

THREE ELECTRIC VECTORS

(ii) E.F. Intensity :- E.F. intensity at any pt. in E.F. is defined as the force experienced by a unit +ve charge placed at that pt.
If F is the force on a pt. charge q ,

$$E = \lim_{q \rightarrow 0} \frac{F}{q}$$

$$E = \frac{q}{\epsilon_0 A}; \quad \epsilon_0 : \text{Permittivity of free space.}$$

ϵ_0 : Permittivity of free space.

A : Area receiving q lines of force.

(iii) Polarization Vector P :- In the presence of an E.F., the molecules of a dielectric become polarized & gain electric dipole moment. This effect is known as electric polarⁿ. The polarⁿ vector is defined as the electric dipole moment induced per unit vol. It has the same dirⁿ as E .

* When a dielectric is placed in a uniform E.F. E_0 & is polarized.

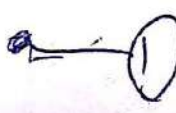
$\epsilon_p \rightarrow$ Density of polarⁿ charge on the surfaces.

$P \rightarrow$ Polarⁿ vector

$A \rightarrow$ Area of X-secⁿ.

$l \rightarrow$ Length of dielectric slab.

$lA \rightarrow$ Vol.

Dipole moment of dielectric = PlA 

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09.00 Considering this dielectric slab as a single dipole with surface charges $= \sigma_p A$ separated by a distance l .

10.00 Dipole Moment = Charge $\times$ length
 $= \sigma_p A l$ — (2)

11.00

① & ② $\Rightarrow$ $P = \sigma_p l$

12.00

01.00 (iii) Electric Displacement (D) :-

→ When a dielectric placed in the II plates of a capacitor, which is subjected to an external E.F. E_0 , then dielectric is polarized.

→ Charges are induced at the surfaces of the dielectric.

04.00 → If q_0 is the charge on the plates of the capacitor.

→ q' is the induced charge on the boundary of dielectric,

Resultant field at any pt. in the dielectric,

06.00

$$E = E_0 - E_p \quad ; \quad E_0 = \frac{q_0}{\epsilon_0 A}, \quad E_p = \frac{q'}{\epsilon_0 A}$$

$$E = \frac{q_0}{\epsilon_0 A} - \frac{q'}{\epsilon_0 A}$$

$$\epsilon_0 E = \frac{q_0}{A} - \frac{q'}{A} P$$

$$\Rightarrow \frac{q_0}{A} = \epsilon_0 E + P$$

Electric displacement

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$$\Rightarrow \boxed{D = \epsilon_0 E + P}$$

Electric displacement Vector (D) or flux density is defined as the no. of lines of force received by a unit area.

In free space, ~~the~~ when there is no dielectric, $P = 0$:-

$$D = \epsilon_0 E$$

$$D = \frac{q_0}{A} = K \epsilon_0 \left(\frac{q_0}{K \epsilon_0 A} \right)$$

$$= K \epsilon_0 \left(\frac{q_0}{\epsilon_0 A} \right)$$

$$\Rightarrow \boxed{D = K \epsilon_0 E}$$

$$\boxed{D = \epsilon E}$$

* E is connected with the charges actually present. Lines of E depend upon the presence of both kinds of charges.

* D is connected with free charges only. These lines Flux of D equals the free charge.

* Polarization (P) is connected with induced surface charge (polarization charge).

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THURSDAY MAY 18 Day 181-235

ELECTRIC SUSCEPTIBILITY

$$D = \epsilon_0 E + P$$

$$K \epsilon_0 E = \epsilon_0 E + P$$

$$\Rightarrow P = K \epsilon_0 E - \epsilon_0 E$$

$$= \epsilon_0 (K - 1) E$$

$$\Rightarrow P = \epsilon_0 (K - 1) E$$

$\epsilon_0 \rightarrow$ Permittivity of free space
 $K \rightarrow$ Const for a medium.

$$P = \epsilon_0 \chi_e E$$

$$\chi_e = \frac{P}{\epsilon_0 E}$$

$\hookrightarrow$ electric susceptibility of dielectric

It is defined as the ratio of polⁿ to the product of E-f. intensity in the dielectric & free space permittivity.

$$\chi_e = K - 1$$

$$\Rightarrow K = \chi_e + 1$$

relⁿ b/w
 D, C & S

19	7	8	9	10	11	12	13
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$$\epsilon_0 K = \epsilon = \epsilon_0 (1 + \chi_e)$$

