BAL BHARATI PUBLIC SCHOOL PITAMPURA

SESSION 2020-21 CLASS 12 PHYSICS

Chapter–1 NCERT Electric Charges and Fields PART 1

INSTRUCTIONS

1 This is one of the most vast and important chapters of class 12th physics which consists of the following topics as per CBSE syllabus

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 fleld. 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)

In this lecture we are going to do the following topics

Electric Charges; Conservation of charge, Coulomb's law-force between two point charges,

2 First 3 chapters of NCERT part 1 have a combined weightage of 16 marks in the CBSE examination.

3 To fully prepare this chapter , you can practice previous year question papers of CBSE given along here.

4 Kindly do the assignment in your physics registers.

5 It is very important to attempt the numericals simultaneously .

Main points of the chapter

Electrostatics means study of charges at rest.

Properties of charge

Electric charge can be defined as simply excess or deficit of electrons in a body. Charge cannot exist without a body carrying it.

It is possible to develop the charge by rubbing two objects together. Process of charging is called **electrification**. Electrification due to friction is called **frictional electricity**.

Since these charges are not flowing it is also called **static electricity**.

There are two types of charges. +ve and −ve.

Similar charges repel each other, Opposite charges attract each other.The number of positive and negative charges are **equal**, hence **matter is basically neutral.**

Inequality of charges give the material a **net** charge which is equal to the difference of the two type of charges.

Triboelectric series *:If two substances are rubbed together the former in series acquires the positive charge and later, the –ve.*

Some of the items in the series are

(i) Glass (ii) Flannel (iii) Wool (iv) Silk (v) Hard Metal (vi)Hard rubber (vii) Sealing wax (viii) Resin (ix) Sulphur

Basic properties of Electric charge

1 Additivity of Charges

Charge on anybody is the algebraic sum of all charges on it.

2 Quantization of Electric charge

Charge on anybody is the integral sum of the basic of basic electronic charge (e). Charge on a body Q is given by

Q = + ne where n is a whole number 1,2,3…..and e = 1.6 x 10^{-19} C

3 Conservation of Charges

The electric charges also follow the rules of conservation.

Isolated (Individual) Electric charge can neither be created nor destroyed, it can only be transferred.

Eg At Nuclear level : Decay of U-238

$^{238}U\ 2 = ^{234}Th + ^{4}He_2$ (Radio active decay)

In any nuclear reaction the total number of charges before and after remain conserved.

Example. Annihilation (destruction in pair)

In a nuclear process an electron -e and its antiparticle positron +e undergo annihilation process in which they transform into two gamma rays

$e^- + e = \gamma + \gamma$

Example Pair production is reverse of annihilation, Charge is also conserved when a gamma ray transforms into an electron and a positron

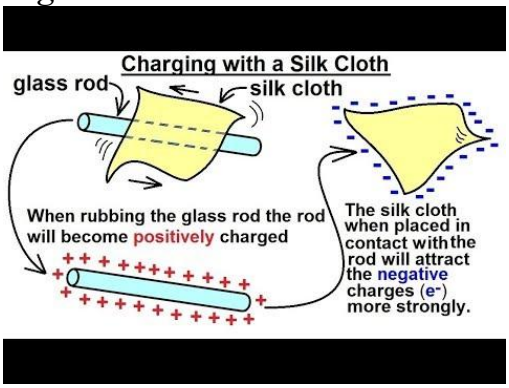
$\gamma = e^- + e^+$ (pair production)

Methods of Charging

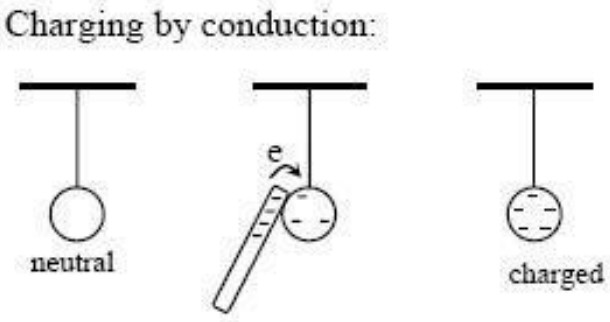
A body can be charged in three ways, charging by friction, charging by conduction and charging by induction.

