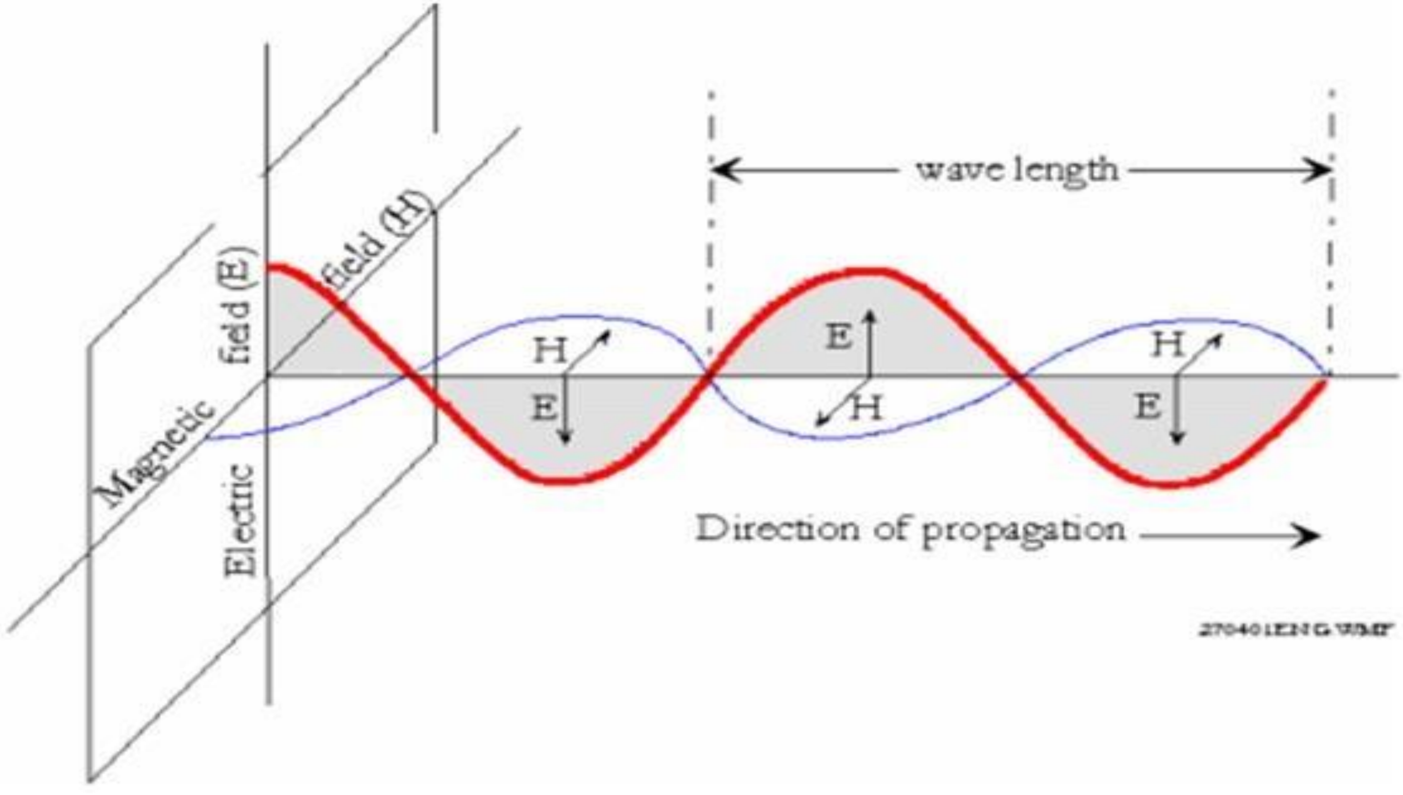
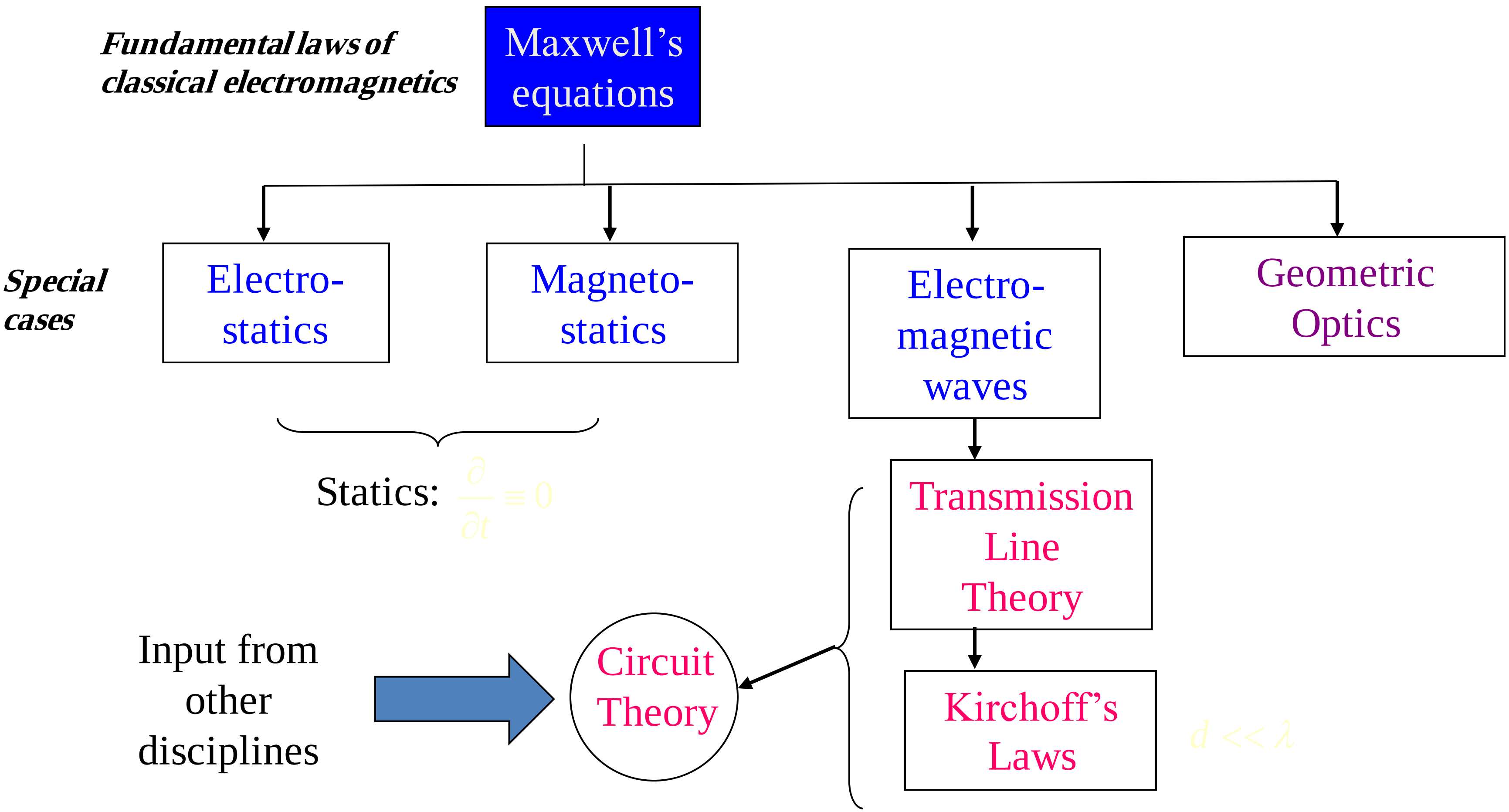
Electricity and Magnetism
Lecture -1-



