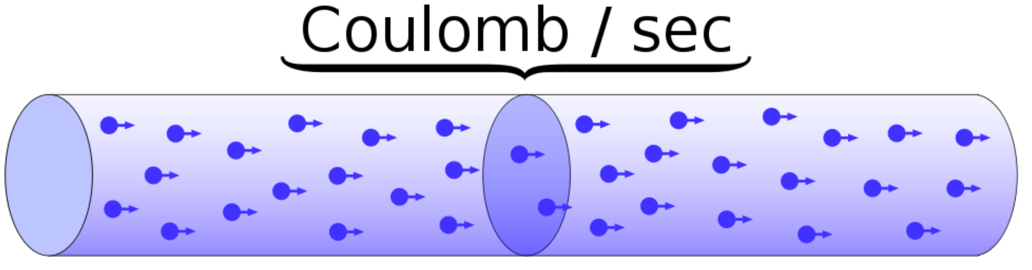
- Valence electrons are hard to dislodge, and so electric current cannot flow easily.
- Typical insulators include:
  - Glass
  - Rubber
  - Most plastics
  - Teflon
  - Ceramics

Some Definitions

- A single electron has too small a charge for practical purposes.
- The coulomb is defined as the charge of 6.28 x 10^{18} electrons.
- The coulomb is used in the definition of the ampere…

Ampere

- Unit of electric current i.e.: the rate of flow of electrons in a conductor.
- 1 ampere = flow of 1 coulomb/second.



- Ampere abbreviated “A”.
- Current abbreviated “I”, e.g.: I = 5A.

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Ampere

- Current measured using Ammeters.

- Milliamperes (mA) = 1/1,000 amperes.
- Microamperes (µA) = 1/1,000,000 amperes.

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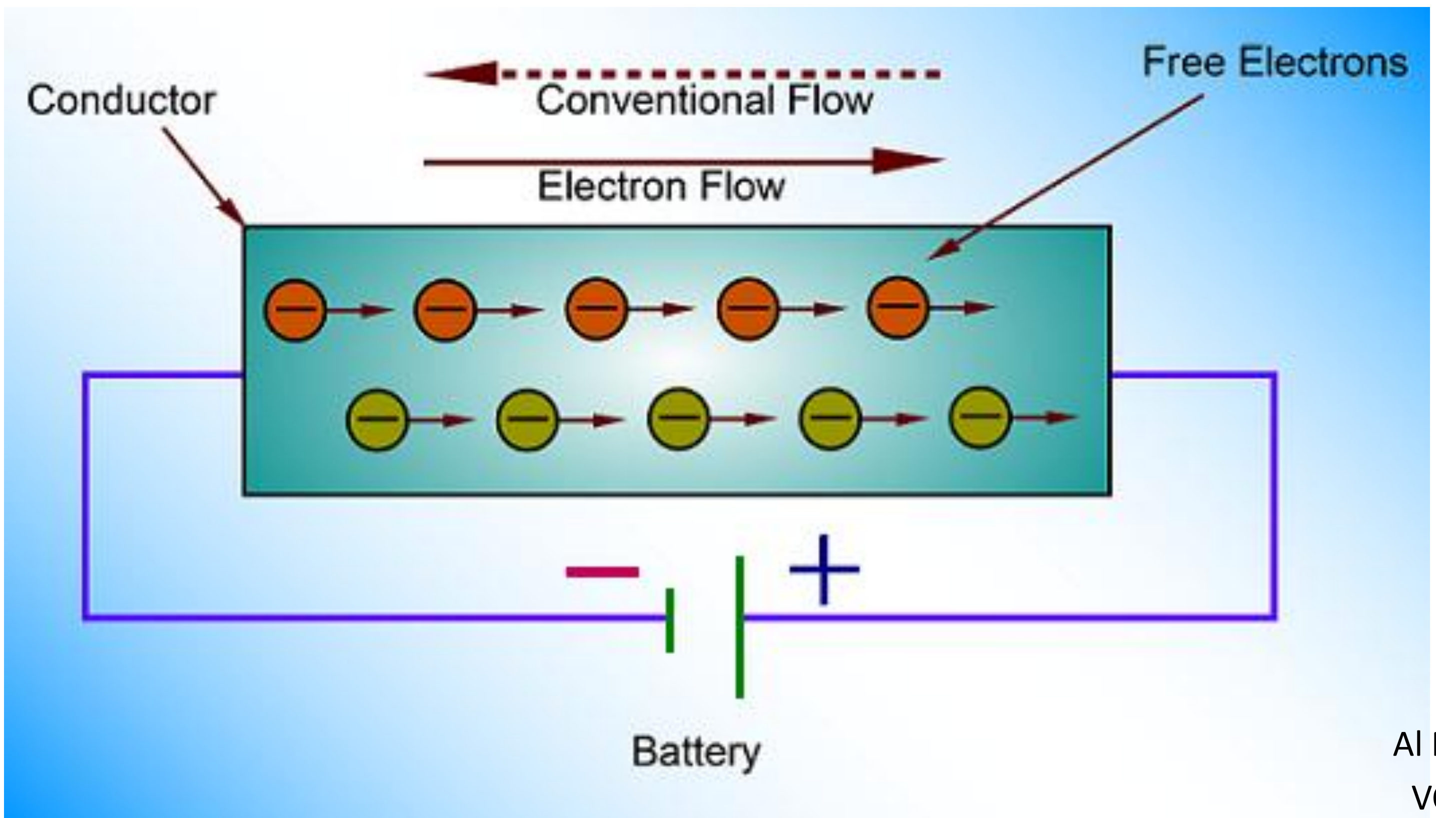
Conventional Current

- Electron flow is negative to positive.
- Conventional Current is positive to negative.



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Voltage

- Valence electrons held in place by electrostatic force.
- For current to flow, work must be done to make electrons move.
- The work done to put an electric charge on a body by adding electrons is measured in Volts.
- Also known as Electromotive Force (EMF) and Potential Difference.

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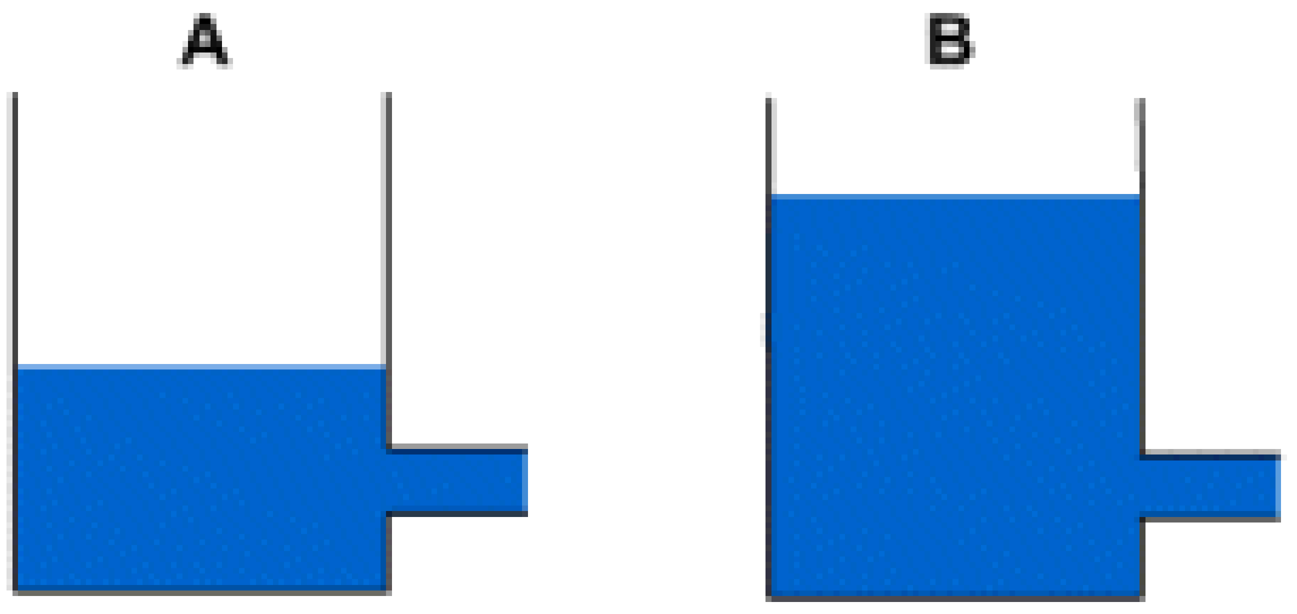
Voltage

- Think of voltage as the “pressure” that pushes electrons through a conductor.



Lower pressure = lower voltage **Higher pressure = higher voltage**

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Voltage

- Electric Potential Difference between two points.
- 1 Volt = 1 Joule / Coulomb
- Symbol is “E” e.g.: E = 5V
- Typical voltages:
  - Alkaline cell: 1.5 volts DC
  - Car battery: 12.6 volts DC
  - Household outlet: 120 volts AC

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Voltage

- Measured with a Voltmeter.

- Millivolt (mV) = 1/1,000 volts.
- Microvolt (µV) = 1/1,000,000 volts.

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Resistance

- Opposition to the flow of current.
- Unit of resistance is the ohm.
- Symbol is the Greek letter Omega: Ω
- Abbreviation for resistance is “R”: e.g.: $R = 5\ \Omega$

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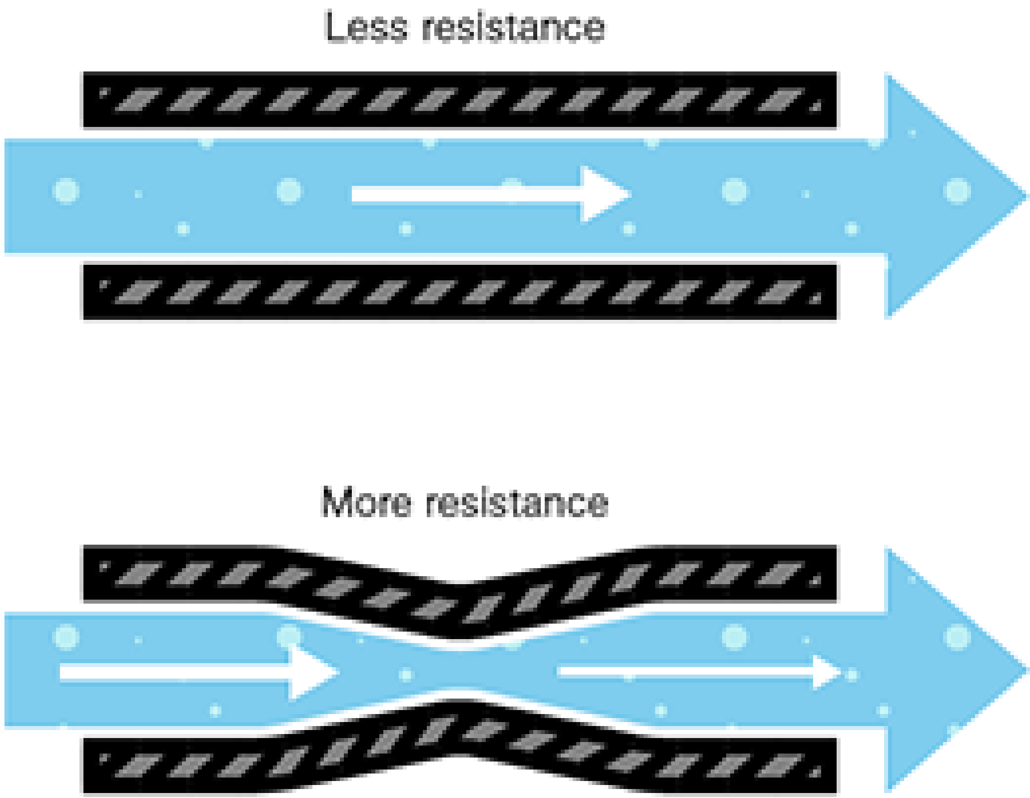
Resistance



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Factors affecting Resistance

- Specific resistance of material e.g. copper is a better conductor than iron.
- Length of the conductor. Longer = greater resistance.
- Diameter of the conductor. Greater diameter = less resistance.
- Temperature:
  - Positive Temperature Coefficient = Resistance increases with temperature (e.g.: most pure metals).
  - Negative Temperature Coefficient = Resistance decreases with temperature (e.g.: semiconductors).