Charging by Friction

When we rub glass rod with a piece of silk, glass rod loses electrons and gains positive charge and silk cloth acquires negative charge as it gains electrons.



Charging by Conduction



When a negatively charged rod touches the metallic sphere , some of the electrons pass to the sphere. As a result the sphere acquires negative charge by conduction.

If the rod were positively charged, then some of the electrons of sphere will move to the rod and the sphere would become positively charged.

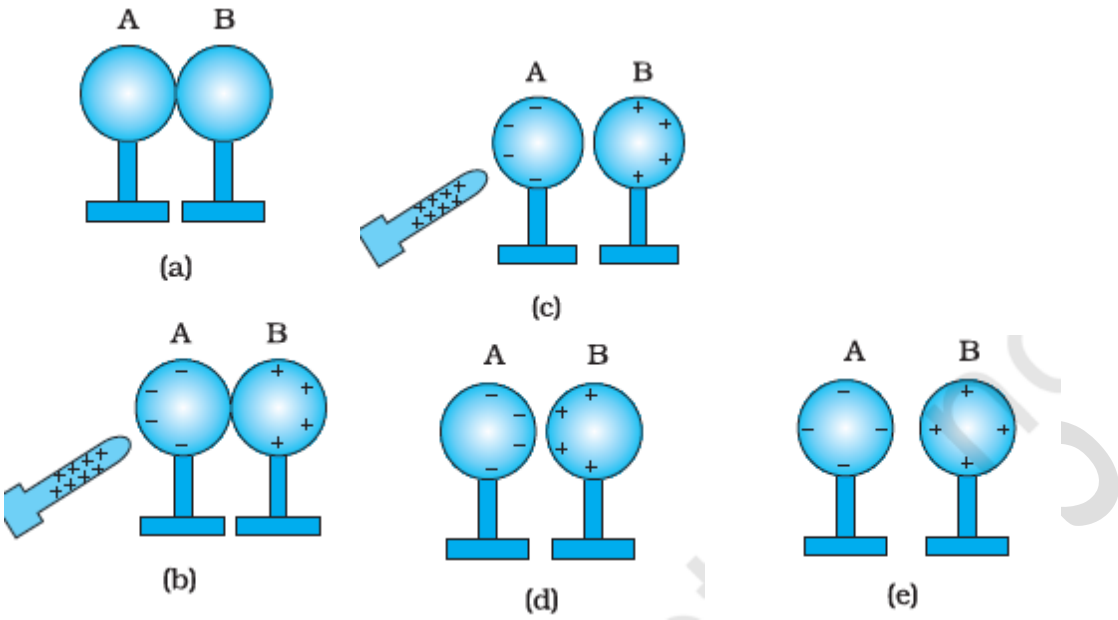
1. When charged object touches a neutral object, they both end up with the same type of charge.
2. When two charged objects are made to touch each other, total charge of the system is conserved and they share the total charge according to their capacities. So if a body had 1 C charge and another had -1C , they would neutralize each other.

If they had different amount of charges after contact, they would be either have negative or positive charged.

If two objects have the same size, they share charges equally after conduction. If they had different sizes, they would end up with charges according to their radii.

Charging by Induction

We can also charge conductors without contact.



A and B conductors are neutral at the beginning. When we bring a positively charged rod near them, it attracts the electrons in the conductors. Electrons move to the left part. Thus, when we separate plates A and B they are charged by induction, A is negatively charged and B is negatively charged.

Coulomb's law in Electrostatics :

Force of Interaction between two stationery point charges is directly proportional to the product of the charges and is inversely proportional to the square of the distance between them and acts along the straight line joining the two charges.

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

The value of k depends upon system of units and on the medium between two charges. ***k is called electrostatic force constant.***

It is seen experimentally that if two charges of 1 Coulomb each are placed at a distance of 1 meter in air or vacuum, then they attract each other with a force (F) of 9×10^9 Newton.

