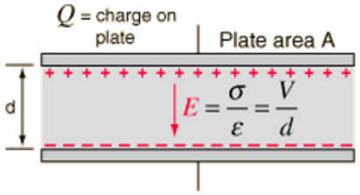
DIELECTRIC MATERIALS

1

Capacitance

$$C = \frac{\varepsilon_0 A}{d}$$



- If there is a material medium between the plates, then the capacitance, the charge storage ability per unit voltage, increases by a factor of ε_r, where ε_r is called the dielectric constant of the medium or its relative permittivity.
- The increase in the capacitance is due to the **polarization** of the medium in which positive and negative charges are displaced with respect to their equilibrium positions.
- The opposite surfaces of the dielectric medium acquire opposite surface charge densities that are related to the amount of polarization in the material.

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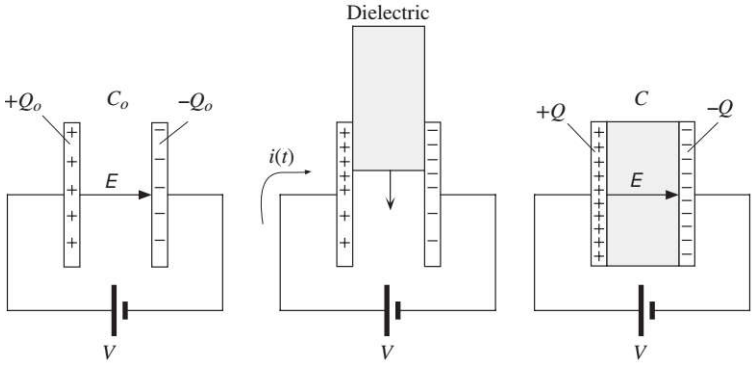
Relative Permittivity



$$C_0 = \frac{Q_0}{V}$$

$$C = \frac{Q}{V}$$

$$C > C_0 \qquad \varepsilon_r = \frac{Q}{Q_0} = \frac{C}{C_0}$$

- Note that electric field remains same when dielectric medium is inserted.

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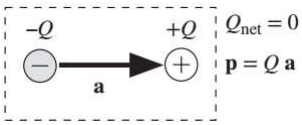
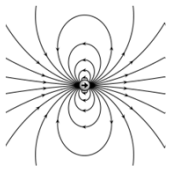
Dipole Moment

- Dipole moment a measure of the electrostatic effects of a pair of opposite charges $+Q$ and $-Q$ separated by a finite distance a

$$p = Qa$$

- Although the net charge is zero, this entity still gives rise to an electric field in space and also interacts with an electric field from other sources.





- An atom is said to be **polarized** if it possesses an effective dipole moment.
- The induced dipole moment depends on the electric field causing it.

$$p = \alpha E$$

α : polarizability

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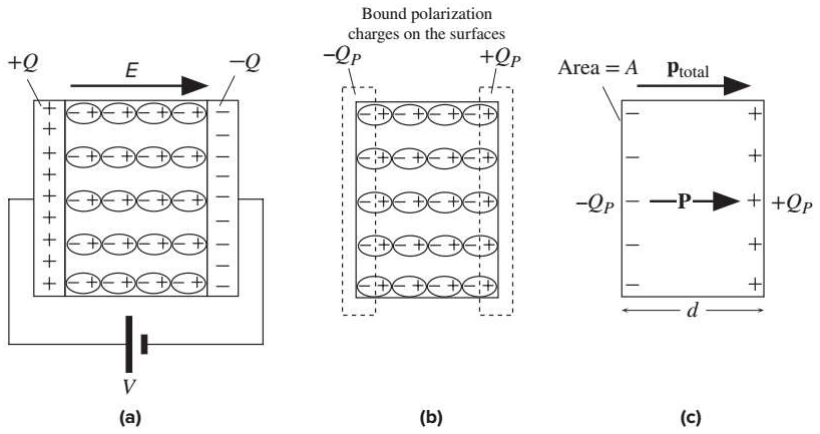
Polarization

- When a material is placed in an electric field, the atoms and the molecules of the material become polarized, so we have a distribution of dipole moments in the material.



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Polarization

- **Polarization P:** If there are *N* atoms →

$$\vec{P} = \frac{1}{V}\left[\vec{p}_1 + \vec{p}_2 + \cdots + \vec{p}_N\right]$$

- If $\vec{p}_{\text{av}}$ is the average dipole moment →

$$\vec{P} = N\,\vec{p}_{\text{av}}$$

N : number of atoms per unit volume.

- Considering $+Q_p$ and $-Q_p$ surface charges separated by a distance *d*

$$p_{\text{total}} = Q_p d$$

$$P = \frac{p_{\text{total}}}{V} = \frac{Q_p d}{Ad} = \frac{Q_p}{A}$$

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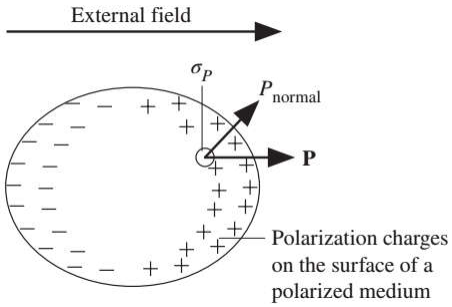
Polarization

$$P = \frac{Q_p}{A} = \sigma_p$$

- The direction of P is normal to the surface. For $+\sigma_p$ (right face), it comes out from the surface and for $-\sigma_p$ (left face), it is directed into the surface.
- Generally: $P_{\text{normal}} = \sigma_p$



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Susceptibility

- The dependence of the induced dipole moment on the electric field:

$$p = \alpha E$$

- The dependence of the polarization on the electric field:

$$P = \chi_e \varepsilon_0 E$$

χ_e: Electric susceptibility

- χ_e relates the effect (P) to its cause (E).
- χ_e may depend on $E \rightarrow P$ may nonlinearly depend on E.

$$P = Np = N\alpha_e E \quad \chi_e = \frac{1}{\varepsilon_0} N\alpha_e$$

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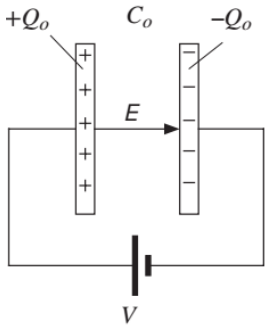
Susceptibility

$$E = \frac{V}{d} = \frac{Q_0}{C_0 d} = \frac{Q_0}{\varepsilon_0 A} = \frac{\sigma_0}{\varepsilon_0}$$



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Susceptibility

$$Q = Q_0 + Q_p$$

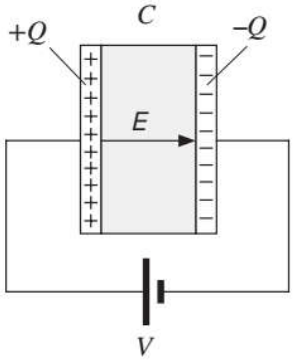
$$\frac{Q}{A} = \frac{Q_0}{A} + \frac{Q_p}{A}$$

$$\sigma = \varepsilon_0 E + \sigma_p$$

$$\sigma = \varepsilon_0 E + P$$

$$\sigma = \varepsilon_0 (1 + \chi_e) E$$

$$\varepsilon_r = \frac{\sigma}{\sigma_0} \rightarrow \varepsilon_r = 1 + \chi_e \rightarrow \varepsilon_r = 1 + \frac{N\alpha}{\varepsilon_0}$$



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Class Test – 3

Day: 31 July 2019

Syllabus: Lectures 19–

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