Lecture 1

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Electrostatics

Materials can be classified as :-

- conductors that permit electrons to flow freely from particle to particle
  this means that → conductors have many free electrons.
- Insulators :- the particles of the insulator do not permit the free flow of electrons.
- Semiconductors.

$\boxed{\text{Charged bodies}}$ → negatively charged bodies

$\boxed{\text{Charged bodies}}$ → positively charged bodies

$$Q = n\,|e|$$

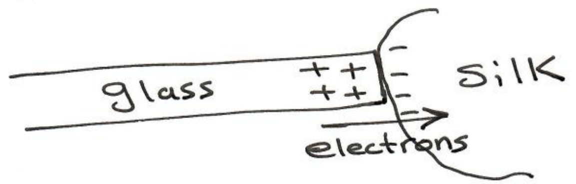
$|e|$ → $1.6 \times 10^{-19}\,C$

Q → charge of the body

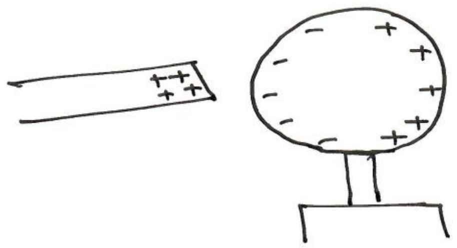
n → no of electrons transferred to or from the body

Charging by friction:

Rubbing two different materials together is the simplest way to give something a charge. The two objects are made of different materials, their atoms will hold their electrons with different strengths. As they pass over each other, electrons with weaker bonds transfer from one material to the other material.



Charging by induction

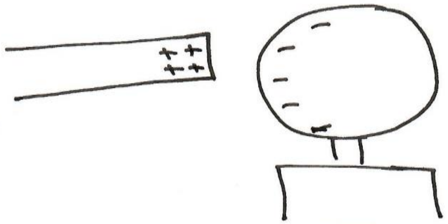


(a)

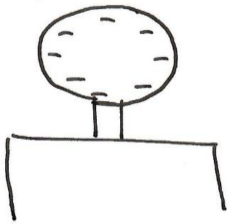
Charging by Induction

(b)

(c)

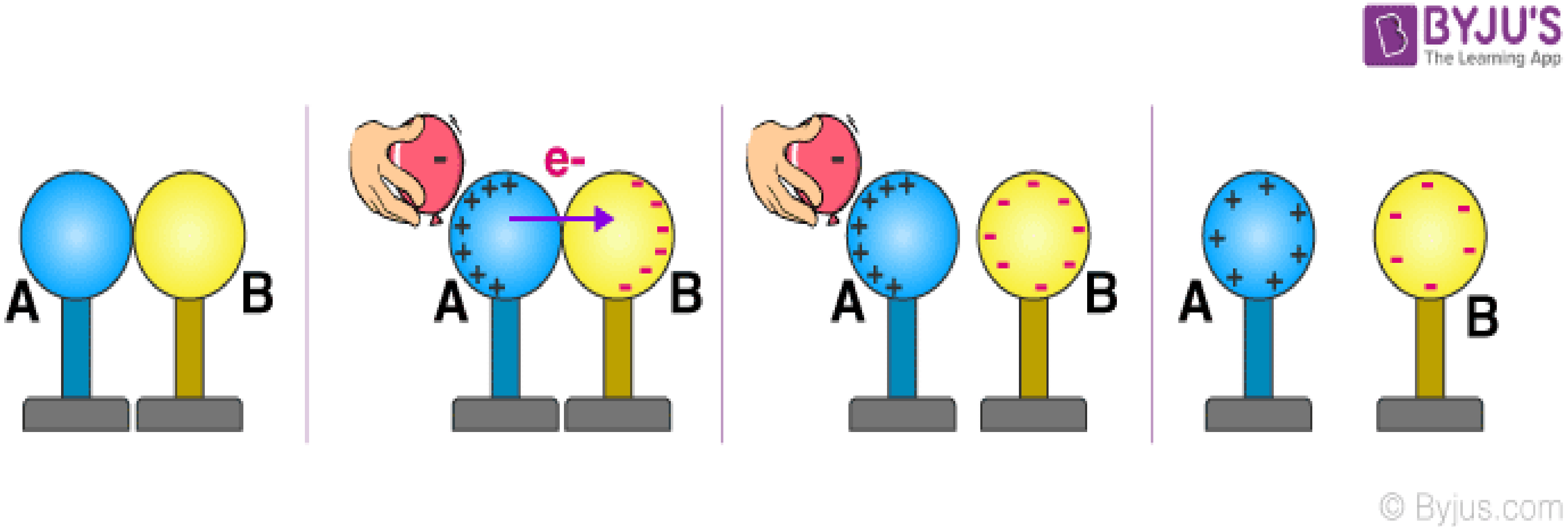


(d)



The material of the sphere is a conducting material.

Charging by Induction



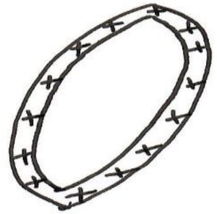
Charged bodies can be classified as:-

[1] point charge $\longrightarrow$ the body has neglected dimensions and can be considered as a point.