Accordingly value of **k is 9×10^9 Newton m^2/C^2**

SI unit of Charge

In S.I. System of units, the unit of charge is **Coulomb.**

One coulomb is defined as that charge, which, when placed at a distance of 1 m in vacuum from an equal and similar charge, will repel it with a force of 9 x 10^9 Newton

k is also equal to $\frac{1}{4\pi\varepsilon_0}$

ε_0 is *permittivity of free space or vacuum and* its value is 8.85 x 10^{-12} C^2 / N m^2

ε_0 is read as epsilon knot

If point charges are immersed in a dielectric medium, then ε_0 is replaced by ε a quantity-characteristic of the material involved . For vacuum *we use* ε_0

Permittivity, Relative Permittivity and Dielectric Constant

Permittivity is a measure of the property of the medium surrounding electric charge which determines the forces between the charges.

$\varepsilon_0$is known as absolute permittivity of that medium .

More is Permittivity of medium, Less is Coulombs Force.

For water, permittivity is 80 times than that of vacuum, hence force between two charges in water will be 1/80 time force in vacuum (or air.)

Relative Permittivity(εr) : It is a dimension-less characteristic constant, which express absolute permittivity of a medium w.r.t. permittivity of vacuum or air. It is also called Dielectric constant (K)

$K = \varepsilon r = \frac{\varepsilon}{\varepsilon_0}$

Relation between Force in Vacuum and Force in medium

Let two charges be placed a distance d apart in vacuum, force between them is

$$F0 = \frac{1}{4\pi\mathcal{E}_0}\frac{q_1 q_2}{r^2}$$

Let two charges be now placed in a medium of permittivity € placed same distance d apart, force between them is

$$Fm = \frac{1}{4\pi\mathcal{E}}\frac{q_1 q_2}{r^2}$$

Dividing the two, we get

$$\frac{F0}{Fm} = \frac{\mathcal{E}}{\mathcal{E}_0} = \boldsymbol{K}\ (\boldsymbol{dielectric\ constant})$$

Vector form of Coulombs" Law

$$\boldsymbol{F0} = \frac{1}{4\pi€0}\frac{q_1 q_2}{\boldsymbol{r}^2}\hat{\boldsymbol{r}}$$