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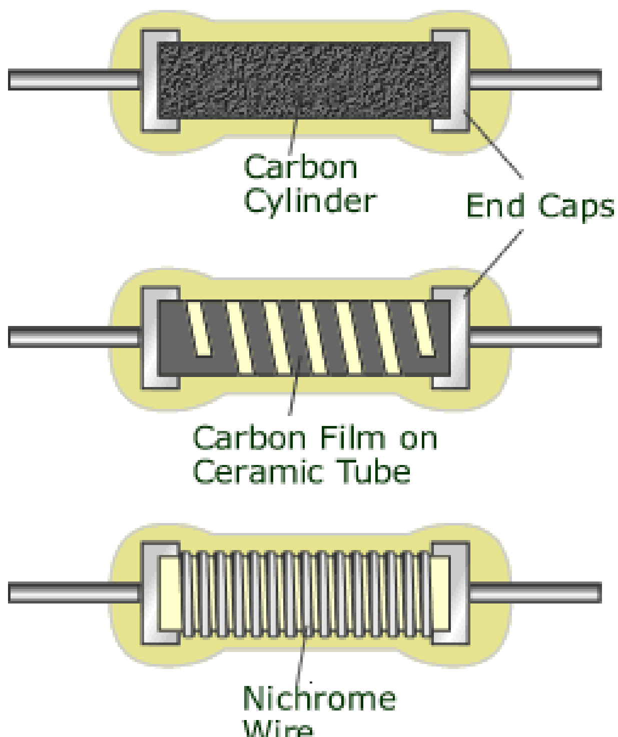
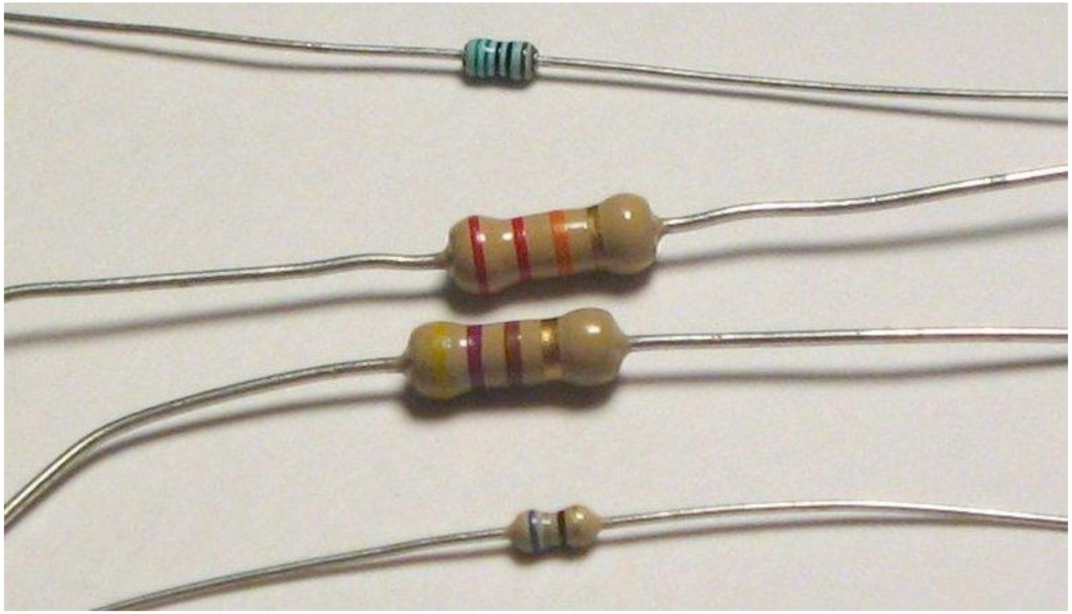
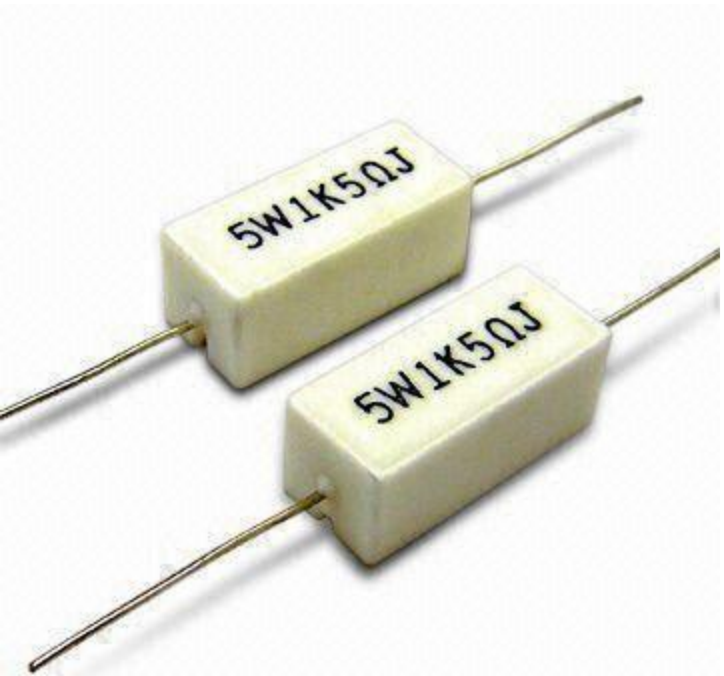
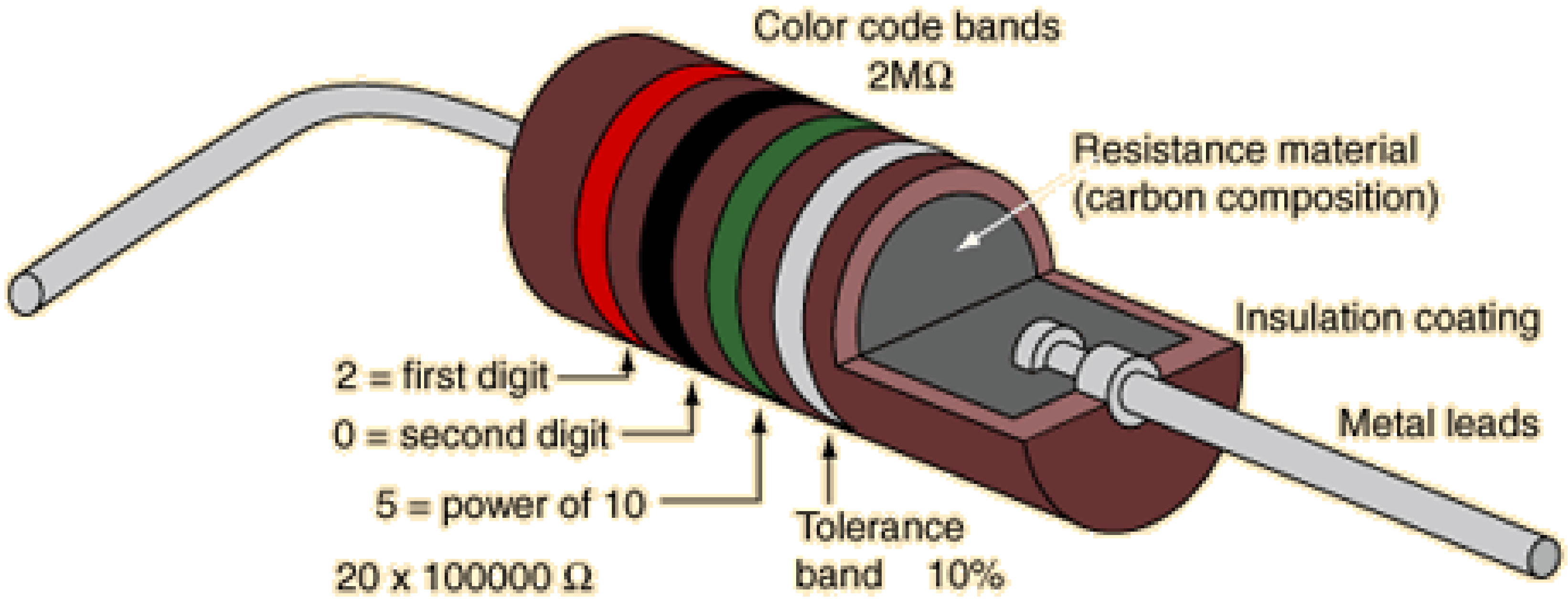
Resistors

- Used in circuits to reduce current and change voltages.
- Use carbon or high-resistance wire.






5W1K5ΩJ
5W1K5ΩJ



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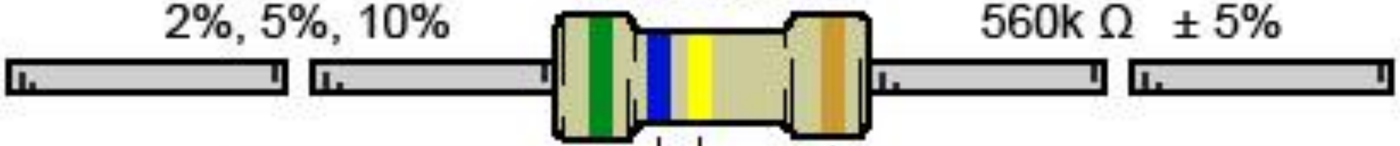
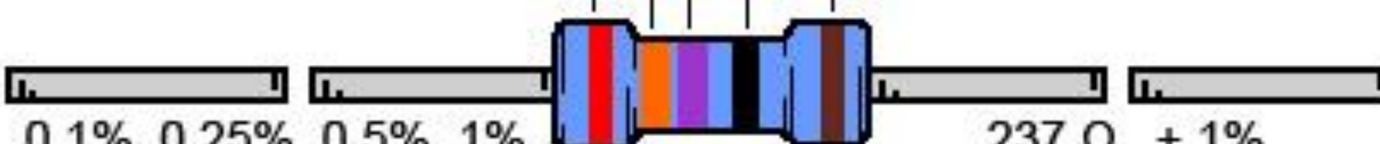
4-Band-Code



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)



5-Band-Code

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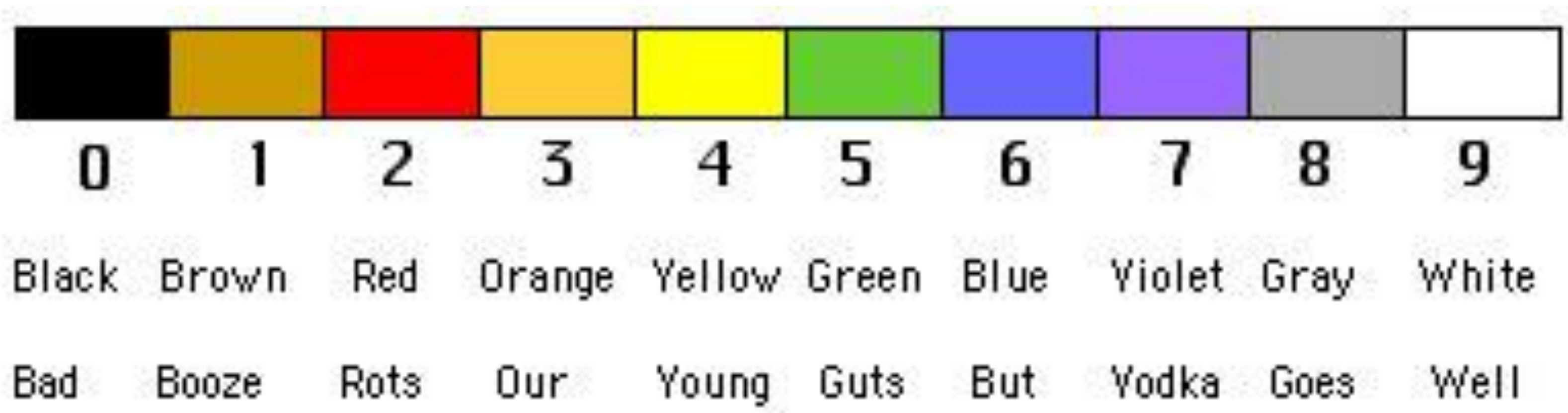
Resistor Colour Code Mneumonic



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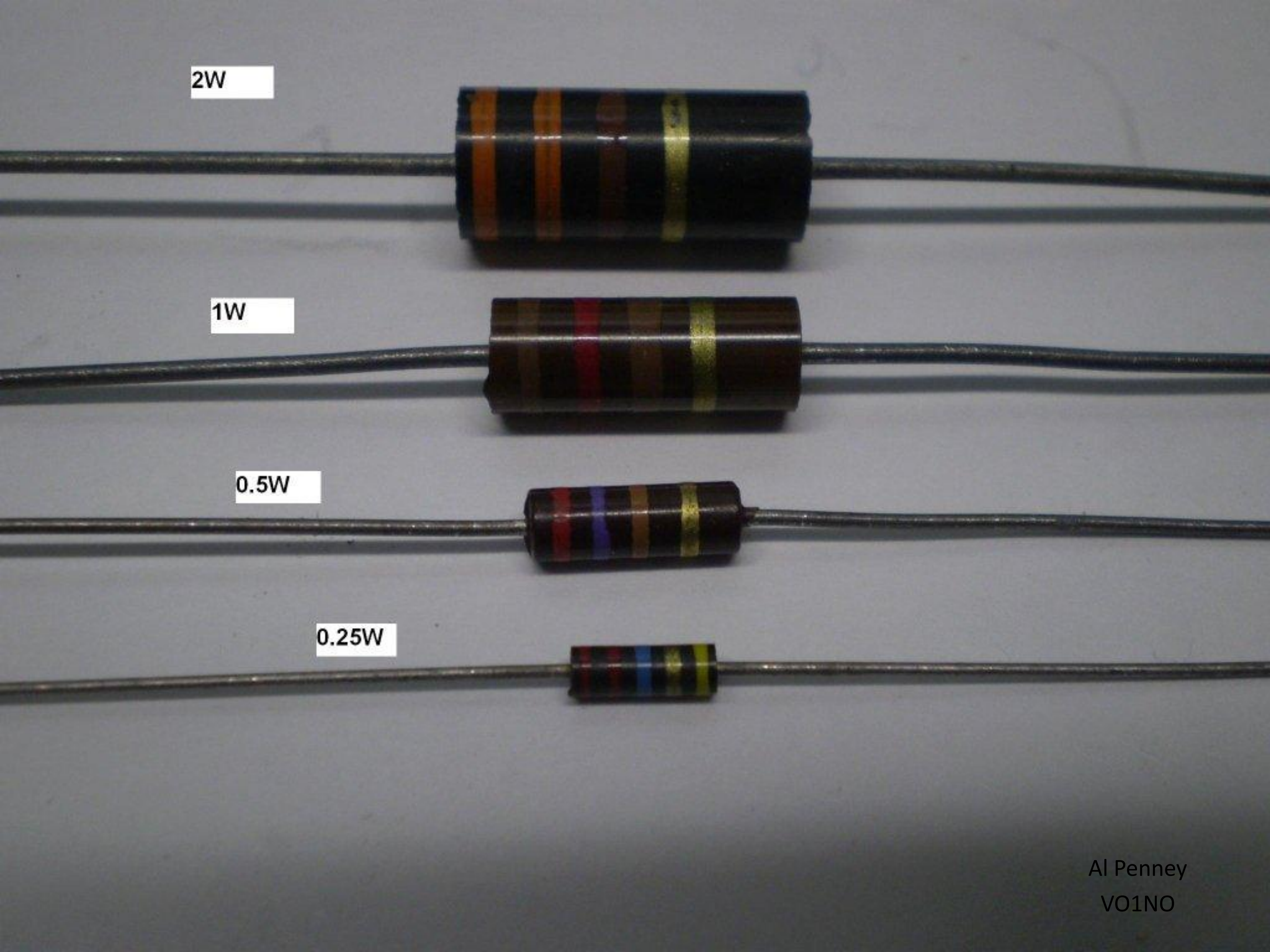
2W
1W
0.5W
0.25W
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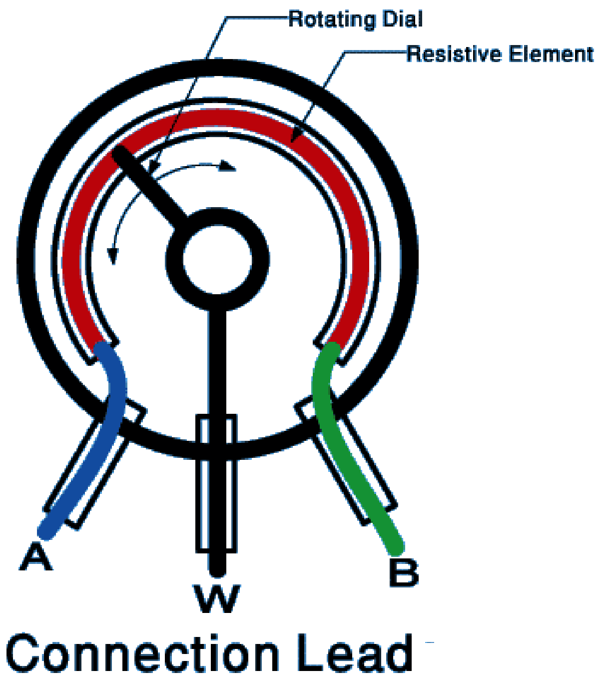
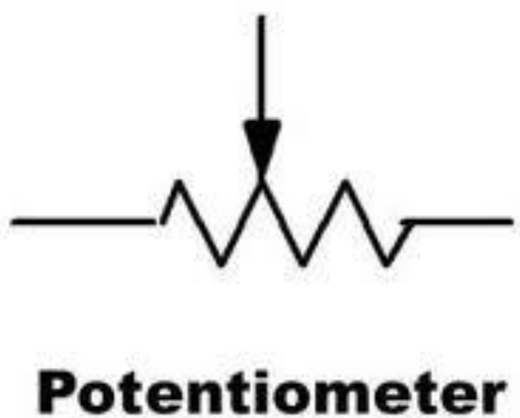
Potentiometers





