DRIFT OF ELECTRONS

The process of supplying the electric charge (electrons) to an object or losing the electric charge (electrons) from an object is called charging. An uncharged object can be charged in different ways.

- Charging by friction
- Charging by conduction
- Charging by induction

- **Charging by friction**

When an object is rubbed over another object, the electrons get transferred from one object to another. This transfer of electrons takes place due to friction between the two objects. The object that transfers electrons loses negative charge (electrons) and the object that accepts electrons gains negative charge (electrons).

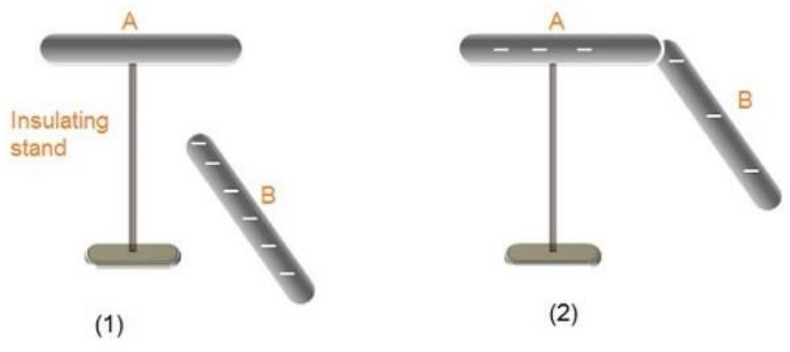
Hence, the object that gains extra electrons becomes negatively charged and the object that loses electrons becomes positively charged. Thus, the two objects get charged by friction. The charge obtained on the two objects is called friction charge. This method of charging an object is called electrification by friction.

- **Charging by conduction**

The process of charging the uncharged object by bringing it in contact with another charged object is called charging by conduction.

A charged object has unequal number of negative (electrons) and positive charges (protons). Hence, when a charged object is brought in contact with the uncharged conductor, the electrons get transferred from charged object to the conductor.

Consider an uncharged metal rod A kept on an insulating stand and a negatively charged conductor B as shown in below figure (1).



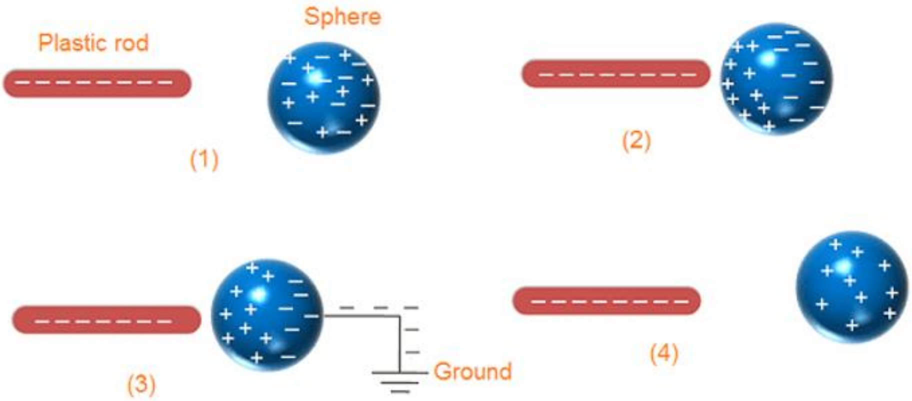
If we touch the uncharged conductor A with the negatively charged conductor B, transfer of electrons from charged conductor to uncharged conductor takes place. Hence, uncharged conductor gains extra electrons and charged conductor loses electrons. Thus, uncharged conductor A becomes negatively charged by gaining of extra electrons.

Similarly, uncharged conductor becomes positively charged if it is brought in contact with positively charged conductor.

- **Charging by induction**

The process of charging the uncharged object by bringing another charged object near to it, but not touching it, is called charging by induction.

Consider an uncharged metal sphere and negatively charged plastic rod as shown in below figure (1). If we bring the negatively charged plastic rod near to uncharged sphere as shown in below fig (2), charge separation occurs.



