2.5 Materials in Electrostatics

<u>Material Medium</u> can be classified

- **Conductors and Semiconductors**
- **Dielectrics**

} **electric property**

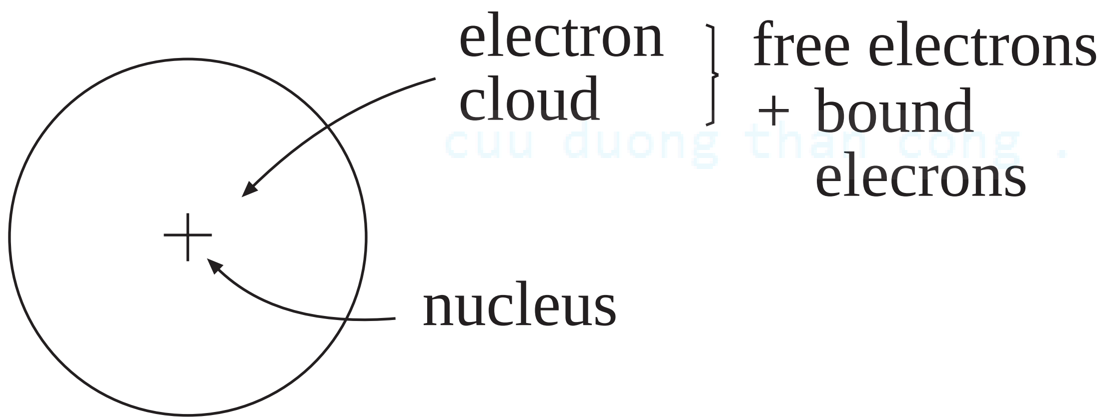
- **Magnetic materials**

} ***magnetic property***

2.5.1 Conductors and Semiconductors :

a) Introduction:

- Conductors are based upon the property of <u>conduction</u>, the phenomenon of drift of free electrons in the material with an average drift velocity proportional to the applied electric field



Electrons

⇓

Current

- In semiconductors, conduction occurs not only by electrons but also by holes – vacancies created by detachment of electrons due to breaking of covalent bonds with other atoms.

Electrons and holes ⇒ **Current**

b) Current density and Elec.Field intensity:

❖ **In conducting materials (conductor and semiconductor), current density : more than current .**

$$\vec{J} = \sigma.\vec{E}$$ ***(Ohm's Law at a point)***

$$\sigma = \text{conductivity (S/m)}$$

$$= \begin{cases} \mu_e N_e |e| & \text{conductors} \\ \mu_h N_h |e| + \mu_e N_e |e| & \text{semiconductors} \end{cases}$$

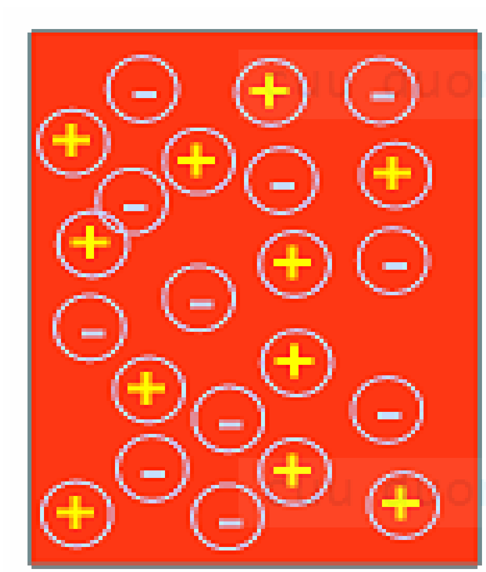
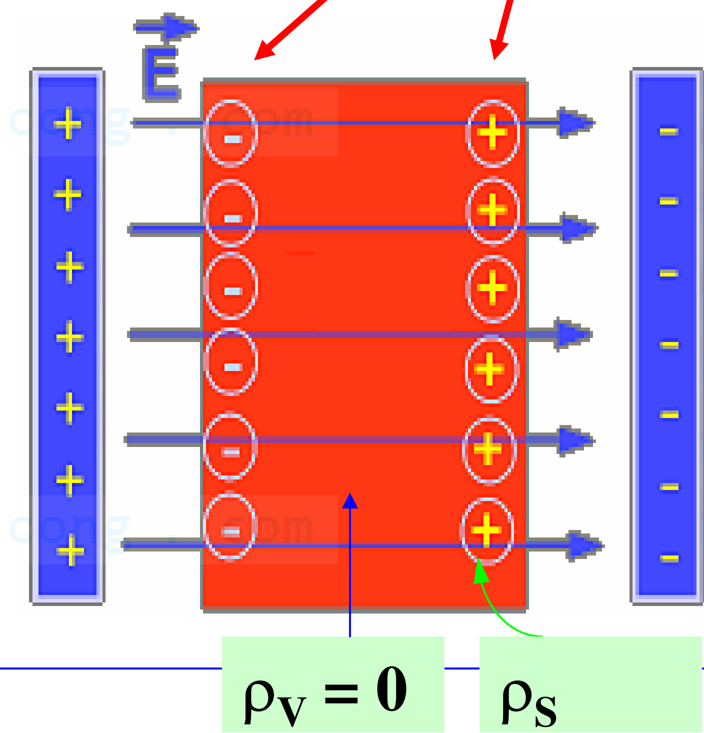
$$\mu = \text{Mobility}$$

