Electric Charges and Their Properties

Objectives

After going through this lesson, the learners will be able to:

- Understand the concept of Electric charge
- Know the basic properties of electric charge
- Differentiate between the charging by induction and conduction.
- State Coulomb's law and understand interaction between charges
- Apply Coulomb's law to solve numerical problems

Content Outline

- Unit syllabus
- Module-wise distribution of unit syllabus
- Words you must know
- Introduction
- Electric charge
- Charging by friction
- Charging by conduction
- Charging by Induction
- Basic Properties of electric charge
- Unit of charge
- Coulomb's law
- Characteristics of Coulomb i.e. (electrostatic) force
- Effect of intervening medium on electrostatic force
- Vector form of Coulomb's law
- Summary

Unit Syllabus

Chapter-1: Electric Charges and Fields

Electric Charges; Conservation of charge, Coulomb's law- force between two point charges, forces between multiple charges; superposition principle and continuous charge distribution Electric field; electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Chapter-2: Electrostatic Potential and Capacitance

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor.

Module-Wise Distribution Of Unit Syllabus

The above unit is divided into 11 modules for better understanding.

Module 1	• Electric charge • Properties of charge • Coulomb's law • Characteristics of coulomb force • Effect of intervening medium on coulomb force • numerical
Module 2	• Forces between multiple charges • Principle of superposition • Continuous distribution of charges numerical
Module 3	• Electric field E • Importance of field and ways of describing field • Point charges superposition of electric field • numerical
Module 4	• Electric dipole • Electric field of a dipole • Charges in external field • Dipole in external field Uniform and non-uniform
Module 5	• Electric flux ,

	• Flux density • Gauss theorem • Application of gauss theorem to find electric field • For a distribution of charges • Numerical

Module 6	• Application of gauss theorem Field due to field infinitely long straight wire
	    ○ Uniformly charged infinite plane
	    ○ Uniformly charged thin spherical shell (field inside and outside)
	    ○ Graphs

Module 7	• Electric potential, • Potential difference, • Electric potential due to a point charge, a dipole and system of charges; • Equipotential surfaces, • Electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field. • Numerical
Module 8	• Conductors and insulators, • Free charges and bound charges inside a conductor. • Dielectrics and electric polarization
Module 9	• Capacitors and capacitance, • Combination of capacitors in series and in parallel • Redistribution of charges , common potential • Numerical
Module 10	• Capacitance of a parallel plate capacitor with and without dielectric medium between the plates • Energy stored in a capacitor
Module 11	• Typical problems on capacitors

Words You Must Know

- **Position vector:** A vector drawn from the origin to a point to show its location with respect to origin (0, 0, 0).
- **Medium:** The material filling up the space between objects.
- **Force:** A push or a pull, attractive forces cause a pull towards each other.
- **Contact forces and forces acting at a distance:** Forces that act only on touching the object are called contact forces. The forces that act at a distance such as gravitational force are forces acting at a distance.
- **Electric Charge:** Electric charge is an intrinsic characteristic of many of the fundamental particles of matter that gives rise to all electric and magnetic forces and interactions.
- **Positive and negative charges:** Charges behave in different ways when subjected to external electrical fields. Conventionally they are called positive and negative.
- **Conductors:** Some substances readily allow passage of electricity through them, others do not. Those which allow electricity to pass through them easily are called *conductors*. They have electric charges (electrons) that are comparatively free to move inside the material. Metals, human and animal bodies and earth are all conductors of electricity.
- **Insulators:** Most of the non-metals, like glass, porcelain, plastic, nylon, wood, offer high opposition to the passage of electricity through them. They are called *insulators.*
- **Induction:** Accumulation of charges in parts of a body due to nearness of other charges.
- **Conservation of charge:** The net electric charge on an isolated system always remains the same.
- **Quantisation of charge:** Charges can exist only as integral multiple of 'e' (electric charge = $1.6\times10^{-19}C$ [q= ne]

Introduction

It is a matter of common experience to see a tiny spark, or hear a crackle, when one takes off synthetic clothes or sweaters, particularly in dry weather. Have you ever tried to find any explanation for this phenomenon? Another common example of electric discharge is the lightning that we see in the sky during thunderstorms. We may also experience a sensation of a mild electric shock either while opening the door of a car or holding the iron bar of a bus after sliding from our seat. The reason for all such experiences is the discharge of electric charges through our body, which were accumulated due to rubbing of insulating surfaces.

