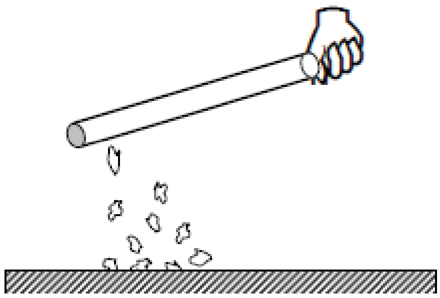
ELECTROSTATIC

Chapter1 : Electric charge and Electrostatic field

1-Electric charge:

A well-dried glass rod, rubbed and held in the hand, attracts small pieces of paper. We say that the glass has been electrified, this phenomenon is called electrification and the branch of physics that deals with such phenomena is electricity.

The same result is obtained if the glass rod is replaced by an ebonite stick and the same operation is repeated. We say that the body has been electrified by friction.



If we try to electrify a metal rod, such as copper, in the same way as before, we get no result. The metal rod, held in the hand, exerts no force on the pieces of paper.

However, if we hold the electrified metal rod by a wooden handle, we observe that attractive forces occur over the entire surface of the metal.

2- Conductor and insulator

A material is said to be a perfect conductor if, when it becomes electrified, the charge carriers can move freely throughout the entire volume occupied by the material.

It will be a perfect insulator if the charge carriers cannot move freely and remain localized at the place where they were deposited.

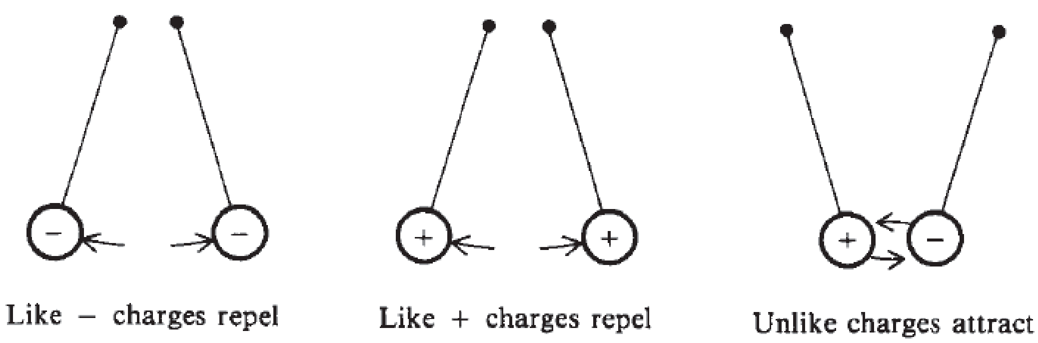
- **Examples of conductors**: Metals, such as copper, silver, and gold, are good conductors of electricity. Other conductors include graphite, salt water, and human flesh.
- **Examples of insulators:** Rubber, plastic, wood, and glass are poor conductors of electricity. Other insulators include air, dry paper, and diamonds.

There are two main ways to electrify an object:

- Electrification by friction.
- Electrification by contact :

Electrification by contact occurs when a charged object is brought into contact with an uncharged object. When this happens, some of the electrons from the charged object are transferred to the uncharged object.

3-The two types of electricity :

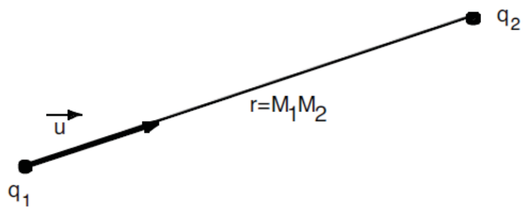


Like charges repel each other; unlike charges attract each other.

Coulomb's Law

Electric force works between electric charges, and this force is called the coulomb force. This force is analogous to universal gravitation between two particles with masses. The Coulomb force on two point charges in vacuum is expressed as follows:
• The force between two electric charges of the same kind (i.e. both positive or both negative) is repulsive and the force between electric charges of different kinds (i.e. one positive and one negative) is attractive.
• The magnitude of the force is proportional to the product of the two electric charges.
• The magnitude of the force is inversely proportional to the square of the distance between the two electric charges.
• The direction of the force lies on the straight line connecting the two electric charges.
We write :

$$\boxed{\overrightarrow{F_{1/2}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\vec{u}}$$



With $K = \frac{1}{4\pi\varepsilon_0} \approx 9\,10^9$

$\vec{u}$ is the unit vector

Where ε_0 is a constant called the permittivity of vacuum,

$$\epsilon_0 = 8.854\,2 \times 10^{-12}\ \mathrm{C^2/Nm^2}$$

The units of [q] = Coulomb

1µC=10^{-6} C µ=micro, 1nC=10^{-9} C µ=nano , 1pC=10^{-12} C µ=pico

r is the distance between the two electric charges.