[2] Linear charge distribution :-

The charge of this body is distributed linearly as (rod or ring)

$$\lambda = \frac{Q}{L}$$



$$\lambda = \frac{Q}{2\pi R}$$

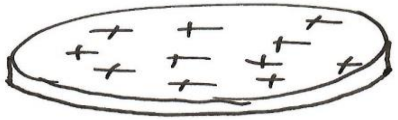
[linear charge density] $\lambda = \dfrac{\text{Total charge}}{\text{total charged length}}$

$\lambda \longrightarrow C/m$

3 Surface charge distribution

The charge of this body is distributed on its surface and the body has nearly two dimensions. as:

Charged disc



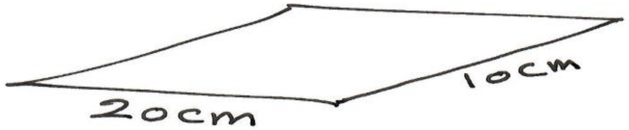
$$\sigma = \frac{Q}{\pi R^2}$$

$$\sigma = \frac{\text{Total charge}}{\text{total charged area}} \quad C/m^2$$

Surface charge density

Charged paper

$\sigma = 5 \mu C/m^2$



$$Q = \sigma A$$
$$= 5 \times 10^{-6} (0.1 \times 0.2) = 10^{-7} C/m^2$$

4 Volume charge distribution

The charged body has three dimensions and the charge is distributed inside its volume

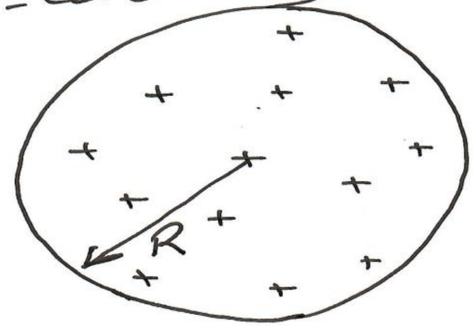
$$\rho = \frac{\text{total charge}}{\text{total charged volume}}$$

$\rho \rightarrow$ Volum charge density in C/m^3

Charged Spheres

The distribution of charges depends on the material of the sphere

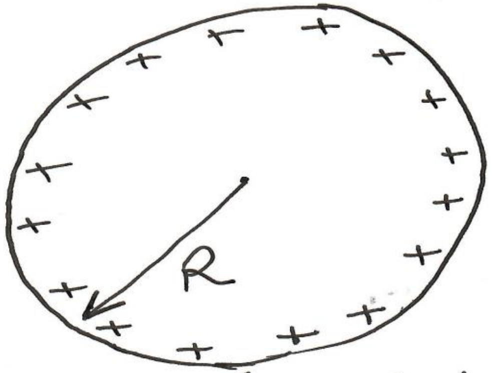
Non-Conducting



Volume dist.

$$\rho = \frac{Q}{\left(\frac{4}{3}\pi R^3\right)}$$

Conducting



Surface dist.

$$\sigma = \frac{Q}{(4\pi R^2)}$$

Note that

We will study only uniform charge distribution.

This means that λ, σ and ρ will be given as constants.

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ex:- A charged arc has radius (5cm) and a charge of (−4 nC). If the angle of that arc equals (60°) find

a- λ ?

b- Number of electrons added to or removed from the arc to have such charge

$$\lambda = \frac{Q}{\text{length}} = \frac{Q}{R\,\theta}$$

$$\lambda = \frac{-4\times10^{-9}}{0.05\ \frac{60\times\pi}{180}} = -7.64\times10^{-8}\ C/m$$

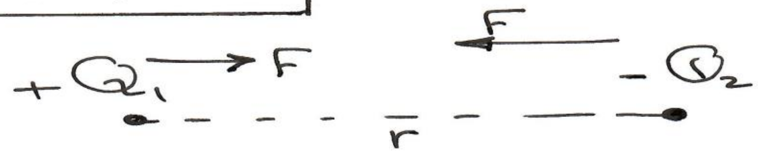
$$= -76.4\ nC/m$$

$$Q = ne$$

$$4\times10^{-9} = n\,(1.6\times10^{-19})$$

$n = 2.5\times10^{10}$ electrons added

Coulomb's Law



$$F = K \frac{|Q_1|\,|Q_2|}{r^2}$$

* The rule is used to get the attraction or repulsion force between Q_1 and Q_2
* The rule is used for point charges.
* r is the distance between Q_1 and Q_2

