Physics 104

Ch 2: Electric Field

Part 1

Ch 23 on textbook

▲ *Mother and daughter are both enjoying the effects of electrically charging their bodies. Each individual hair on their heads becomes charged and exerts a repulsive force on the other hairs, resulting in the "stand-up" hairdos that you see here. (Courtesy of Resonance Research Corporation)*

Lecture Content

- Concept of electric charges.
- Charging object by *induction.*
- Coulomb's Law.

Electric Charges

- Electromagnetic forces between charged objects are one of the fundamental forces in nature.
- Concentrate on Electric Force in this part.
- Experiment: comb your hair, approach the comb from bits of papers, what will happen? Why?
- Rub a balloon to your hair or a wool and then approach it to a wall. What will happen? And Why?

(a) The charged object on the left induces a charge distribution on the surface of an insulator due to realignment of charges in the molecules. (b) A charged comb attracts bits of paper because charges in molecules in the paper are realigned.

Electric Charges

The material is electrically charged, or electrified.

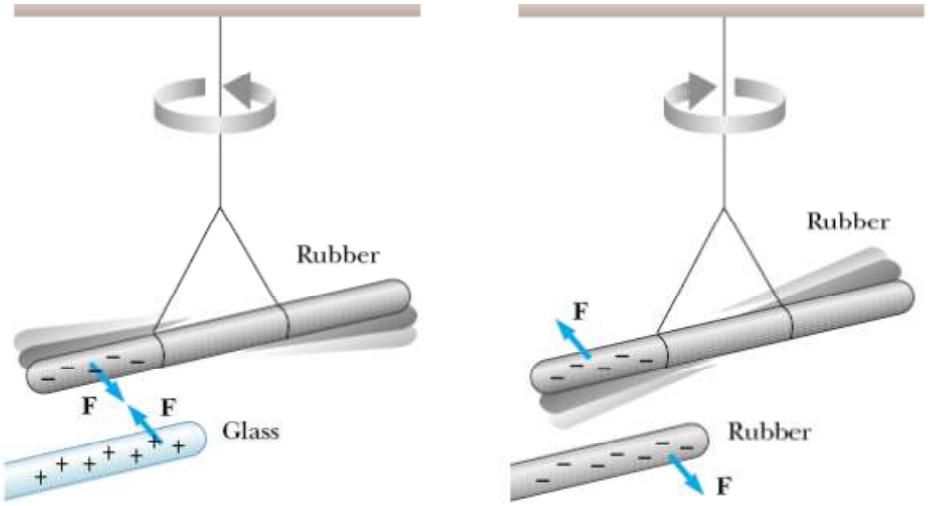
Experiment:

Rub rod of rubber with fur, suspend it.

Rub rod of glass with silk, approach the rubber rod.

What's happened?

Rub another rubber rod with fur, approach from the suspended rubber rod. What will happen?



Conclusions

- There is a force acting between the rods. It is attractive and repulsive depending on???
- The electric charge on each object. (+ve, -ve, or neutral). When objects are neutral no electric force between them.
- Charges of the same type repel each other when they in close by (Rubber rods), and different types attract each other (Rubber and glass rods).

Properties of Electric Charges

- Charges always conserved in isolated system. (Electrons transferred from fur '+ve' to the rubber rod '-ve'.
- The electric charge (q) is quantised. $q = N\,e$. Millikan's experiment in 4 wks time.
- $e = 1.6 \times 10^{-19}$ C.

Material Electrical Classification

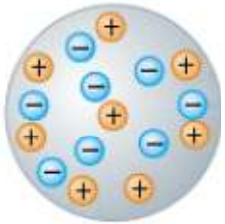
•Conductors: Cu, Fe, Human body. Free electron not bound to the atoms and can move freely through the material.

•Isolators: Wood, rubber, glass. Atoms bound to the material and cannot move freely. (realignment of charges in molecules).

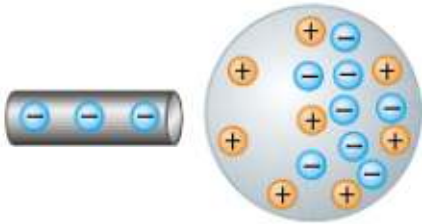
•Semiconductors: between Conductors and isolators. Silicon and germanium. Chips fabrication. Electrical properties can be changed over orders of magnitude by addition of a controlled amount of certain atoms to the material.

Charging Object by *Induction*

Charging a conductor with positive charge using Induction



(a)



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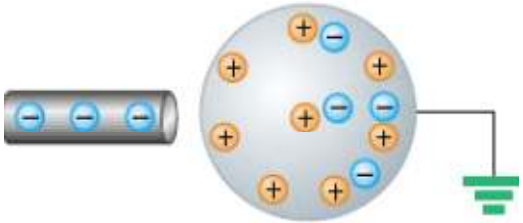

