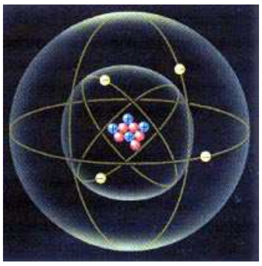
ELECTRICITY

Electrostatics



Electrostatics (الكهرستاتية) is the study of static electric charges (الشحنات الكهربائية الساكنة).

The Atom

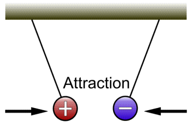
$$Q_{proton} = -\,Q_{electron} = 1.6 \times 10^{-19}\ \text{C}$$

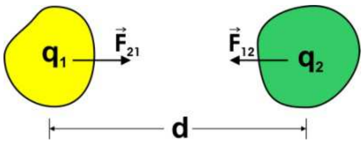
This means that the number of electrons needed to make a charge of $q = -1$ C is:

$$N = (-1\ \text{C} / Q_{electron}) = 6.25 \times 10^{18}\ \text{electrons}$$

Coulomb's Law

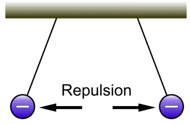
The **electrostatic force is directly proportional to the charges and inversely proportional to the square of the separating distance.**





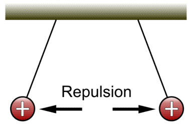
$$\boxed{F_{12} = F_{21} = k.\ q_1 \, .\ q_2 / d^2} \quad \text{with } k = 9 \times 10^{9}\ [\text{N.m}^2/\text{C}^2]$$

$$\text{Ex. } F = 9 \times 10^{9} \times 1\text{C} \times 2\text{C} / (10\ \text{km})^2 = 180\ \text{N}$$



We should note the following:

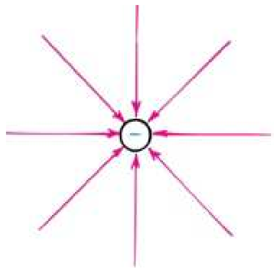
1. By Newton's 3rd law, $\vec{F}_{12}$ and $\vec{F}_{21}$ are equal in magnitude but opposite in direction.



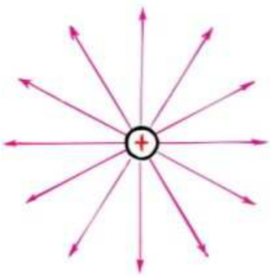
2. The Coulomb force is negative when the charges q_1 and q_2 are opposite (i.e., attraction), and positive when q_1 and q_2 are alike (i.e., repulsion).

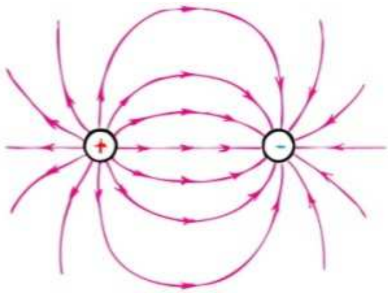
Electric Field

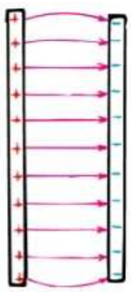
We define the **electric field** at any particular point as the electrostatic force that would be felt by a unit positive charge (i.e., q = 1 C) placed at that point. Thus, the electric field arising at a distance d from a point-charge Q (شحنة بشكل نقطة) is a vector given by:



$$\vec{\mathcal{E}} = \frac{\vec{F}}{q} \Rightarrow \mathcal{E} = k\,\frac{Q}{d^2} \quad [\text{N/C}]$$







Electric Potential

Electric potential energy is **the energy a charged particle has because of its location in an electric field**. It is the work done on the charge to move it from a very far place to a place within an electric field.

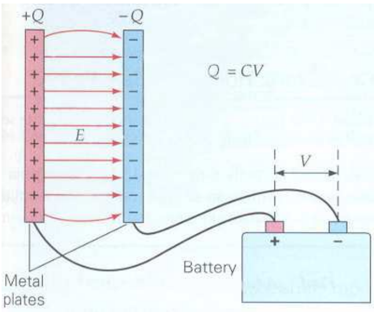
We can increase the gravitational potential energy of an object by doing work on it as we lift it in a gravitational field. We can increase the elastic (مرونة) potential energy of a spring by compressing or expanding it from its normal length. Similarly, we can increase the potential energy of a charged particle by moving it in an electric field.

$$E_{p\text{-electric}} = F \cdot d = k\,\frac{q \cdot Q}{d^2} \cdot d = k\,\frac{q \cdot Q}{d} \quad [J]$$

Electric potential or **voltage** is **the electric potential energy for a unit positive charge**.

$$V = E_{p\text{-electric}} / q = k\,\frac{Q}{d} \quad [V = J/C]$$

Capacitors



Parallel-plate capacitor

A **capacitor** (مكثف) is an electric device (أداة) that can hold (تمسك) electric charges. The charges then establish an electric field that stores (يخزن) energy. In its simplest form, a capacitor consists of two metal plates separated by air and charged with a battery.

Electrodynamics

Electrodynamics (الكهروديناميكا) is the study of moving electric charges and currents (الشحنات والتيارات الكهربائية المتحركة).

