DIELECTRICS

1. Introduction
2. Dielectric polarization
   Dielectric polarizability
   Electric Susceptibility
   Dielectric Constant
3. Types of polarizations
   Electronic (Quantitative)
   Ionic (Quantitative)
   Orientational (Qualitative)
4. Lorentz Internal field
5. Claussius Mossoti equation
6. Frequency dependence of polarization.
7. Applications of Dielectrics

Introduction :-

→ Electrically non-conducting materials such as glass, mica, rubber, paper and wood are known as dielectric materials.

→ All dielectric materials are insulators but all electrical insulators need not be dielectrics. For example the vacuum is a perfect insulator but is not a dielectric.

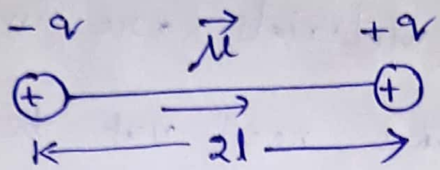
→ The function of a dielectric material is to store electric energy, whereas the function of an insulating material is to resist the flow of electric current through it when a potential difference is applied across its ends.

→ In dielectric material, all the electrons are tightly bound to the nucleus of the atom. and there are no free electrons for conduction.

→ Generally, the dielectrics are non metallic materials of high specific resistance and have negative temperature Coefficient of resistance.

Electric dipole :-

→ A System (or) arrangement consisting of two equal and opposite charges at a fixed distance is called electric dipole.



Electric dipole moment :

→ The product of magnitude of any one of the charge of the dipole and the distance between the two charges is called electric dipole moment. It is denoted by μ.

$$\boxed{\mu = 2lq}$$

→ Electric dipole moment is a vector quantity and its direction is from negative charge to positive charge

→ Units : coulomb - metre

Types of Dielectrics :-

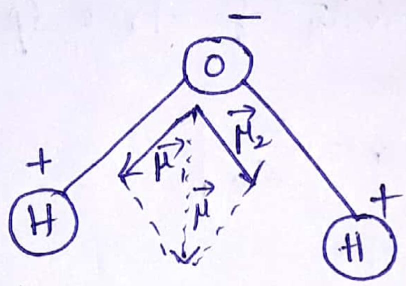
There are 2 types of dielectrics

1. Polar dielectrics
2. Non - polar dielectrics.

Polar Dielectrics :

→ In polar dielectrics, centers of positive and negative charge distributions of molecules constituting the dielectric material do not coincide and hence the molecule has permanent electric dipole moment. The molecule is called polar molecule.

→ Ex: H_2O, HCl, CO, NH_3 ... etc

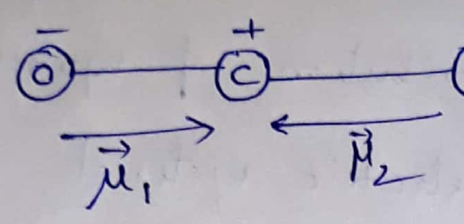


H_2O – polar molecule

Non-polar Dielectrics :

→ In non-polar dielectrics, the centers of positive and negative charge distributions of molecules constituting the dielectric material are coincide and hence the molecule has zero electric dipole moment. The molecule is called non-polar molecule.

→ Ex: H_2, N_2, CO_2 and CH_4 O_2 C_6H_6



CO_2 – Non-polar Molecule.

$$\vec{\mu} = \bar{\mu}_1 - \bar{\mu}_2 = 0$$

Relative permittivity (or) Dielectric Constant

ϵ_r (or) k

Def ①:

→ The dielectric constant (or) relative permittivity is defined as the ratio between the permittivity of the medium ϵ and the permittivity of free space ϵ_0.

i.e., $\boxed{\epsilon_r = \dfrac{\epsilon}{\epsilon_0}}$.

Def ②:

→ The dielectric constant is defined as the ratio between the capacitance of a capacitor with dielectric between the plates to the capacitor capacitance with air between the plates.

i.e., $\boxed{\epsilon_r = \dfrac{C}{C_0}}$

→ ϵ_r is a dimensionless quantity and varies from material to material.

Electric Polarization (P) :-

Def ①:

"The electric dipole moment per unit volume of the dielectric material is called electric polarization (P).

$$P = \frac{\text{Dipole moment}}{\text{volume}}$$

→ If μ is the average dipole moment of the molecule and N is the number of molecules per unit volume, then the electric polarization P is given by

$$P = N\mu$$

→ Electric polarization is a vector quantity and its direction is along the direction of dipole moment.

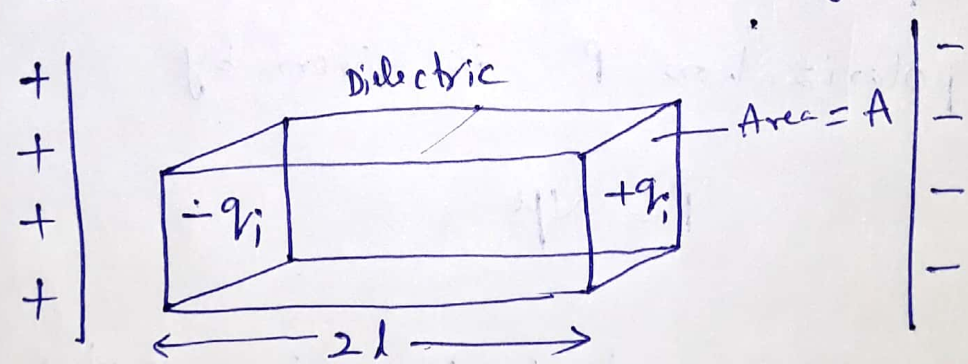
Def (2):

