# Dielectric

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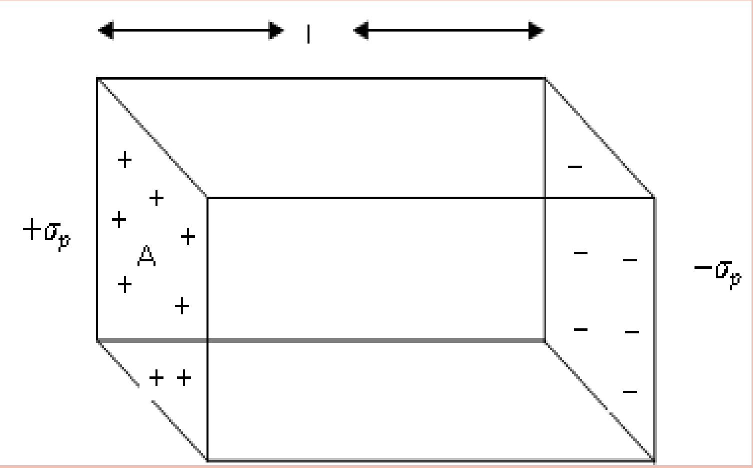
# Dielectric

When a dielectric slab having length (l) and area of cross section be (A) is placed between in an electric field than it become polarised. Let E be the applied electric field and separation between positive and negative charges be changed by small amount of distance (dl) than change in dipole moment is

$dp = q.dl - - - - - - - - (1)$ $[dipole\ moment = charge\ x\ displacement]$




$The\ force\ on\ polarisation\ charge \quad F = q\ xE - - - - - -(2)$

$Thus\ workdone\ for\ (dl) displacement of\ charge (dw) = force\ x\ dis.$

$dw = qE\ x\ dl = (q.dl)E - - - - - - - - - - - - - - - - - - - (3)$

Putting the value of equation (1) in equation (3) we get

$dw = E.dp - - - - - - - - - - - - - - - - - - - - - (4)$

$we\ know\ that\ D = \varepsilon_0 E + P - - - - - - -(5)\ \ and\ D = \varepsilon E$

# Dielectric

Putting value of D in equation (5) we get

$$\varepsilon E = \varepsilon_0 E + P - - - - - - - - - - - - - - (6)$$

By definition of di-electric constant we know that

$$K = \frac{\varepsilon}{\varepsilon_0} \quad \boldsymbol{or} \quad \varepsilon = K\varepsilon_0 - - - - - - - - - - - - - (7)$$

$$KE\varepsilon_0 = \varepsilon_0 E + P \quad or \ (K-1)\varepsilon_0 E = P - - - - - -(8)$$

Where **(P)** is the induced dipole moment per unit volume. On differ-enacting equation (7) we get

$$dP = (K-1)\varepsilon_0 dE - - - - - - - - - - (9)$$

$By\ definition\ of\ polarisation(P)\ that\ is\ dipole\ moment\ per\ unit\ volume$

$P = \frac{p}{V}\ \ or\ p = PV$ On differenacting we get

$$dp = VdP - - - - - - - - - - - - - - - - - - - - (10)$$

$putting\ value\ of\ equation\ (9)\ in\ equation\ (10)\ we\ get$

$$dp = V(K-1)\varepsilon_0 dE - - - - - - - - - - - - - - - - - - (11)$$

# Dielectric

*putting value of equation* (11) *in equation* (4) *we get*

$$dw = V(K-1)\varepsilon_0 E\, dE ---------------------(12)$$

*work − done for polarisation of dielectric*

$$\int dw = \int E.dp = \int V(K-1)\varepsilon_0 E\, dE = \frac{V(K-1)\varepsilon_0 E^2}{2}$$

*work − done per unit volume are called energy density*

$$Energy\ density = \frac{w}{V} = \frac{(K-1)\varepsilon_0 E^2}{2}$$

This equation gives the energy density due to polarisation. Therefore the total energy density is equal to the energy density in free space plus the energy density due to polarisation.

$$Total\ energy\ density = \frac{(K-1)\varepsilon_0 E^2}{2} + \frac{\varepsilon_0 E^2}{2} = \frac{K\varepsilon_0 E^2}{2} ----(13)$$

In free space K=1 then equation (13) become

$$Energy\ density\ in\ free\ space = \frac{\varepsilon_0 E^2}{2}$$