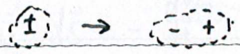
第15章 静电场中的电介质

1. 电介质插入使电场减弱.

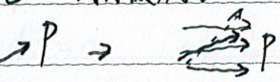
$E = \frac{E_0}{\varepsilon_r}$ → 相对介电常量 ($\varepsilon_r > 1$).

2. 极化机制.

(1) 位移极化　对无极分子、有极分子都有.



(2) 取向极化　对有极分子.



注: ①由于热运动, $\vec{p}$不是都平行于$\vec{E}$.

②静电场中, 取向极化为主, 高频场, 取向极化次要.

3. 电极化强度.

$$\vec{P} = \lim_{\Delta V \to 0} \frac{\sum \vec{p}_i}{\Delta V} \quad (C/m^2).$$

E不太强, 对各向同性的电介质.

$$\vec{P} = \varepsilon_0(\varepsilon_r - 1)\vec{E}.$$

4. 面束缚电荷密度. (在电介质表面上出现的(负)正电荷的电荷层)

$$\sigma' = P_n \text{ (法向)}.$$

5. 整个封闭面向外移出的电荷.

$$q'_{out} = -q'_{in} = \oint_S \vec{P} \cdot d\vec{S}.$$

6. 极化体电荷.

$$\rho' = -\lim_{\Delta V \to 0} \frac{\oint_S \vec{P} \cdot d\vec{S}}{\Delta V} = -\nabla \cdot \vec{P} = -\left(\frac{\partial P_x}{\partial x} + \frac{\partial P_y}{\partial y} + \frac{\partial P_z}{\partial z}\right)$$

7. D的高斯定律.

$$D = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 \varepsilon_r \vec{E} \quad \text{(电位移)} \ (C/m^2).$$

$$\oint_S \vec{D} \cdot d\vec{S} = \sum q_{0in}.$$

☆小汇总: $E = \frac{E_0}{\varepsilon_r}$

$P = \varepsilon_0(\varepsilon_r - 1)E = \varepsilon_0\left(1 - \frac{1}{\varepsilon_r}\right)E_0 = \left(1 - \frac{1}{\varepsilon_r}\right)D$

$D = \varepsilon_0 \varepsilon_r E = \varepsilon_0 E_0.$

8. 静电场的边界条件

(1) 切向: $E_{1t} = E_{2t}$.

(2) 法向: $D_{1n} = D_{2n} \Rightarrow \frac{E_{1n}}{\varepsilon_{r1}} = \frac{E_{2n}}{\varepsilon_{r2}}$.

☆用环路解决E, 用高斯解决D.

9. 电容器和电容.

$C = \frac{Q}{U}$.　$(F = C/V)$

平行板电容器. $U = Ed = \frac{Qd}{\varepsilon_0 \varepsilon_r S}$

$\Rightarrow C = \frac{\varepsilon_0 \varepsilon_r S}{d}$.

圆筒电容器. $U = \int_{R_1}^{R_2} E \cdot dr = \int_{R_1}^{R_2} \frac{Q\,dr}{2\pi r \varepsilon_0 \varepsilon_r L} = \frac{Q}{2\pi \varepsilon_0 \varepsilon_r L} \ln\frac{R_2}{R_1}$

$\Rightarrow C = \frac{2\pi \varepsilon_0 \varepsilon_r L}{\ln\frac{R_2}{R_1}}$

球形电容器. $U = \int_{R_1}^{R_2} E\,dr = \int_{R_1}^{R_2} \frac{Q\,dr}{4\pi \varepsilon_0 \varepsilon_r r^2} = \frac{Q}{4\pi \varepsilon_0 \varepsilon_r}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\Rightarrow C = \frac{4\pi \varepsilon_0 \varepsilon_r R_1 R_2}{R_2 - R_1}$

这类问题: $E \to Q \to C$, $E \to U \to C$

10. 串并联电容器.

串联: $\frac{1}{C} = \sum \frac{1}{C_i}$

并联: $C = \sum C_i$.

11. 电容器的能量、能量体密度.

能量 $W = \frac{1}{2} QU = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CU^2$.

能量体密度. $w_e = \frac{1}{2} \varepsilon_0 \varepsilon_r E^2 = \frac{1}{2} DE$.

$W = \int w_e \, dV$.