Week 12.

Microteaching: Conductors, Insulators & permeable subs

1. EM in wire
2. Polarization ($\vec{P}$)
3. magnetization ($\vec{H}$)

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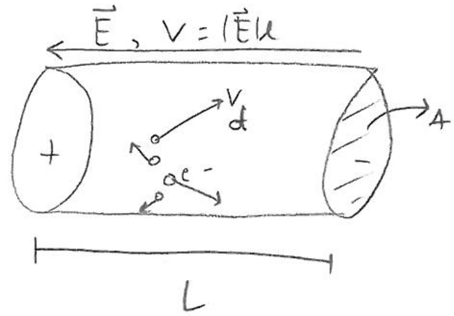
1. EM in a wire



$$V_f = \sqrt{\frac{2E_f}{m_e}} \quad ; \quad E_f : \text{property of metal}$$

$$\boxed{V_d = \frac{e|E|}{m_e}\tau} = \frac{e|E|}{m_e} \cdot \frac{\lambda}{V_f} \quad ; \quad \tau = \text{mean collision time}, \quad \lambda = \text{Mean free path.}$$

$$J = \frac{I}{L.A} = \frac{dq}{dt} = neV_d = \frac{ne^2\tau|E|}{m_e} \quad ; \quad n = \text{mean \# } e^- \text{ per unit Volume}$$

$$R = \frac{\rho L}{A} \; ; \; I = \frac{V}{R} \Rightarrow \vec{J} = \frac{\vec{V}}{RA} = \frac{\vec{V}}{\rho \frac{L}{A} . A} = \frac{\vec{V}}{L} \cdot \frac{1}{\rho} = \frac{\vec{E}}{\rho}$$

$$\vec{J} = \vec{E} . \sigma$$

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2. Polarization:

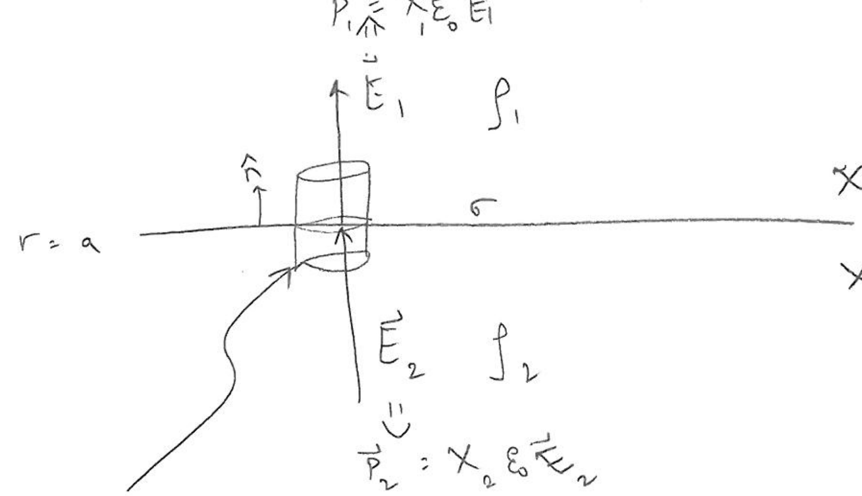
what happens when material is not vacuum &
has permitivity $\neq \varepsilon_0$; $\varepsilon = \varepsilon_r \varepsilon_0 = (1+\chi)\varepsilon_0$

χ : Susceptibility $\qquad \varepsilon_r = (1+\chi)$

define $\vec{D} \equiv \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 \vec{E} + \varepsilon_0 \chi \vec{E} = \varepsilon_0 (1+\chi) \vec{E}$

where $\vec{P} \equiv \varepsilon_0 \chi \vec{E}$ $\qquad \vec{D} = \varepsilon_0 \varepsilon_r \vec{E} = \varepsilon \vec{E}$

$\vec{P}$: Polarization Vector , $\vec{D}$: Displacement $\vec{E}$ field.



$\chi_1 \Rightarrow \varepsilon_1 = \varepsilon_0 (1+\chi_1)$

$\chi_2 \Rightarrow \varepsilon_2 = \varepsilon_0 (1+\chi_2)$

Volume charge density

connected to this Gaussian surface: $\rho_i = -\nabla \cdot \vec{P}_i$ (Gauss Law)

$$\sigma \Big|_{r=a} = \sum \hat{n} \cdot \vec{P}(r=a) \quad \text{.................} \quad \text{(Continuity Law)}$$

$$\sigma = \hat{n} \cdot \vec{P}_1 - \hat{n} \cdot \vec{P}_2 = \hat{n}\, \varepsilon_0 (\chi_1 \vec{E}_1 - \chi_2 \vec{E}_2)$$

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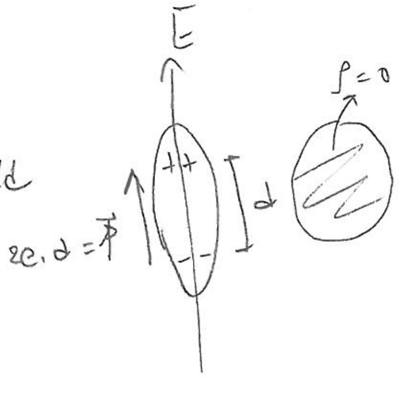
in Electrostatics you can only have $\vec{E} \perp$ interface surface