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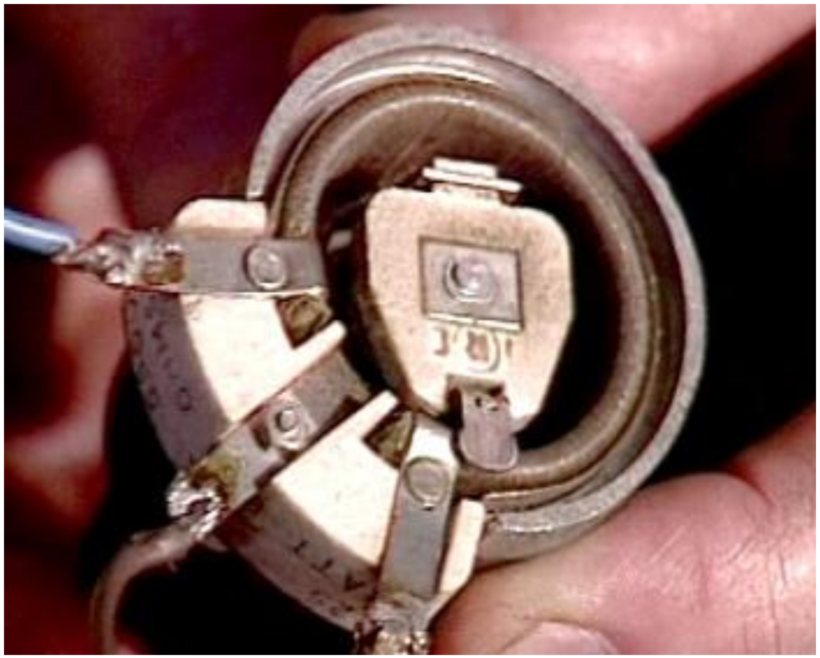
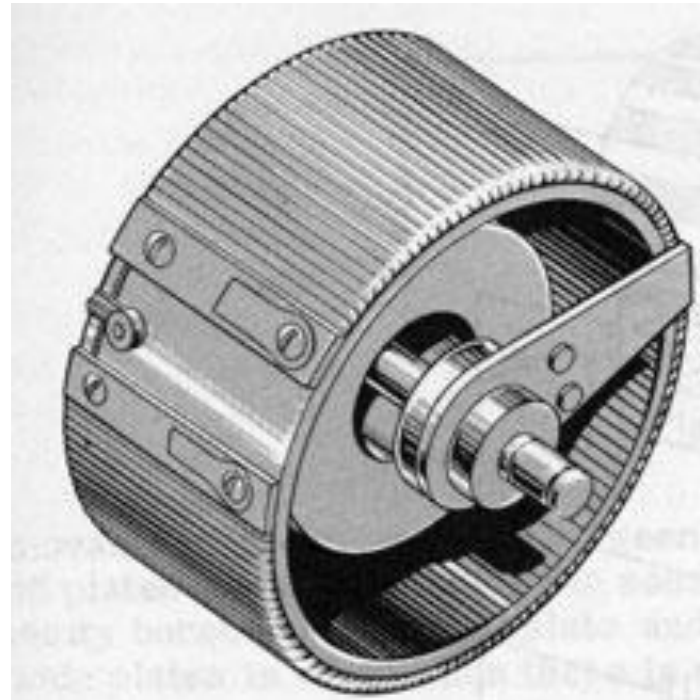
Wirewound Potentiometer





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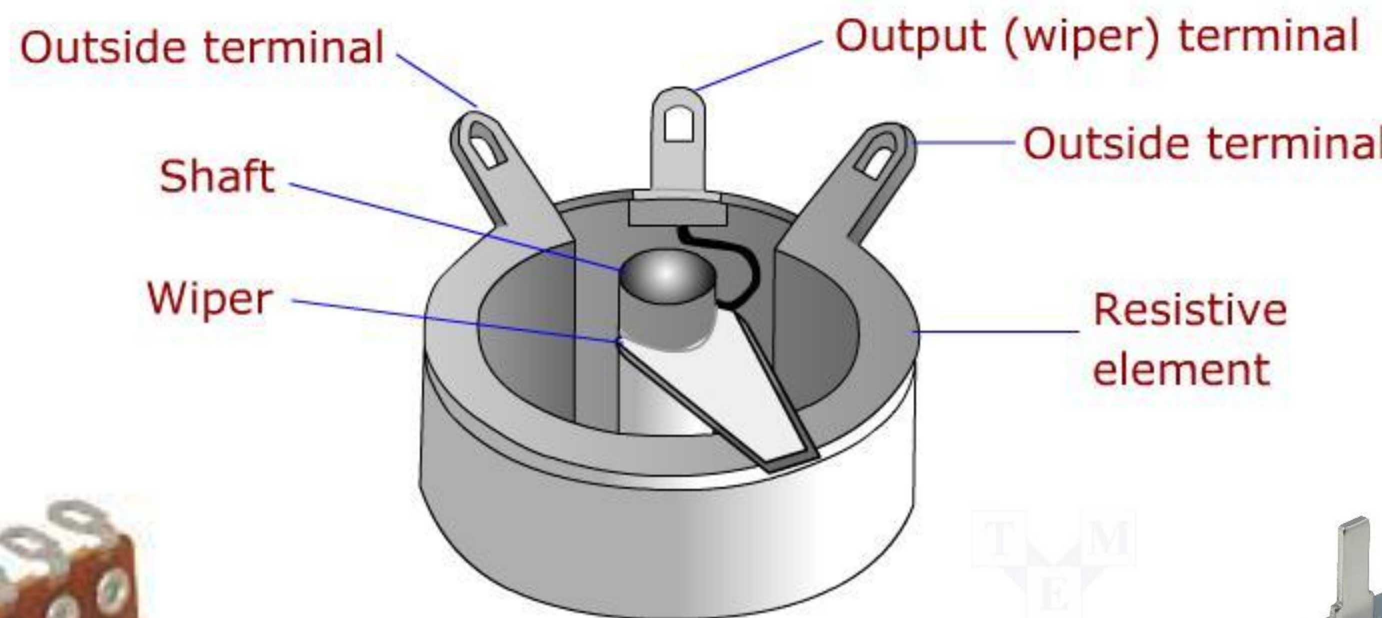
Composition Potentiometer



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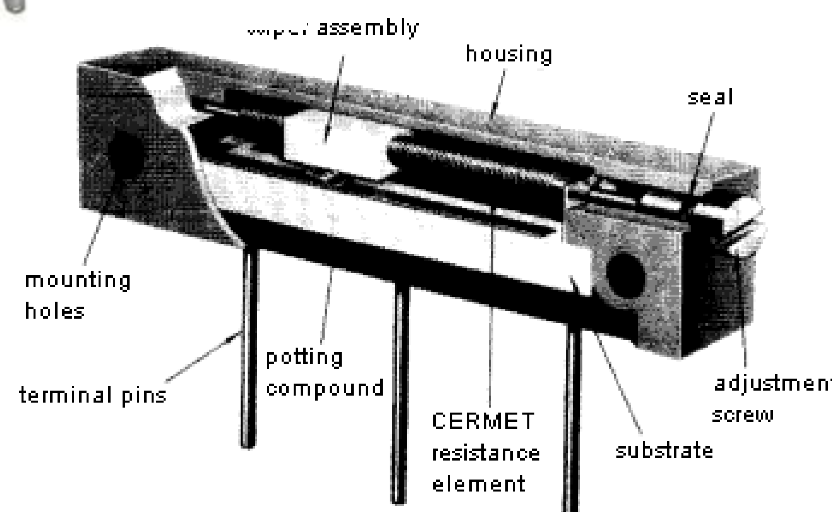
Trimmers


3266
BOURNS


PIHER


assembly
housing
seal
mounting holes
terminal pins
potting compound
CERMET resistance element
substrate
adjustment screw

Conductance

- Sometimes easier to consider how well a material conducts rather than its resistance.
- Conductance is reciprocal of resistance.
- Symbol for Conductance is G: $G = 1/R$
- Unit of measure is the siemen, abbreviated S (formerly the mho – ohm spelled backwards).
- Example: If $R = 10\ \Omega$, then $G = 1/10\ S = 0.1\ S$

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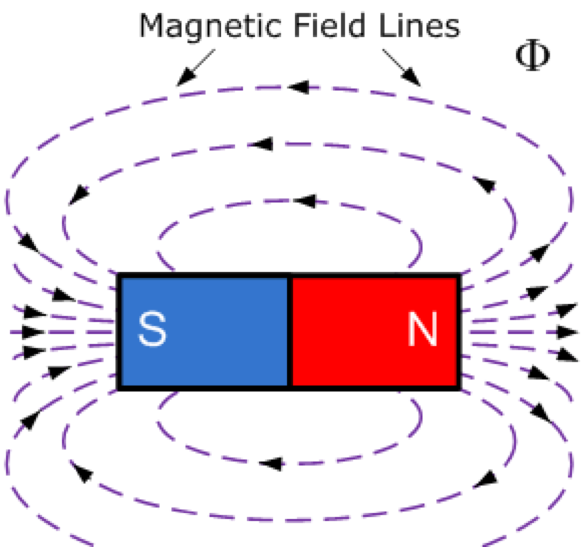
Magnets

- Magnetism is one of the 4 basic forces of nature.
- A force of attraction or repulsion that acts at a distance.
- Magnets have a North and South pole.



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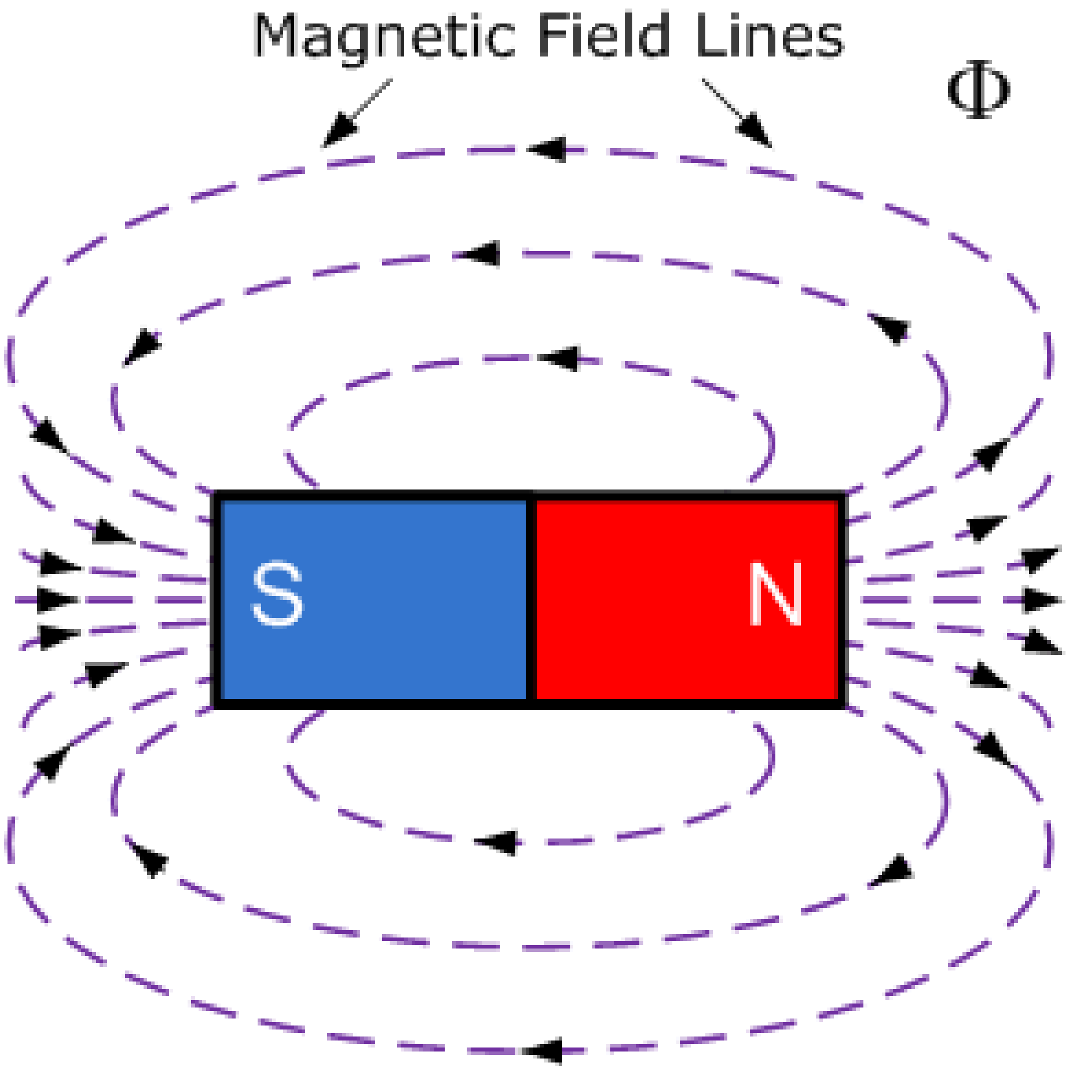
Magnetic Fields