You might have also heard that this is due to the generation of **static electricity**. This is precisely the topic we are going to discuss in this unit.

Static means anything that does not move. Electrostatics deals with the study of forces, fields and potentials associated with static charges.

Electrostatics is a branch ofPhysics that deals with the phenomena and properties of stationary or very slow-moving electric charges.

Electric Charge

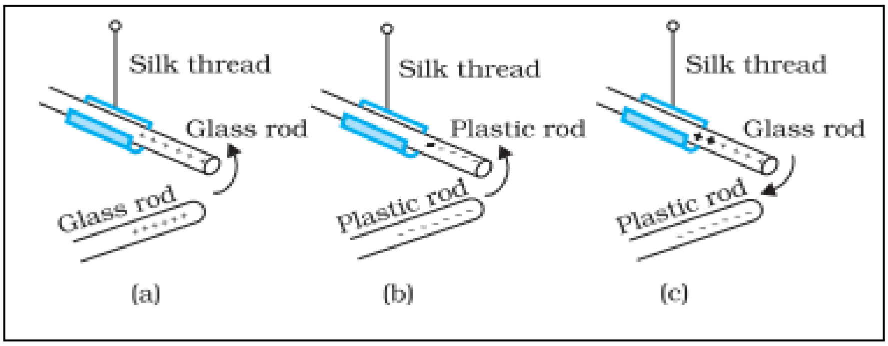
Rub a glass rod with silk. Suspend the rod by means of a thread. Bring another similarly charged rod near it. The rods repel each other.

The figure (a) shows the suspended rod repelled by the second glass rod.

Likewise, if two plastic rods / rulers are rubbed with woolen cloth, say a sweater and if one was suspended as shown in fig (b) the same repulsion can be observed between the two charged plastic rods/ rubbers.

But if the interaction between the rubbed glass rod and rubbed plastic rod is observed they would attract.

The rubbed plastic rod attracts the rubbed glass rod. (Fig. C)



We say that the bodies like glass or plastic rods, silk and wool are electrified. The experiments on frictional electricity suggested that there are two kinds of electric charges.

- **Like charges repel and**
- **Unlike charges attract each other**

It was concluded, after many careful studies by different scientists,

- There are only two kinds of *electric charge*; positive charge and negative charge.
- The rubbing results in transfer of charge
- A pair of objects on rubbing acquire opposite charges
- Charged objects lose their charge after sometime
- Hot dry weather allowed charges to remain on the object for a longer duration

https://www.youtube.com/watch?v=jpOZWnWD3W8

Pitch ball experiment

The property which differentiates the two kinds of charges is called the polarity of charge.

But how do we know which of the two rubbing bodies have positive and which one has a negative charge?

Two known combinations which have experimentally observed and have been universally accepted

- **On rubbing glass rod with silk cloth**
  Glass rod acquires positive charge and silk cloth gets negative charge
- **On rubbing plastic rod (or ebonite rod) with wool (or cat's fur)**
  Plastic rod acquires negative charge and wool gets positive charge

The above experiments just tell us that unlike charges acquired by the rubbed objects neutralize or nullify each other's effect. It was for this reason that the two kinds of charges were named as *positive* and *negative* by the American scientist **Benjamin Franklin**.

We know that when we add a positive number to a negative number of the same magnitude, their sum becomes zero. This might have been the philosophy behind naming the charges as positive and negative. By convention, the charge on the rubbed glass rod or wool is called positive and that on the rubbed plastic rod or silk is termed negative. If an object possesses an electric charge, it is said to be electrified or charged. When it has no charge it is said to be neutral.

Charging By Friction

'By Friction' implies on rubbing any two bodies/objects together. There will be friction between the surfaces in contact.

When a glass rod is rubbed with silk, the rod acquires one kind of charge while the silk acquires the second kind of charge. This is true for any pair of objects that are rubbed to get them electrified. Now if the electrified glass rod is put in contact with silk, (with which it was rubbed), the two no longer attract each other. They also do not attract or repel other light objects as they did on being electrified.