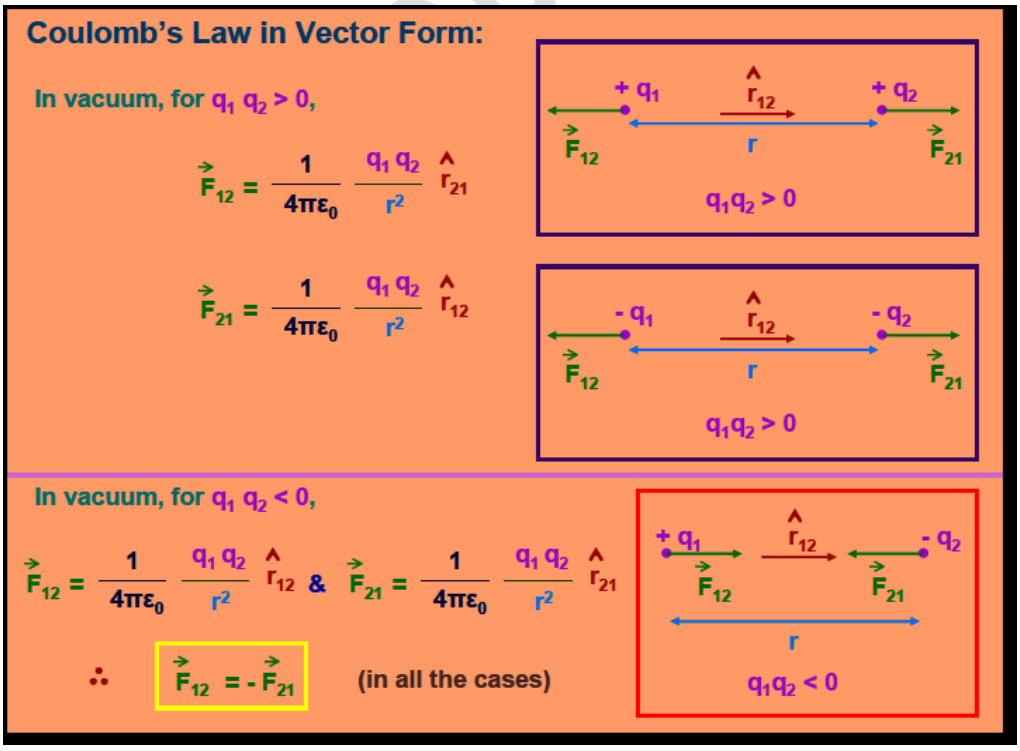


Image courtesy Prayash Mohapatra

Video links

Methods of Charging

https://www.youtube.com/watch?v=UKdtJeH63eU

Prof Walter Lewin's lecture (long but amazing)(*covers this topic and beyond)*

https://www.youtube.com/watch?v=x1-SibwIPM4

Coulombs law experimental

https://www.youtube.com/watch?v=B5LVoU_a08c

ASSIGNMENT

1 Two protons placed near one another with no other objects close by would

a) accelerate away from each other.
b) remain motionless.
c) accelerate toward each other.
d) be pulled together at constant speed.
e) move away from each other at constant speed.

2 Two point charges are in placed in vacuum exert F on each other. If they are placed in a medium of constant K and distance between them is halved, find the new force.

3 Two point charges repel each other with a force F when placed in water of dielectric constant 81.What will the force between them when placed the same distance apart in air?

4 Two electrons have been removed from each atom. Find the distance between two such atoms, if they repel each other with a force of 8.8×10^{-9} N, when placed in free space.

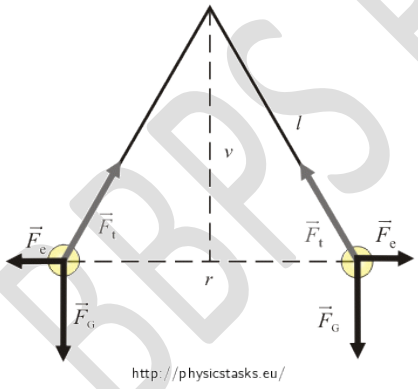
5 If two point charges q1 and q2 are 3m apart and their combined charge is 20μC. If one repels the other with a force of 0.075 N, What are the two charges?

6 Two equal and similar charges separated by a distance of 2 cm repel each other with a force of 1.25×10^7 N. Find the magnitude of the charges in coulomb.

7 In hydrogen atom, the electrical force of attraction between the electron and proton is 8.1×10^{-8} N. Calculate the distance between the electron and proton. Given charge of electron $= 1.6 \times 10^{-19}$ C.

8.Two insulated charged copper spheres A and B have identical sizes and the charge on each of them is 6.5×10^{-7} C repel each other with a force F. A third sphere of same size but uncharged is brought in contact with the first and then brought in contact with the second and finally removed from both. What is the force of repulsion between A and B.

9 Two pith balls of mass 2 g each are suspended from a common point by means of a silk threads, each of length 20 cm. When the balls are given equal and similar charges, the balls are repelled so that each of the two threads makes an angle of 30° with the vertical. Determine the charge on each ball.(hint , loo at the diagram and make FBD of any one ball)



10 Two point charges 4e and e each, at a separation r in air, exert force of magnitude F. They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged?

11 Plot a graph showing the variation of coulomb force F versus where r is the distance between the two charges of each pair of

charges: (1μC, 2μC) and (2μC, -3μC) Interpret the graphs obtained. [Hint : graph can be drawn choosing –ve axis for force only]

12 What is the difference between charging by induction and charging by friction?

13 Compare Electrostatic force with the Gravitational force. You can give both similarities and differences.

14 Two spheres; 4.0 cm apart, attract each other with a force of 1.2 x 10^{9} N. Determine the magnitude of the charge on each, if one has twice the charge (of the opposite sign) as the other.