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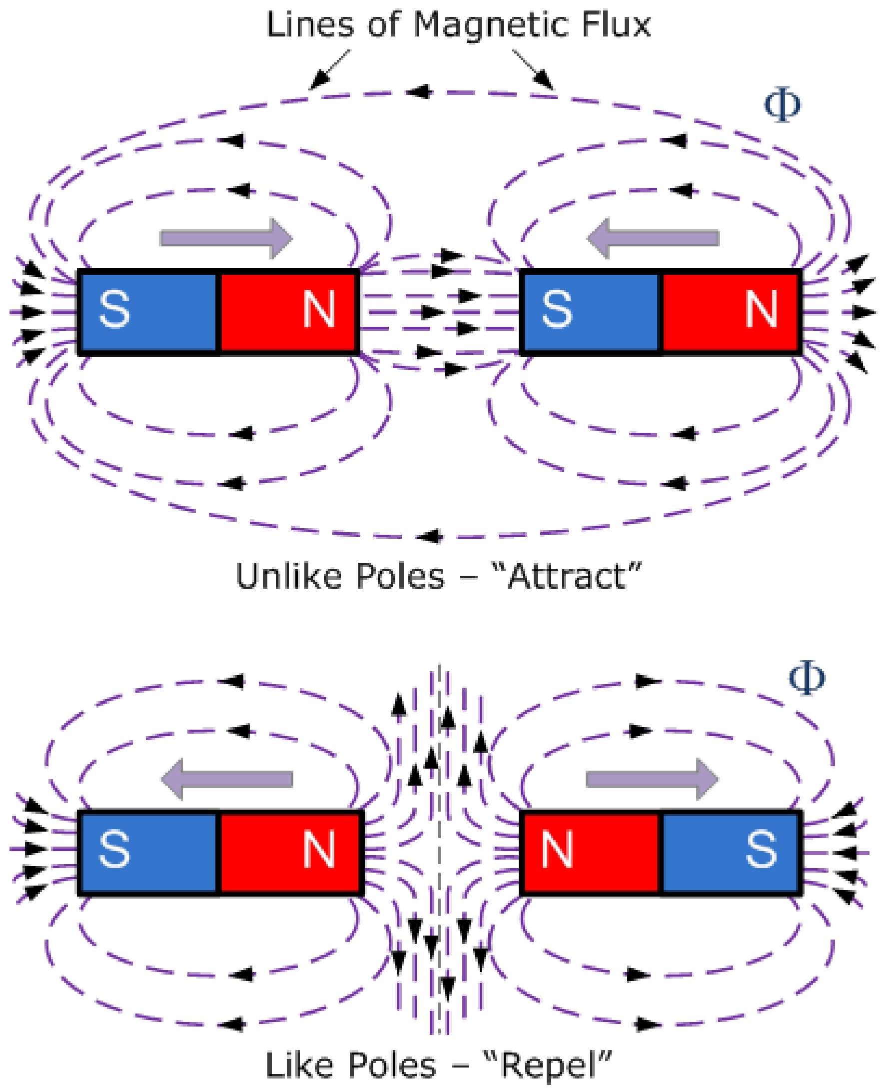
Magnetic Poles



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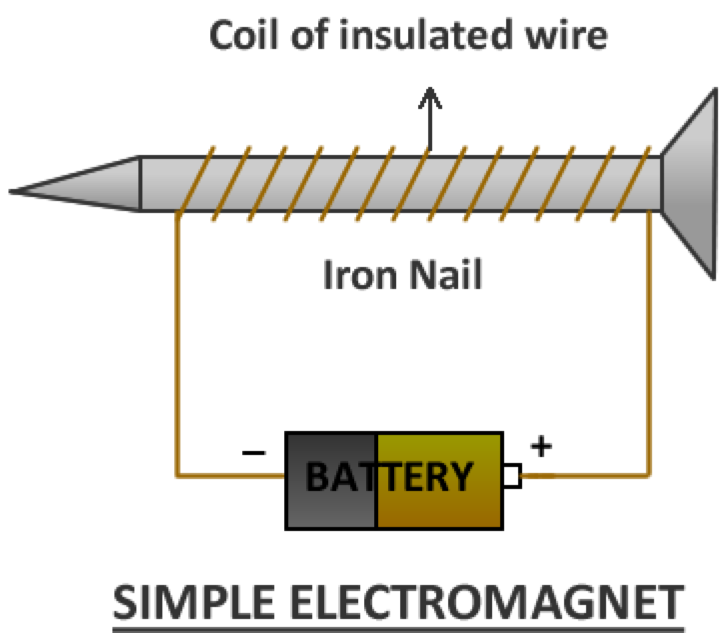
Types of Magnets



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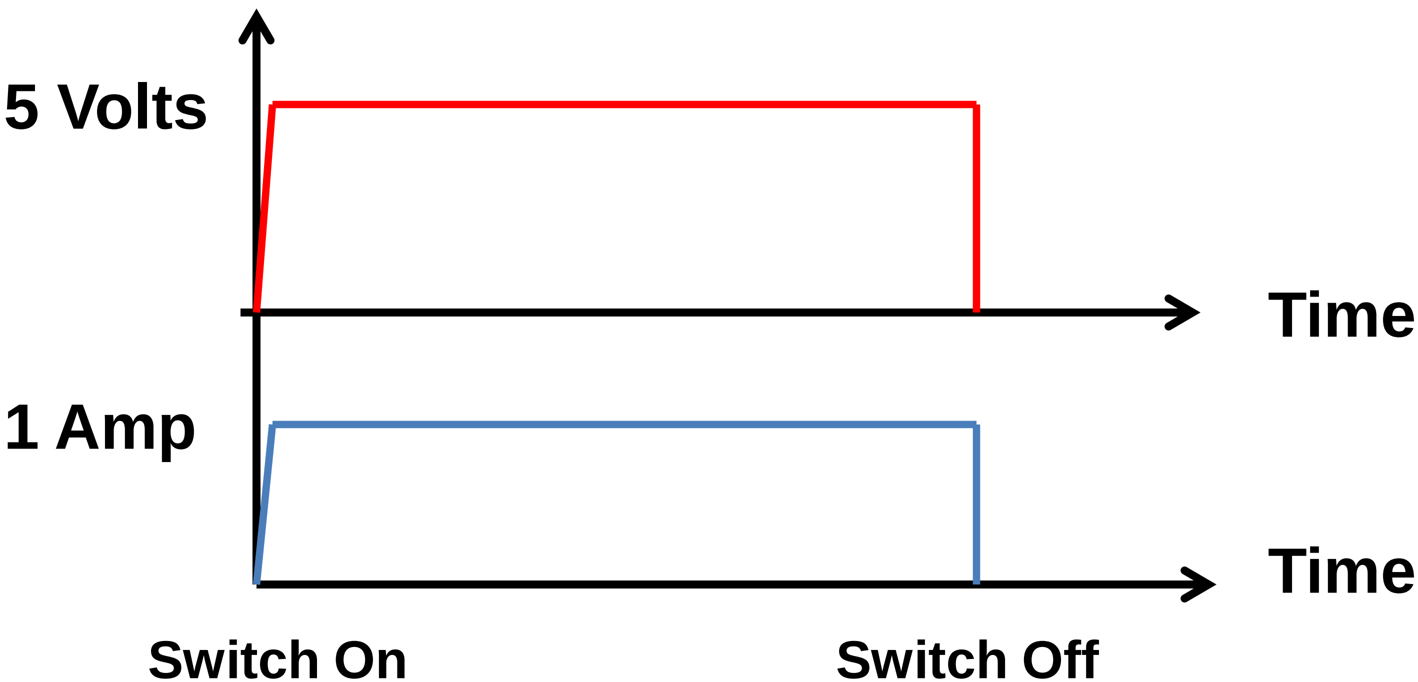
Direct Current (DC)

- Current flows in one direction only.
- Electrons enter one end of a conductor, and exit the other end.



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Sources of Direct Current

- Friction e.g.: static electricity
- Heat e.g.: filament in an electron tube.
- Pressure e.g.: piezoelectric microphones.
- Magnetism e.g.: conductor moving 1 way in a magnetic field.
- Photoelectricity e.g.: solar cell
- Chemical Action e.g.: flashlight cell

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Cells and Batteries

- Cell:
  - Short for Electrochemical Cell.
  - Any device that converts chemical energy into electrical energy.
- Battery:
  - A group of cells connected together.
  - In practice, both terms are used interchangeably.

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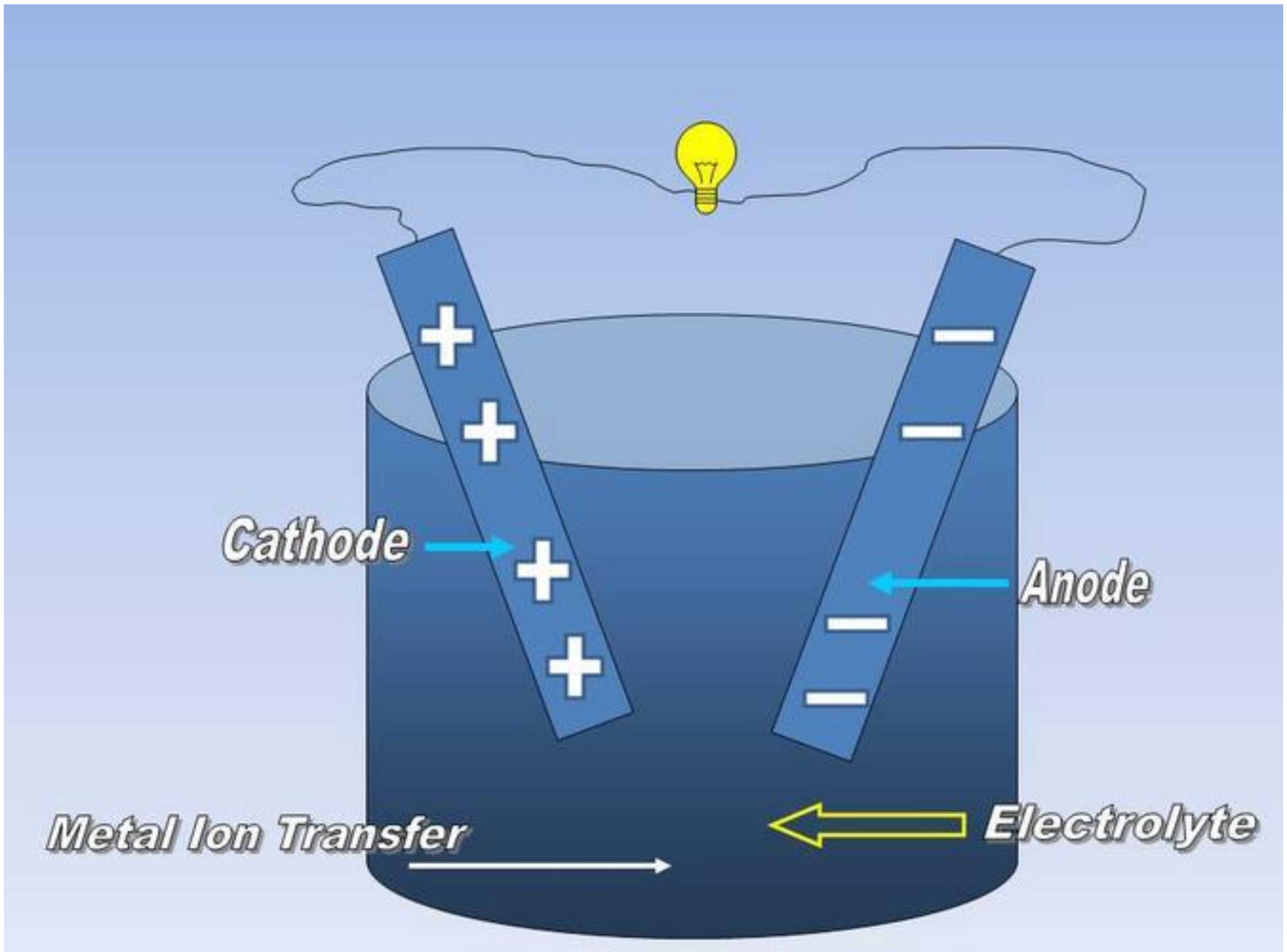
Electrochemical Cells



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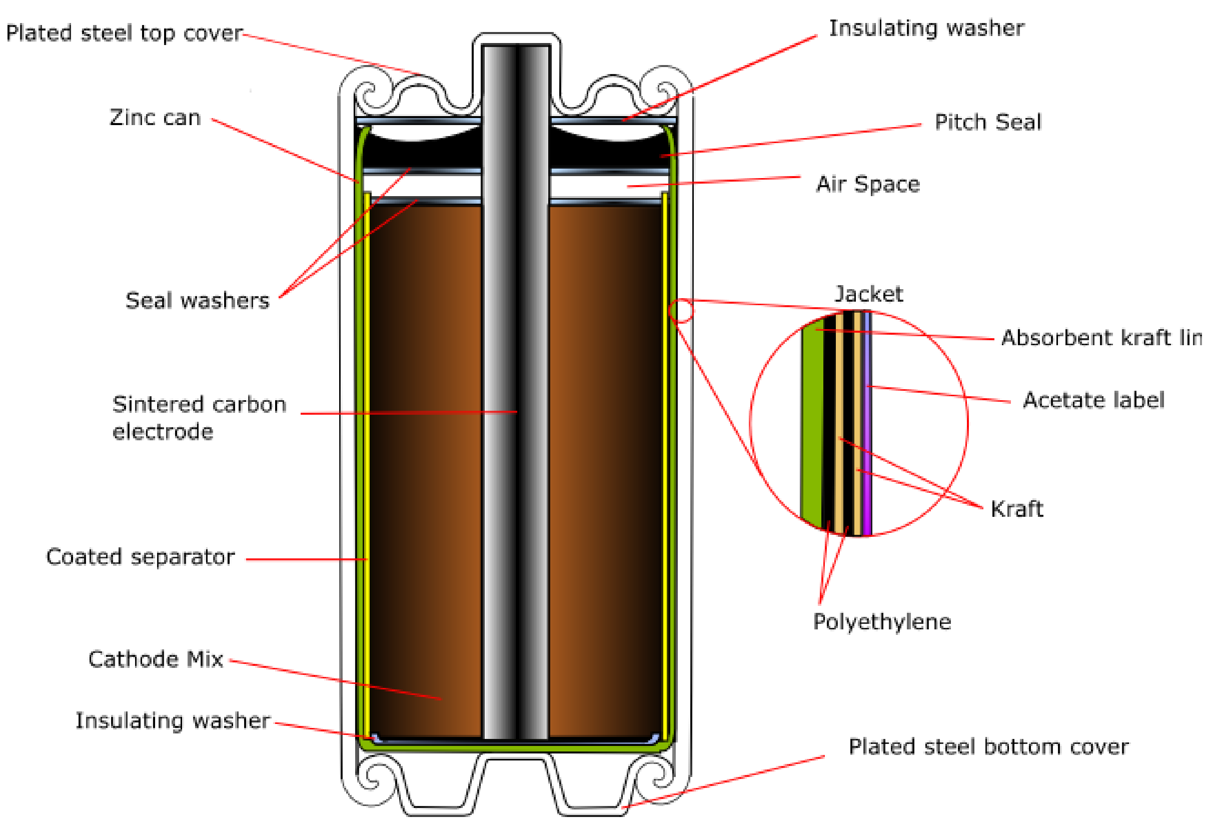
Zinc-Carbon Cell