The positive charges in the sphere get attracted towards the plastic rod and move to one end of the sphere that is closer to the plastic rod. Similarly, negative charges get repelled from the plastic rod and move to another end of the sphere that is farther away from the plastic rod. Thus, the charges in the sphere rearrange themselves in a way that all the positive charges are nearer to the plastic rod and all the negative charges are farther away from it.

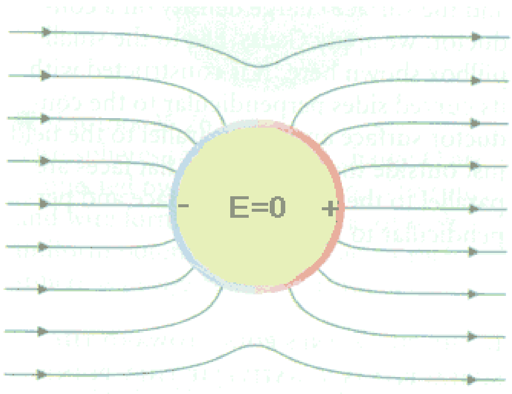
If this sphere is connected to a ground through the wire as shown in fig (3), free electrons of the sphere at farther end flow to the ground. Thus, the sphere becomes positively charged by induction. If the plastic rod is removed as shown in fig (4) all the positive charges spread uniformly in the sphere.

Conductors in electrostatics

Materials can be classified according to the ease with which electrons can freely move through the material. In some materials the outer electrons are firmly bound to their respective nuclei. They can be pulled more towards one or the other side of the nucleus they are bound to, but they cannot leave it. Those materials are called **insulators**. In other materials the outermost electrons are free to move through the material. They cannot easily leave the material but can move freely from atom to atom. Those materials are called **conductors**. Some materials are insulators at low temperatures, but become conductors as the temperature is raised. The number of electrons that can freely move through the material increases with temperature. Those materials are called **semiconductors**.

In a conductor electrons are free to move. If they are acted on by a force, they will accelerate in the direction of the force. If a conductor is placed into an external electric field, a force **F** =

-e**E** acts on each free electron. Electrons accelerate and gain velocity in a direction opposite to the field. Soon electrons will pile up on the surface on one side of the conductor, while the surface on the other side will be depleted of electrons and have a net positive charge. These separated negative and positive charges on opposing sides of the conductor produce their own electric field, which opposes the external field inside the conductor and modifies the field outside.



When enough electrons have piled up on one side and enough positive charge has been left on the other side, then the field produced by these separated charges exactly cancels the external field inside the conductor, and electrons inside the conductor no longer experience a force. This is the case in the picture shown above. The inside of the conducting sphere is field-free, while the previously constant external field outside has been modified.

In static equilibrium the inside of a conductor is field free. If it were not, electrons would move and distribute themselves, so as to cancel out the field. The inside of a conductor cannot contain any net charge. Such charges would produce a field inside the conductor, and electrons would move and cancel out the field and neutralize the charge. Any excess charge on a conductor must therefore reside on the surface. The field just outside the conductor at the surface must be perpendicular to the surface. If it were not, electrons would redistribute themselves to cancel out the field.

The surface of any conductor is an equipotential surface. The field is everywhere perpendicular to the surface. The strength of the electric field near the surface of a conductor is

$E = \sigma/\varepsilon_0$,

Where σ is the surface charge density, $\sigma = \Delta Q_{surface}/\Delta A$.

No work is being done moving a charge along on the surface.

The surface of a spherical conductor with radius R, carrying a charge Q is at a potential

