2.4 ELECTRIC FIELD IN FREE SPACE ,CONDUCTOR AND DIELECTRIC

A conductor has an abundance of charge that is free to move. When an external electric field $\boldsymbol{E}$ is applied, the positive free charges are pushed along the same direction as the applied field, while the negative free charge move in the opposite direction. This charge migration takes place very quickly. The free charges do two things. First they accumulate on the surface of the conductor and form an induced surface charge. Second, the induced charges set up a internal induced field $\boldsymbol{E}$., which cancles the externally applied field $\boldsymbol{E}$.This leads to an important property of a conductor

If the valence band merges smoothly into a conduction band, then additional kinetic energy may be given to the valence electrons by an external field, resulting in an electron flow. The solid is called a metallic conductor. Since there is no forbidden energy gap for metal, the required applied energy is extremely small. It has an excellent conductivity.

A **perfect conductor** $(\boldsymbol{\sigma} = \infty)$ cannot contain an electrostatic field with it.

Consider ohm's law $\boldsymbol{J} = \boldsymbol{\sigma E}$ .To maintain a finite current density$\boldsymbol{J}$, in a perfect conductor $(\boldsymbol{\sigma} \rightarrow \infty)$,requires that the electric filed inside the conductor $\boldsymbol{\sigma} = \infty$,vanish. In the other word, $\boldsymbol{E} \rightarrow \mathbf{0}$ **because** $\boldsymbol{\sigma} \rightarrow \infty$ in a perfect conductor. If some charges are introduced in the interior of such a conductor, the charges will move to the surface and redistributed themselves quickly in such a manner that the filed inside the conductor vanishes. According to Gauss's law, if $\boldsymbol{E} = \mathbf{0}$ **,** the charge density $\boldsymbol{\rho_v}$ must be zero. we conclude again that a perfect conductor cannot contain an electrostatic field within it.

Under static condition

$$\boldsymbol{E} = \mathbf{0}, \quad \boldsymbol{\rho_v}, \quad \boldsymbol{V_{ab}} = \mathbf{0} \quad \textit{inside a conductor}$$

Where $\boldsymbol{V_{ab}}$is the potential difference between points $\boldsymbol{a}$ and $\boldsymbol{b}$

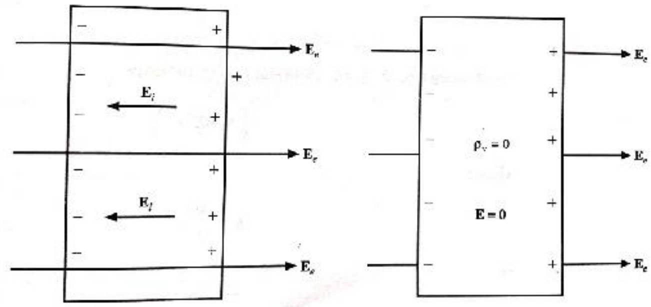

Figure 2.4.1 An isolated conductor under the influence of an applied voltage

[Source: "Elements of Electromagnetics" by Matthew N.O.Sadiku, page-173]

If the forbidden energy gap between valance band and conduction band of a material is high, it requires large applied energy to conduct. The material is called an dielectric. In dielectric electrons are tightly bounded.

In electromagnetic, conductors and dielectrics are defined based on the ratio of conduction to displacement currents ratio of conduction. Current to displacement current is $\frac{\sigma}{\omega\varepsilon}$ where σ the conductivity of the medium is, ε is the permittivity of the medium and ω is the angular frequency $\frac{\sigma}{\omega\varepsilon}$=1 is considered to mark the dividing line between conductors and dielectrics. For good conductors $\frac{\sigma}{\omega\varepsilon}$ much greater than 1 and for good dielectric S is less than 1 in the ratio frequency range.

The molecules of dielectric material have two types. They are non-polar molecules and polar molecules. The molecules whose centre of positive and negative charges coincides are called non-polar molecules. The molecules whose centre of charges is displaced from each other are called polar molecules. When dielectric material made up of non-polar molecules is placed in an electric field a displacement of negative and positive charges takes place in opposite directions and produces a dipole which is aligned with the electric field.