Structure of a Zinc/Carbon Cell



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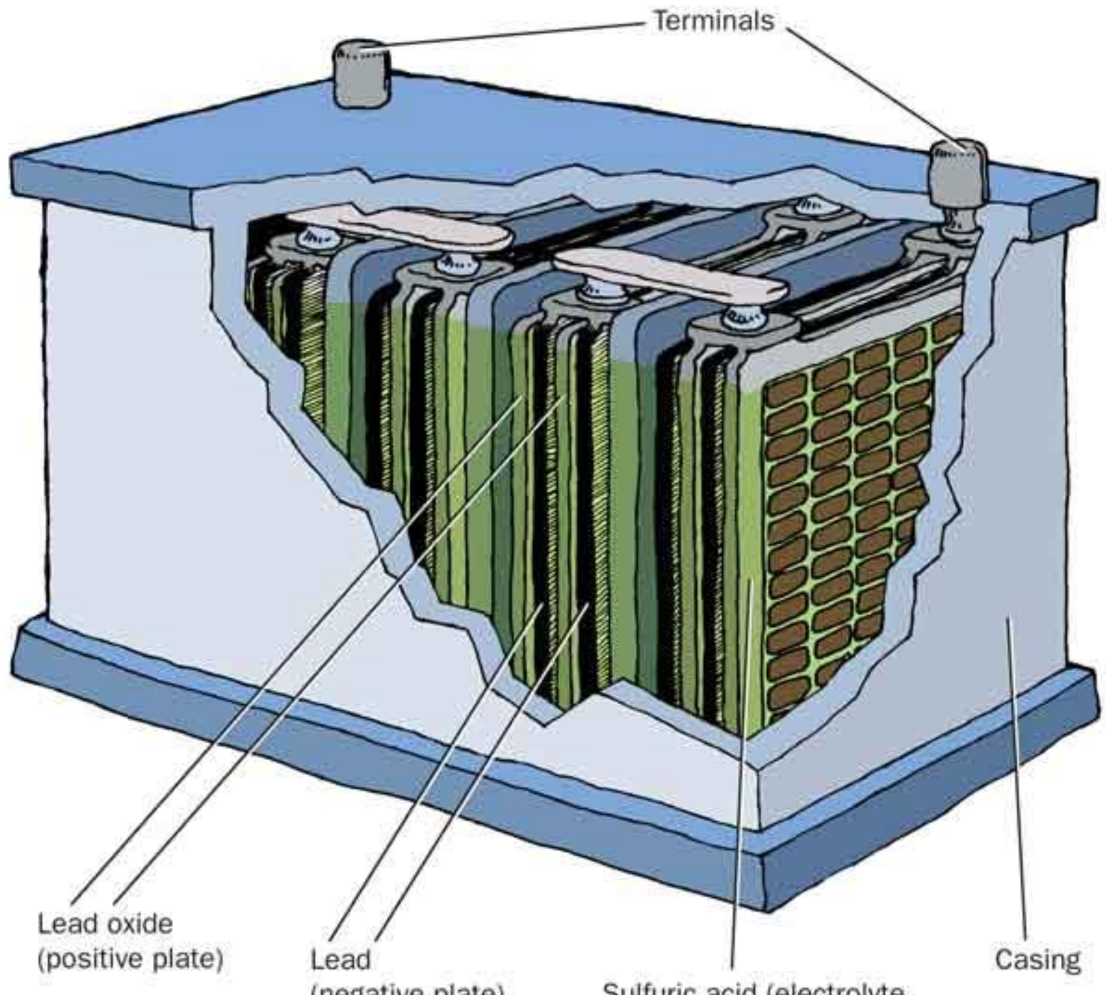
12 Volt Car Battery



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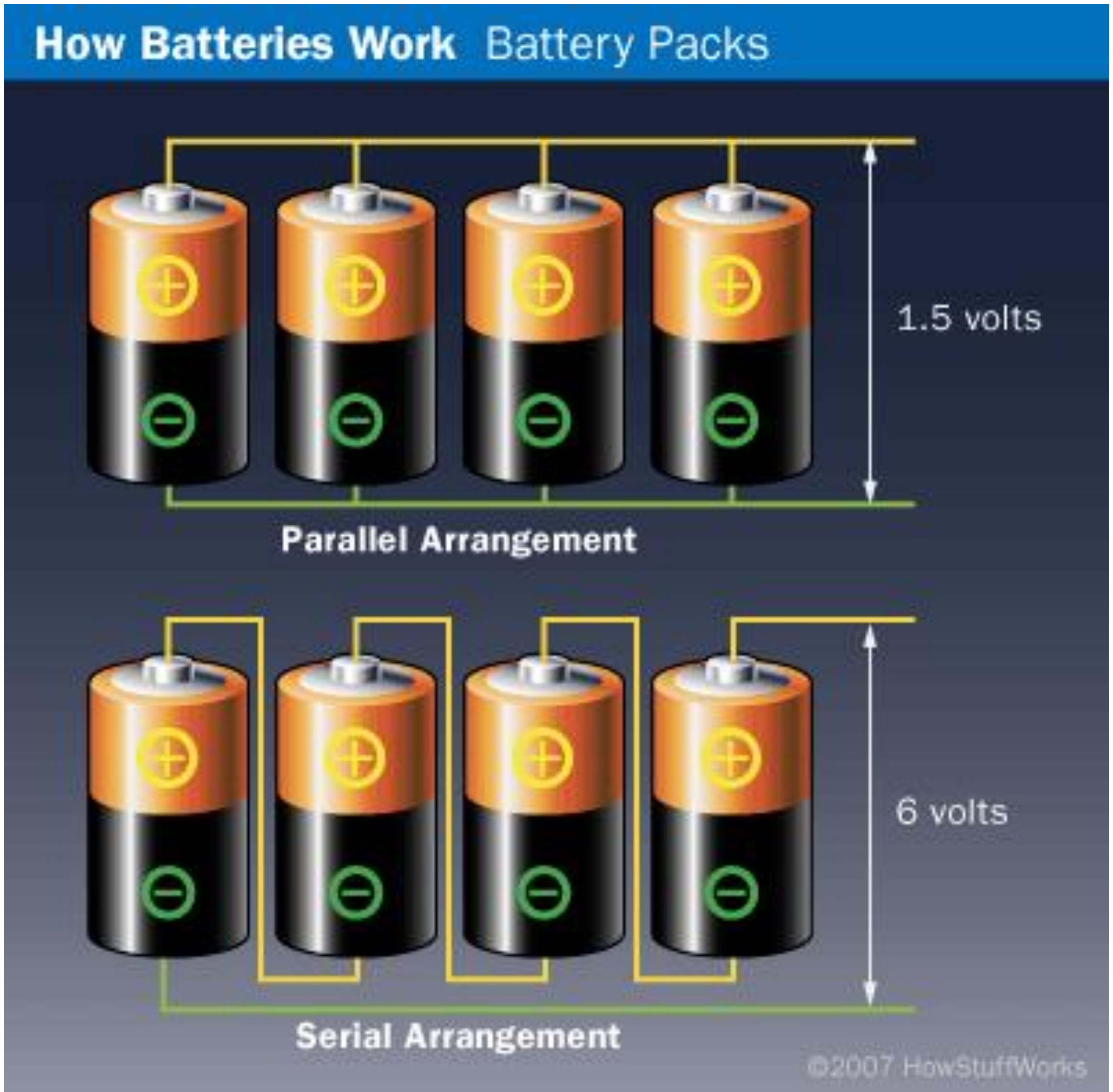
Cells in Parallel and Series



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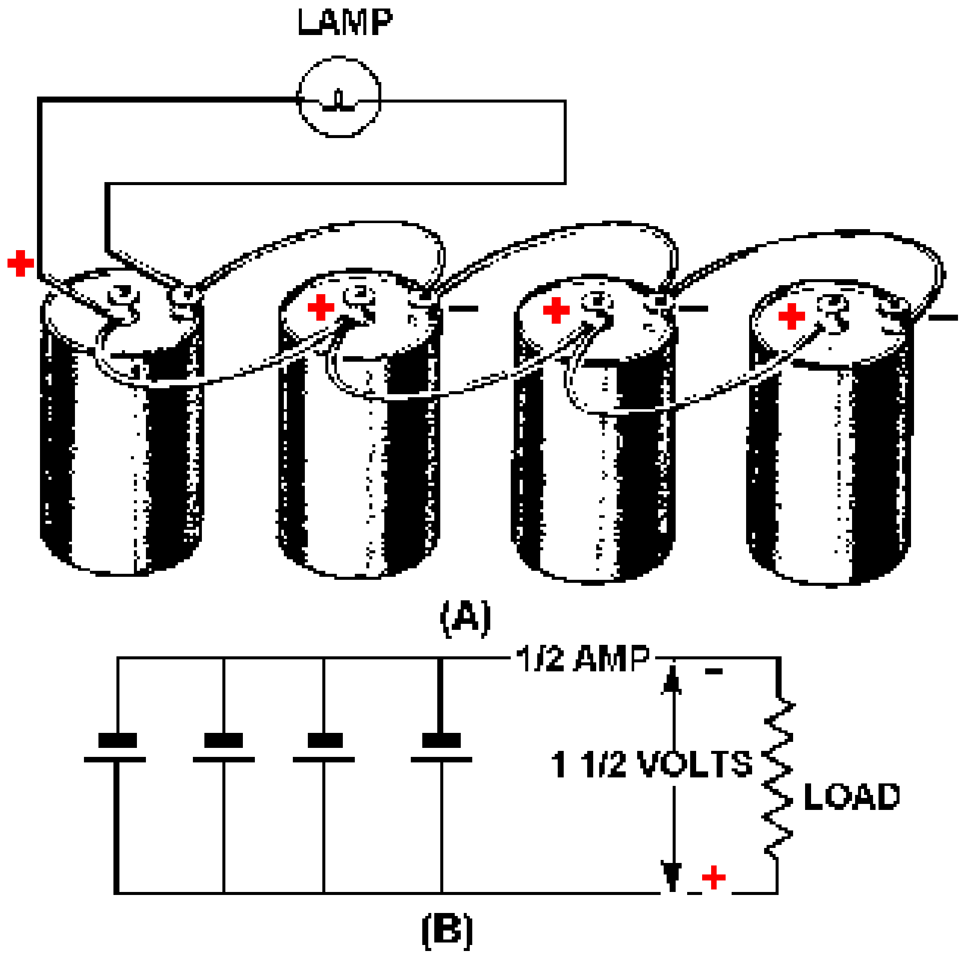
Cells in Parallel



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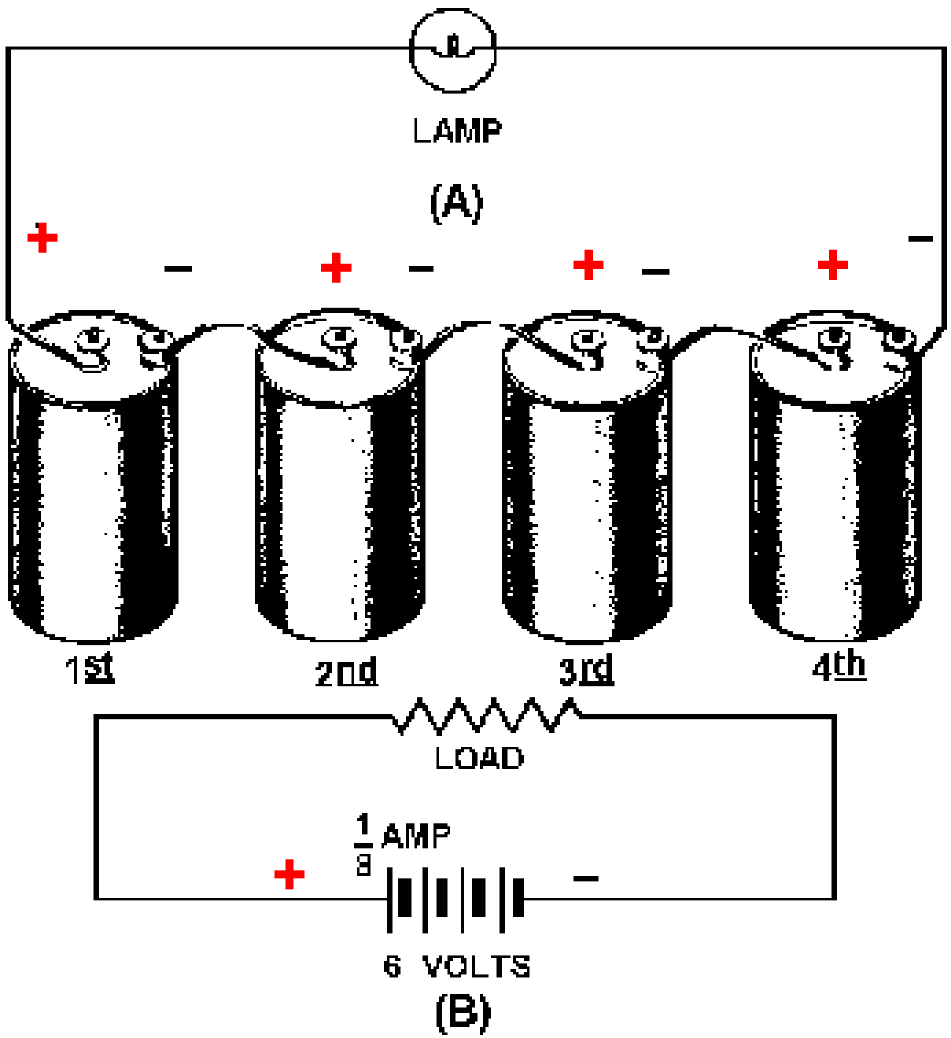
Cells in Series



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Primary vs Secondary Cells

- Primary Cell or Battery
  - Cannot be recharged when chemical energy consumed.
  - Zinc carbon cell is an example.
- Secondary Cell or Battery
  - Can be recharged.
  - Car battery (lead acid battery) is an example.