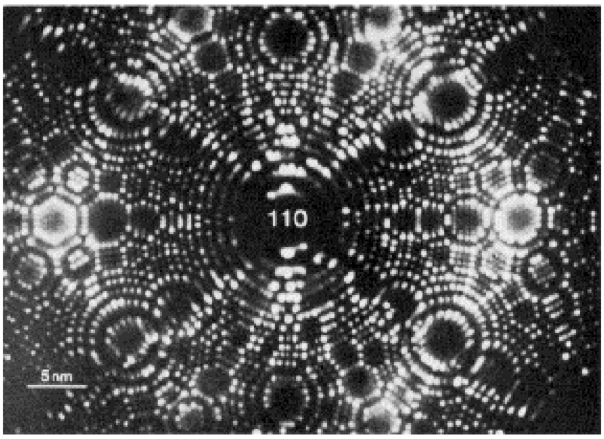
$$V = k_eQ/R.$$

If we have two spherical conductors with radii R_1 and R_2, respectively, at the same potential V, they carry charges $Q_1 = R_1V/k$ and $Q_2 = R_2V/k$, respectively. The electric fields near their surfaces are $E_1 = k_eQ_1/R_1^2 = V/R_1$ and $E_2 = k_eQ_2/R_2^2 = V/R_2$ respectively. The smaller the radius, the larger is the electric field.

Near the surface of a conductor, the field is largest in places with the smallest local radius of curvature.

Very strong fields are found near sharp conducting tips. Air molecules will be stripped of electrons if the field becomes too large (~3*10^6 V/m). The free electrons accelerate and collide with other molecules to make more ions and electrons. A plasma forms between the conductor and the ground and the conductor discharges. This is called a **corona discharge**.

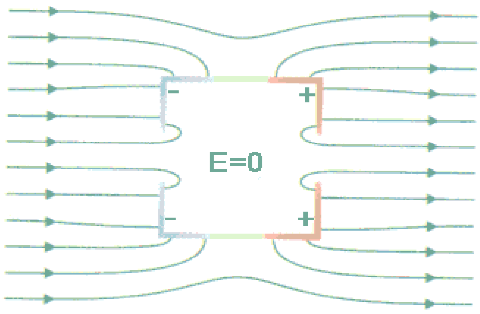
A device that makes use of the strong field near a tip is the field ion microscope. The field ion microscope has a sharp tip with a local radius of curvature of ~10 - 100 nm. This tip faces a phosphor screen. Under vacuum, a potential difference is established between the tip and the screen. The tip is held at the more positive potential. A small amount of inert gas is admitted, and gas atoms near the tip are ionized. Electrons are ripped off these atoms. The positively charged ions are accelerated by the intense electric field along a straight line toward the phosphor screen, where they are detected by converting their kinetic energy into light. Each point on the tip maps into a different point on the screen, so that a magnified, image of the tip can be viewed. Since the tip is only 10 - 100 nm in radius, one can achieve atomic resolution. A typical field ion microscope image of a 'single crystal' tungsten tip is shown below.



The bright spots correspond to positions on the tip where the electric field is particularly high, i.e. where the local radius of curvature is particularly small. This happens near atoms, so the microscope images the position of atoms in the tip.

In electrostatic equilibrium a conductor has the following properties.

- Any excess charge resides on the surface of the conductor.
- The electric field is zero within the solid part of the conductor.
- The electric field at the surface of the conductor is perpendicular to the surface.
- Charge accumulates, and the field is strongest, on pointy parts of the conductor.



The entire conductor is at the same potential. There is no field inside the conductor. A cavity inside a conductor, completely surrounded by conducting material, also is free of electric fields, if it does not contain any net charge itself. A conductor shields its interior from any outside electric fields**.** A charge located within a cavity in a conductor at equilibrium feels no force from charges outside the conductor. Even if there are holes in the surface, the electric field does not penetrate very far. A rule of thumb is that the electric field falls to zero over a distance approximately equal to the diameter of the hole.

In the diagram on the right, the field only penetrates a small distance through the holes into the box with conducting walls.

Charge Distribution in Clouds

- lightning is generated to reduce a build-up of positively and negatively charged areas in a cloud
- Most all lightning is observed in cold clouds - those containing water, super cooled water, and ice.
- within a cold cloud, a region of positive charge is generated at the top of the storm
- a region of negative charge builds up in the lower part of the storm

How is this charge distribution created??

- this process is not completely understood
- Leading theories suggest that the charge separation is created as hail and graupel fall through supercooled drops and ice crystals.
- the resulting collisions separate the charge -
    - the large hail and graupel particles acquire a negative charge and fall to the lower part of the storm.
    - the smaller supercooled water particles and ice crystals acquire a positive charge - are carried to the top of the storm in the updraft.