"The induced surface charge per unit area is called electric polarization.

i.e., $\boxed{P = \frac{q_{induced}}{A}}$ → Induced surface charge density

Explanation:

→ If a dielectric slab with length $2l$, area of cross section (A) and volume (V) is placed between the plates of parallel plate capacitor, then induced charges $+q_i$ and $-q_i$ appeared on opposite faces of the dielectric as shown in the fig.



from the def. of electric polarization,

$$P = \frac{\text{Dipole moment}}{\text{volume}} = \frac{2l\,q_i}{A \times 2l}$$

$$\boxed{P = \frac{q_i}{A}}$$

Polarizability (α) :-

→ If a dielectric material is placed in an external electric field, then the induced dipole moment of an atom is directly proportional to the electric field

$$\text{i.e., } \mu \propto E$$

$$\Rightarrow \mu = \alpha E$$

where α is constant of proportionality called polarizability.

$$\boxed{\alpha = \frac{\mu}{E}}$$

"The induced dipole moment per unit electric field is called polarizability"

→ The units of polarizability : Coulomb/metre^2

NOTE: Polarizability is not a bulk property of the material but it is property of individual atom (or) molecule.

Electric Susceptibility (χ) :-

→ If a dielectric material is placed in an electric field, then the dielectric polarization is directly proportional to the applied electric field

i.e., $P \propto E$

$$P = \chi E \Rightarrow \boxed{\chi = \frac{P}{E}}$$

Where χ is a proportionality constant and is called dielectric susceptibility of the material.

In SI system, $P = \epsilon_0 \chi E \Rightarrow$

$$\Rightarrow \boxed{\chi = \frac{P}{\epsilon_0 E}}$$

→ The electric susceptibility is a dimensionless proportionality constant that indicates the degree of polarization of a dielectric material in response to an applied electric field.

The greater the electric Susceptibility, the greater the ability of a material to polarize in response to the electric field and thereby reduce the total electric field inside the material (and store energy).

Electric Displacement vector ($\vec{D}$):

· "The free surface charge per unit area is called electric displacement".

$$D = \frac{q}{A} \quad \text{(Free surface charge density)}$$

Relation between three vectors $\vec{D}$, $\vec{E}$ and $\vec{P}$:

→ When a dielectric material is placed between the plates of a charged capacitor, then the charges are induced on the surface of the dielectric.

→ If q be the charge on the plates of a capacitor and q_i be the charge induced on the Surface of dielectric material,

Then the resultant electric field between the plates of a Capacitor is given by

$$E = E_0 - E_i \quad \text{--- (1)}$$

Where E_0 = Electric field due to free charge on the Capacitor plates

$$= \frac{q}{\epsilon_0 A}$$

E_i = Electric field due to induced charge on the Surface of dielectric

$$= \frac{q_i}{\epsilon_0 A}$$

From eq (1),

$$E = \frac{q}{\epsilon_0 A} - \frac{q_i}{\epsilon_0 A}$$

$$\epsilon_0 E = \frac{q}{A} - \frac{q_i}{A}$$

$$\epsilon_0 E = D - P \qquad \left(\because \; P = \frac{q_i}{A}, \; D = \frac{q}{A}\right)$$

$$\Rightarrow \boxed{D = \epsilon_0 E + P} \quad — (2)$$

This is the relation between three vectors D, E and P.

→ In free space $P = 0$

from eq (2), $D = \epsilon_0 E$

$$= \frac{q}{A}$$

$$= \epsilon_0 \epsilon_r \frac{q}{\epsilon_0 \epsilon_r A}$$

$$= \epsilon_0 \epsilon_r \frac{q}{\epsilon A}$$

$$D = \epsilon_0 \epsilon_r E \qquad \left(\because E = \frac{q}{\epsilon A}\right)$$

$$\boxed{D = \epsilon E} \; - (3) \; (\because \epsilon = \epsilon_0 \epsilon_r)$$

→ from eq (2),

$$D = \epsilon_0 E + P$$

$$\epsilon E = \epsilon_0 E + P$$

$$\epsilon_0 \epsilon_r E = \epsilon_0 E + P$$

$$\boxed{P = \epsilon_0 (\epsilon_r - 1) E} \quad \text{—— (4)}$$

$$\therefore \quad P = \epsilon_0 \chi E$$

Where $\chi = \epsilon_r - 1$

$$\boxed{\epsilon_r = 1 + \chi} \quad \text{—— (5)}$$

This is the relation between dielectric constant and electric Susceptibility.

Types of Polarization Mechanisms :

1. Electronic Polarization
2. Ionic Polarization
3. orientational Polarization.

Electronic polarization :

" Electronic polarization occurs due to the displacement of the positively charged nucleus and the negatively charged electrons of an atom in the presence of an external electric field."

Expression for electronic Polarization

→ Let us consider an atom of a dielectric material placed in an electric field of intensity E.

→ Let us assume that the nucleus of charge ze is surrounded by an electron cloud of charge −ze distributed uniformly in a sphere of radius R.

→ When the external electric field is absent, the centres of positive charge (Nucleus) and negative charge (electron cloud) are at the same point.