Cell & Battery Characteristics

- Shelf life
- Internal resistance
- Energy capacity
- Cell voltage

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Types of Popular Cells

- Zinc Carbon
  - Primary cell.
  - Cheap, readily available.
  - Low current applications only.
  - Corrosion a problem!
  - High internal resistance.
  - Deliver 1.5 volts when fresh.

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Types of Popular Cells

- Alkaline
  - Primary cell.
  - Similar to zinc carbon, but different chemistry gives greater capacity.
  - More expensive.
  - Longer shelf life.
  - Do not freeze!
  - Deliver 1.35 volts.

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Types of Popular Cells

- Mercury Cells
  - Primary cell.
  - Long working life.
  - More expensive.
  - Maintains full working voltage until end.
  - Used as voltage references in test equipment.
  - Deliver 1.4 volts

Types of Popular Cells

- Nickel-Cadmium
  - Secondary cell.
  - Abbreviated Nicad.
  - Until recently, very popular in Amateur equipment.
  - Very low internal resistance.
  - Memory effect possible.
  - Deliver 1.25 volts.

Types of Popular Cells

- Lead Acid
  - Secondary cell.
  - Car battery most common example.
  - Can deliver very high power for brief periods.
  - Inexpensive, but need to be cared for.
  - Produce hydrogen gas when charging.
  - Sulphuric acid electrolyte is corrosive.
  - Deliver 2.2 volts per cell.

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Types of Popular Cells

- Nickel-Metal Hydride
  - Secondary cell.
  - Abbreviated NiMH.
  - Related to Nicad, and has supplanted it.
  - Greater capacity than Nicads.
  - Self discharges 4% per day.
  - Use ONLY chargers for NiMH, not nicads.
  - Deliver 1.2 volts.

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Types of Popular Cells

- Lithium Cell
  - Secondary cells.
  - More expensive than alkalines.
  - Sometimes called Lithium-Ion or Li-Ion.
  - Useable over a wide temperature range.
  - Often used for memory backup in computers.
  - Also used in pacemakers and medical devices.
  - Can last up to 15 years depending on application.
  - Delivers 1.5 – 3.7 volts, depending on design.

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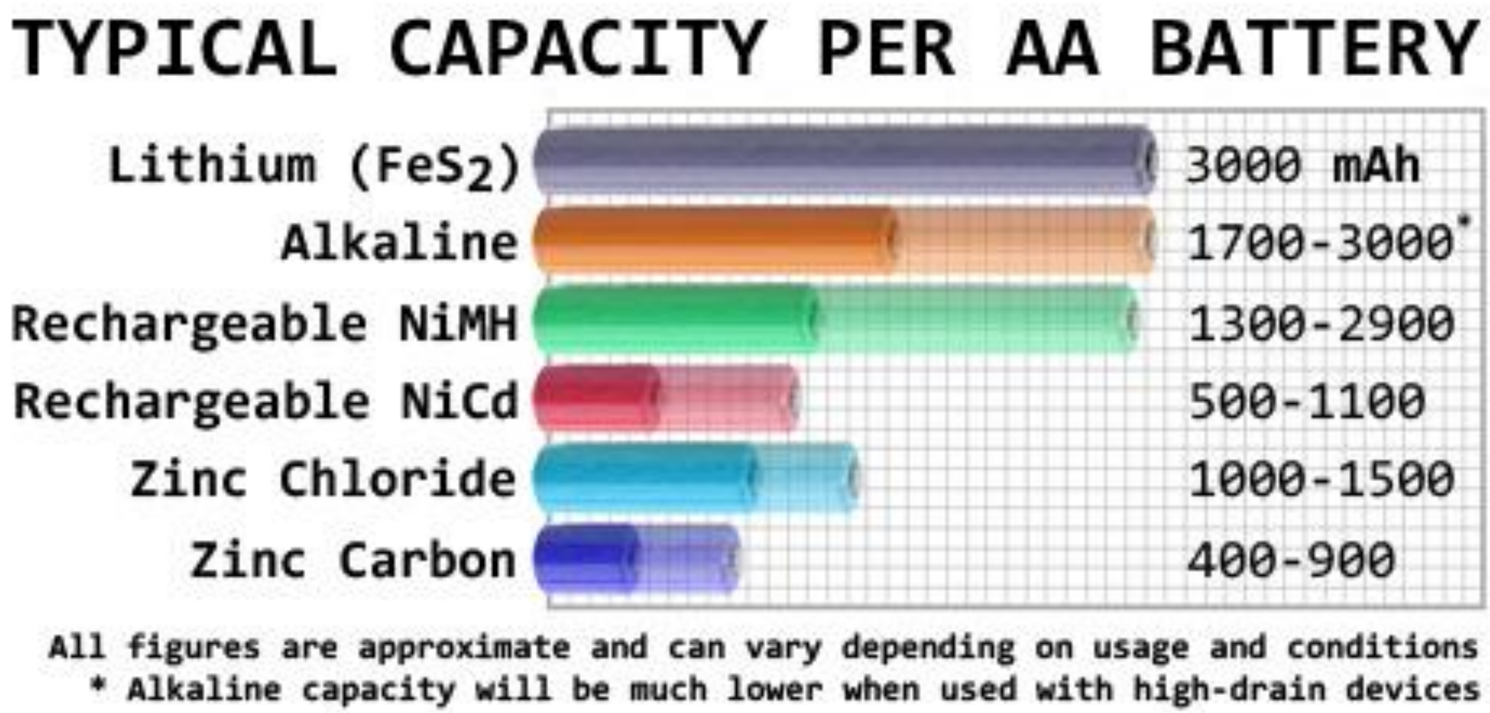
Battery Capacity Comparison



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Battery Disposal

- Batteries contain toxic materials.
- Dispose of old batteries in an approved manner!

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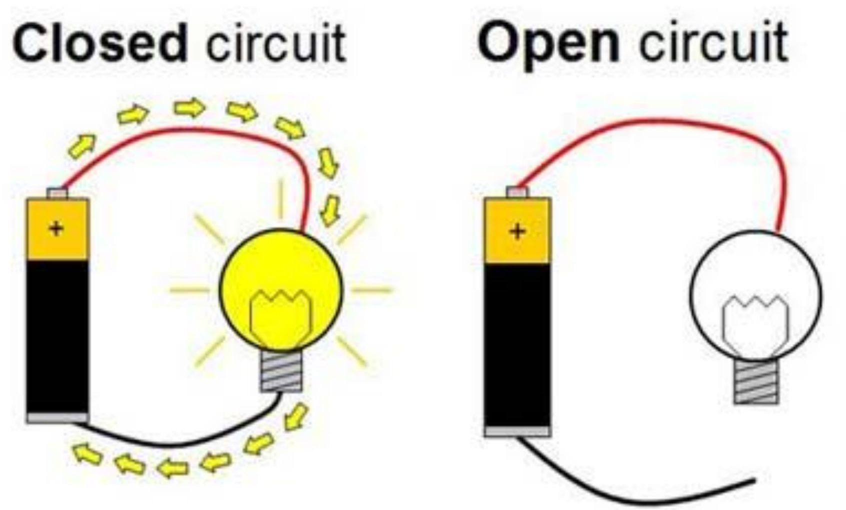
Closed and Open Circuits

- Closed Circuit: Circuit is complete and current will flow when voltage is applied.
- Open Circuit: Circuit does not provide a path for current to flow. Could be deliberate (switch) or accidental (broken wire).



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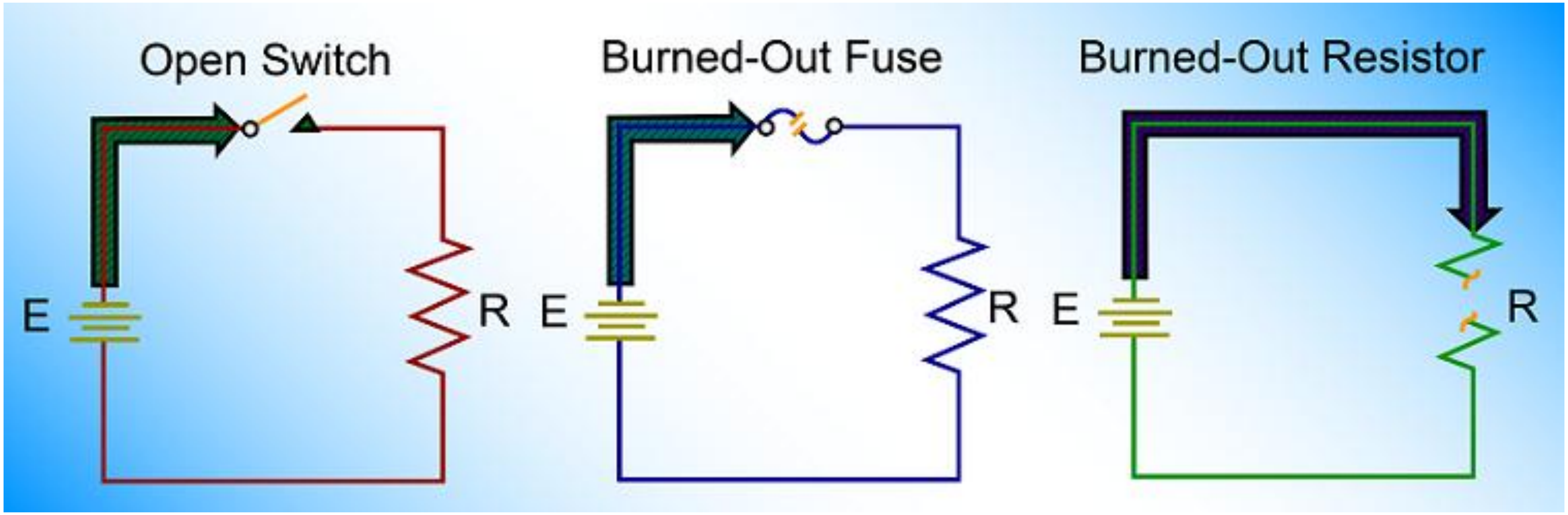
Open Circuit



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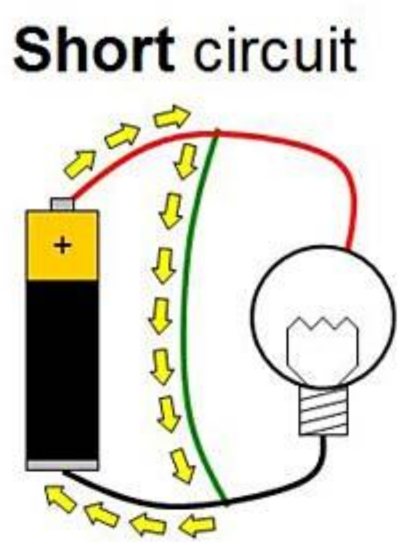
Short Circuit

- Abnormal connection of relatively low resistance between two points in a circuit.



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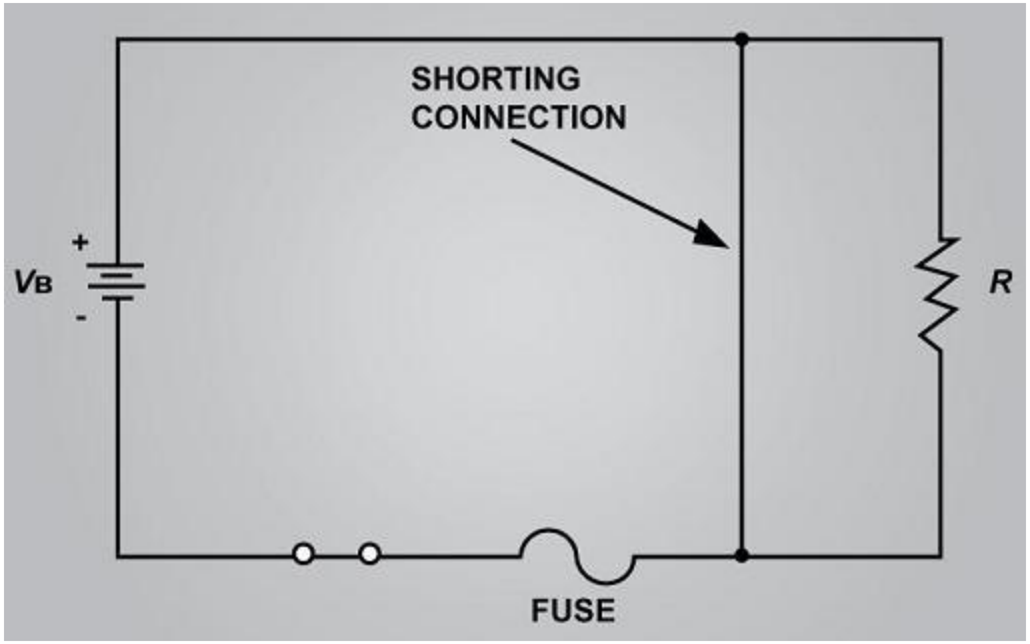
Fuses