Thus, the charges acquired after rubbing are lost when the charge bodies are brought in contact. What can one conclude from these observations?

Both glass rod and plastic ruler in the experiments above were insulators

Do you think it is only possible to charge an insulator? What about other materials?

A metal rod held in hand and rubbed with wool will not show any sign of being charged. However, if a metal rod with a wooden or plastic handle is rubbed without touching its metal part, it shows signs of charging.

Suppose we connect one end of a copper wire to a neutral plastic ball and the other end to a negatively charged plastic rod. We will find that the plastic ball acquires a negative charge.

If a similar experiment is repeated with a synthetic thread or a rubber band, no transfer of charge will take place from the plastic rod to the plastic ball. Why does the transfer of charge not take place from the rod to the ball?

Some substances readily allow passage of electricity through them, others do not. Those which allow electricity to pass through them easily are called ***conductors.*** They have electric charges (electrons) that are comparatively free to move inside the material. Metals, human and animal bodies and earth are conductors.

Most of the non-metals like glass, porcelain, plastic, rubber, wood offer high resistance to the passage of electricity through them. They are called ***insulators.***

Most substances fall into one of the two classes stated above.

Charging is due to free electrons transfer from one object to the other on rubbing caused by friction.

Electrons transfer from a body with free electrons to the one that does not have the electrons as free

Let us say,

All bodies are neutral to start with, due to friction some electrons get transferred from one body to another.

The body with extra electrons gets negatively charged and deficiency of electrons in the second one gives it a positive charge.

Charging by Conduction or by Contact

When a negatively charged ebonite rod is brought in contact with a metal object, such as a sphere mounted on an insulated stand, some of the excess electrons from the rod are transferred to the sphere. Once the electrons are on the metal sphere, where they can move readily, they repel one another and spread out over the sphere’s surface. The insulated stand prevents them from flowing to the earth. If the rod is now removed, the sphere is left with a negative charge distributed uniformly all over its surface.

In a similar manner the sphere will be left with a positive charge after being put in contact with a positively charged rod. In this case, electrons from the sphere would be transferred to the rod. This process of giving one object a net electric charge by placing it in contact with another object that is already charged is known as charging by conduction/contact.

Think About This

Why should electrons from a charged ebonite rod go on to the neutral metal sphere?

What will happen if we replace the negatively charged ebonite rod with a positively charged glass rod?

Charging By Induction

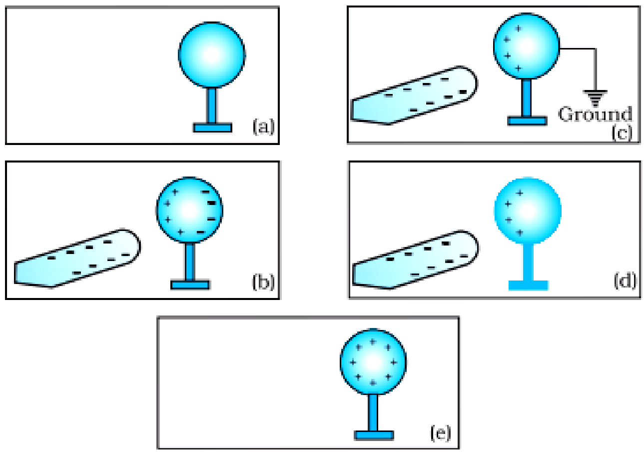
It is also possible to charge a conductor in a way that does not involve contact.

Imagine a conducting sphere mounted on an insulated stand as in Fig (a).

In Fig (b) a negatively charged rod is brought close to (but is not made to touch) the metal sphere. In the sphere, the free electrons close to the rod move to the other side (by repulsion). As a result, the part of the sphere nearer to the rod becomes positively charged and the part farthest from the rod gets negatively charged.