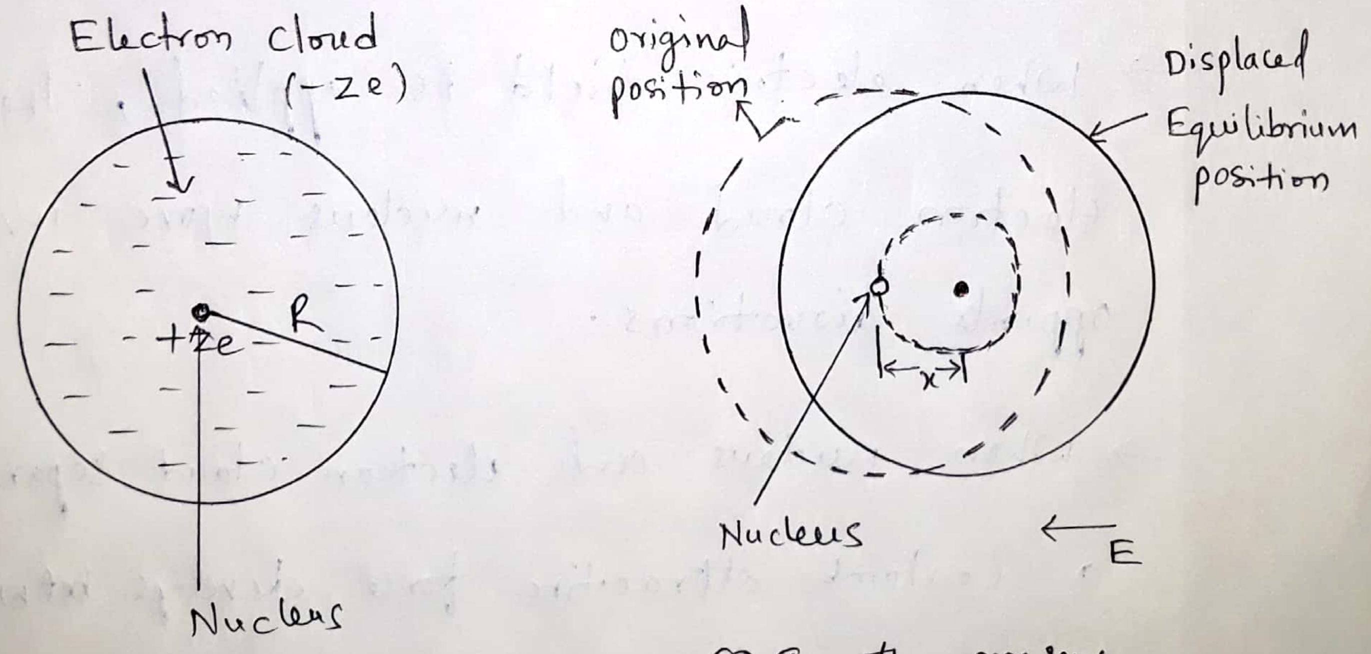
→ When electric field is applied, the electron cloud and nucleus move in opposite directions.

→ When nucleus and electron cloud separated a Coulomb attractive force develops between them, which tends to opposed the displacement.

→ Finally, a new equilibrium position is reached when there two forces are equal and opposite.

→ Let "x" be the separation between two charge centres under new equilibrium position.

→ Since nucleus is heavier than the electron cloud it is assumed that only the electron cloud is displaced when external electric field is applied.



(a) In absence of Electric field

(b) In the presence of Electricfield

→ The charge density $\rho = \frac{\text{Charge}}{\text{volume}}$

$$= \frac{-Ze}{\frac{4}{3}\pi R^3} \quad \text{—— (1)}$$

→ The negative charge in the sphere of radius 'x' is given by

$q = \rho \times$ volume of the sphere of radius x

$$= \rho \times \frac{4}{3}\pi x^3$$

$$= \frac{-Ze}{\cancel{\frac{4}{3}\pi} R^3} \times \cancel{\frac{4}{3}\pi} x^3$$

$$\therefore \boxed{q = \frac{-Zex^3}{R^3}} \quad \text{—— (2)}$$

→ ∴ coulomb force $= \frac{1}{4\pi\epsilon_0} \frac{(+Ze)(q)}{x^2}$

$$F_c = \frac{1}{4\pi\epsilon_0} \frac{(+Ze)(\text{charge enclosed in the sphere of radius } x)}{x^2}$$

$$F_c = \frac{1}{4\pi\epsilon_0} \cdot \frac{(+Ze)\left(-\frac{Zex^3}{R^3}\right)}{x^2}$$

$$= -\frac{Z^2e^2x}{4\pi\epsilon_0 R^3} \quad \text{—— (3)}$$

→ The Lorentz force acting on electron cloud } $F_L = -ZeE$ —— (4)

→ under equilibrium condition,

$$F_L = F_c$$

$$\therefore \frac{+Z^2e^2x}{4\pi\epsilon_0 R^3} = +ZeE$$

$$\Rightarrow \boxed{x = \frac{4\pi\epsilon_0 R^3 E}{Ze}} \quad \text{—— (5)}$$

→ As two electric charges +Ze and −Ze are separated by a distance "x" under the action of the applied electric field, an induced electric dipole is created.

Scanned with CamScanner

∴ Induced electric Dipole moment

$$\boxed{\mu_e = Zex} \quad \text{——— (6)}$$

$$+Ze \xrightarrow{x} -Ze$$

$$= Z\cancel{e} \cdot \frac{4\pi\epsilon_0 R^3 E}{Z\cancel{e}}$$

$$\mu_e = \underbrace{4\pi\epsilon_0 R^3}\, E$$

$$= \alpha_e E$$

Where $\boxed{\alpha_e = 4\pi\epsilon_0 R^3}$ = Electronic polarizability

Hence the electronic polarizability is proportional to the volume of the atom and is independent of temperature.

