Dielectric

CONTENTS

Types of dielectric

Polar-dielectric

Non Polar-Dielectric

Polarisation of dielectric

Dielectric Constant

Electric Polarisation

Electric polarisation vector

Electric Susceptibility

Relation between Dielectric constant and Susceptibility

Dielectric

Dielectrics are the materials which contain no free electron so that no current can flow through them. As a result the electrical conductivity of dielectric is poor and for ideal dielectric it is zero.

According to band theory of solids dielectric are the materials in which the energy band gap between valence band and conduction band is more than 3ev. For example glass, mica, rubber etc

Types of dielectric:

There are two types of dielectric:

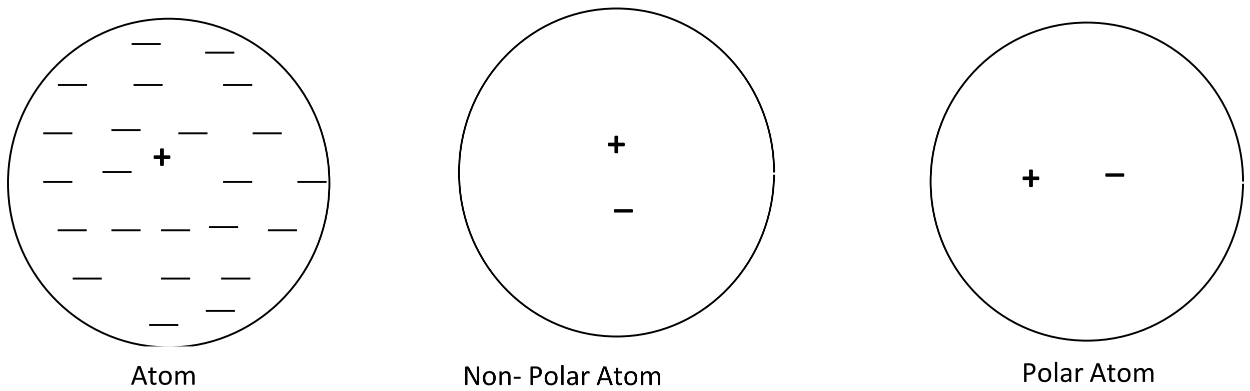
(1) Non-polar dielectric.

(2) Polar dielectric.

Dielectric

Polar-dielectric:

The positive charge of a nucleus may suppose to be concentrated at a point say the centre of gravity of positive charge. Similarly the whole of negative charge due to electron in an orbit may be supposed to be concentrated at a point called centre of gravity of negative charge.



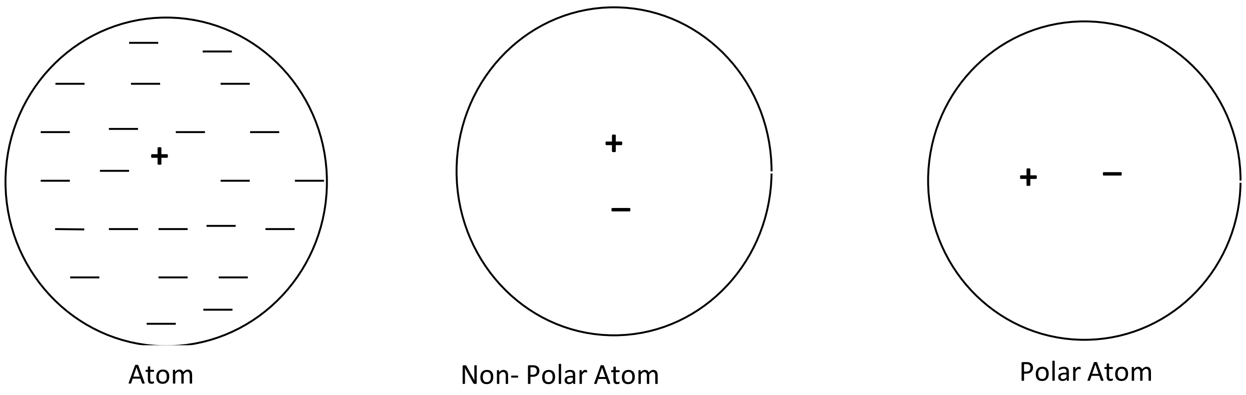
In case of the two centre of gravity do not coincide that they are displaced from each other, thus the molecule as a whole possess some charge and has permanent electric dipole moment, and the molecule is said to be a polar molecule. And the dielectrics which contain polar molecule are called polar dielectric.

