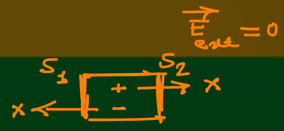
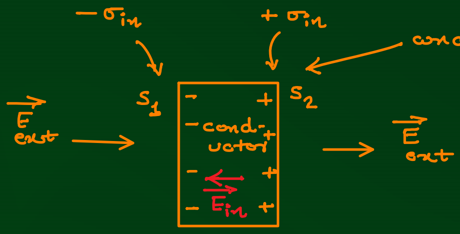
Capacitors

11 July 2020 11:30



Dielectrics :→ Any non-conducting material is called Dielectric.
Eg: wood, plastic, rubber, air, CO_2, H_2O, HCl etc.



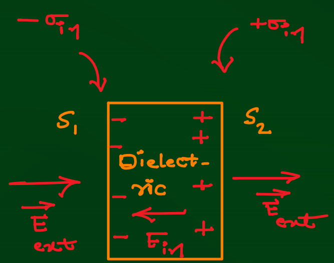
conductors posses excess of charge carriers

Total Electric field inside the conductor

$$\left(\vec{E}_{total}\right)_{inside} = \vec{E}_{ext} + \vec{E}_{induced} = 0$$

$$\therefore \vec{E}_{induced} = -\vec{E}_{ext}$$

Distribution of free charge carriers happens in such a manner that field induced is always equal & opposite to the applied external field.



inside a Dielectric total electric field

$$\left(\vec{E}_{total}\right)_{Dielectric} = \vec{E}_{ext} + \vec{E}_{induced} \neq 0$$

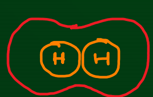
$$\because E_{induced} < E_{ext}$$

inside any dielectric the movement of free charge carriers is not that much easy as it was inside the conductors. Therefore the induced field in the opposite direction of the applied field is less than the external field.

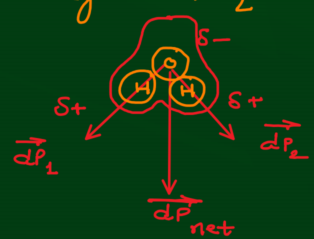
Types of Dielectrics :→ There are 2 types of Dielectrics

i) Non-polar Dielectric
Eg: H_2, CO_2 etc.

ii) polar Dielectric
Eg: HCL, H_2O etc



there will be no Dipole moment already present inside a non-polar Dielectric

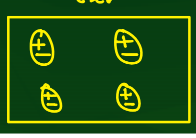


there will be a slight Dipole moment already present inside a polar Dielectric

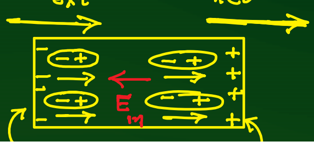
Non-polar Dielectrics inside an external field:→

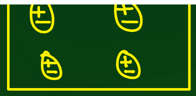
in the presence of an external field the charge carriers Displace in the opposite direction of the field but the Displacement stops due to

$\vec{E}_{ext} = 0 \Rightarrow \vec{P}_{net} = 0$

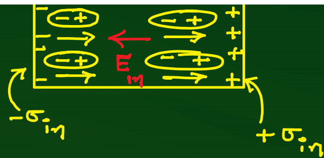


$\vec{E}_{ext} \neq 0$; $\vec{P}_{net} \neq 0$





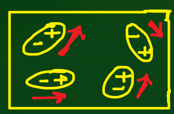
non-polar Dielectric



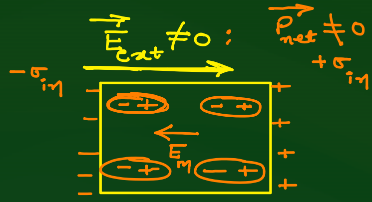
The Displacement stops due to internal opposing forces. Therefore a non-polar Dielectric induces a net dipole moment when kept in external field.