→ ∴ Electronic polarization $P_e = N\mu_e$

$$= N\alpha_e E$$

$$= N(4\pi\epsilon_0 R^3)E$$

We have $P_e = \epsilon_0(\epsilon_r - 1)E$

$$\therefore \quad \epsilon_0(\epsilon_r - 1)\cancel{E} = N\alpha_e \cancel{E}$$

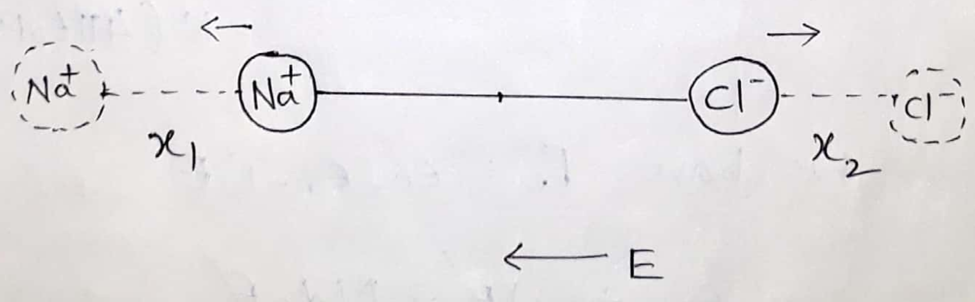
$$\boxed{\alpha_e = \frac{\epsilon_0(\epsilon_r - 1)}{N}}$$

Ionic Polarization :

→ The Ionic polarization is due to the displacement of Cations and anions in the ionic Crystal in the opposite directions when an electric field is applied.

Expression for Ionic polarization

→ When an electric field E is applied to an ionic crystal, the positive ions are displaced through a distance x_1 in the direction of applied electric field and negative ions are displaced through a distance x_2 in the opposite direction of electric field as shown in the fig.



→ The Lorentz force acting on the positive ion $\Big\}$ $F_{L,Na^+} = eE$ — ①

→ The Lorentz force acting on the negative ion $\Big\}$ $F_{L,Cl^-} = -eE$ — ②

→ When ions are displaced due to applied electric field, a restoring force developed on the ions, which tends to move the ions back to the mean position.

→ The restoring force acting on the positive ion $\Big\}$ $F_{R,Na^+} = k_1 x_1$ — ③

→ The restoring force acting on the negative ion $\Big\}$ $F_{R,Cl^-} = k_2 x_2$ — ④

Where $k_1 = M\omega_0^2$, $k_2 = m\omega_0^2$ $\Big\}$ Restoring force constants.

Here. $M =$ Mass of the positive ion.

$m =$ Mass of the negative ion

$\omega_0 =$ Natural frequency of the ionic molecule.

→ At equilibrium, the Lorentz force and restoring force will be equal and opposite.

Hence $eE = K_1 x_1 \Rightarrow x_1 = \frac{eE}{K_1}$

$$= \frac{eE}{M\omega_0^2} \quad -(5)$$

and

$$eE = K_2 x_2 \Rightarrow x_2 = \frac{eE}{m\omega_0^2} \quad -(6)$$

$\therefore x = x_1 + x_2$

$$= \frac{eE}{M\omega_0^2} + \frac{eE}{m\omega_0^2}$$

$$= \frac{eE}{\omega_0^2}\left[\frac{1}{M} + \frac{1}{m}\right] \quad -(7)$$

$\therefore$ The Induced dipole moment $\mu_i = ex$

$$\mu_i = e(x_1 + x_2)$$

$$= \frac{e^2 E}{\omega_0^2}\left(\frac{1}{M} + \frac{1}{m}\right)$$

$$= \frac{e^2}{\omega_0^2}\left(\frac{1}{M} + \frac{1}{m}\right) E$$

But $\mu_i = \alpha_i E$

$$\therefore \boxed{\alpha_i = \frac{e^2}{\omega_0^2}\left(\frac{1}{M} + \frac{1}{m}\right)} \rightarrow \text{Ionic polarizability}$$

Hence the ionic polarizability is inversely proportional to the square of the natural frequency of the ionic molecule and to its reduced mass which is equal to $\left(\frac{1}{M} + \frac{1}{m}\right)^{-1}$.

$\rightarrow$ Ionic polarization $P_i = N\mu_i$

$$= N\alpha_i E$$

$$= N\frac{e^2}{\omega_0^2}\left(\frac{1}{M} + \frac{1}{m}\right) E$$

$\rightarrow$ α_i is independent of temperature.

Orientational polarization :

(OR)

