## Electrostatics

The properties of electricity (electric charge) play an essential role in our everyday lives. For example:

1. Matter is composed of atoms which are in turn composed of electric charges (protons (positive) and electrons (negative)).
2. We wouldn't be able to move without electricity because; our muscle contraction requires electricity.
3. Our heart wouldn't beat without electricity.
4. We wouldn't have computers without electricity.
5. Overall, we wouldn't be around without electricity.

The Atom

The atom consists of a very small nucleus that contains protons and neutrons. The protons have positive charge and the neutrons have NO charge. The number of protons is equal to the atomic number of the element. Moving around the nucleus are particles called electrons. The electrons have negative charge. The magnitude of the charge on the electron is equal to that of the proton. The atom is held by the electric force between the protons and the electrons.
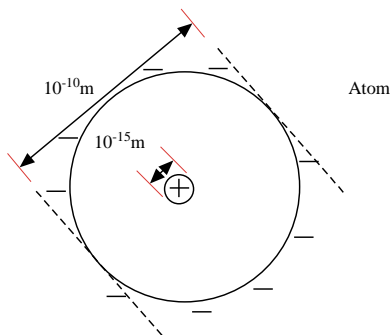
m_p=1.67 x 10^{-27}kg ≈ m_n
m_e = (1/1800) m_p

In a neutral atom, the number of electrons is equal to the number of protons. If they are different, we say that atom is ionized. In general, when we talk about the charge on an atom or any body, we mean the net charge.

Electric Charge

A neutral body acquires a net negative charge by gaining negative charges or losing positive charges. A neutral body acquires a net positive charge by gaining positive charges or losing negative charges.

In metals, the transfer of charge is due solely to the motion of the valence electrons in the atoms and not the protons in the nucleus. The protons are extremely tightly bound to the nucleus and cannot be added or removed from the nucleus.

This brings up the following question:

Can charge move freely on any type of material? NO!!!

Material are sometimes classified in terms of their ability to conduct electric charges.

Conductors and Insulators

Conductors – materials in which electric charges move freely.
Ex. Cu, Al, Ag

Insulators – materials in which electric charges cannot move freely.
Ex. glass, rubber, wood

Semiconductors – materials that have electrical properties between those of
conductors and insulators. Ex. Si, Ge

Experimental Proof of Electrical Charge

Rubbing a rod with certain materials will cause the rod to become charged. According to the convention established by Benjamin Franklin (which we still use) a plastic rod rubbed with fur becomes negatively charged and a glass rod rubbed with silk becomes positively charged. Since we now know that rubbing a plastic rod transfers electrons to the rod, then we say that electrons have negative charge.

Ex. Plastic rod rubbed with fur placed near a neutral conductor

plastic rod rubbed with fur

conductor

Ex. Plastic rod rubbed with fur placed near a neutral conductor
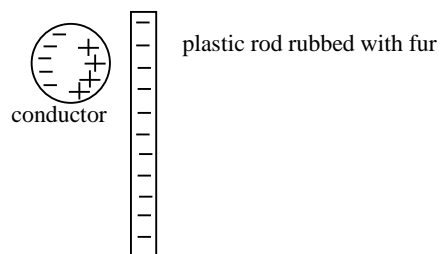
plastic rod rubbed with fur
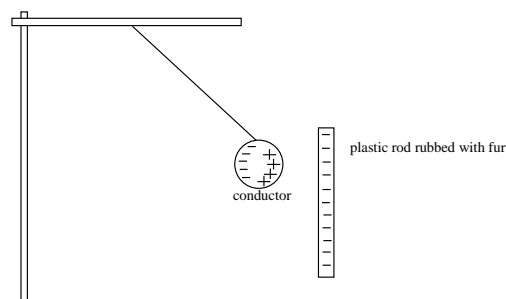
conductor

Ex. If rod makes contact with conductor then it will transfer its charge to the conductor and the conductor becomes negatively charged! If we now charge the rod once again and move it close to the charged conductor, they now repel each other.


plastic rod rubbed with fur
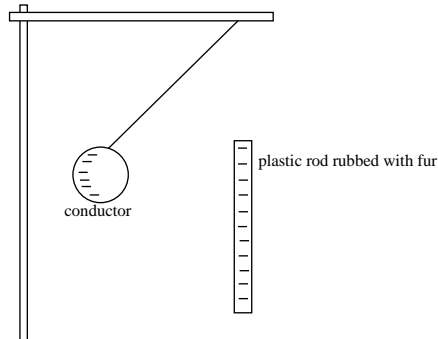
conductor

Ex. Glass rod rubbed with silk. If we now move the glass rod near the negatively charged conductor above we see that it now attracts the conductor proving that the rod must have opposite charge.