Dielectric

Non Polar-Dielectric

When these two centre of gravity coincide in a molecule, such a molecule will have no resultant charge and such type of molecule have no permanent dipole moment.

Therefore such type of molecule are called non-polar molecule, and the dielectric which contain non-polar molecule are called non-polar dielectric.

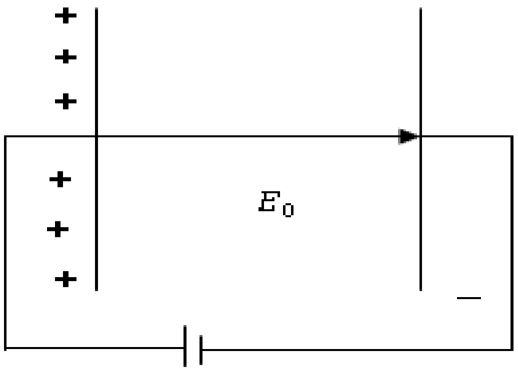


Dielectric

Polarisation of dielectric

Consider a parallel plate capacitor having vacuum between the plate. Suppose that the capacitor is charged with the help of a battery. So that electric field of strength is set up between the plates of the capacitor, then the electric field between two plates is given by

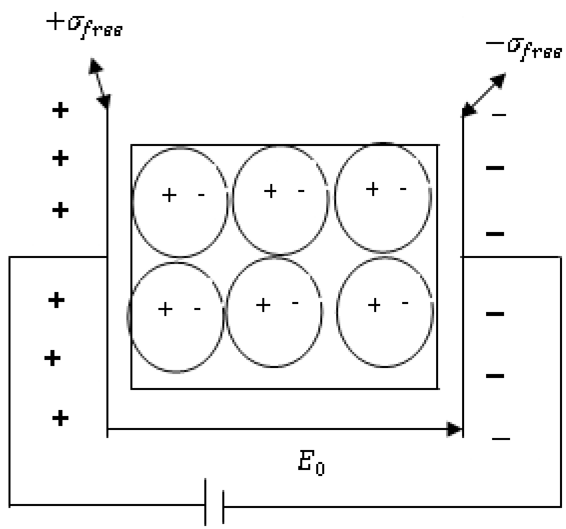
$$E_o = \frac{\sigma}{\varepsilon_0}$$

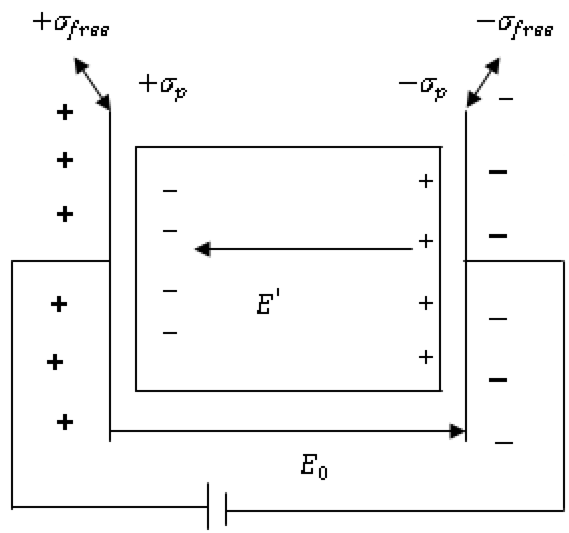


Dielectric

Suppose that a dielectric slab is placed between the plates of capacitor, then each molecule of dielectric slab gets polarised in such a way that positive and negative charges gets displaced from each other, therefore in such a way that net negative charge appears on one face of dielectric slab and net positive charge appear on other face of dielectric slab.