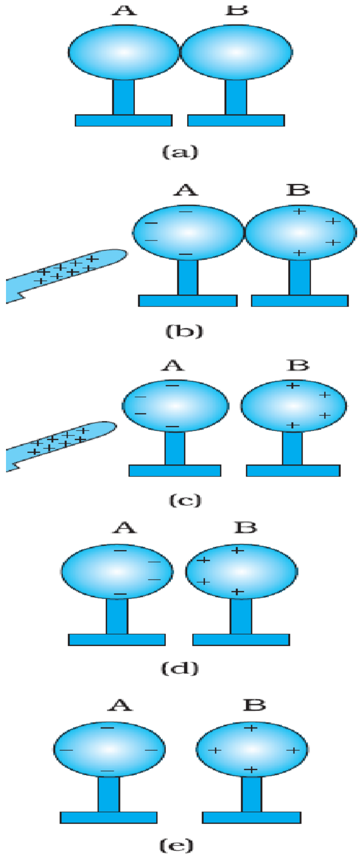
The phenomenon of temporary separation of charges in a conductor due to a charge in its vicinity is called electrostatic Induction.

We call it temporary because the separation is a result of repulsion or attraction between free electrons of the material and the external charged body, which in our case is the negatively charged ebonite rod.



The word Induction means forcing an effect.

Now if the rod is removed, the free electrons move back to their original places and the charged regions disappear. Under most conditions Earth is a good electric conductor. Hence, if a metal wire is attached between the sphere and the ground as in Fig. (c) Some of the free electrons leave the sphere and distribute themselves on the much larger earth. If the grounding wire is then removed, followed by moving away from the ebonite rod, the sphere is left with a net positive charge. This process of giving one object a net electric charge without touching it with a second charged object is called **charging by induction**.



The process could also be used to give the sphere a net negative charge, if a positively charged rod were used. Then, electrons would be drawn up from the ground through the grounding wire and onto the sphere.
So in step you:

- Mount a metal sphere on an insulated stand,
- Charge an ebonite(plastic) rod by rubbing it with wool,
- Take the negatively charged ebonite rod close to the metal sphere,
- Do not touch it,
  The free electrons would be repelled to the far end of the sphere,
- Keeping the ebonite rod in place touch (ground)the far end of the sphere,
- Remove the earthing,
- Remove the ebonite rod.

The metal sphere is positively charged.
Answer the following:

- **What if you touched the metal sphere with the charged rod?**
- **What if you remove the rod before you remove the earthing?**
- **Can we perform the above experiment with a wooden sphere?**
- **When we are charged by conduction, the same kind of charge develops on the second body, while in case of induction we give opposite charge to the body. Why?**

If the sphere were made from an insulating material like plastic, instead of metal, the method of producing a net charge by induction would not work, because very little charge would flow through the insulating material down to the grounding wire. However, the electric force of the charged rod would still have some effect as shown in figure. The electric force would cause the positive and negative charges in the molecules of the insulating material to get separated slightly, with the negative charges being pushed away from the negative rod. The surface of the plastic sphere does acquire a slight induced positive charge, although there is no net charge on it.

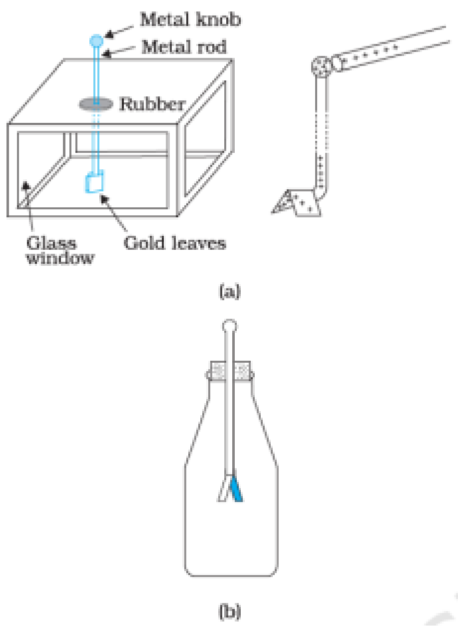
Think – About This

- **Why do the two spheres get oppositely charged?**
- **Why did we not use earthing?**
- **Is the magnitude of charge same on both the spheres?**
- **What is the source of charge on the two spheres?**

How Do We Detect Charge On A Body?

A simple apparatus to detect charge on a body is the *gold-leaf electroscope.*

It consists of a vertical metal rod housed in a box, with two thin gold leaves attached to its bottom end. When a charged object touches the metal knob at the top of the rod, charge flows on to the leaves and they diverge. The degree of divergence is an indicator of the amount of charge.