$$N_{h,e} = \text{Density of holes } (h) \text{ or electrons } (e)$$

c) Conductor in electrostatic field :

c_1) property 1: $\rho_V = 0$; $\rho_S \neq 0$.

Induced surface charge

E applied = 0	E applied ≠ 0
	

❖Ví dụ1: Vật dẫn trong trường điện tĩnh

Gọi ρ_0 là mật độ điện tích khối tự do tại t = 0 trong vật dẫn bạc ($\varepsilon = \varepsilon_0$; $\sigma = 6{,}17.10^7$ S/m) , tìm qui luật thay đổi của ρ_v trong vật dẫn khi đặt nó trong TĐ tĩnh tại t = 0 ?

Giải

- **Từ ptrình liên tục :** $\mathrm{div}\,\vec{J} + \dfrac{\partial \rho_V}{\partial t} = 0 \quad \Rightarrow \quad \mathrm{div}\dfrac{\sigma}{\varepsilon}\vec{D} + \dfrac{\partial \rho_V}{\partial t} = 0$

$$\Rightarrow \quad \frac{\partial \rho_V}{\partial t} + \frac{\sigma}{\varepsilon}\rho = 0 \quad \Rightarrow \quad \rho_V = \rho_0 e^{-\frac{\sigma}{\varepsilon}t}$$