Conductors and Insulators

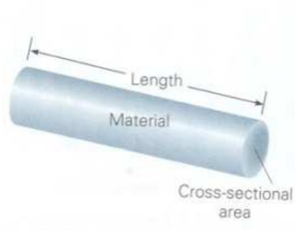
Materials vary in regard to the ease of flow of electrons (or electric field) through them, and may be divided into conductors and insulators.

Electric Current

When there is an electric potential (الجهد) difference V_{AB} between two points A and B of a conductor, charges (electrons) flow (تجري) from the point of higher potential to that of lower potential. **The charge flow per unit time** is called: **electric current**, I. Thus:

$$\boxed{I = \Delta Q / \Delta t} \quad [A = C/s]$$

Electric Resistance



All materials have opposition (ممانعة) to the flow of charges. This opposition is expressed by the resistivity (مقاومية) **ρ (Ωm)**.

For a wire of length "ℓ" and cross-sectional area (مساحة مقطعية) "A", its resistance "R" is proportional to ρ and ℓ, and inversely proportional to A:

$$R = \rho \times \ell / A$$

As an example, a copper wire has ℓ = 100 km, A = 0.1 mm^2.

$$R = (1.7 \times 10^{-8}\ \Omega m) \times (10^5\ m) / (0.1 \times 10^{-6}\ m^2) = 1.7 \times 10^4\ \Omega = 17\ k\Omega$$

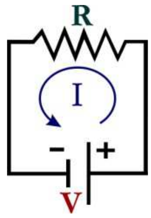
Electric Circuits

Batteries & Generators

Batteries and generators are the "pumps" that can provide a potential difference that can produce a steady (مستمر) current in a circuit.

Batteries use chemical reactions to convert (تحو□) chemical energy into electric potential. Generators use mechanical energy for the same purpose. Thus, they both do work to pull negative charges away from positive ones.

Ohm's Law



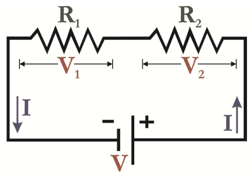
Any complete path that allows electrons to flow is called an electric circuit (دائرة كهربائية).

The electric current in a circuit increases with voltage and decreases with resistance. This is Ohm's law. In equation format, it says:

$$I = V / R \quad \text{or, } V = I \cdot R \quad [\Omega = V/A]$$

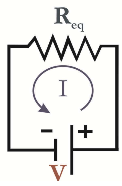
Ex. $I = 12\ V / 12\ k\Omega = 12\ V / 12 \times 10^3\ \Omega = 10^{-3}\ A = 1\ mA$.

Series circuits



A series (متو□) circuit is a single path for the current. This means that the current must be the same throughout the circuit, and any break in the circuit stops the current in all parts.

$V = V_1 + V_2 \Rightarrow I.R_{eq} = I.R_1 + I.R_2 \Rightarrow \boxed{R_{eq} = R_1 + R_2 = \Sigma R_i}$



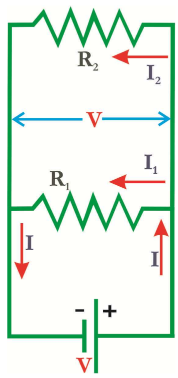
The **equivalent resistance in a series circuit is always larger** than any individual (إفرادي) resistance.

Ex. $V = 12\ V$, $R_1 = R_2 = R_3 = 9\ \Omega \Rightarrow R_{eq} = 27\ \Omega$, and $I = V/R_{eq} = 0.44\ A$

Parallel circuits

A parallel (متواز) circuit has multiple paths for the current.

$I = I_1 + I_2 \Rightarrow V/R_{eq} = V/R_1 + V/R_2 \Rightarrow \boxed{1/R_{eq} = 1/R_1 + 1/R_2 = \Sigma\ 1/R_i}$



Ex. $V = 12\ V$, $R_1 = R_2 = R_3 = 9\ \Omega \Rightarrow R_{eq} = 3\ \Omega$, and $I = V/R_{eq} = 4\ A$

The equivalent resistance in a parallel circuit is always smaller than any individual resistance. Also, as the number of branches is increased, the overall resistance of the circuit decreases.

As we add more parallel circuits to an outlet, we decrease the overall resistance and the total circuit can become overloaded and heat the components to dangerous levels.

Fuses and circuit breaker are installed in series with many parallel circuits to prevent overloading and protect for short circuits.

Electric Power

The **rate at which electrical energy is converted into other forms of energy is called electrical power**. We define the electric power, P, as:

$$\text{Power} = \text{current} \times \text{voltage, or, } \boxed{P = I.V = V^2/R = I^2.R} \quad [W = A.V]$$

Ex. $V = 9\ V$, $R = 1\ k\Omega \Rightarrow P = 81/1000 = 0.081\ W = 81\ mW$

On our electric bill, we are charged for the energy (not power) that we use. Since energy = power × time, the energy unit commonly used by electric companies is the kWh (kilowatt-hour).

Alternating Voltage

Alternating current (or ac) circuits (تيار متردد) are more practical and prevalent (غالب) in our homes and workplaces.