The units of [r] = meter.

Electric field:

An electric force field is any region in space where an electric charge is subject to the action of an electric force.

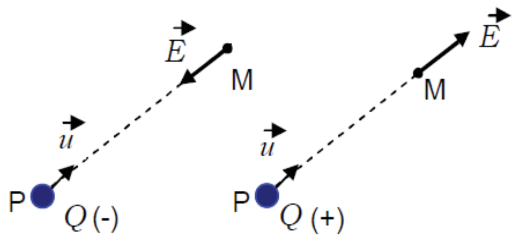
When a point charge Q, is placed at the origin, the Coulomb force on another point

charge, q, at the position r is given by

$$\vec{F} = K\frac{Q\,q}{r^2}\,\vec{u}$$

With

$$\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}\,\vec{u}$$

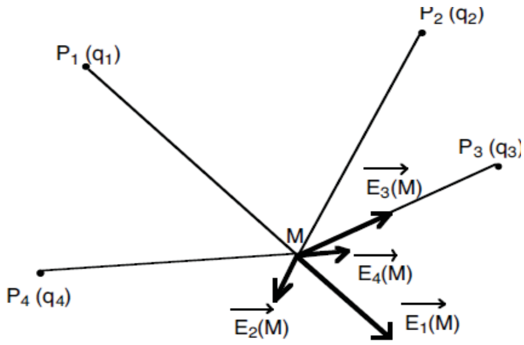


This quantity $\vec{E}$ is called the electric field, and its magnitude is called electric field strength. Its sense and direction are those of the force.
The unit of electric field strength is [N/C]. This is also expressed as [V/m] using the unit [V] (volt) of electrostatic potential, which will be defined later.

In analogy with mechanics, if in the vicinity of the earth, where the gravity field reigns, we place a mass m, it will be subject to its weight. We have:

$$\vec{W} = m\,\vec{g}$$

Case of n charges :



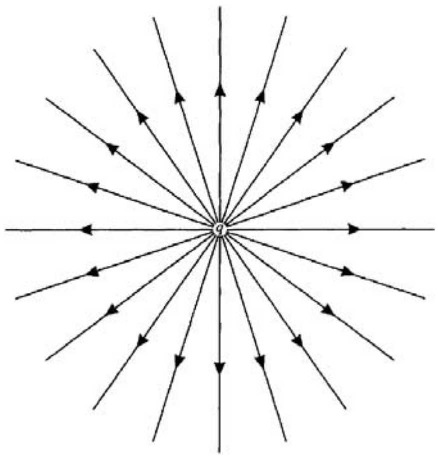
Here, we calculate the electric field strength for electric charges distributed in space. When an electric charge, q_i , is placed at position r_i (i = 1,2,……., n), with the superposition principle, the electric field strength at r is given by

$$\vec{E}(M) = \sum_{i=1}^{n} \frac{1}{4\pi\varepsilon_0} \frac{q_i}{r_i^2} \vec{u_i}$$

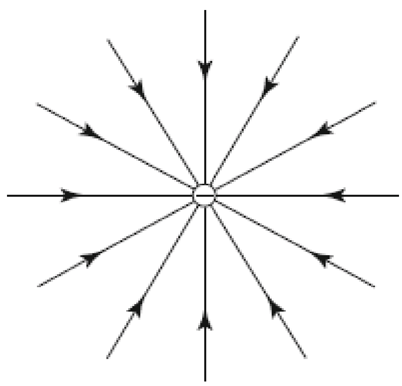
We can visualize the field using electric field lines (lines of electric force), which help us to understand the field easily. We can refer to a line of electric force as an electric field line, and take the tangent to an electric field line at an arbitrary point as being parallel to the direction of the electric field at this point.
It can be shown that electric field lines never cross each other.

