4.2 CHARGE ON METALS

The movement of the conduction electrons

In metals there are a large number of freely movable electrons, called conduction electrons. For instance, in sodium, a good conductor, each atom has 11 electrons, ten of which are tightly bound to the nucleus containing 11 protons and twelve neutrons, and one electron per atom is free to roam in the sample.

When you place a piece of a metal near a positive charge, the conduction electrons in the metal will be attracted to the external positive charge and migrate freely towards that region. The region the electrons move to now will have an excess of electrons over protons in the nuclei of atoms and the regions from where the electrons have migrated out will have more protons than electrons. Consequently, the metal will develop a negative region near the charge and a positive region at the far end as shown in Fig. 4.2. This separation of equal magnitude and opposite type is called polarization of the metal body. If you remove the external charge, the electrons migrate back and neutralize the positive region.

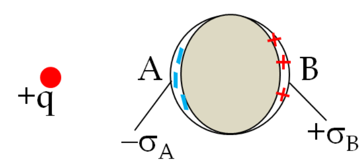

Figure 4.2: Polarization of metallic sphere by an external point charge $+q$. The near side of the metal is oppositely charged compared to the far side of the metal. The metal is said to be "polarized". When you remove the external charge, the polarization of the metal also disappears.

The polarization of the metal happens only when there are external charges around. You can think of this in terms of electric fields. The external charge creates an electric field, which we can call external electric field. When the metal is placed in the region of this electric field, the electrons and protons of the metal experience electric force due to this external electric field but only the conduction electrons are free to move in the metal over macroscopic distances. The movement of the conduction electrons leads to the polarization which creates electric field in addition to the external electric field. The external electric field and internal electric field act on the charges of the metal and will be balanced when the static condition reaches in the metal.

The inside surface versus the outside surface

An interesting property of a conductor in a static equilibrium is that extra charges on the conductor end up at the outer surface of the conductor no matter where they originate from. Figure 4.3 illustrates a situation when we bring an external positive charge inside the cavity of a metal and then touch at the inside surface. Initially the inside surface of the cavity is negatively charged and the outside surface of the conductor is positively charged. When we touch the inside surface of the cavity the induced charge is neutralized leaving the outside surface and the whole metal charged with a net positive charge.

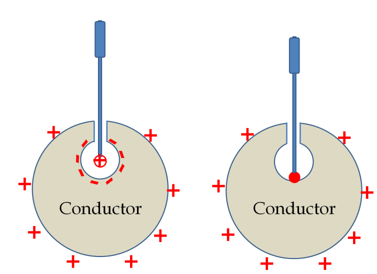

Figure 4.3: Electric charges on a conductor migrate to the outside surface of a conductor no matter where you put them initially.

The fact that electric charges reside only upon the outside surface of a conductor can be illustrated with a rather simple experiment. Place an aluminum cup on plastic plate. Put charges on it either by induction from a charged glass rod, or transferring charges from a van de Graaf generator, or some other means at your disposal. Now, bring a metal ball suspended by an insulating cord, touch the outside surface of the cup, and then bring the ball near the knob of an electroscope. You will find that the leaves of the electroscope separate, proving that there is charge on the outside surface side of the cup. Repeat the experiment by touching the metallic ball to the inside surface of the cup. When you bring the metallic ball to an electroscope, now you will find no deflection, proving no charge on the inside surface of the cup. Suppose you charge the metallic ball, touch the inside surface of the aluminum cup, and bring the ball to an electroscope. What would you observe? Once again, you will find that there is no charge on the ball: the ball loses all its charge, and the charges migrate out to the outside surface of the cup.

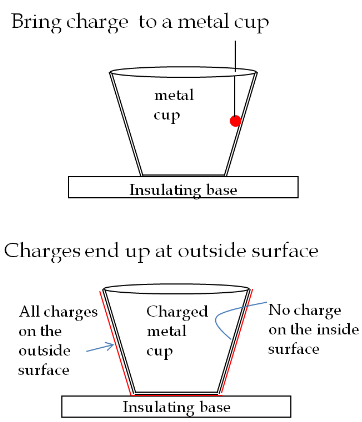

Figure 4.4: Electric charges reside only on the outside surface of a conductor

Distribution of charges on the surface

Another interesting aspect of charge distribution on a conductor is that charges tend to be denser where the curvature of the surface is greater as demonstrated by the charge distribution on an oblong-shaped metal (Fig. 4.5). The surface charge density will be higher near the tip than the other side. You can use a proof plane, a small flat metal disk with an insulting handle, and an electroscope. Touch different parts of the charged oblong metal with the proof plane, and then touch the knob of an electroscope with the charged proof plane. The amount of deflection of the leaves will be the greatest when the proof plane touches at the tip of the oblong metal, demonstrating a highest charge density at the point when the surface has the largest curvature.

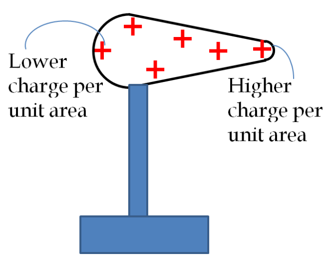

Figure 4.5: The distribution of charge density in an oblong-shaped conductor.