Dipolar polarization

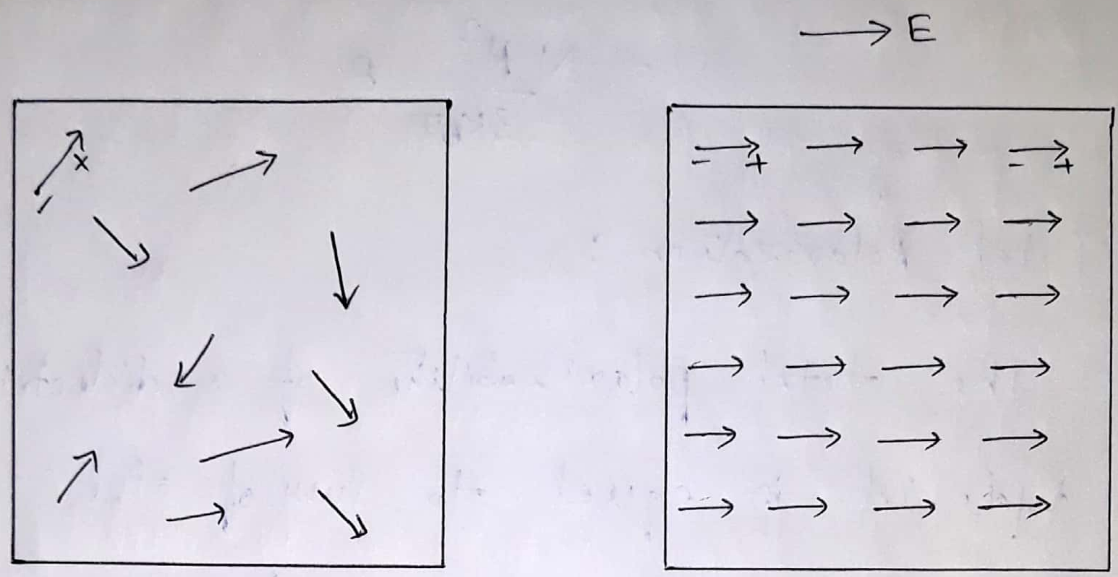
→ The orientational polarization occurs in polar dielectrics. In polar dielectrics molecules have permanent dipole moment.

→ In the absence of electric field all the dipoles (Molecular dipoles) oriented randomly and hence the net dipole moment is zero.

→ The zero net dipole moment results the zero polarization.

→ When an electric field is applied, the molecules (dipoles) tend to align themselves in the direction of applied electric field.

→ The contribution to the polarization due to the orientation of the molecular dipoles is called dipolar (or) orientational polarization.



$E = 0$
(Absence of electric field)

$E \neq 0$
(presence of electric field)

Expression for orientational polarization

orientational polarizability $\boxed{\alpha_0 = \dfrac{\mu^2}{3 K_B T}}$

Where K_B = Boltzmann's Constant

T = Absolute temperature

μ = Dipole moment of the Molecule.

Hence the orientational polarizability is inversely proportional to absolute temperature

Scanned with CamScanner

$\therefore$ orientational polarization $P_o = N\mu_o$

$$P_o = N \alpha_o E$$

$$= \frac{N \mu^2}{3K_BT} E$$

Total Polarization :

The total polarizability of a dielectric material is equal to sum of the electronic, ionic and orientational polarizabilities.

$$\alpha_{Total} = \alpha_e + \alpha_i + \alpha_o$$

$$= 4\pi\epsilon_0 R^3 + \frac{e^2}{\omega_0^2}\left(\frac{1}{M}+\frac{1}{m}\right) + \frac{\mu^2}{3K_BT}$$

$\therefore$ The total polarization $P_{Total} = N\mu$

$$P_{Total} = N \alpha_{Total} E$$

$$= N \cdot \left[4\pi\epsilon_0 R^3 + \frac{e^2}{\omega_0^2}\left(\frac{1}{M}+\frac{1}{m}\right) + \frac{\mu^2}{3K_BT} \right] E$$

Internal field (or) Local Field :

"If a dielectric material is placed in an external electric field, then the total electric field acting on an atom is called local field an internal field".

Expression for the Local field :

→ Consider a dielectric material with Cubic Symmetry placed between the plates of a parallel plate Capacitor as shown in the fig.

→ The plates of the Capacitor are Connected to a battery due to which +ve and -ve charges are presented on the Surfaces of the plates.

→ Let us calculate the total electric field acting on an atom A (reference atom).

→ Let us consider an imaginary

spherical Cavity around the atom A inside the dielectric. It is assumed that the radius of the Cavity is large compared to the radius of the atom.

→ The total electric field (internal field) acting on an atom A is sum of 4 electric fields namely E_0, E_1, E_2 and E_3.