$K \longrightarrow$ The electric constant

- for free space $K = 9\times10^9 = \dfrac{1}{4\pi\epsilon_0}$

  ϵ_0 is called permitivity for free space

- for any medium

$$K = \frac{9\times10^9}{\epsilon_r} = \frac{1}{4\pi\epsilon_0\epsilon_r}$$

ϵ_r is called relative permittivity for medium

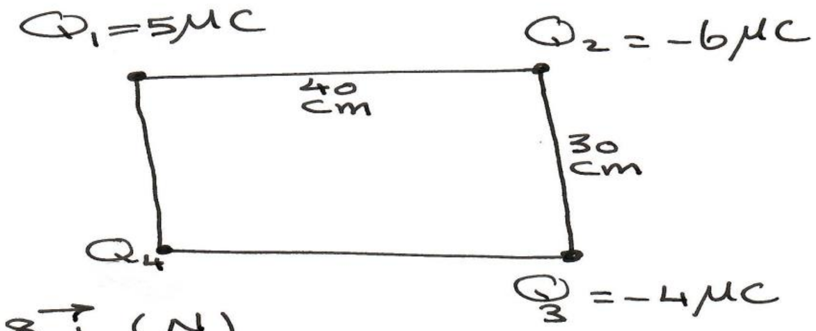
$$\epsilon_r \geqslant 1$$

it equals one for air or vacuum.

* Note that F is vector it has a magnitude and a direction

prob.

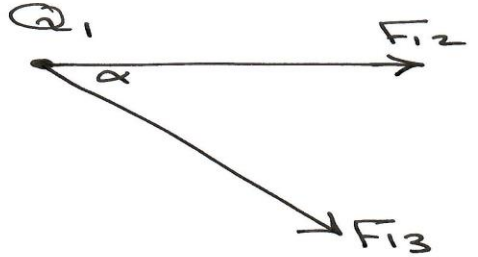
If the elect. force acting on Q_1 is given as



$F_1 = x\vec{i} + 0.568\vec{j}$ (N)

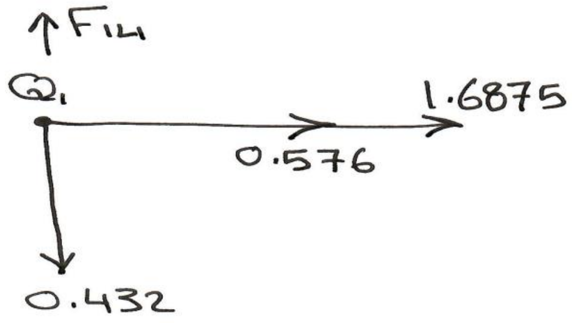
find Q_4 and x

Soln



$$F_{12} = \frac{9 \times 10^9 \times 30 \times 10^{-12}}{(0.4)^2} = 1.6875\ N$$

$$F_{13} = \frac{9 \times 10^9 \times 20 \times 10^{-12}}{(0.5)^2} = 0.72\ N$$



$F_{13} \cos\alpha = 0.72 \frac{40}{50}$
$= 0.576\ N$

$F_{13} \sin\alpha = 0.72 \frac{30}{50}$
$= 0.432\ N$

$\therefore F_{1y} = 0.568$

$\therefore 0.568 = F_{14} - 0.432$

$F_{14} = 1.0\ N$

$$1.0 = \frac{9 \times 10^{9} \times 5 Q_4 \times 10^{-12}}{(0.3)^2}$$

$Q_4 = 2\ \mu C \quad (+ve)$

$x = F_{1x} = 1.6875 + 0.576$

$= 2.2635\ N.$

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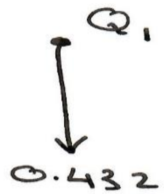
* If $F_{1y} = -1.2\ N$



$-1.2 = -0.432 + F_{14}$

$F_{14} = -0.768\ N$

it is directed down and the force is att.

$\therefore Q_4$ is $(-ve)$.

* Two isolated small spheres with the same diameter are made from a conducting material. The distance between the spheres equals (0.3 m). If the charge of the first sphere is (12 nC) and that for the second sphere is (-18 nC) find the electric force between them in (N).

(A) 2.16×10^{-5} rep. **(B)** 9×10^{-7} att. **(C)** 2.16×10^{-7} att.
(D) 9×10^{-5} rep. **(E)** 2.16×10^{-5} att.

* In the previous problem, if the two spheres are connected using a conducting wire calculate the force between them. Note that the distance between the spheres is kept constant.

(A) 2.16×10^{-5} rep. **(B)** 9×10^{-7} att. **(C)** 2.16×10^{-7} att.
(D) 9×10^{-5} rep. **(E)** 2.16×10^{-5} att.

$\because R_1 = R_2$ $\therefore$ $\boxed{Q_1' = Q_2' \text{ after connection}}$

$Q_1 + Q_2 = Q_1' + Q_2'$ → Conservation of charges

$= 2Q_1'$

$12 - 18 = 2Q_1'$

$Q_1' = -3\,nC$, $Q_2' = -3\,nC$

Befor connection

$$F = \frac{9\times10^{9}\times12\times18\times10^{-18}}{(0.3)^2} = 2.16\times10^{-5}\,N \text{ (att.)}$$

After connection

$$F' = \frac{9\times10^{9}\times3\times3\times10^{-18}}{(0.3)^2} = 9.0\times10^{-7}\,N \text{ (rep.)}$$

Note $Q_{trans.} = -15\,nC$