Polarizability, α : $\vec{p} = \alpha \varepsilon_0 \vec{E}$ ← Electric field

↑ dipole moment



$$\vec{P} = \frac{d\vec{p}}{dV} = \varepsilon_0 \chi \vec{E}$$

$$\vec{\nabla} \cdot \vec{D} = \rho_{free}$$

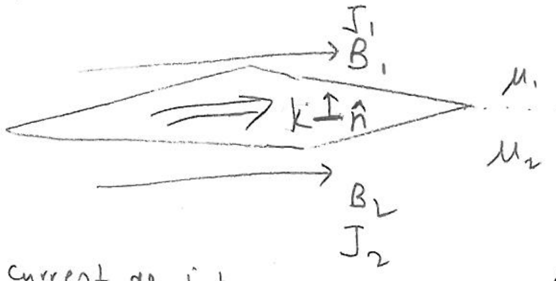
$$\vec{\nabla} \cdot \vec{P} = -\rho_{bound}$$

$$\vec{\nabla} \cdot \vec{E} = \rho_{tot}$$

3. Magnetization; $\vec{H} \equiv \frac{\vec{B}}{\mu_0} - \vec{M}$; $\vec{\nabla} \times \vec{H} = J_{free}$

$(\vec{m} = \chi_m \vec{H})$ $\nabla \times \vec{m} = J_{bound}$

$\mu_0(\chi_m + 1) = \mu$ $\nabla \times \vec{B} = J_{tot}$



volume current density

$_{bound} J_i = \vec{\nabla} \times (\vec{M}_i)$ $\Rightarrow$ $\vec{K} \times \hat{n} = \vec{M}_1 - \vec{M}_2$

surface current density

Continuity

In magnetostatics: $M_1, M_2 \perp \hat{n}$

Similar to $\vec{p}, \vec{P}$; $\frac{d\vec{m}}{dV} = \vec{M}$ where $\vec{m}$ = magnetic moment

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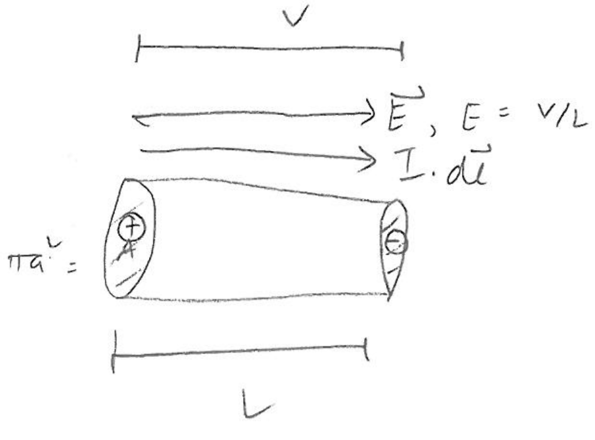
Maxwell's Eq.

$\vec{\nabla} \times \vec{H} = 0$	$\vec{\nabla} \cdot \vec{D} = \rho_{free}$
$\vec{\nabla} \cdot \vec{H} = -\vec{\nabla} \cdot \vec{m}$	$\vec{\nabla} \times \vec{D} = \vec{\nabla} \times \vec{P}$

1.



a. $EL = V = IR$, use microscopic Ohm's Law

b. Ampere's Law application

c. use a., b. ; d. $\int_V \vec{J} \cdot dV = |\vec{S}| \cdot AL$

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2. use micro teaching Equations.

always start with $\vec{E} \to \vec{P} \to \sigma_{surface}$

$\Delta V = -\int_c^a E \cdot dr = -\int_c^b - \int_b^a \Rightarrow C$

Consider $r = a$, $r = b$, $r = c$ junctions where

materials with different $\varepsilon = \varepsilon_0 (1 + \chi)$ meet

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3. Consider $k \cdot \vec{x} = q\vec{E}$ & $\vec{p} = q\vec{x} \Rightarrow \alpha ? \to p, \vec{P}$

Notice $\vec{P} = \varepsilon_0 \chi \vec{E}$ & just combine all eq. in microteaching

4. use micro teaching equations ρ

always start with $\vec{H} \longrightarrow$, then $|\vec{B}_i| = \frac{\mu_i \mu_0 I}{2\pi r} \Rightarrow \vec{M}$,

once you have $\vec{M}_i \rightarrow \vec{J}_{i\,bound}$?

$\Delta M_i \longrightarrow \vec{K}$?

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5. $\vec{\mu} = V.\vec{M} = \chi_m V \vec{H}$ $\quad (\vec{M} = \chi_m \vec{H})$

$\vec{Force} = \nabla(\underbrace{\vec{\mu}.\vec{B}}_{\text{gives potential }(V)}) \approx \vec{E} = -\vec{\nabla}V$

like field