2.7 Materials in Static E-Field

Materials classify:

Conductor, Semi-conductor, Insulator (ideal Dielectrics)

§ 2.7.1 Conductor in Static E-Field

- What is ***Conductor***?
  - A material that possesses a relatively large number of *free electric* charge.
- What is *free electron*:
  1) Is loosely associated with its nucleus
  2) Is free to wander throughout the conductors
  3) Responds to almost an infinitesimal electric field
  4) Continues to move as long as it experience a force
- Conductor is ***electrically neutral*, w/o *excess charge in it***.

§ 2.7.1 Conductor in Static E-Field

- Conductor in static E-field
  - E-intensity inside a isolated conductor is always 0.
  - Net volume charge density within the conductor is 0.
  - Net charges contained by the conductor must distribute on the （outside） **surface**.
  - The conductor is an equi-potential region of space and its surface is an equi-potential surface.
  - Lines of E-force are always normal to the equi-potential surface, which means …?

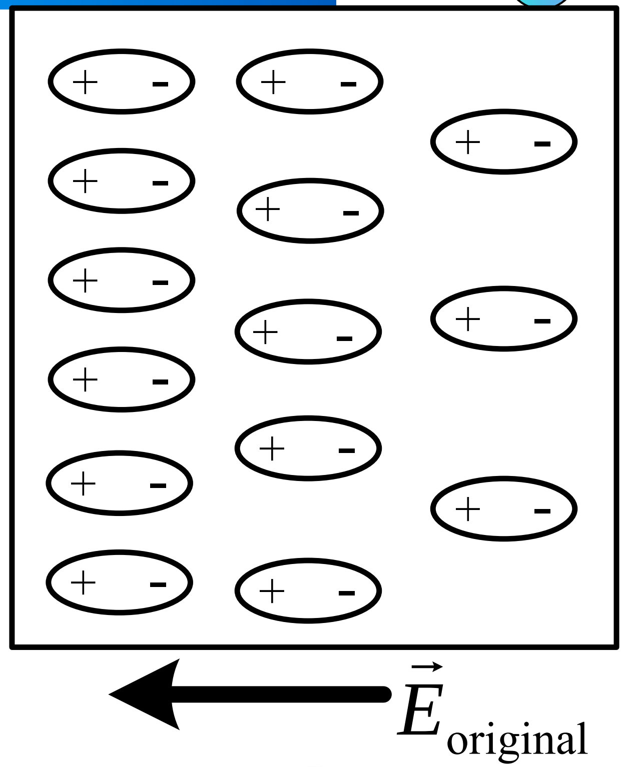
Semiconductor

- A semiconductor behaves no differently than a conductor when subjected to static E-fields.
- Therefore, for static E-fields, we group all materials into 2 categories
  - Conductors
  - Dielectrics

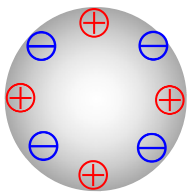
§ 2.7.2 Dielectric in Static E-Field

Behavior of substance in static E-field

- Dielectric --- Polarization
- What is polarization?
  - The partial or complete polar separation of positive and negative electric charge in substances.



$$\vec{E}_{\text{new}} = \vec{E}_{\text{original}} + \vec{E}_{\text{polarization}}$$



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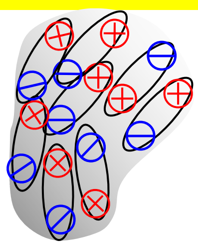

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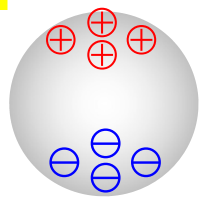

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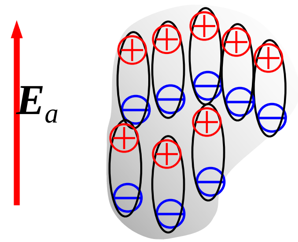

有极分子

极化的动画演示

微波炉的工作原理——介质极化

- 1946年，美国人斯潘瑟(Dr. Percy Spencer).
- 食物中含有水分，水分子为极性分子，一端为正，一端为负，其实就是电偶极子。
- 微波炉采用约24.5亿Hz的超短波来工作，该波的电场方向在1秒钟内变换正负极24.5亿次，每换一次，由于极化效应水分子方向随之反转一次；剧烈的运动产生了大量的热能，也就是摩擦生热，热被食物分子吸收，食物就会变热、变熟。
- 并不是任何容器都适合装食物放进微波炉内加热的，譬如金属容器就不能。
    - 大家今后不妨做个试验，把手机放进不锈钢饭盒，搁在微波炉里加热！