Electroscopes: (a) The gold leaf electroscope, (b) Schematics of a simple electroscope.

Make one yourself

https://www.youtube.com/watch?v=2PmWlPjV6n0

Easy to follow and make the electroscope.

Example

If we vigorously comb our hair on a dry day and bring the comb near small pieces of paper, the comb attracts the paper pieces, why?

Solution

This is an example of frictional electricity and induction. When we comb our hair, the comb gets negatively charged by rubbing. When the comb is brought near the pieces of paper some of the electrons move away from at the edge of the paper piece which is closer to the comb. At the farther end of the piece there is an excess of electrons and hence, a negative charge appears there. Such a redistribution of charge in a material, due to presence of a nearby charged body is called **induction**. The comb exerts larger attraction on the positive charges at the near end of the paper piece as compared to the repulsion on the farther away negative charges.

This is because the positive charges are closer to the comb. Hence, there is a net attraction between the comb and the paper piece.

Example

Does the attraction between the rubbed comb and the piece of papers last for a long period of time?

Solution

No, because the comb loses its net charges after some time. The excess charges on the comb are lost to the atmosphere.

Example

Can two similarly charged bodies attract each other?

Solution

Yes, when the charge on one body (q_1) is much greater than that on the other (q_2) and they are close enough to each other so that force of attraction between q_1 and the induced charge on the other exceeds the force of repulsion between q_1 and q_2. However two similar point charges can never attract each other because no net induction effects will take place in them.

Example

Does the mass of a body change due to charging?

Solution

Yes, as charging a body means addition or removal of electrons .The electron has a small but finite mass.

Example

Why is a third hole in electrical sockets provided?

Solution

All metal parts of electric appliances may end with some charge due to faulty connections. In such a situation charge can get accumulated on the surface of the appliance. When the user touches the appliance he/she may get a shock.

Human bodies are good conductors of electricity. charges can flow through the body to /from the earth.

The third hole is provided for 'grounding' the surface of electrical appliances. Through this grounding, all accumulated charge is discharged to the ground and this makes the appliance safe.

Example

An inflated balloon is charged by rubbing it to our head. Will there be a change in its size?

Solution

Because the balloon can expand the like charges repelling each other will cause the balloon to increase in size.

Basic Properties of Electric Charge

We have seen that there are two types of charges, namely positive and negative

Here, we shall now describe some **properties** of the electric charge.

- **Quantization of charge**

  Electric charge can have only discrete values. As we have learnt above, it is the electron transfer from one body to another which results in excess charge on one body and deficiency of electrons in the other.

  The smallest discrete charge that can exist in nature is the charge on electron 'e'.

  The Charge present on any object always exists in integral multiples of a fundamental unit of electric charge. Thus charge q on a body is always given by $q = ne$, where n is any integer, positive or negative, e is the magnitude of the charge on the electron.

- **Charge is conserved**

  For an isolated system, the total charge remains constant, charge is neither created nor destroyed, and it can be transferred from one body to the other.

- **Charge is additive**

  If a system contains 'n' charges q_1, q_2, q_3 ---- q_n then the total charge of the system is $q_1 + q_2 + q_3 + \text{-----} + q_n$

  Should charges add up like integers or as scalars like mass?

Yes, but they can be positive and negative, hence proper signs have to be used while adding charges .If we have $_{1}, \; _{2}, - \; _{3}, \; _{4},$. Than total charge

$q_1 + q_2 - q_3 + q_4,$ and if they were all equal in magnitude = q, the net charge will be 3q

- **Charge is invariant**

  The numerical value of charge is independent of velocity. Which means charged bodies may be stationary or moving the magnitude of charge on the body remains the same

Unit of Charge

In the International System (SI) of Units, a unit of charge is called a **coulomb** and is denoted by the symbol C.

A coulomb is defined in terms of the unit of the electric current. In terms of this definition, one coulomb is the charge flowing through a wire in 1 s, if the current is 1 A (ampere). There are other ways of defining coulomb which you will learn as we get on with the course.

In this system, **the value of the basic unit of charge is $e = 1.602192 \times 10^{-19}$ C**

Example

How many electrons are there in one Coulomb of negative charge?