- **Có thể thấy :**

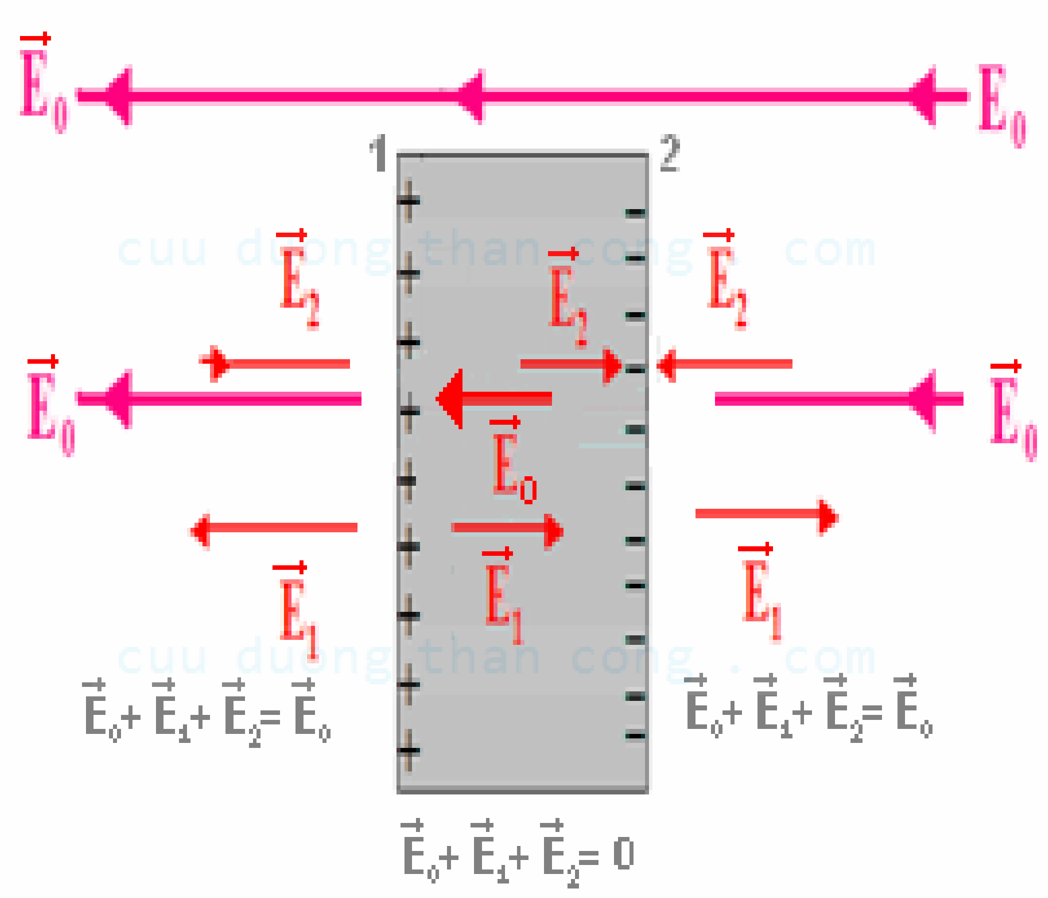
tại t = τ = ε/σ = $1{,}43.10^{-19}$ s ⇒ **$\rho_v = 0{,}368.\rho_0$**

tại t = 5τ ⇒ **$\rho_v = 6{,}7.10^{-3}.\rho_0$**

c) Conductor in electrostatic field :

c_2) **property 2:** **Electric field intensity inside a conductor is zero.**

Induced field <> applied field

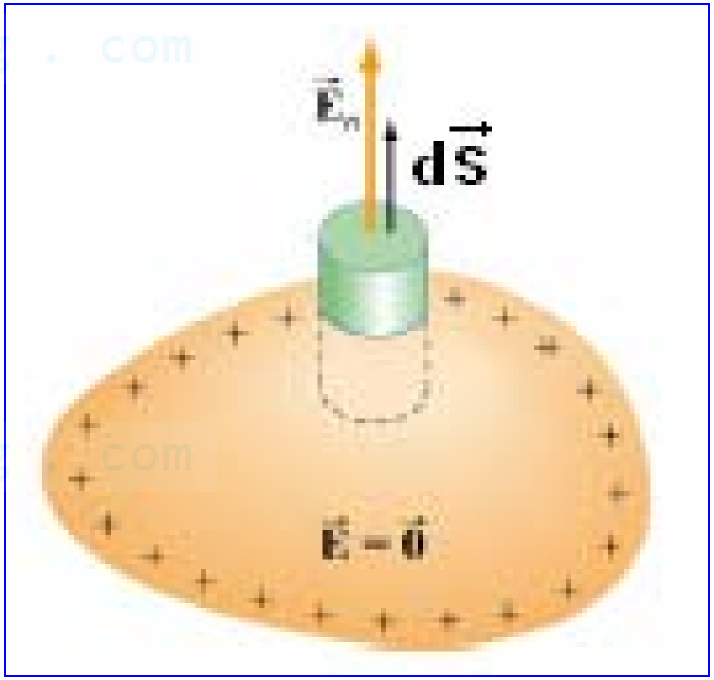


c) Conductor in electrostatic field :

c_3) **property 3:** Conductor surface = equipotential surface.

