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B.Sc. II Physics Hons

Paper - 4.

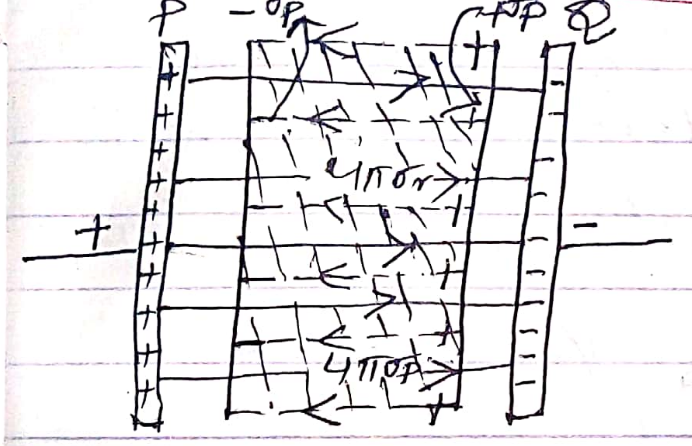

Fig. 3(a) Polarisation in a dielectric.

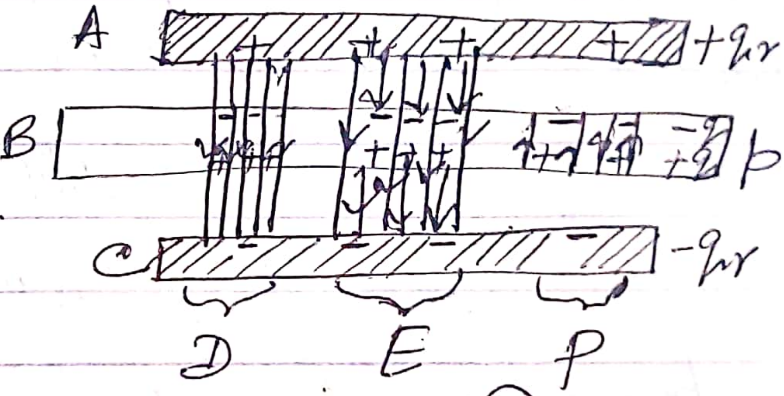

Fig. 3(b).

When an electric field is applied between two plates having a dielectric between them, there are two kinds of electric charges to be considered: (1) bound charges in the dielectric, which are produced due to polarisation in the dielectric and are called fictitious or polarisation charges; these charges are bound to the atoms; (2) Free charges called real charges which are present on the plates of the condenser. The fictitious charges thus have their origin in the dielectric and develop their own electric field.

If E_r = electric intensity produced without the dielectric, then $E_r = \frac{\sigma_r}{\epsilon_0}$. When the dielectric K fills the space between the two plates, let the surface density of the fictitious or polarisation charges, which appear on two sides of the dielectric be $-\sigma_p$ and $+\sigma_p$. These charges will produce their own electric intensity $E_p = \frac{\sigma_p}{\epsilon_0}$ and is opposite in direction to the first, Fig. 3(a). Hence the intensity of the field is reduced. This results in the reduction of the potential difference between the plates, hence the increase in the capacity of the arrangement, and enables the plates to take up more charge.

The resultant intensity E and the induced charge on the surface of the dielectric is as follows:

If E_p = induced electric intensity in the dielectric, &

E_r = Original electric intensity before the insertion of the dielectric, the resultant field is weakened, i.e., it becomes

$$E = E_r - E_p = \frac{\sigma_r}{\epsilon_0} - \frac{\sigma_p}{\epsilon_0} = \frac{\sigma_r}{\epsilon_0 K}$$

$$\therefore \sigma_p = \sigma_r \left(\frac{K-1}{K} \right)$$

and $q_p = q_r\left(\frac{K-1}{K}\right) = q_r\left(1-\frac{1}{K}\right)$

[$\because q_p < q_r$].

$$\therefore \frac{q_p}{A} = \frac{q_r}{A} - \frac{q_r}{AK}$$

Thus the induced surface charge per unit area i.e., $\frac{q_p}{A}$ is called electric polarisation and is denoted by P.

$$\therefore \frac{q_r}{A} = \left(\frac{q_r}{\epsilon_0 A K}\right)\epsilon_0 + P$$

or, $$\frac{q_r}{A} = \epsilon_0 E_r + P = D.$$

$\therefore$ Electric induction or displacement

$$D = \epsilon_0 E + P \text{ --- } (2)$$

Since in isotropic media

$$P \propto \epsilon_0 E;$$

let $P = \chi \epsilon_0 E$, or $\chi = \frac{P}{\epsilon_0 E}$ --- (3)

$= \left[\frac{\text{Polarisation}}{\text{Applied Field}}\right]$;

χ is called the dielectric susceptibility, a dimensionless ratio and is analogous to magnetic susceptibility.

$$D = \sigma_r = \epsilon_0 K E. \quad \text{--- (4)}$$

From (2):

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

or, $P = \epsilon_0 E (K - 1)$

for an ideal dielectric

$$K = 1 + \chi. \quad \text{--- (5)}$$

(c.f. $\mu = 1 + K$) in magnetism.

It must be noted that E is the local field within the dielectric, i.e., the vector sum of the external field and that due to molecular or atomic dipoles formed when the dielectric becomes polarised. This holds in the case of any condenser of any form. Hence Eqn. (4) is a general one, and it states that electric induction in an isotropic medium equals the product of the dielectric constant and the electric intensity.

D is also called the density of the lines of induction.

$D = \epsilon_0 K E$ lines of induction per sq. metre, and $E = \frac{P}{\epsilon_0 K}$ per unit charge. In free space $K = 1$ and $D = \epsilon_0 E = \sigma$

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From the discussion of the above phenomenon we find that

1.) D is connected with the free charge only, and lines of D begin and end on the free charges.

2.) P is connected with the polarisation charges only, and lines of P begin and end on polarisation charges.

3.) E is connected with all charges that are actually present (real and fictitious).

It may be noted that the unit of E is newtow/coulombe in the S.I. system, while those of P and D are Coulomb/metre^3.

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