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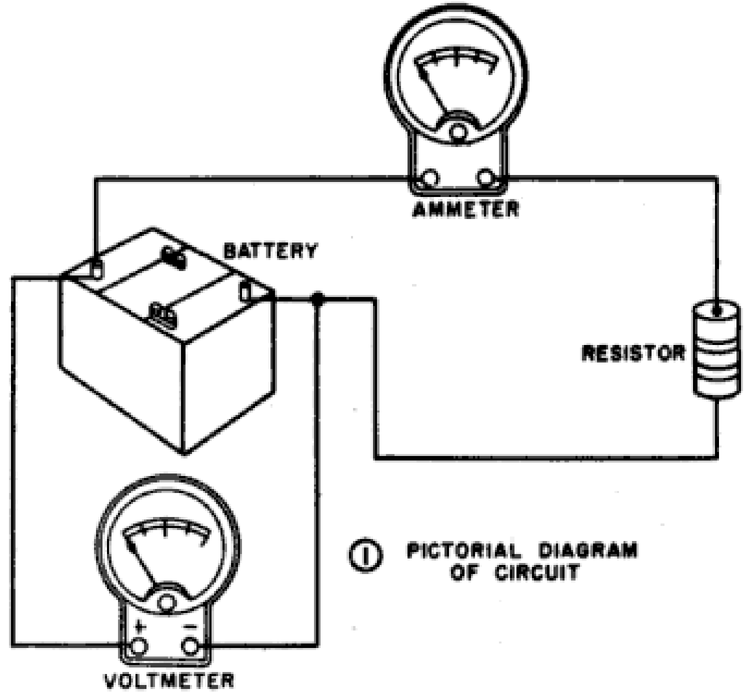
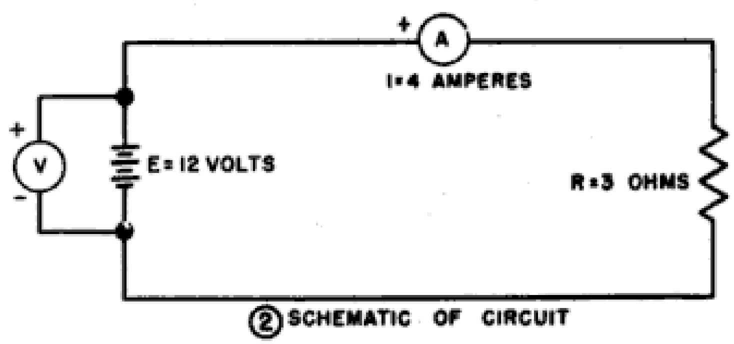
Schematic Diagrams





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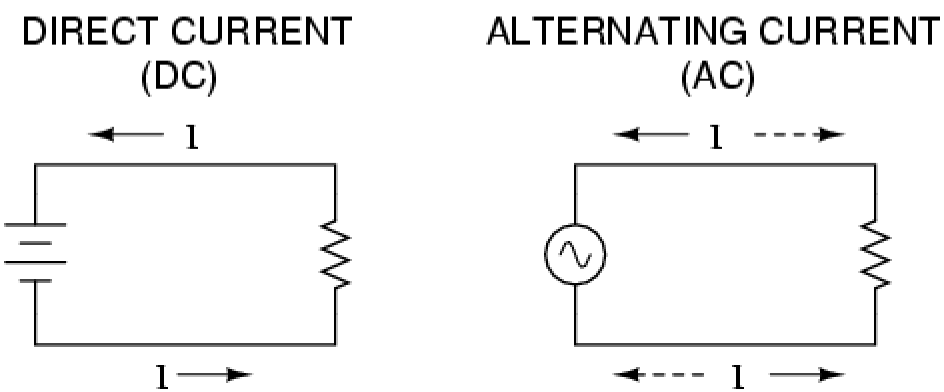
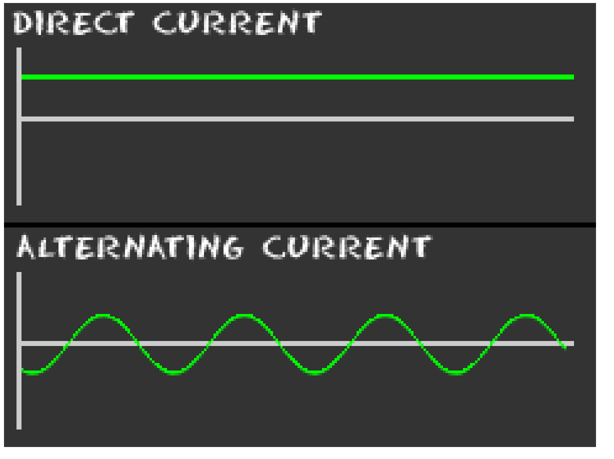
Alternating Current

- Current flows in one direction, and then another at a regular periodic rate.
- Number of alterations per second is frequency.
- In North America frequency is 60 cycles per second, or 60 hertz.
- So, 1 cycle per second = 1 hertz, abbreviated Hz.

Direct vs Alternating Current

- Direct Current (DC) – flows in one direction only.
- Alternating Current (AC) – flows in one direction, then the other, in a regular sequence.





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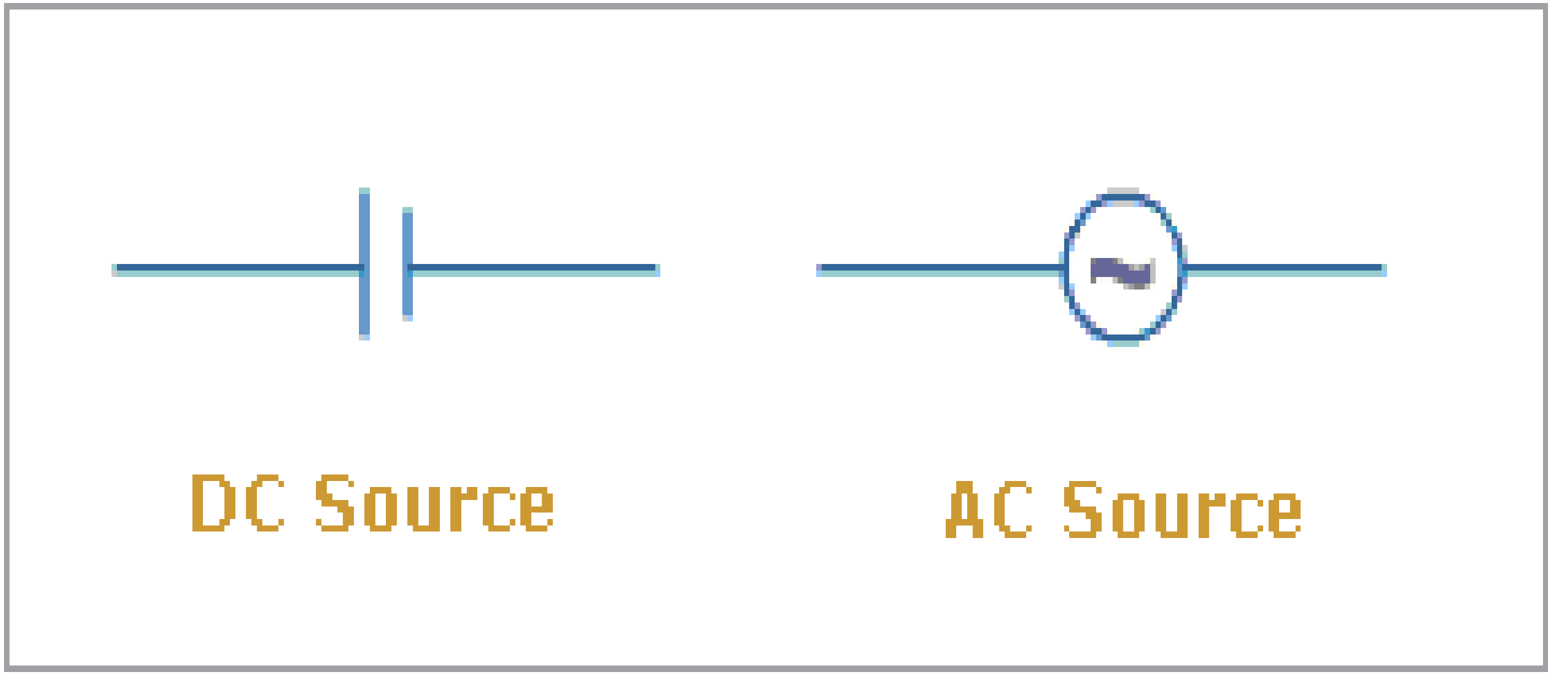

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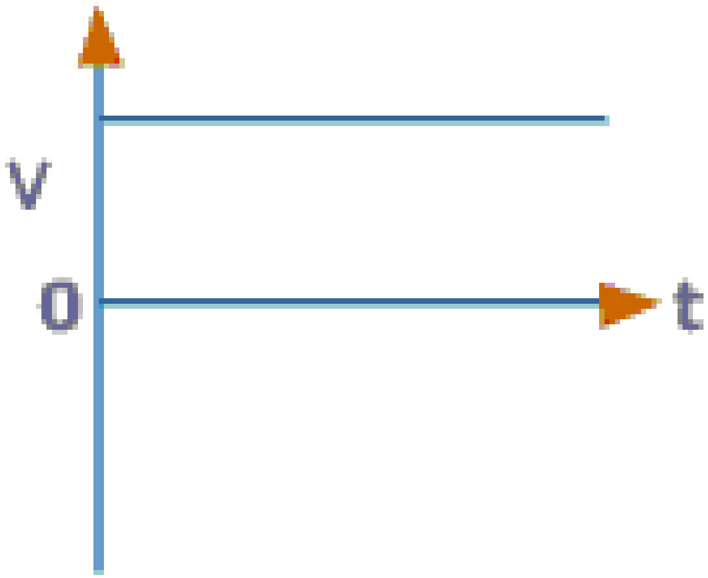
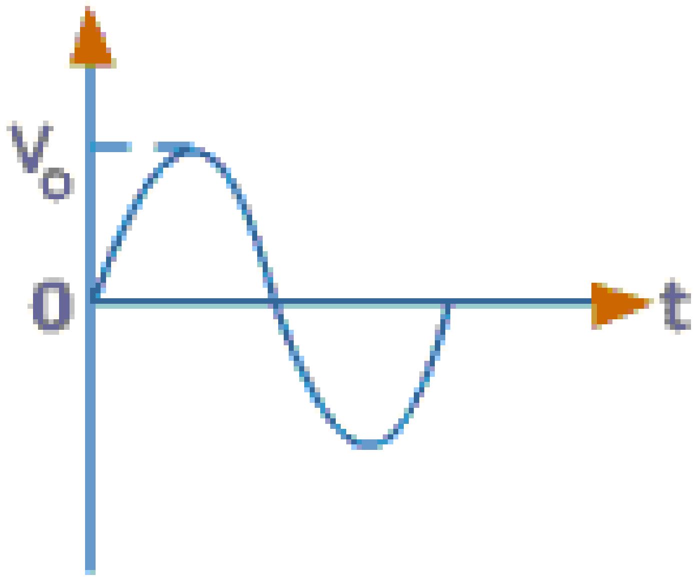
Direct vs Alternating Current



DC Source



AC Source

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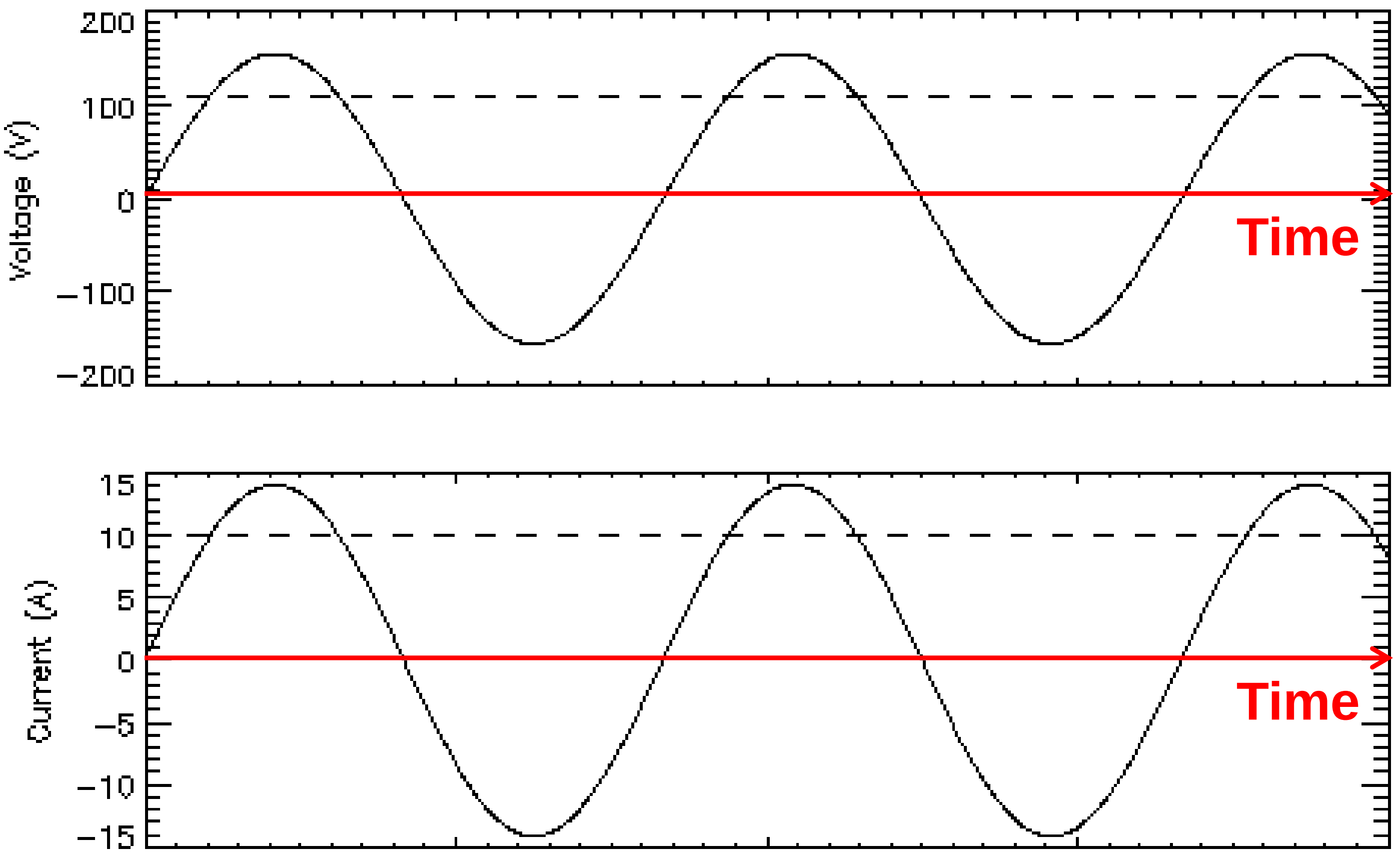
AC Voltage and Current