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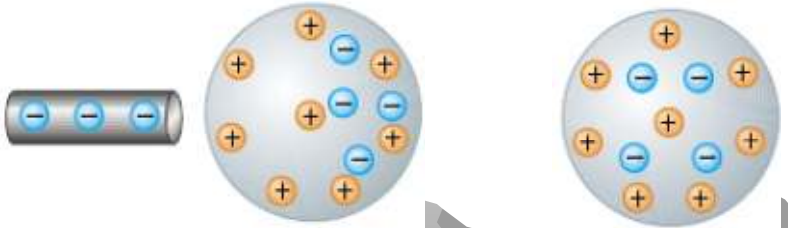
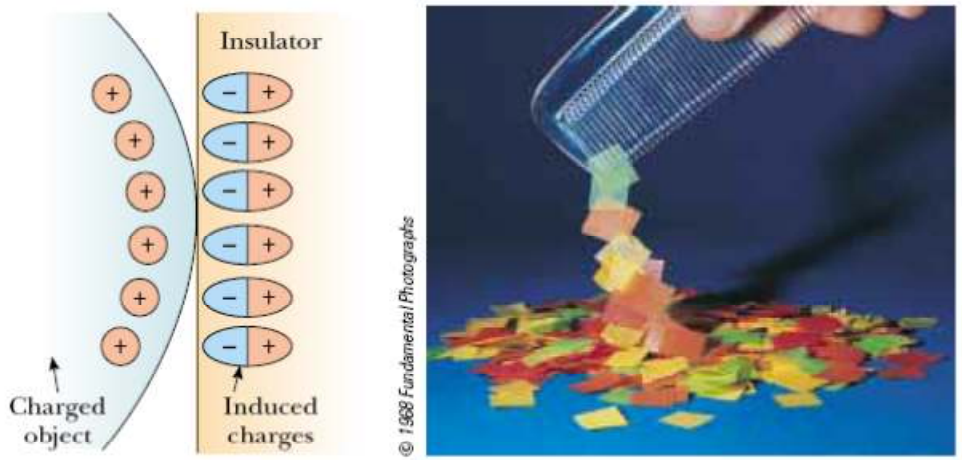


(d) (e)

- Bring neutral (uncharged) sphere conductor. (protons = electrons).
- Approach a negatively charged rubber rod from the sphere.
- Connect the sphere to the ground by a wire (conductor).
- Approach the rod again. Some electrons will migrate to the ground. < electron on the sphere.
- Disconnect the wire from the sphere. Let the rod away from the vicinity of the sphere. The sphere will be effectively POSITIVELY charged. Why?
- Does the rubber lose some of its negative charge?

Charging Object by *Induction*

- Charging by induction requires no contact.
- Charging object by rubbing (like rubber and fur) is by conduction. Realignment of charges in the material molecules at the surface of each bit of the paper below.



(a) The charged object on the left induces a charge distribution on the surface of an insulator due to realignment of charges in the molecules. (b) A charged comb attracts bits of paper because charges in molecules in the paper are realigned.

Coulomb's Law

•The Magnitude of electric force between point charges q_1 and q_2 (particles of zero size that carries charge):

$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

•F_e is the electric force between the charges q_1 and q_2 which are separated by a distance r. k_e is Coulomb's constant. Its value depends on the system of units used. For SI units, it is:

$$k_e = \frac{1}{4\pi\epsilon_0} \qquad k_e = 8.987\,5 \times 10^9\ \mathrm{N \cdot m^2/C^2}$$

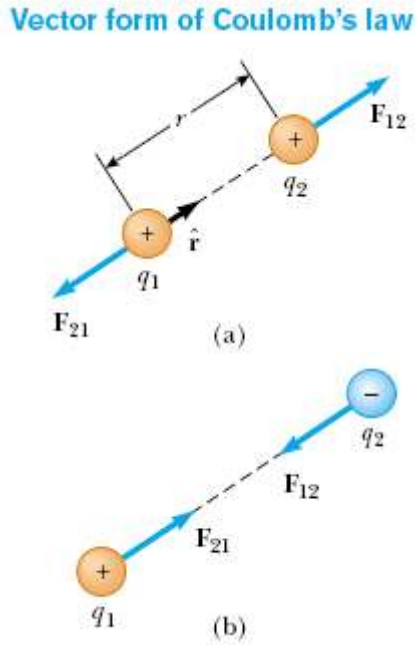
•ε_0 is the permittivity of the free space and has the value of:

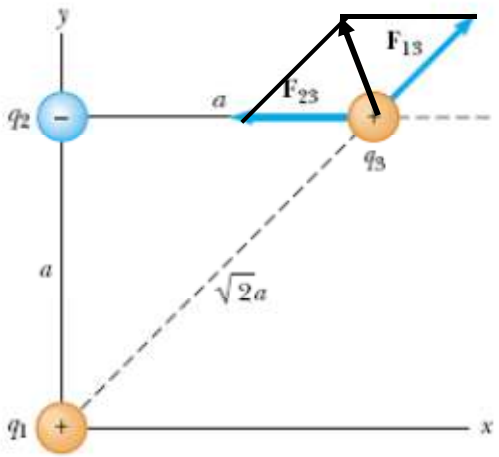
$$\epsilon_0 = 8.854\,2 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$$

•F_e is a vector!!! Different charges attractive force, similar charges repulsive force.

Coulomb's Law

- F_e is a vector!!! Different charges attractive force, similar charges repulsive force.
- When more than two charges are present, the resultant electric force acting on one of them will be the vector sum (ΣF_e) of the various forces acting by all surrounding charges on the target charge.





Conclusions

- Charges are conserved, quantified.
- Materials either conductors, isolators, or semiconductors.
- Charging objects (conductors) by induction.
- Coulomb's law. Electric force is a vector quantity.
- The electric force between similar charges is repulsive, while in different charges is attractive.
- What's next? Examples on Coulomb's Law, electric fields.

Possible exam questions

- How to charge a sphere conductor by a negative charge?
- Problem solving on Coulomb's Law