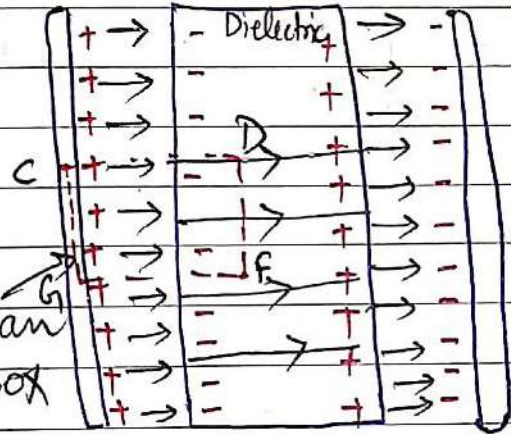
$$P = \epsilon_0 \left(\frac{\epsilon - \epsilon_0}{\epsilon_0} \right) E = (\epsilon - \epsilon_0) E$$

PARALLEL PLATE CAPACITOR WITH DIELECTRIC

→ Consider a || plate capacitor having free charges on its plates with surface density σ . A B

→ Imagine space b/w plates is filled with dielectric of susceptibility χ_e .

→ Dielectric will get polarized. Gaussian pill box



→ Let σ_p & ρ_p be the surface & vol. charge densities equivalent to the polarized dielectric.

→ Assume dielectric to be ideal, homogenous & isotropic.

→ Both E & P are regarded as having a const. value & directed normal to the plates.

$$\therefore \rho_p = -\nabla \cdot \vec{P} = 0 \quad (\because \vec{P} = \text{const.})$$

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→ Consider Gaussian pill box $CDFG$,

Using Gauss theorem,

$$\int_s \mathbf{E} \cdot d\mathbf{s} = \int_s E ds = \frac{q}{\epsilon_0}$$

$q \rightarrow$ Total net charge enclosed in the G.S.
& includes conduction as well as polar charges.

→ If A' is the area of the face CG & DF of the pill box,

$$q = (\sigma - \sigma_p) A'$$

$$\int_s E ds = \frac{1}{\epsilon_0} (\sigma - \sigma_p) A'$$

$$E \cdot A' = \frac{(\sigma - \sigma_p) A'}{\epsilon_0}$$

$$\Rightarrow E_{total} = \frac{\sigma - \sigma_p}{\epsilon_0}$$

$$\Rightarrow E_{total} = \frac{\sigma - P}{\epsilon_0}$$

$$P = \epsilon_0 \kappa E_{total}$$

$$\sigma_p = P$$

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Day 135-231 WK 20 MONDAY

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$$E_{\text{total}} (1 + \chi_e) = \frac{\sigma}{\epsilon_0}$$

$$\Rightarrow \boxed{E_{\text{total}} = \frac{\sigma}{\epsilon_0 (1 + \chi_e)}}$$

$\Rightarrow$ Pot. diff b/w the plates,

$$V_d = E_{\text{total}} \cdot d = \frac{\sigma d}{\epsilon_0 (1 + \chi_e)}$$

$$C = \frac{Q}{V_d} = \frac{\sigma A}{V_d} = \frac{\sigma A \epsilon_0 (1 + \chi_e)}{\sigma d}$$

$$= \frac{\epsilon_0 A (1 + \chi_e)}{d} = \frac{\epsilon_0 \epsilon_r A}{d}$$

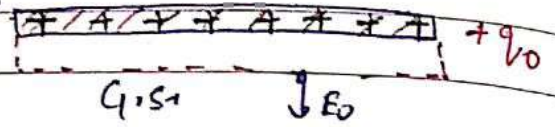
if there is no dielectric,

$$\frac{\epsilon}{\epsilon_0} = (1 + \chi_e) = \epsilon_r = k$$

GAUSS LAW IN DIELECTRICS

09.00

→ In the absence of dielectric, Gauss law states that the surface integral of the normal component of E.F. over any closed surface is $\frac{1}{\epsilon_0}$ times the total charge enclosed by the surface i.e.



11 plate capacitor without dielectric.

01.00

$$\oint E_0 \cdot dA = \frac{q_0}{\epsilon_0}$$

02.00

03.00

$E_0 \rightarrow$ E.F. at any pt. on the G.S.