i.e., $\boxed{E_{local} = E_0 + E_1 + E_2 + E_3}$

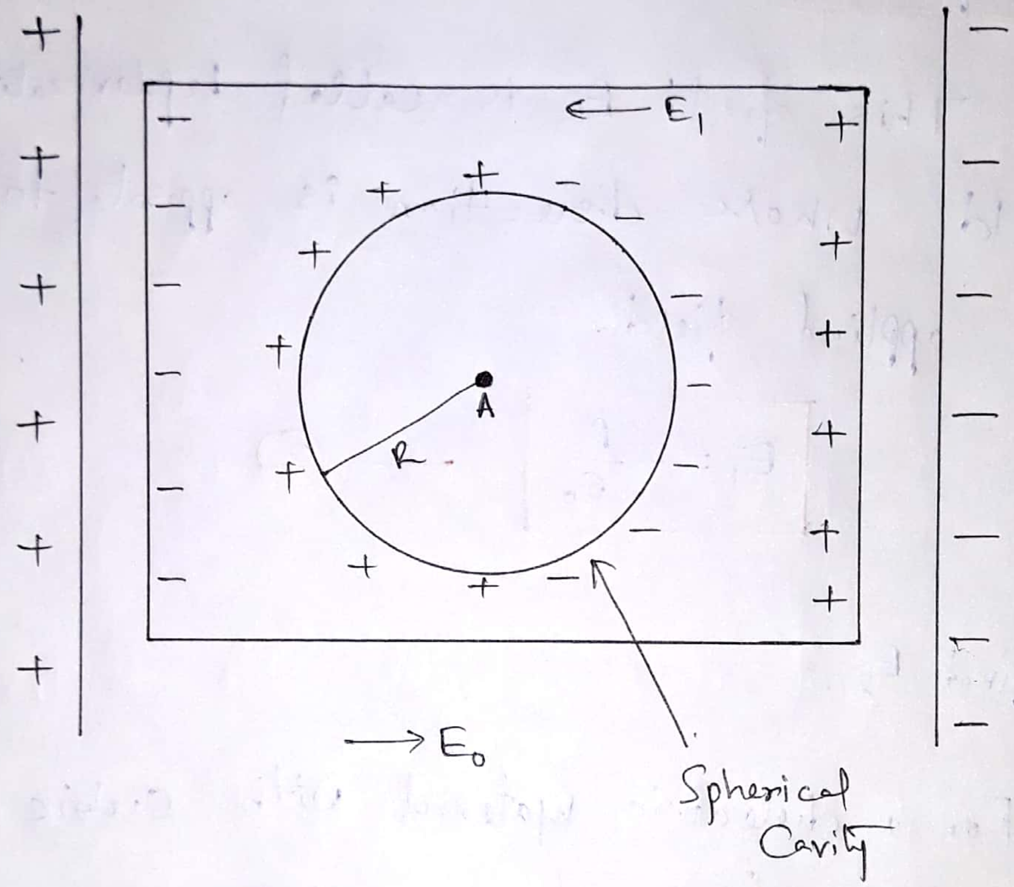
where

E_0 = Electric field due to Charges (free charges) on the Capacitor plates.

E_1 = Electric field due to induced Charges on the Surface of the dielectric.

E_2 = Electric field due to all the dipoles inside the imaginary spherical Cavity.

E_3 = Electric field due to polarization charges on the surface of the spherical Cavity.



To find E_0 :

from the field theory,

$$E_0 = \frac{q_0}{\epsilon_0 A} = \frac{D}{\epsilon_0} \qquad \left(\because D = \frac{q_0}{A}\right)$$

We know that

$$D = \epsilon_0 E + P$$

$$\therefore \quad E_0 = \frac{D}{\epsilon_0} = \frac{\epsilon_0 E + P}{\epsilon_0}$$

$$\Rightarrow \boxed{E_0 = E + \frac{P}{\epsilon_0}} \quad \text{——} \ (1)$$

To find E_1 :

This field E_1 is called depolarization field whose direction is opposite to the applied field.

$$\boxed{E_1 = -\frac{P}{\epsilon_0}} \quad \text{——} \ (2)$$

To find E_2 :

For a dielectric material with cubic symmetry $\boxed{E_2 = 0}$ —— (3)

To find E_3 :

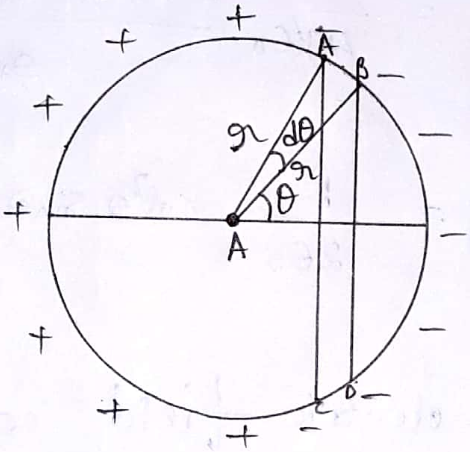
Consider an elementary ring on the surface of the sphere as shown in the fig. The radius of the ring is $a\sin\theta$ and its width is $a\,d\theta$.

→ The Surface area of the elementary ring $\Big\}$ $= 2\pi r \sin\theta \cdot r d\theta$

$= 2\pi r^2 \sin\theta \, d\theta$ — (4)

where r is the radius of the spherical cavity.

$AB = r d\theta$



→ The surface charge density on the surface of the sphere $= P\cos\theta$ —— (5)

→ The charge on the surface of the elementary ring dq $= (P\cos\theta)$ (surface area of the ring)

$= (P\cos\theta)(2\pi r^2 \sin\theta \, d\theta)$

$$dq = \rho \, 2\pi r^2 \sin\theta \, c\delta\theta \, d\theta \quad \text{---} \; (6)$$

→ The electric field at atom A due to The ~~d~~ charge dq in the field direction (in the direction $\theta = 0$) $= dE_4$

$$dE_4 = \frac{1}{4\pi\epsilon_0} \times \frac{dq}{r^2} \times c\delta\theta$$

$$= \frac{1}{\cancel{4\pi}\epsilon_0} \frac{\rho \, \cancel{2\pi} \cancel{r^2} \sin\theta \, c\delta^2\theta \, d\theta}{\cancel{r^2}}$$

$$\therefore \; dE_4 = \frac{\rho}{2\epsilon_0} \cdot c\delta^2\theta \sin\theta \cdot d\theta \quad \text{---} \; (7)$$

→ The total electric field due to the Charges on the surface of the entire spherical Cavity is obtained by integrating dE_3 between the limits 0 and π.

$$\therefore \; E_3 = \int_0^{\pi} dE_3$$

$$= \int_0^{\pi} \frac{\rho}{2\epsilon_0} \cdot c\delta^2\theta \cdot \sin\theta \, d\theta$$

Scanned with CamScanner

$$E_3 = \frac{P}{2\epsilon_0}\int_0^{\pi} \cos^2\theta \cdot \sin\theta \cdot d\theta$$

$$\boxed{E_3 = \frac{P}{3\epsilon_0}} \quad \text{--- (8)}$$

$\therefore$ Local field (or) internal field

$$E_{Local} = E_0 + E_1 + E_2 + E_3$$

$$= E + \frac{P}{\epsilon_0} - \frac{P}{\epsilon_0} + 0 + \frac{P}{3\epsilon_0}$$

$$\boxed{E_{Local} = E + \frac{P}{3\epsilon_0}}$$

This is also called Lorentz field.