Voltage

Current



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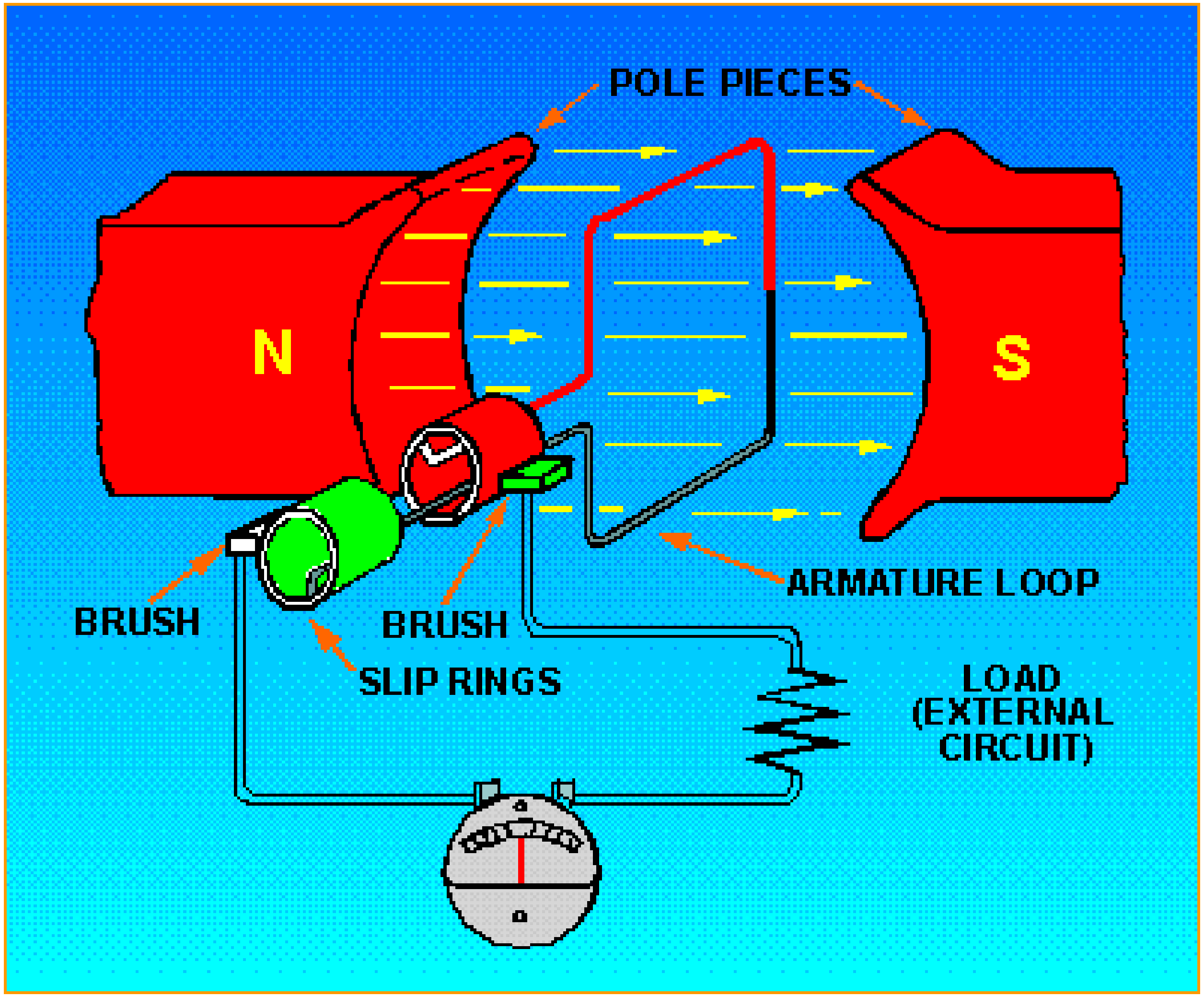
Elementary Generator



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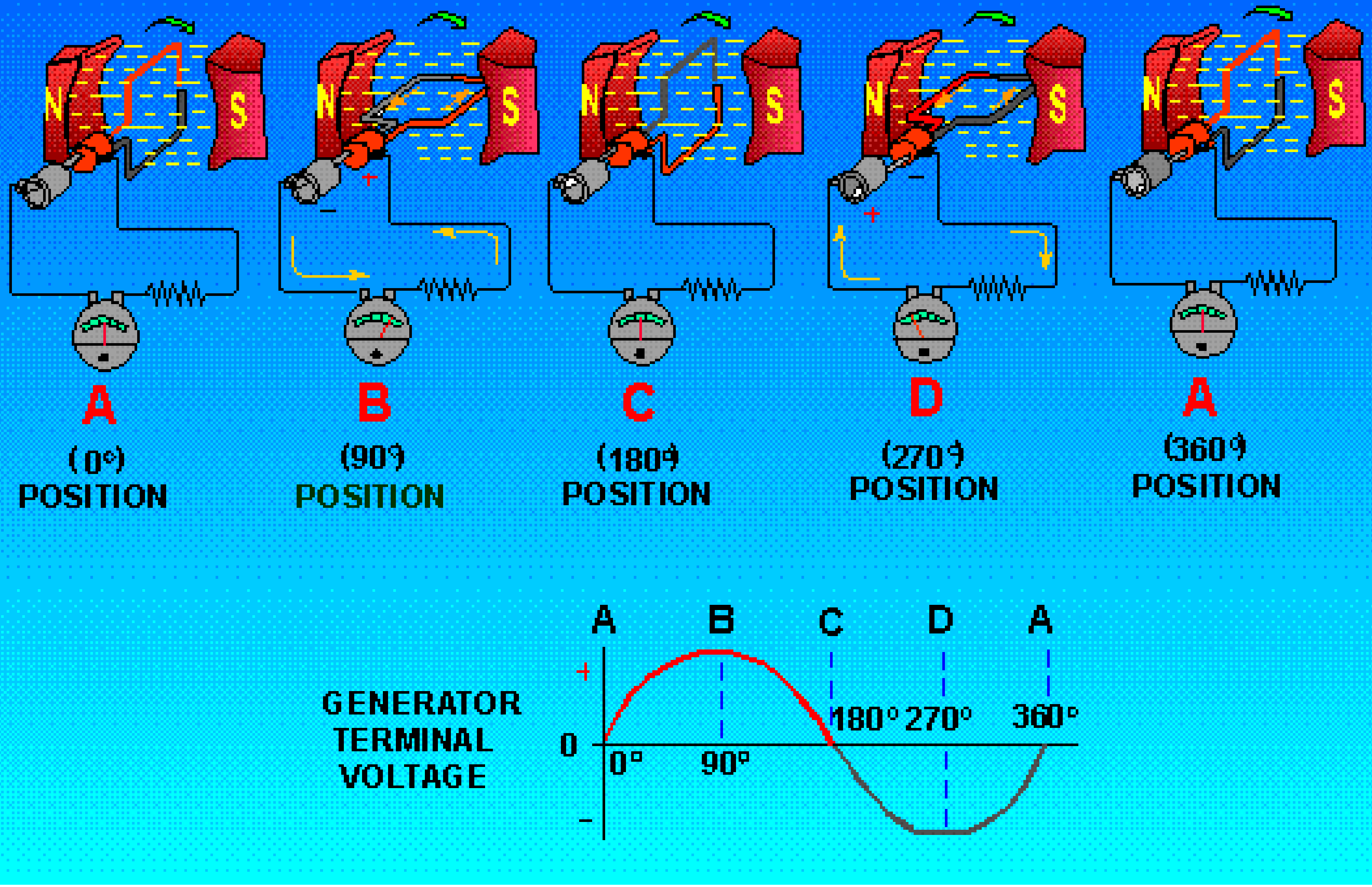

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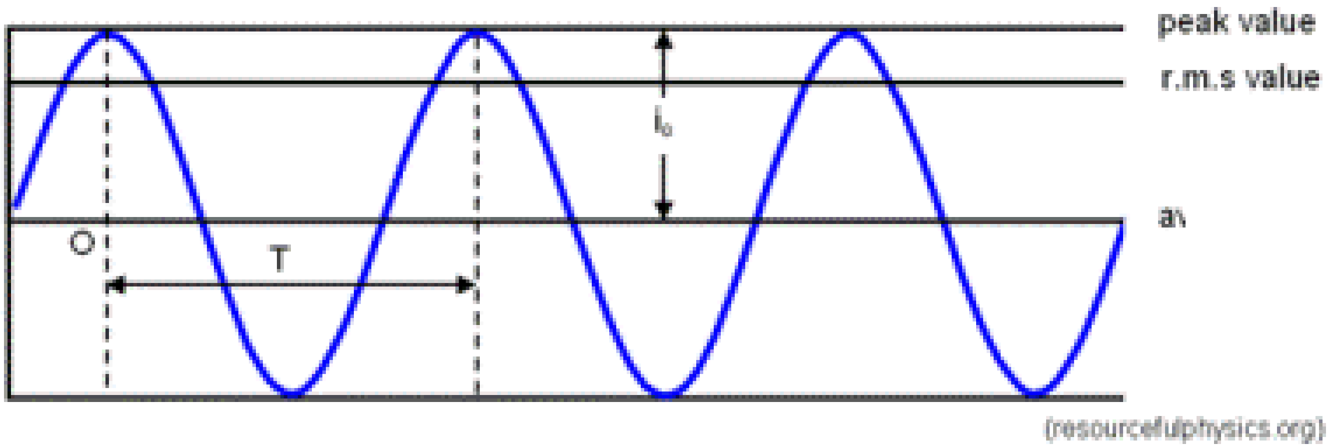
Energy of AC versus DC

- For AC waveform to have same energy as DC, the peak AC voltage must be greater.
- For energy equivalence, peak AC voltage = 1.414 DC voltage, or DC = 0.707 peak AC voltage.
- This is the Root Mean Square value (RMS value).



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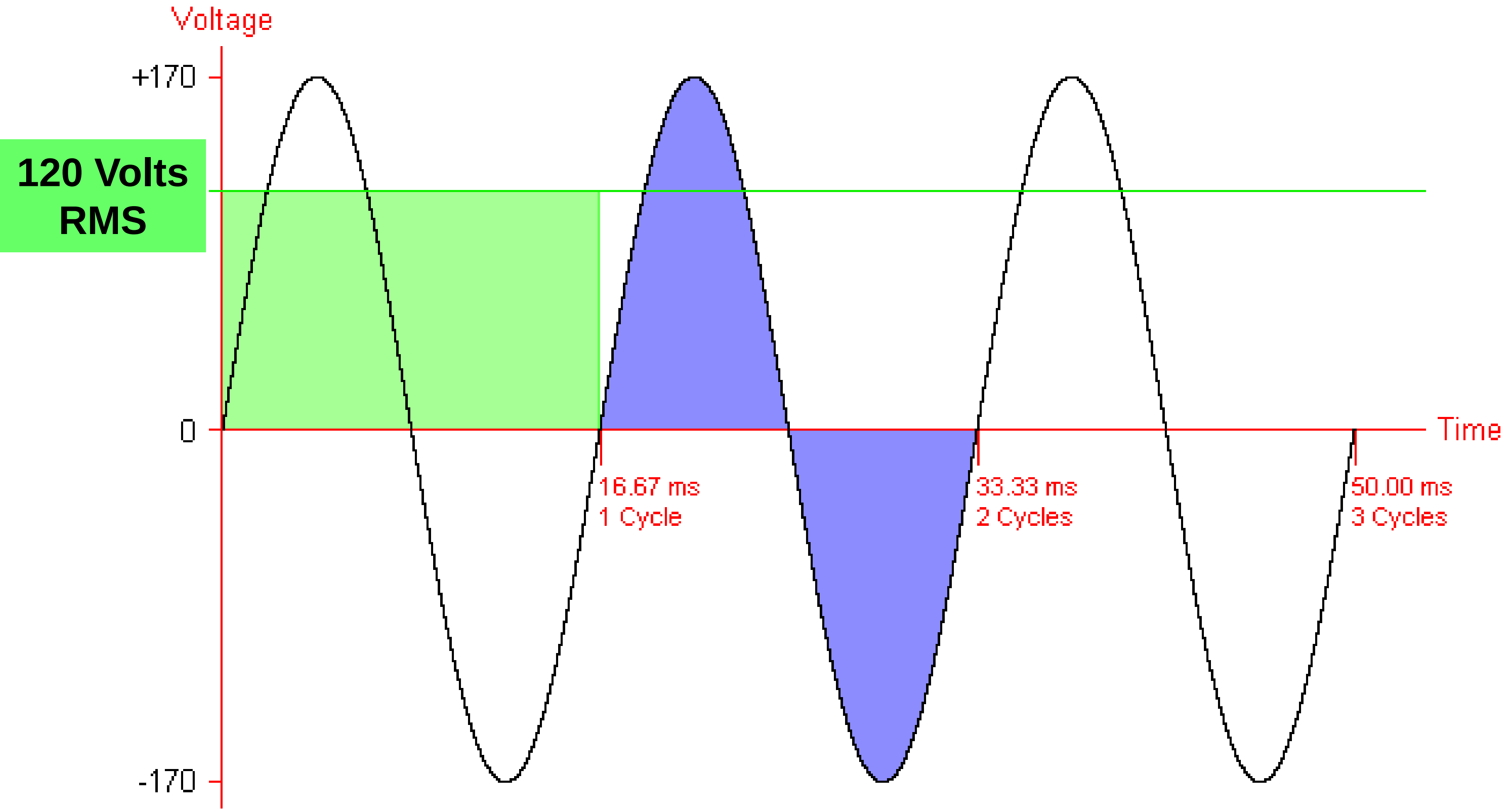

RMS Voltage = 0.707 x Peak AC voltage

= 0.707 x 170 volts

= 120 volts

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Questions?

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