04.00

$q_0 \rightarrow$ free charge on both plates of the capacitor.

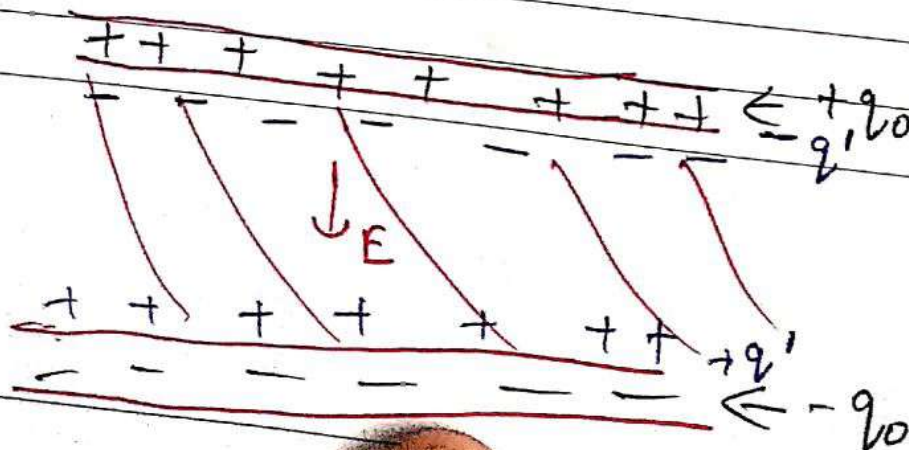
05.00

06.00

$$E_0 A = \frac{q_0}{\epsilon_0}$$

$$\Rightarrow E_0 = \frac{q_0}{\epsilon_0 A}$$

Capacitor with Dielectric



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When dielectric is placed b/w plates of the capacitor and is under the action of E.F.

The E.F. induces appropriate charges on the surfaces of the dielectric & these induced charges produce their own field within dielectric. This field opposes the external field E_0 .

If q' is the induced charge on the surfaces of the dielectric, then effective charge within the G.S. is $(q_0 - q')$.

If E is the resultant field within the dielectric then Gauss law :-

$$\oint E \cdot dA = \frac{q_0 - q'}{\epsilon_0}$$

$$EA = \frac{q_0}{\epsilon_0} - \frac{q'}{\epsilon_0}$$

$$E = \frac{q_0}{\epsilon_0 A} - \frac{q'}{\epsilon_0 A}$$

$\Rightarrow q'$ weakens the original field ($E < E_0$)
 $\Rightarrow$ redⁿ of Pot. diff. b/w the plates.

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THURSDAY WK 20 Day 138-228

If V_d & V_0 are the pot. diff. b/w plates with
or without dielectric,

10.00

$$\frac{E_0}{E} = \frac{V_0}{V_d} \quad \text{--- (1)}$$

11.00

12.00

If C_d & C_0 are corresponding capacitances,

01.00

$$\frac{C_d}{C_0} = K = \frac{V_0}{V_d} \quad \text{--- (2)}$$

02.00

from (1) & (2)

03.00

04.00

$$\frac{E_0}{E} = K \quad \text{OR} \quad E = \frac{E_0}{K}$$

05.00

$$E = \frac{q_0}{K \epsilon_0 A}$$

06.00

$$\text{As } E = \frac{q_0}{\epsilon_0 A} - \frac{q'}{\epsilon_0 A}$$

$$\frac{q_0}{K \epsilon_0 A} = \frac{q_0}{\epsilon_0 A} - \frac{q'}{\epsilon_0 A}$$

$$\Rightarrow q_0 - q' = \frac{q_0}{K}$$

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Day 139-227 WK 20 FRIDAY

$$\Rightarrow q' < q_0 \quad \& \quad q' = 0 \quad \text{When } K = 1$$

$$\text{Using this exp. in } \oint E \cdot dA = \frac{q_0 - q'}{\epsilon_0}$$

$$\Rightarrow \oint E \cdot dA = \frac{q_0}{K\epsilon_0} = \frac{q_0}{\epsilon} \quad \because K = \epsilon$$

ϵ is the permittivity of the dielectric.

$$\Rightarrow \oint \epsilon E \cdot dA = q_0$$

$$\Rightarrow \oint D \cdot dA = q_0$$

→ Gauss law
in presence of
dielectric.