Clausius - Mosotti equation :

→ It gives the relation between dielectric Constant (Macroscopic quantity) and polarizability (Microscopic quantity) of a dielectric Material.

→ Let us consider elemental dielectric having Cubic structure. In such Material there are no permanent dipoles (or) ions.

Hence the ionic polarizability α_i and orientational polarizability α_o are zero.

i.e. $\alpha_i = \alpha_o = 0$.

$\therefore$ Total polarizability $\alpha = \alpha_e + \alpha_i + \alpha_o$

$$\boxed{\alpha = \alpha_e} \quad \text{—— (1)}$$

$\therefore$ Total polarization $P = N\alpha_e E_{Local}$

$$= N\alpha_e \left(E + \frac{P}{3\epsilon_0} \right)$$

$$P = N\alpha_e E + \frac{N\alpha_e P}{3\epsilon_0}$$

$$\Rightarrow P\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right) = N\alpha_e E$$

$$\Rightarrow P = \frac{N\alpha_e E}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)} \quad \text{—— (2)}$$

We know that

$$P = \epsilon_0 (\epsilon_r - 1) E \quad \text{—— (3)}$$

From eq's (2) and (3), we get

$$\epsilon_0(\epsilon_r - 1)\cancel{E} = \frac{N \alpha_e \cancel{E}}{1 - \frac{N\alpha_e}{3\epsilon_0}}$$

$$\Rightarrow \quad 1 - \frac{N\alpha_e}{3\epsilon_0} = \frac{N\alpha_e}{\epsilon_0(\epsilon_r - 1)}$$

$$\Rightarrow \quad 1 = \frac{N\alpha_e}{3\epsilon_0} + \frac{N\alpha_e}{\epsilon_0(\epsilon_r - 1)}$$

$$\Rightarrow \quad 1 = \frac{N\alpha_e}{3\epsilon_0}\left(1 + \frac{3}{\epsilon_r - 1}\right)$$

$$\Rightarrow \quad 1 = \frac{N\alpha_e}{3\epsilon_0}\left(\frac{\epsilon_r + 2}{\epsilon_r - 1}\right)$$

$$\therefore \quad \boxed{\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{N\alpha_e}{3\epsilon_0}} \quad \text{— (4)}$$

This is Clausius – Mosotti equation.

– x –

Scanned with CamScanner

PIEZOELECTRICITY

→ Piezo in a greek word for pressure. Hence piezoelectricity means electricity from pressure.

→ Curie brothers discovered the phenomenon of piezoelectricity in 1880.

Direct piezoelectric effect :

→ When some ferroelectric crystals are compressed (or) stretched in a certain direction, then they get polarized.

→ Hence positive and negative charges appear on opposite surfaces in a direction perpendicular to the direction of applied force.

→ This effect is known as the direct piezoelectric effect.

Inverse piezo electric effect:

→ "If a voltage is applied to the faces of a crystal, then mechanical deformation produced in the crystal." This effect is known as inverse piezoelectric effect.

→ The piezoelectricity exhibited by crystals which do not have center of Inversion.

→ Energy can be given to a piezoelectric element either mechanically by stretching it (or) electrically by charging it. All the energy given to it is not converted in producing the effect.

Hence the piezo electric materials are characterised by strength of piezoelectric effect.

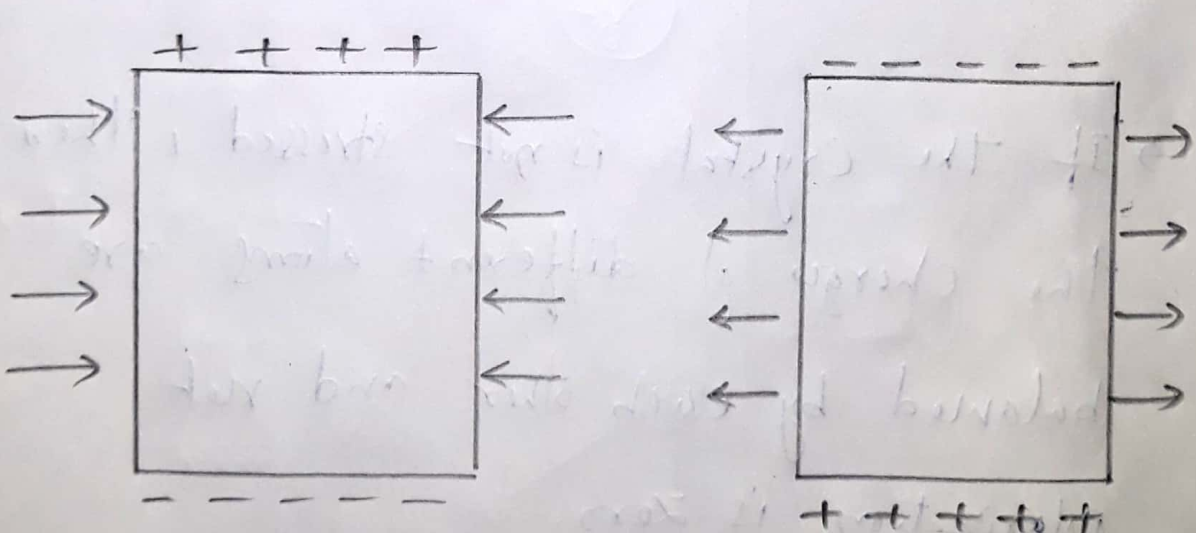
→ The strength is measured by the electromechanical coupling factor k.