Introduction to Electromagnetic Fields

- Electromagnetics is the study of the effect of charges at rest and charges in motion.
- Some special cases of electromagnetics:
  - Electrostatics: charges at rest
  - Magnetostatics: charges in steady motion (DC)
  - Electromagnetic waves: waves excited by charges in time-varying motion

Introduction to Electromagnetic Fields



Introduction to Electromagnetic Fields

- When an event in one place has an effect on something at a different location, we talk about the events as being connected by a "field".
- A ***field*** is a spatial distribution of a quantity; in general, it can be either *scalar* or *vector* in nature.

Introduction to Electromagnetic Fields

- A ***scalar*** is a quantity having only an amplitude (and possibly phase).

  Examples: voltage, current, charge, energy, temperature

- A ***vector*** is a quantity having direction in addition to amplitude (and possibly phase).

  Examples: velocity, acceleration, force

Introduction to Electromagnetic Fields

- Fundamental vector field quantities in electromagnetics:
  - Electric field intensity $(\underline{E})$

    units = volts per meter (V/m = kg m/A/s^3)
  - Electric flux density (electric displacement) $(\underline{D})$

    units = coulombs per square meter (C/m^2 = A s /m^2)
  - Magnetic field intensity $\boxed{(\underline{H})}$

    units = amps per meter (A/m)
  - Magnetic flux density $(\underline{B})$

    units = teslas = webers per square meter (T = Wb/ m^2 = kg/A/s^3)

Introduction to Electromagnetic Fields

- Universal constants in electromagnetics:
  - Velocity of an electromagnetic wave (e.g., light) in free space (perfect vacuum)

$$c \approx 3\times 10^{8} \text{ m/s}$$

  - Permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

  - Permittivity of free space:

$$\varepsilon_0 \approx 8.854\times 10^{-12} \text{ F/m}$$

  - Intrinsic impedance of free space:

$$\eta_0 \approx 120\pi \ \Omega$$

Introduction to Electromagnetic Fields

- Relationships involving the universal constants:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad \eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

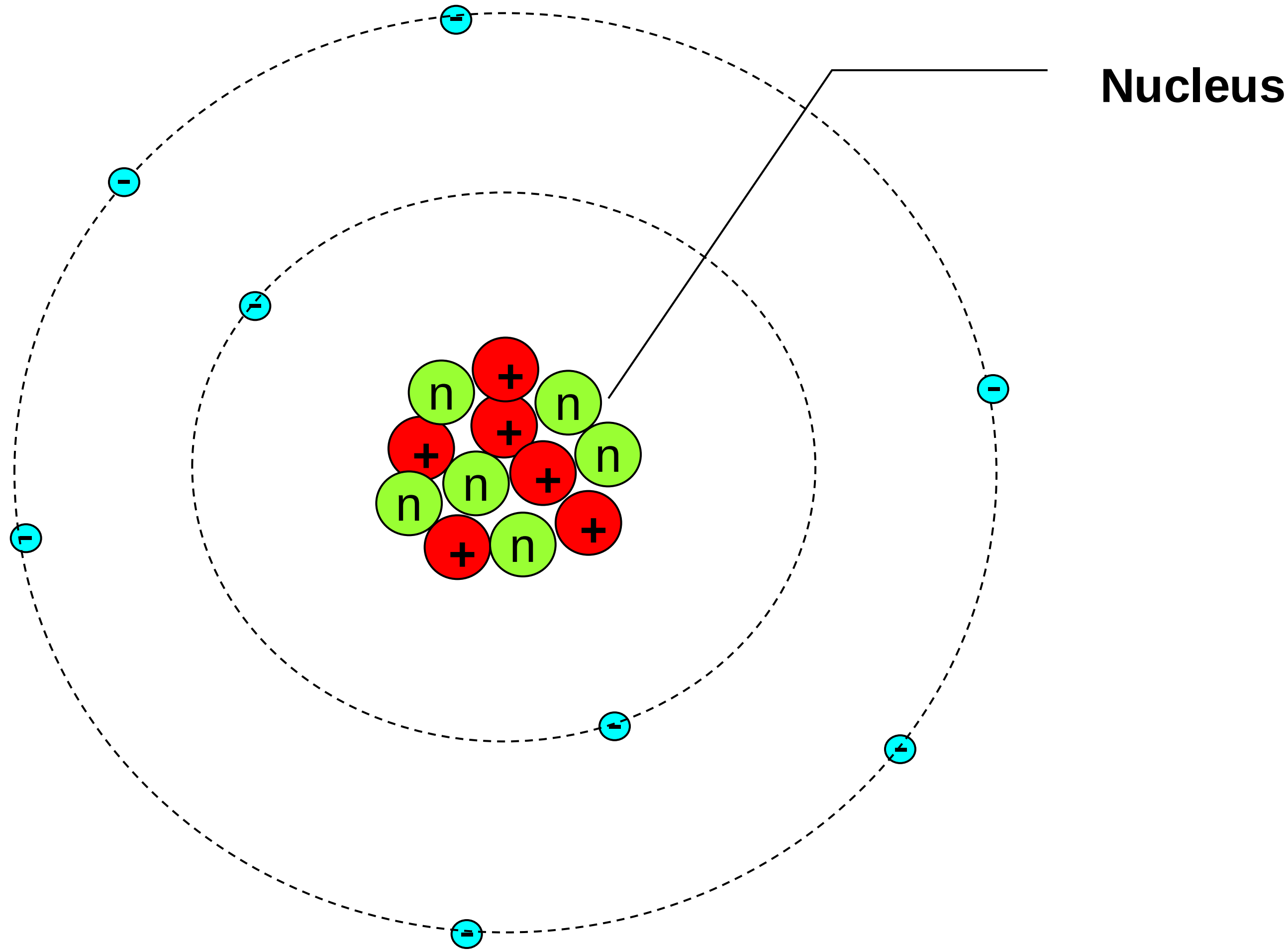
In free space:

$$\underline{B} = \mu_0 \underline{H}$$

$$\underline{D} = \varepsilon_0 \underline{E}$$

Electrostatics

- ***Electrostatics*** is the branch of electromagnetics dealing with the effects of electric charges at rest.
- The fundamental law of *electrostatics* is ***Coulomb's law***.



Negative Atom

Neutral Atom

Positive Atom

Number of electrons > Number of protons

Number of electrons = Number of protons

Number of electrons < Number of protons

$-2e = -3.2 \times 10^{-19} C$

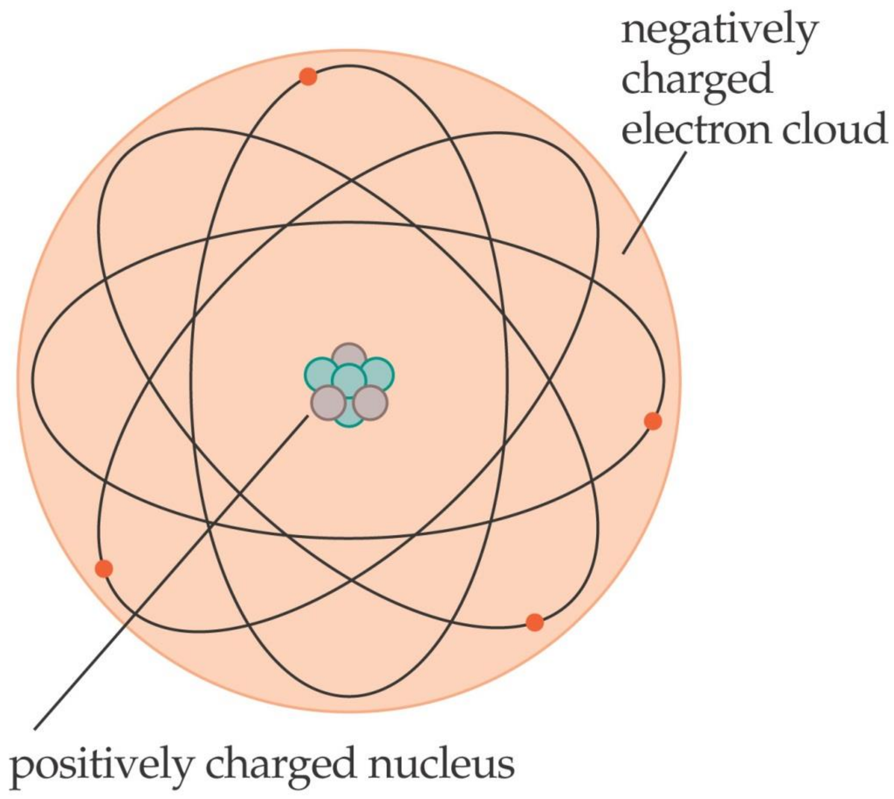
$+2e = +3.2 \times 10^{-19} C$

Electric Charge and Coulomb's Law

- **Atom: is the smallest of an element consisting of negative charged (electrons)arranged in defined shells about positively charged (nucleus)containing combinations of neutrons and protons.**
- **most of the atoms volume is occupied sparsely by electron tiny compared with the rest of the atom , the nucleus contains over 99.9% of the atoms mass.**
- **Nucleus radius $\approx \mathbf{10^{-15}}\ \boldsymbol{m}$**
- **Atom radius $\approx \mathbf{10^{-10}}\ \boldsymbol{m}$**

atom **>** nucleus $= \mathbf{10^{5}}$

The electrons in an atom are in a cloud surrounding the nucleus, and can be separated from the atom with relative ease.



- **Electron: avery small partical of matter that has negative charge of electricity and that travels around the nucleus of an atom.**

- Charge of proton (+ve) = charge of electron (-ve) = 1.6 x 10^{-19} coul
- Charge body : the excess in the electron (-ve) or proton (+ve) .

Two types of charge:

Positive Charge: A shortage of electrons.

Negative Charge: An excess of electrons.

Conservation of charge – The net charge of a closed system remains constant.

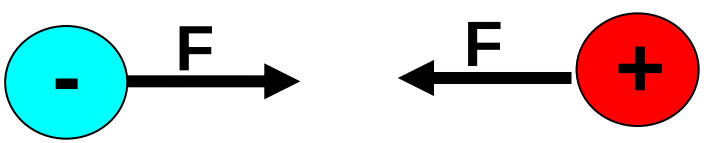
Like charges repel and opposite charges attract each other. The unit of charge is called coulomb (C)

Electric Forces

Like Charges - Repel

Charge q_1 δ q_2 have the same sign, electric force is repulsive

Unlike Charges - Attract



Charge q_1 δ q_2 have opposite, electric force is attractive

The smallest unit of " free " charge known in nature is the charge of an electron or proton , which has a magitude of

$$e = 1.6 \times 10^{-19}\ C$$

In a closed system, the total amount of charge is conserved since charge can neither be created nor destroyed.
A charge can, however, be transferred from one body to another.

19-2 Insulators and Conductors

Conductor: A material whose conduction electrons are free to move throughout. Most metals are conductors.

Insulator: A material whose electrons seldom move from atom to atom. Most insulators are non-metals.

Semiconductors have properties intermediate between conductors and insulators; their properties change with their chemical composition.

Photoconductive materials become conductors when light shines on them.

Coulomb's Law

Coulomb's Law – Gives the force of attraction or repulsion between two point charges. If two point charges q_1 and q_2 are separated by a distance r .