Thus these negative and positive charge appears on the two surface of dielectric slab are called the induced charge. Due to these induced charge electric field E' is set up inside of the dielectric slab in opposite of applied electric field, that electric field are set up due to polarisation. Thus the resultant electric field in the dielectric is $E = E_o - E'$





Dielectric

Dielectric Constant

Dielectric constant is defined as the ratio of the applied electric field strength to the strength of the reduced value of electric field when dielectric slab is placed between parallel plate capacitor is called dielectric constant that is:

$$K = \frac{E_o}{E} \; or$$

Dielectric constant is defined as the ratio of permittivity of medium to permittivity of vacuum is called dielectric constant that is $K = \frac{\varepsilon}{\varepsilon_0}$

Electric Polarisation

When a dielectric slab is placed in an external electric field, then its molecule gain dipole moment and the dielectric is said to be polarised. The dipole moment induced per unit volume of dielectric material is called the electric polarisation. It is denoted by P. Consider a rectangular block of the polarised dielectric of length (L) and cross sectional area A. Let surface charge densities of charge appearing at the end faces be $+\sigma_p$ and $-\sigma_p$

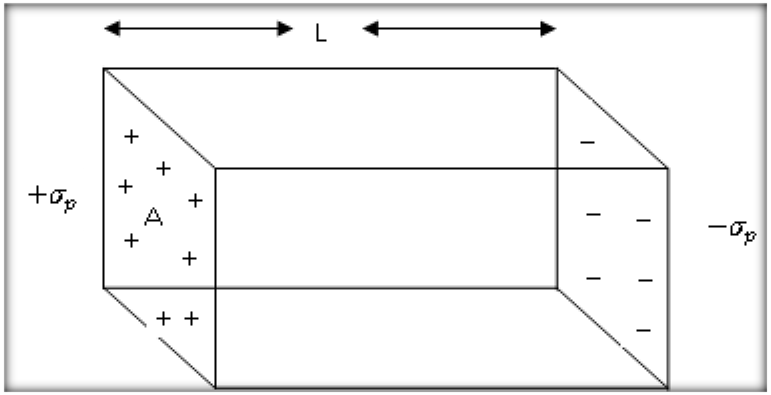
Dielectric

Surface charge density=

$$\frac{charge\ induced\ on\ each\ face}{Area\ of\ block} ------- (1)$$

$$q = \sigma_p A ---------------- (2)$$

$$Induced\ dipole\ moment = charge\ X\ distance -------- (3)$$



$Putting\ value\ of\ equation\ (2)\ in\ equation\ (3)\ we\ get$

$$Total\ induced\ dipole\ moment(ql) = \sigma_p Al ---------- (4)$$

$But\ volume\ of\ block = Al$

By definition induced dipole moment per unit volume are called polarisation and is denoted by P. Thus

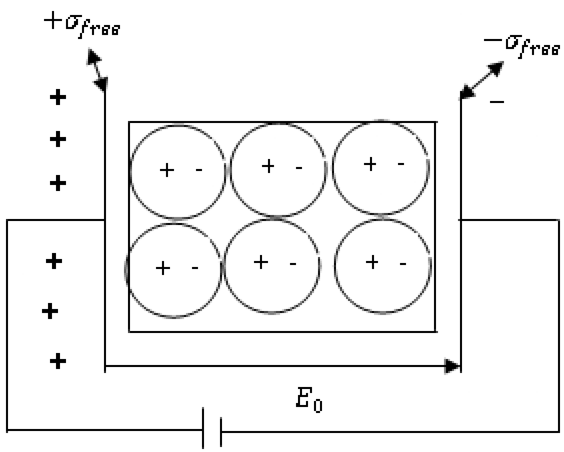
$$P = \frac{induced\ dipole\ moment}{volume\ of\ block} = \frac{\sigma_p Al}{Al} = \sigma_p$$