In direct piezoelectric effect,

$$k^2 = \frac{\text{Mechanical Energy converted into Electrical Energy}}{\text{Total input Mechanical Energy}}$$

In inverse piezoelectric effect,

$$k^2 = \frac{\text{Electrical energy converted into Mechanical Energy}}{\text{Total input Electrical Energy}}$$

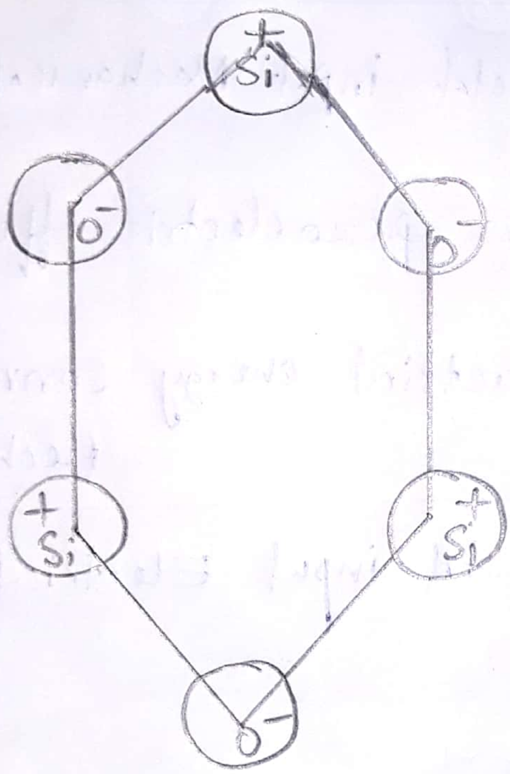


Compression Tension

→ <u>Ex</u>: Quartz

Explanation for the origin of piezoelectricity in Quartz:

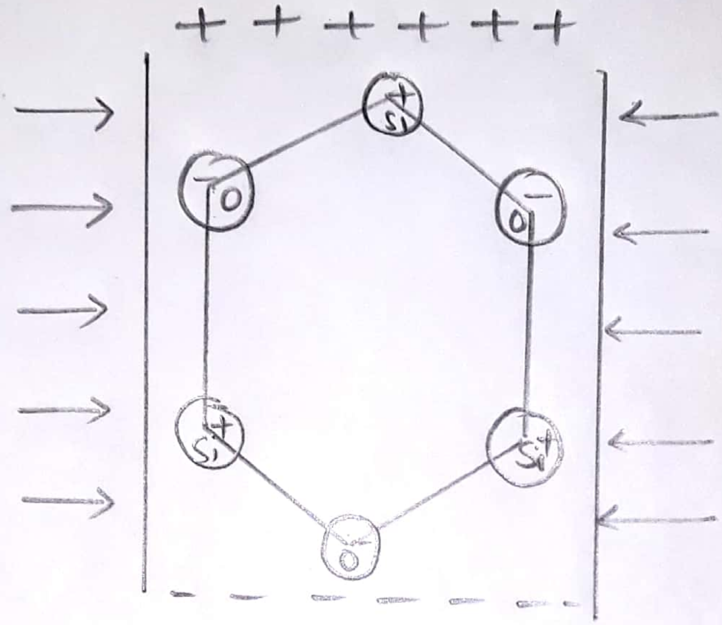
→ The fig shows the arrangement of atoms Si and O_2 in the quartz crystal.



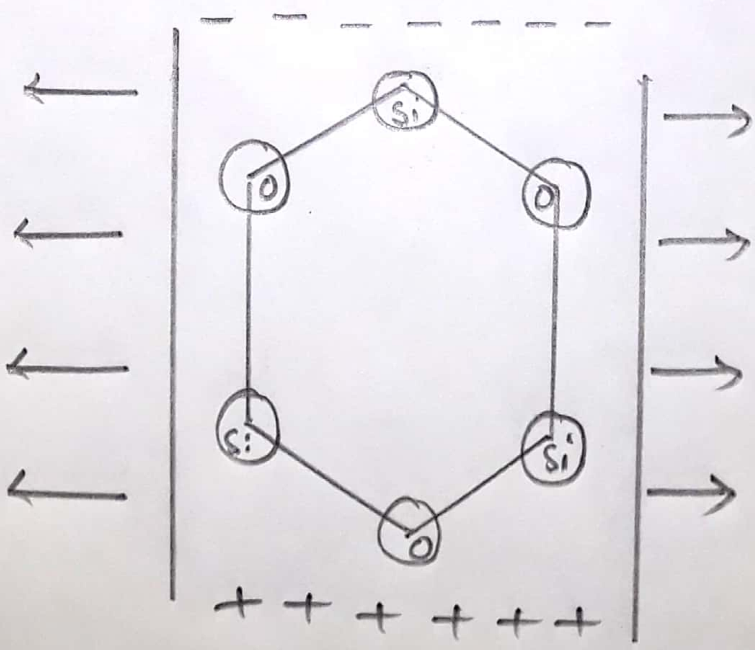
No stress

→ If the crystal is not stressed, then the charges of different atoms are balanced by each other and net polarization is zero.

→ If the crystal experiences stress, then the balance between the charges is disturbed and hence the charges of equal and opposite nature are produced on the faces normal to the applied mechanical stress.



Compression



Tension.