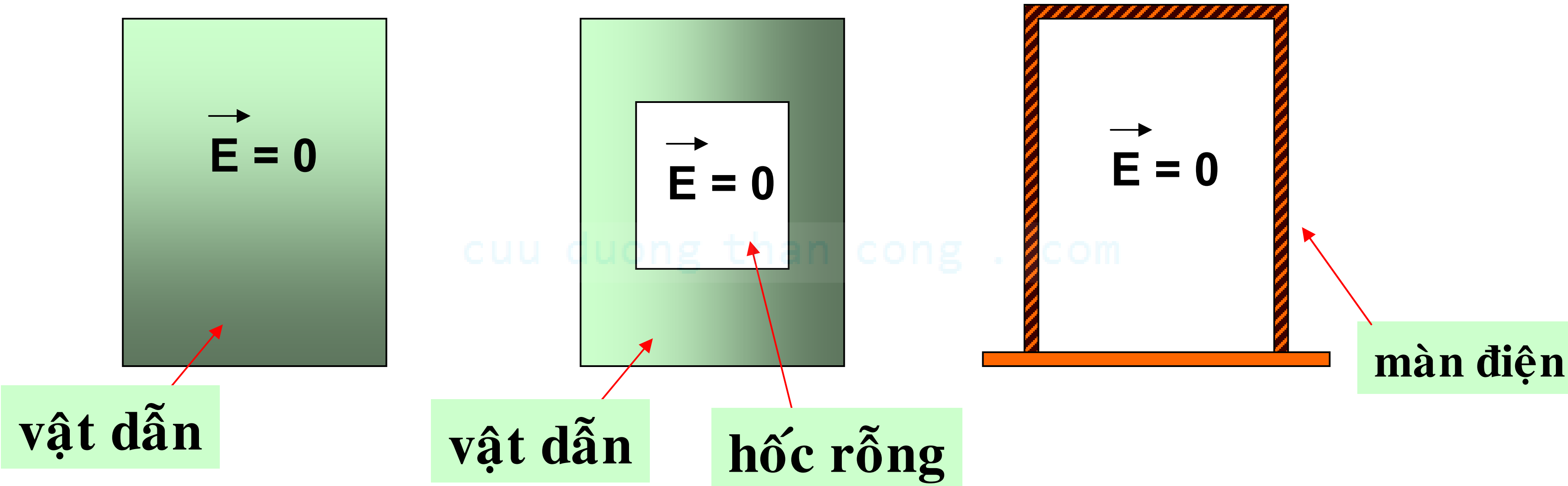
c_4) **property 4:** Electric field intensity at the surface is normal to that sueface.

$$\vec{E} = \frac{\rho_s}{\varepsilon_0}\vec{a}_n$$



d) Màn điện

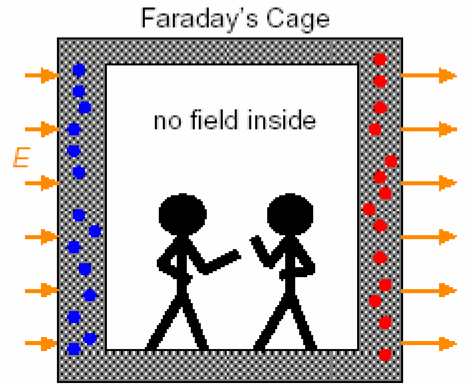
❖ Hốc rỗng bên trong vật dẫn : trường điện trong hốc rỗng sẽ bằng 0 : nguyên lý màn điện .



❖ Màn điện được dùng để chắn nhiễu của trường ngoài, hay không cho nhiễu từ thiết bị ảnh hưởng lên môi trường ngoài.

❖ Trong thực tế màn điện thường là lưới kim loại .

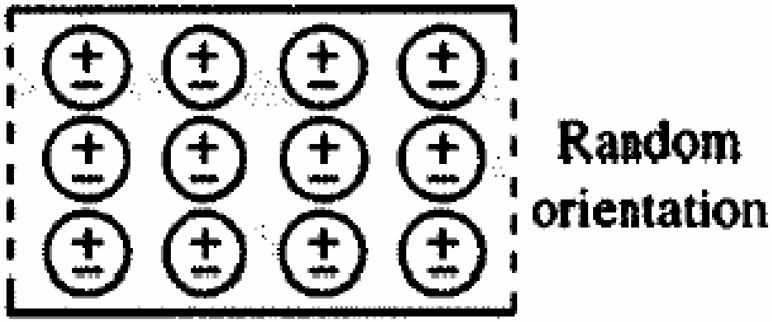
❖ Lồng Faraday:



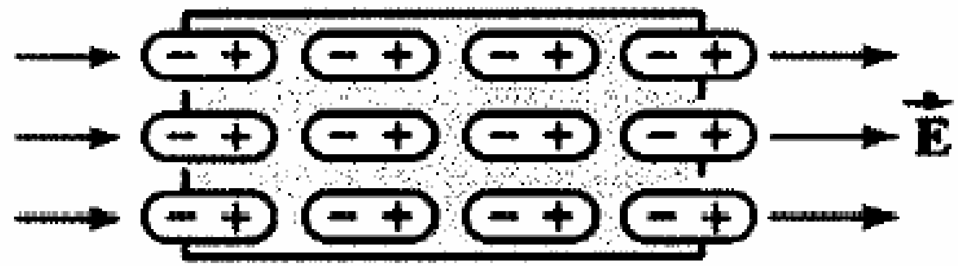
Don't Try This at Home!

2.5.2 Dielectrics in Electrostatics:

a) Polarization in dielectrics:



a) A dielectric in its normal



b) A polarized dielectric

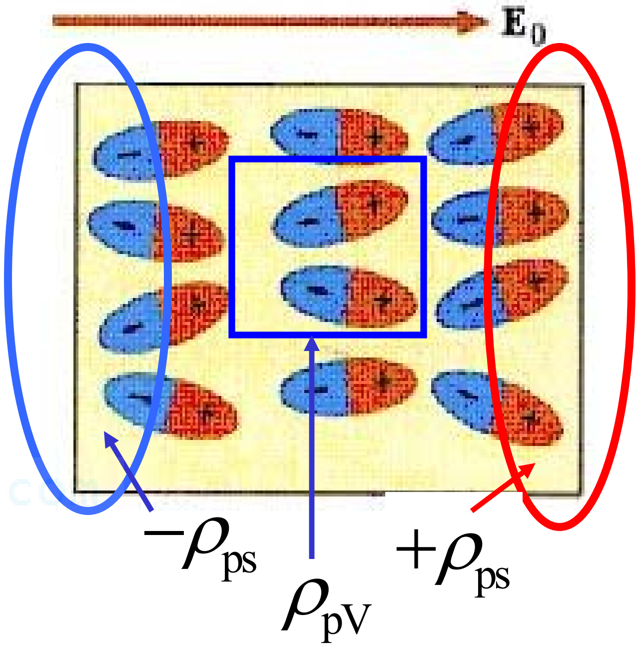
❖ To measure of inensity of polarization, we defined polarization vector. For linear , isotropic and homogeneous dielectrics:

$$\vec{P} = \chi_e \varepsilon_0 \vec{E} = \vec{D} - \varepsilon_0 \vec{E} = (\varepsilon - \varepsilon_0)\vec{E} \; [C/m^2]$$

b) Polarization charge :

- **Polarization surface charge density:**

$$\rho_{pS} = -\vec{a}_n\left(\vec{P}_1 - \vec{P}_2\right) = -P_{1n} + P_{2n} \;\; [C/m^2]$$

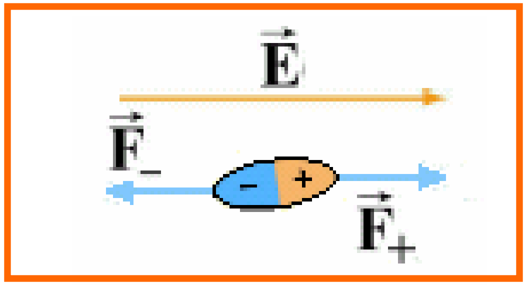


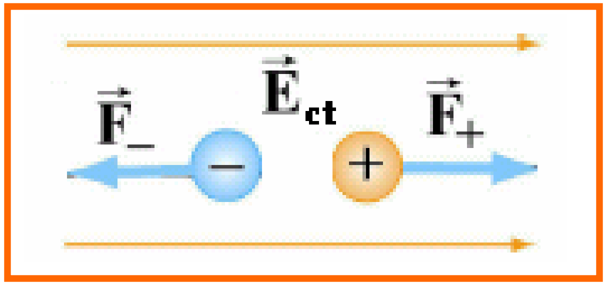
- **Polarization volome charge density:**

