Introduction to Electric Circuits

System of Units:

The International System of Units, Systeme International des Unites (SI unites), is used when analyzing electric circuits.

tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
fempto	f	10^{-15}

Electric Charge

Atoms possess:
- electrons --> negative charge
- protons --> positive charge
- neutrons --> no charge

Charge is measured in coulombs (C)

Properties:
1. Charge is conserved, and is never created or destroyed.
2. Charge is quantized.

The smallest unit charges are those possessed by electrons and protons.
electron -> $q_e = -1.602 \times 10^{-19}$ C
proton -> $q_p = + 1.602 \times 10^{-19}$ C

Note: Their charges are equal in magnitude but opposite in sign.

Taking the inverse, we see that 1 C is the charge on 6.2 x 1018 electrons.
Thus, 1 C is a very large amount of charge.

Electric Force

$$F = k\frac{q_1 q_2}{d^2}$$

where q_1 and q_2 are the charges on the bodies,

d is the distance separating the bodies,

and k is the Coulomb constant.

$$k = 9.9875\text{x}10^9\,\frac{Nm^2}{C^2} \qquad k = \frac{1}{4\pi\varepsilon_0}$$

where ε_0 is the permittivity of free space (ε_0 = 8.8542 x 10^{-12} C^2/Nm^2).

Like charges repel and opposite charges attract

Example: What is the force of attraction between an electron and a proton which are 1 meter apart?

$$F = k\frac{q_1 q_2}{d^2} = 8.9875\text{x}10^9 \frac{Nm^2}{C^2}\text{x}\frac{(-1.602\text{x}10-^{19}C)(1.602\text{x}10-^{19}C)}{(1m)^2}$$

$=2.307 \text{ x } 10^{-28}\ N$

Example: What is the force on a 1 C charge by another 1 C charge separated by 1 m.?

$$F = k\frac{q_1 q_2}{d^2} = 9\text{x}10^9 \frac{Nm^2}{C^2}\text{x}\frac{(1C)(1C)}{(1m)^2} = 9\text{x}10^9 N$$

Electric Field and Voltage:

A charge can be said to produce an “electric field” which causes forces on other charges.

The electric field due to a charge Q:

$$\left|\vec{E}\right| = k\frac{Q}{r^2} \qquad \vec{F} = q\vec{E}$$

If the charge q moves due to the force F, work is done on it.

Voltage is a measure of the work done on a charge q when it moves in an electric field between 2 points

(say a and b).

$$V_{ab} = \frac{W_{ab}}{q}$$

The voltage difference between two points A and B is 1 V if 1 J of work is required to move 1 C of charge from A to B. Thus,

V_{ab} = 1 V = 1 J /C = Work / Charge

The unit of voltage is the volt (V)

In a circuit, voltage is the potential for doing work, and is the force which moves electric charge.

Higher voltages will push/pull more electrons.

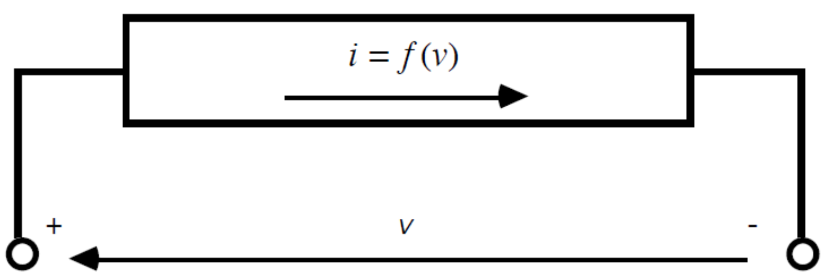
Voltage is always measured between two points.

Sometimes one of the points is assumed to be a standard location (i.e. earth).

When people say voltage at point X is 5 V, they mean that the voltage between X and earth is 5 V.

Note: Electrons are **attracted to** and want to **flow towards** high potential energies, i.e. more positivevoltages.

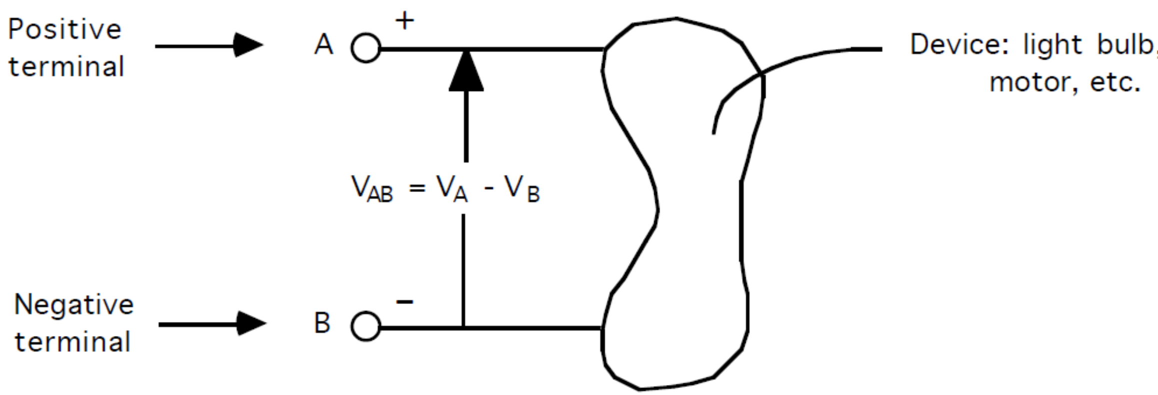
The current vector is drawn from the more positive voltage towards the more negative voltage, i.e. opposite to the electron flow.

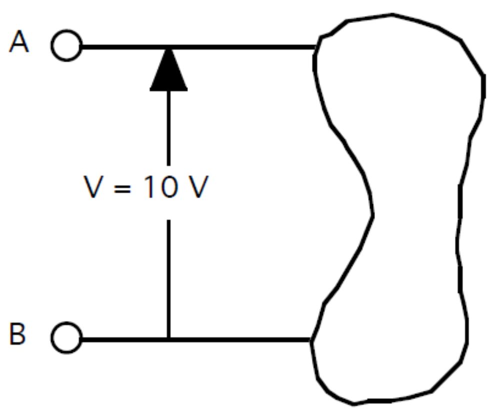


Voltage is a vector and so has **magnitude** and **direction**.

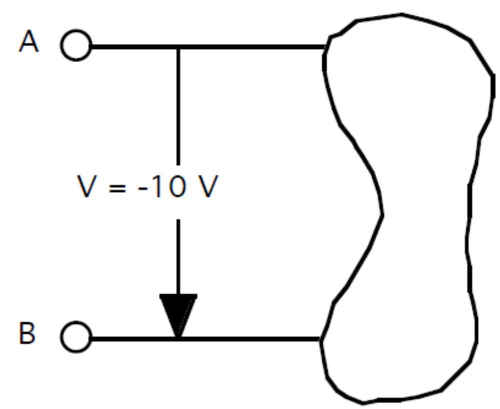
Voltage is not a fixed quantity, but it is a **relative** quantity.

i.e. an object’s voltage is always in reference to another object’s voltage.





Equivalent to



Examples of Electric Voltage:

10^7 - 10^8 V	Lightning bolt
10^5 - 10^6	V High voltage transmission line
10^4 V	Voltage on a TV picture tube
220 V	Household wiring in Europe
120 V	Household wiring in North America