conductor
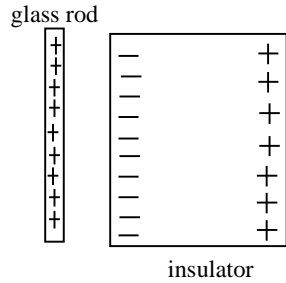
glass rod rubbed with silk
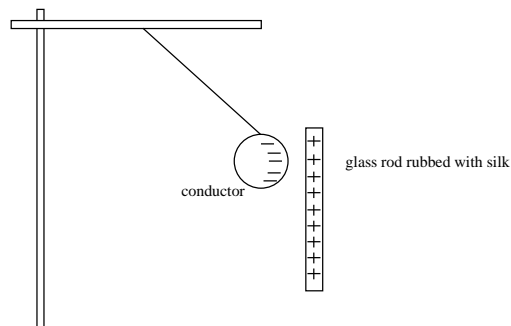
Charge Polarization
Charge polarization is the separation is the slight charge separation in a neutral object.
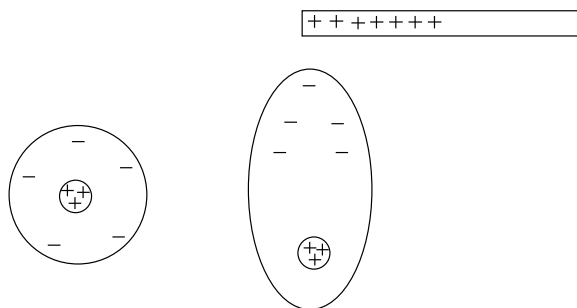
This slight separation of charge is what causes a neutral conductor or insulator to be attracted to a charged object.
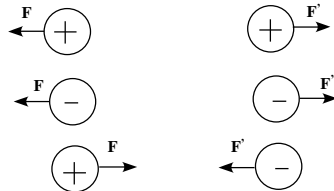
glass rod

insulator

Demo 1 – show positive and negative grids superimposed
Demo 2 – show electroscope
Demo 3 – show balloon (insulator) attracted to a charged rod
Demo 4 – show lighting up neon electric discharge tube

A. Qualitative

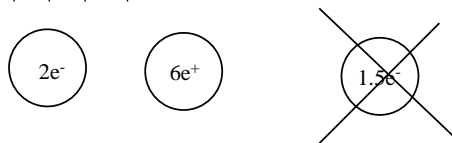1. There are two types of charges: positive and negative
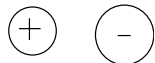
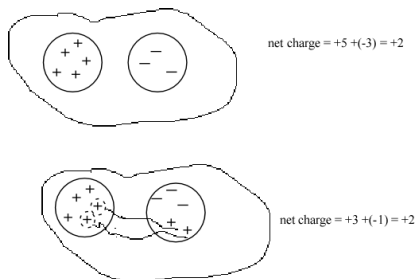2. Unlike charges attract and like charges repel

3. Charge is quantized. Electric charge always occurs as an integer multiple of some fundamental unit of charge. The fundamental unit of charge is the charge on the electron or proton.

$$\left|e^-\right|=\left|p^+\right|=1.6\times10^{-19}C$$

4. Charge is conserved
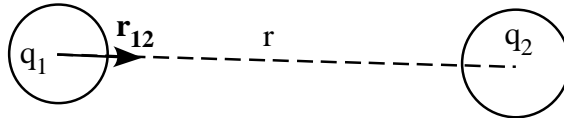

net charge = +5 +(-3) = +2

net charge = +3 +(-1) = +2

5. Neutral objects have same number of positive and negative charges.

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B. **Quantitative**

1. Coulomb's Law

$$\vec{F}_{12} = \frac{kq_1q_2}{r^2}\hat{r}_{12}$$

$$k = 9.0 \times 10^9 \frac{Nm^2}{C^2} = \text{Coulombs constant}$$

* note that this equation is sign sensitive

$F = Newton$

$q = Coulombs$

$r = meters$

$k = \dfrac{Nm^2}{C^2}$

The Coulomb constant is sometimes written in the following form:

$$k = \frac{1}{4\pi\varepsilon_o}, \text{ where } \varepsilon_o = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

ε_o = permittivity of free space

1 C of charge is a very large quantity of charge. Typical value of charges are μC and nC.

When dealing with Coulomb's Law you must remember that force is a vector quantity and must be treated vectorially.

Superposition Principle – The net force on a charge is equal to the vector sum of the forces due to all the surrounding charges.