Examples:

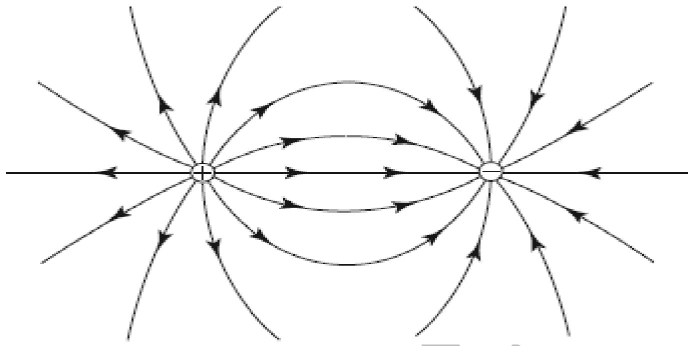
Electric field lines of
Single positive charge:



Single negative charge:



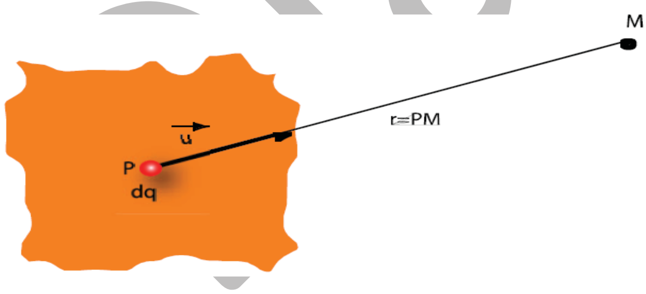
Pair of positive and negative charges:



Two parallel plates case :

Electric field with surface charge distribution

In this case, we have:



$$\vec{E}(M) = \int \overrightarrow{dE}(M)$$

With

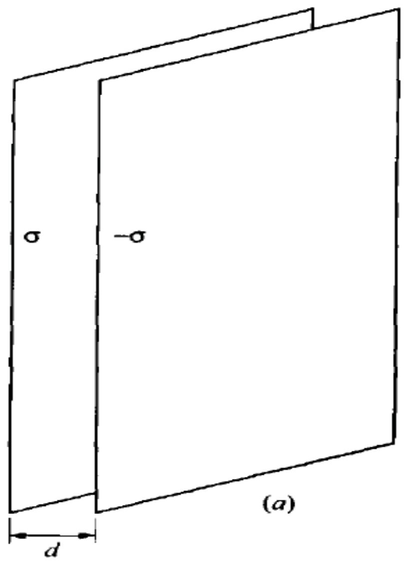
$$\overrightarrow{dE}(M) = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}\vec{u}$$

If σ is the surface charge density (units: $C.m^{-2}$) with

$$\sigma = \frac{dq}{dS}$$

Then the electric field is given by:

$$\vec{E}(M) = \iint_{Surface} \frac{1}{4\pi\varepsilon_0}\frac{\sigma}{r^2}\vec{u}\,dS$$



Volume charge distribution

We define ρ as the volume charge density (units: $C.m^{-3}$). The electrostatic field created by such a distribution is :

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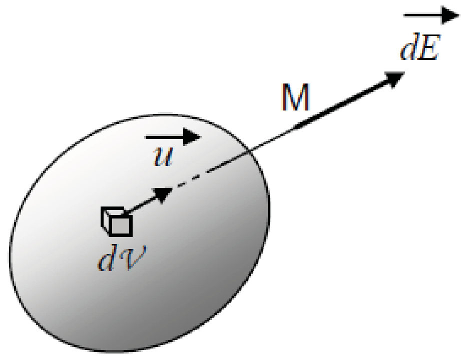
$$\vec{E}(M) = \iiint_{Volume} \frac{1}{4\pi\varepsilon_0} \frac{\rho}{r^2} \vec{u}\, dv$$

With

$$\rho = \frac{dq}{dv}$$



Linear charge distribution

We define $\lambda = \frac{dq}{dl}$ as the linear charge density (units: $C.\ m^{-1}$). The electrostatic field created by such a distribution is:

$$\vec{E} = \frac{1}{4\pi\varepsilon_o} \int_l \frac{\lambda\, dl}{r^2} \vec{u}$$