Solution

The number of electrons is equal to the charge *q* divided by the charge *e* on each electron. Therefore, the number *n* of electrons is

$$n = q/e = 6\times10^{18} \text{ electrons.}$$

Thus, there are about 6×10^{18} electrons in a charge of –1C.

In electrostatics, charges of this large magnitude are seldom encountered and hence we use smaller units 1 μ C (micro coulomb) = 10^{-6}C or 1 m C (milli-coulomb) = 10^{-3} C.

Example

How can we explain quantisation of charge?

Solution

If the protons and electrons are the only basic charges in the universe, all the observable charges have to be integral multiples of *e*. Thus, if a body contains n_1 electrons and n_2 protons, the total amount of charge on the body is

$$n_2 \times e + n_1 \times (-e) = (n_2 - n_1)\, e.$$

Since n_1 and n_2 are integers, their difference is also an integer. Thus the charge on any-body is always an integral multiple of e and can be increased or decreased in multiples of e.

Coulomb's Law

We have observed that like charges repel and unlike charges attract.

How much is the repulsion? How much is the value of attraction? Can we find its magnitude and express the force of attraction or repulsion mathematically?

The law that describes how charges interact with one another was discovered by Charles Augustine de Coulomb in 1785. With a sensitive torsion balance, Coulomb measured the electric force between charged spheres. In Coulomb's experiment the charged spheres were much smaller than the distance between them so that the charges could be treated as point charges. The results of the experiments of Coulomb and others are summarized in Coulomb's law.

The Law states that-

The electrostatic force F exerted by one point charge on another acts along the line between the charges. It varies inversely as the square of the distance separating the charges and is directly proportional to the product of charges.

The magnitude of the electric force exerted by a charge q_1 on another charge q_2 at a distance r away is thus, given by-

$$F = \frac{kq_1q_2}{r^2}$$

Where k is proportionality constant and depends upon the nature of medium between the charges and the system of unit used.

In S.I. units, for vacuum it is given by:

$$\mathbf{k = \frac{1}{4\pi\epsilon o} = 9 \times 10^9\ Nm^2/C^2}$$

Where, $\epsilon_0 = 8.85 \times 10^{-12} C^2/Nm^2$ and is called **permittivity of free space.**

Thus $$F = \frac{1}{4\pi\epsilon o}\frac{kq_1q_2}{r^2}$$

The force is repulsive if the charges have the same sign and attractive if the charges have opposite signs.

Characteristics of Coulomb (Electrostatic) Force

Regarding Coulomb's law the following points are worth noting:

- Electrostatic force produces mechanical displacement of objects that are charged, this effect is seen if the objects on which the force is applied are allowed to move, like we saw in the case of suspended ebonite or glass rods or pieces of paper charged by induction are attracted towards the plastic comb.
- Electrostatic force acts along the line joining the centers of the two spherical charged bodies, for charged distributions points may be obtained depending upon the distribution of charges.
- Coulomb's law stated above describes the interaction of two point charges. When two charges exert forces simultaneously on a third charge, the total force acting on that charge is the vector sum of the forces that the two charges would exert individually. This important property, called the principle of superposition of forces, holds for any number of charges.
- The electric force is an action reaction pair, *i.e.*, the two charges exert equal and opposite forces on each other.
- The electric force is conservative in nature.
- Electric forces are very much stronger than the gravitational forces. For example, the electric force between a proton and an electron is nearly 10^{39} times the gravitational force between them.

Constant of Proportionality and the Intervening Medium

Coulomb's law, as we have stated above can be used for charges in vacuum. If some dielectric (insulator) is present in the space between the charges, the net force acting on each charge is altered because charges are induced in the molecules of the intervening medium.
The electrostatic or Coulomb force decreases K times of the intervening medium. Here K is a dimensionless constant which depends on the medium and called **dielectric constant** of the medium.
For medium other than air or vacuum, the electrostatic/coulomb force 'F' is given by:

$F = \frac{1}{4\pi\epsilon_0 \kappa k} \frac{k q_1 q_2}{r^2}$ where κ (kappa) is called relative permittivity or dielectric constant of the medium.

Permittivity or **absolute permittivity** is the measure of influencing effect on a medium affected by the presence of a charge. The permittivity of a medium describes how much electric effect is 'generated' per unit charge in that medium.