Then the magnitude of the force of repulsion or attraction between them

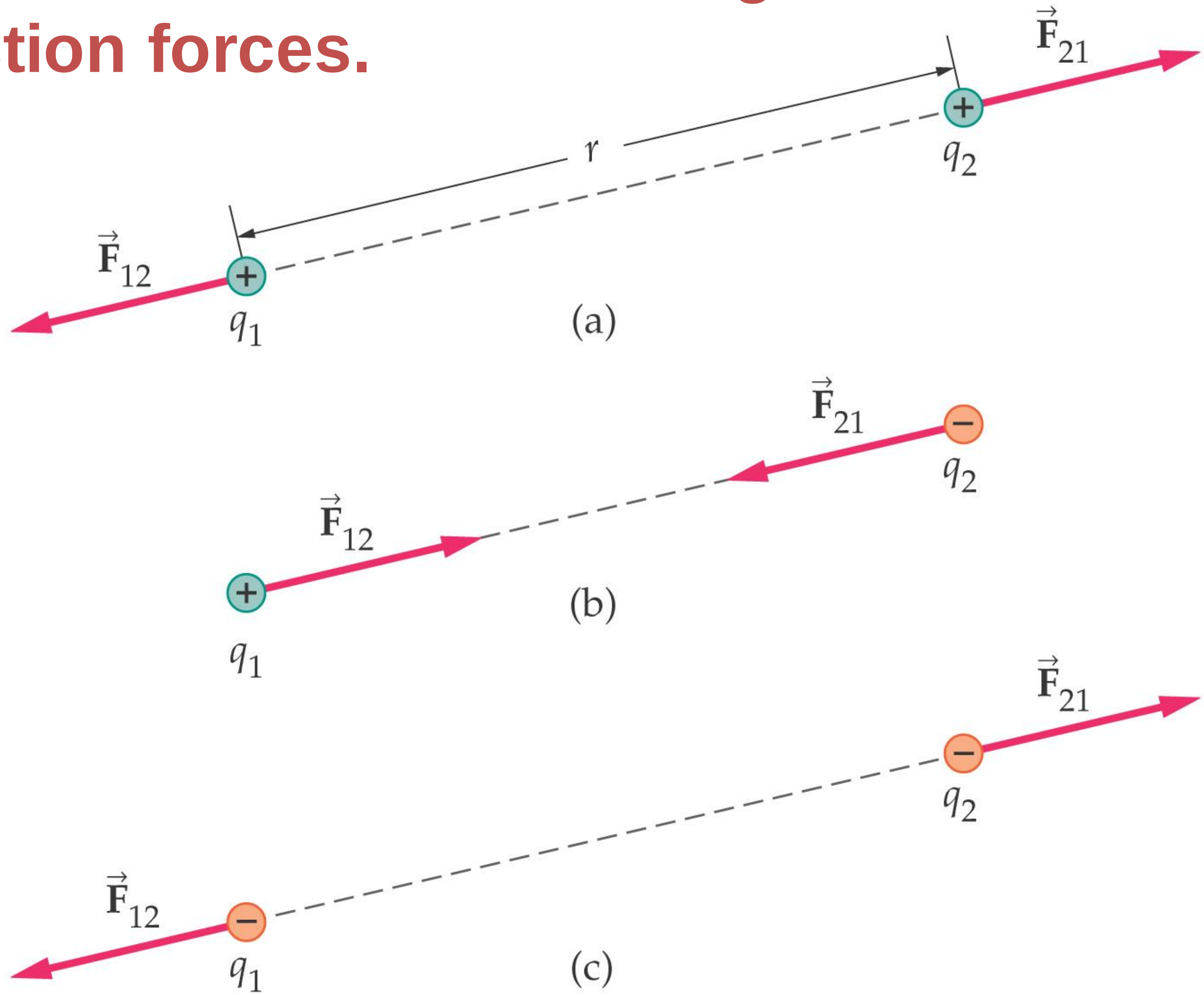
$$F \,\alpha\, \frac{q_1\, q_2}{r^2} \quad \Longrightarrow \quad F = k\frac{q_1 q_2}{r^2}$$

The constant K is often written as

$$k = \frac{1}{4\pi\epsilon_o} = 8.988 \times 10^9 \ \mathrm{N} . m^2 / C^2$$

Coulomb's Law

The forces on the two charges are action-reaction forces.



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

k = Coulomb's Constant = $9.0x10^9$ Nm^2/C^2

q_1 = charge on mass 1

q_2 = charge on mass 2

r = the distance between the two charges

Where

$$\epsilon_o = 9x10^{-12} \frac{C^2}{N.m^2}$$

Is called the permittivity constant

(K) depend on :

1. the medium when the charge body exist.
2. On the kind of those charge's.
3. on the distance between the charge.

The Coulomb's Law is same than the gravitational force where

$$F \gamma \frac{m_1 \ m_2}{r^2}$$

Example/