Two Type of Charges

- Free charges
  - Real ones, able to float
- Polarization charges 极化电荷
  - Or bound charges 束缚电荷
  - Unreal ones, unable to move freely, bound onto the dielectrics due to polarization

(^_^)

Now, let's go on --->>>>>>>>>>>>>

Polarization Intensity

- Or so called polarization vector
- It's **the volume density of the E-moment** (偶极距) due to polarization.
- Unit: C/m^2

$$\vec{P} = \lim_{\Delta\tau \to 0}\left(\frac{\sum \vec{p}}{\Delta\tau}\right) = N\vec{p}_{av}$$

Volume density of polarization charges

$$\boxed{\rho_{pc} = -\nabla \bullet \vec{P}}$$

Surface density of polarization charges

$$\boxed{\sigma_{pc} = \vec{P} \bullet \vec{a}_n}$$

For **isotropic homogeneous dielectrics**, the volume density of polarization charges is always ZERO.

Gauss's Law in a Dielectric

Dielectric in Static E-Field → Polarization Charges → $\vec{E}_{\text{polarization}}$

$$\vec{E} = \vec{E}_{\text{original}} + \vec{E}_{\text{polarization}}$$

$$\oint_S \vec{E} \cdot d\vec{S} = \frac{Q_{fc} + Q_{pc}}{\varepsilon_0}$$

fc: Free Charge
pc: Polarization Charge

$$Q_{fc} = \oint_S \varepsilon_0 \vec{E} \cdot d\vec{S} - Q_{pc} = \oint_S \varepsilon_0 \vec{E} \cdot d\vec{S} - \int_V \rho_{pc} dV \xrightarrow{\rho_{pc} = -\nabla \cdot \vec{P}}$$

$$= \oint_S \varepsilon_0 \vec{E} \cdot d\vec{S} + \int_V \nabla \cdot \vec{P} dV = \oint_S \varepsilon_0 \vec{E} \cdot d\vec{S} + \oint_S \vec{P} \cdot d\vec{S}$$

$$\xrightarrow{\vec{D} = \varepsilon_0 \vec{E} + \vec{P}} \boxed{\oint \vec{D} \bullet d\vec{S} = Q_{fc}}$$

Displacement in Dielectric

For isotropic homogeneous dielectrics

$$\boxed{\vec{D} = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 (1 + \chi_e) \vec{E}}$$

χ_e : polarization coefficient, or electric susceptibility

Relative Dielectric Constant $\varepsilon_r = (1 + \chi_e)$ Unit: null

$$\therefore \vec{D} = \varepsilon_0 \varepsilon_r \vec{E} = \varepsilon \vec{E}$$

ε (Permittivity介电常数)
(Dielectric Constant介电常数)

Conclusion for polarization

Displacement Polarization ... E-Intensity

$$\boxed{\vec{D} = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 (1 + \chi_e) \vec{E} = \varepsilon \vec{E}}$$

Gauss's Law in a Dielectric

$$\boxed{\oint_S \vec{E} \bullet d\vec{S} = \frac{\sum q_{fc} + \sum q_{pc}}{\varepsilon_0}}$$

$$\boxed{\oint_S \vec{D} \bullet d\vec{S} = \sum q_{fc}}$$

$$\boxed{\nabla \bullet \vec{E} = \frac{\rho_{fc} + \rho_{pc}}{\varepsilon_0}}$$

$$\boxed{\nabla \bullet \vec{D} = \rho_{fc}}$$

知识扩展－1：Dielectric Strength 电介质强度

- 电场使电介质材料中的束缚电荷产生小位移
  ——极化
- 电场足够强,就会将电子完全“拉离”分子
  ——出现自由电荷
- “强”电场下,介质中产生电流,材料变成导体
  ——breakdown电击穿
- 电介质强度：
  - 电介质材料所能承受(不被击穿)的最大电场强度
  - 单位：v/m，就是场强的单位！

几种电介质的电介质强度

标准大气压下,空气：	3000kV/m
矿物油：	15000kv/m
橡皮：	25000kv/m
玻璃：	30000kv/m
云母：	200000kv/m

^_^

Now, let's go on --->>>