Example

A charge Q is to be distributed over into two small objects. What should be the value of the charge on the objects so that force between the two objects becomes maximum, when they are kept a given distance apart?

Solution

Let charge on one body be ‘q’ hence on the other it will be Q - q

Therefore, $$F = \frac{1}{4\pi\epsilon o}\frac{q(Q-q)}{r^2}$$

For F to be maximum,

$$\frac{dF}{dq} = 0$$

$$\therefore \frac{1}{4\pi\epsilon_0 r^2}\frac{d}{dq}\left(qQ - q^2\right) = 0$$

Or

$$Q - 2q = 0$$

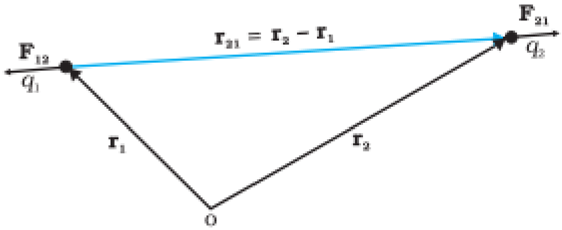
$$\therefore q = \frac{Q}{2}$$

Thus, for maximum force, at a given distance both the objects should have equal charges.

Vector Form of Coulomb’s Law

Since force is a vector, it is necessary to write Coulomb’s law in its full vector form.

Let the position vectors of charges q_1 and q_2 be $\mathbf{r_1}$ and $\mathbf{r_2}$ respectively



We denote force on q_1 due to q_2 by $\mathbf{F_{12}}$ and force on q_2 due to q_1 by$\mathbf{F_{21}}$.

The two point charges q_1 and q_2 have been numbered 1 and 2 for convenience and the vector leading from 1 to 2 is denoted by r_{21}:

$$\mathbf{r}_{21} = \mathbf{r}_2 - \mathbf{r}_1$$

In the same way, the vector leading from 2 to1 is denoted by r_{12}:

$$r_{12} = r_1 - r_2 = - r_{21}$$

The magnitude of the vectors $\mathbf{r}_{21}$ and $\mathbf{r}_{12}$ is denoted by r_{21} and r_{12}, respectively ($r_{12} = r_{21}$). The direction of a vector is specified by a unit vector along the vector.

Coulomb's force law between two point charges q_1 and q_2 located atr_1 and r_2 is then expressed as-

$$F_{21} = \frac{1}{4\pi\epsilon_{\circ} k}\frac{q_1 q_2}{r^2} r_{21}$$

Hence we find that-

$$\mathbf{F}_{21} = -\mathbf{F}_{12}$$

Summary

- From simple experiments on frictional electricity, one can infer that there are two types of charges in nature; and that two like charges repel and two unlike charges attract each other. By convention, the charge on a glass rod rubbed with silk is taken as positive; that on a plastic rod rubbed with wool, is taken as negative.
- Conductors allow easy movement of electric charge through them, insulators do not. In metals, the mobile charges are electrons; in electrolytes both positive and negative ions are mobile.
- Electric charge has three basic properties: quantization, additivity and conservation.
- Quantization of electric charge means that total charge (q) of a body is always an integral multiple of a basic quantum of charge (e) i.e.,
  $q = n\,e$, where $n = 0, \pm 1, \pm 2, \pm 3$,.... Proton and electron have charges
  $+e$, $-e$, respectively. For macroscopic charges for which n is a very large number, quantization of charge can be ignored, we can think of their charges as being (almost) continuous.

- Additivity of electric charges means that the total charge of a system is the algebraic sum (i.e., the sum taking into account proper signs) of all individual charges in the system.

- Conservation of electric charges means that the total charge of an isolated system remains unchanged with time. This implies that when two objects are charged through friction, there is a transfer of electric charge from one object to another, there is no net creation or destruction of charge.
- Coulomb's Law: The mutual electrostatic force between two point charges q_1 and q_2 is proportional to the product q_1q_2 and inversely proportional to the square of the distance r separating them.
- The ratio of electric force and gravitational force between a proton and an electron is of the order $10^{39.}$ Electrical forces are, therefore, very much stronger than gravitational forces.