polar-Dielectrics when kept inside an external Electric field

$\vec{E}_{ext} = 0$; $\vec{P}_{net} \approx 0$

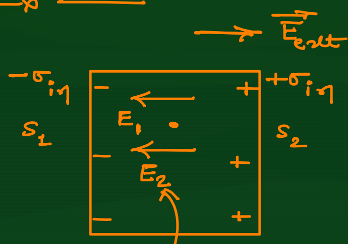


$\vec{E}_{ext} \neq 0$; $\vec{P}_{net} \neq 0$



when a polar Dielectric is kept in an external field its randomly distributed dipoles get aligned opposite to the applied field due to torque on them & the substance get polarised.

for any type of dielectric :→



K = Dielectric constant

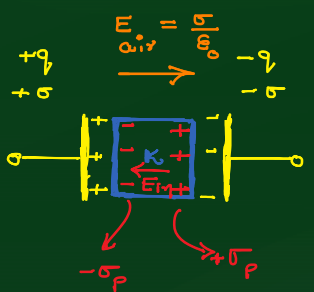
field induced inside any polarised Dielectric

$$E_{in} = E_1 + E_2$$

$$= \frac{\sigma_{in}}{2K\varepsilon} + \frac{\sigma_{in}}{2K\varepsilon}$$

$$\Rightarrow \boxed{E_{in} = \frac{\sigma_{in}}{K\varepsilon}} \text{ N/C} \longrightarrow \star$$

Dielectric inside a capacitor :→



Electric field in the absence of dielectric $(E_{air}) = \frac{\sigma}{\varepsilon} \longrightarrow ①$

Electric field due to polarised dielectric

$$E_{in} = \frac{\sigma_p}{\varepsilon} \longrightarrow ②$$

∴ net field inside the capacitor

$$\vec{E}_{net} = \vec{E}_{air} + \vec{E}_{in}$$

$$\Rightarrow \frac{\sigma}{K\varepsilon} = \frac{\sigma}{\varepsilon} + \left(-\frac{\sigma_p}{\varepsilon}\right)$$

$$\Rightarrow \frac{\sigma}{K} = \sigma - \sigma_p$$

charge density due to polarisation $\Rightarrow \boxed{\sigma_p = \sigma\left(1 - \frac{1}{K}\right)} \text{ C.m}^{-2} \longrightarrow \star$

if the surface area of the Dielectric is same as plate area :

$$\sigma_p \times A = \sigma \times A \cdot \left(1 - \frac{1}{K}\right)$$

$$\because \sigma \times A = q$$

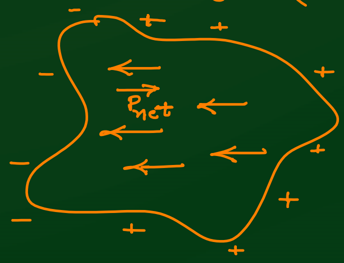
charge due to polarisation $\Rightarrow q_p = q \cdot \left(1 - \frac{1}{K}\right) \longrightarrow \star$

$\because \sigma \times A = q$

charge due to polarisation $\Rightarrow q_p = q\cdot\left(1-\frac{1}{K}\right)$ —— ★

Amount or Intensity of polarisation ($\vec{I}$) :→ The Dipole moment which get induced in the substance per unit volume when it is kept in an external field is called amount or intensity of polarisation. it is a vector qty. & always opposite to the applied polarising external field.

$\longrightarrow \vec{E}_{ext}$ (polarising External field)



$\boxed{\vec{I} = \frac{\vec{P}_{net}}{V}}$; $\frac{C\cdot m}{m^3} = C\cdot m^{-2}$

D.F. = $[A T^{-2}]$

Electric Susceptibility (χ_e) : it is the ratio of the Intensity of polarisation of the substance to the intensity of the polarising electric field.

$\boxed{\chi_e = \frac{\vec{I}}{\vec{E}}}$ $N^{-1}C^{2}\cdot m^{-2}$: D.F. = $[M^{-1}L^{-3}T^{2}A^{2}]$

it is a qty. which gives the amount of polarisation of the dielectric & is its charecteristic property

$\vec{I} = \chi_e \cdot \vec{E}$

always −ve as $\vec{I} \uparrow\downarrow \vec{E}$