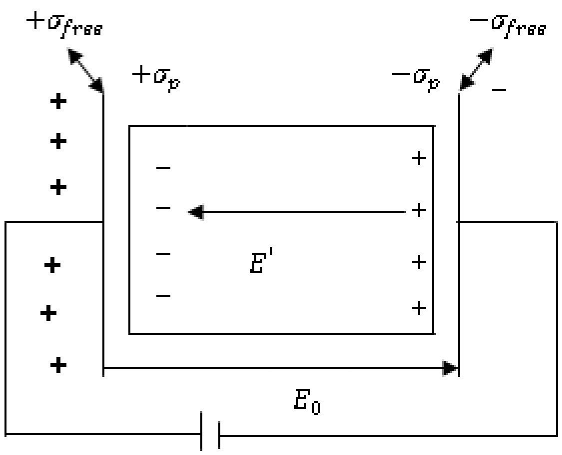
$$P = \sigma_p$$

Dielectric

Electric polarisation vector

Let us consider a dielectric slab placed between the plates of a parallel plate capacitor then let σ_{free} be the surface charge density on the parallel plate capacitor and σ_p be the polarisation charge. Then electric field strength due to σ_{free} and σ_p are given by:





$$E_0 = \frac{\sigma_{free}}{\varepsilon_0} - - - - - - - - - - - - - - - - - (1)$$

$$E' = \frac{\sigma_p}{\varepsilon_0} - - - - - - - - - - - - - - - - (2)$$

Dielectric

The net electric field with in the dielectric is given by: $E = E_0 - E' - - - (3)$
Putting value of equation (1) and (2) in equation (3) we get

$$E = E_0 - E' = \frac{\sigma_{free}}{\varepsilon_0} - \frac{\sigma_p}{\varepsilon_0} = \frac{\sigma_{free} - \sigma_p}{\varepsilon_0} - - - - - - - (4)$$

Putting vulue of $P = \sigma_p$ *in equation (4)we get*

$$E = \frac{\sigma_{free} - \sigma_p}{\varepsilon_0} = \frac{\sigma_{free} - P}{\varepsilon_0} \qquad or$$

$$\varepsilon_0 E = \sigma_{free} - P \qquad or$$

$$\varepsilon_0 E + P = \sigma_{free} \qquad or$$

$$D = \sigma_{free} - - - - - - - - - - - - - - - - - - - (5)$$

$$where\ D = \varepsilon_0 E + P - - - - - - - - - - - - - - (6)$$

Electric Susceptibility:-

When dielectric material placed in an electric field, it becomes polarised. In most of dielectric polarisation is founds proportional to electric field. Thus $P \alpha E$

$$P = \varepsilon_0 \chi_e \mathbf{E} \text{--} \quad (9)$$

Relation between Dielectric constant and Susceptibility

By definition we know that the displacement vector

$$D = \varepsilon_0 E + P \text{--} \quad (10)$$

$$D = \varepsilon E$$

$$P = \varepsilon_0 \chi_e \mathbf{E}$$

Putting these values of D and P in equation (10) we get

$$\varepsilon E = \varepsilon_0 E + \varepsilon_0 \chi_e \mathrm{E}$$

$$\varepsilon E = \varepsilon_0 E(1 + \chi_e$$

$$\frac{\varepsilon E}{\varepsilon_0 E} = (1 + \chi_e) \qquad \frac{\varepsilon}{\varepsilon_0} = (1 + \chi_e) \qquad K = \frac{\varepsilon}{\varepsilon_0} = (1 + \chi_e)$$