$$\rho_{pV} = -\mathrm{div}\,\vec{P}$$

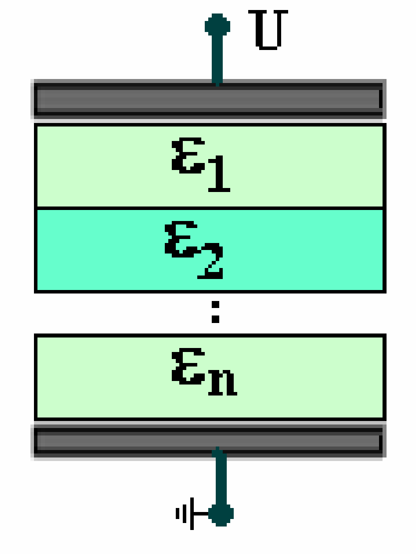
c) Dielectric breakdown (strength):

- When E in dielecric > E_{ds} : dielectric becomes conducting !!!





- U_{brk}: produces E = E_{ds} .



- If dielectric is not uniform:

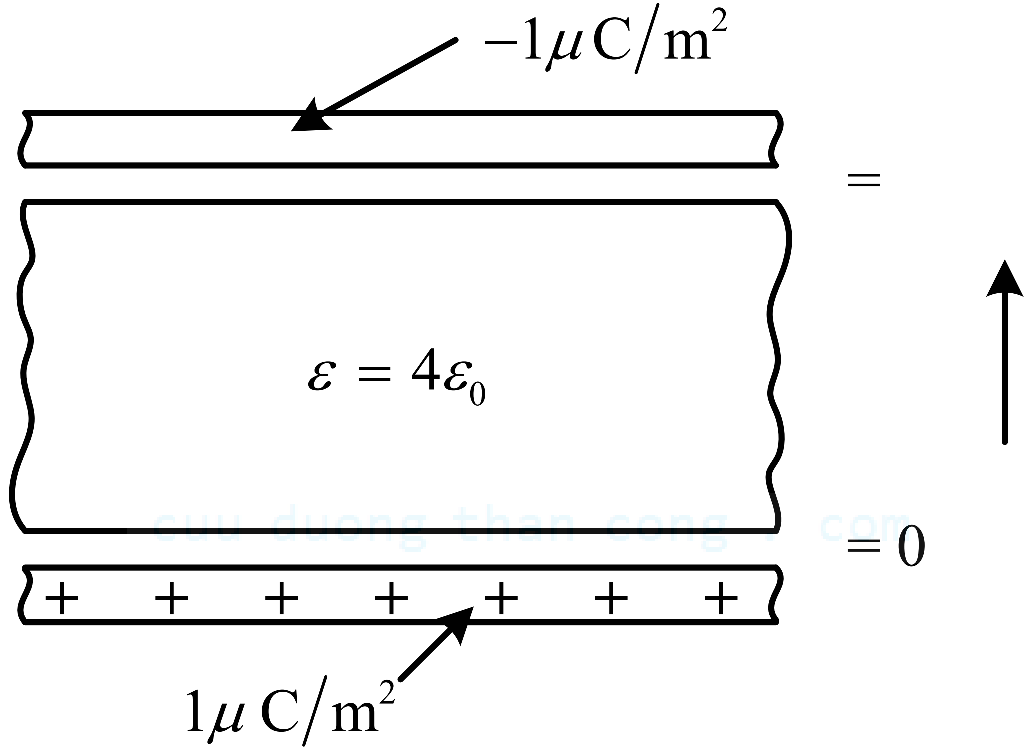
$$U_{brk} = \min\{U_{brk1}, U_{brk2}, \ldots, U_{brkn}\}$$

Dielectric strength:

Approximate dielectric constant and dielectric strength of some materials

Dielectric material	Dielectric constant	Dielectric strength (kV/m)
Air	1.0	3,000
Bakelite	4.5	21,000
Ebonite	2.6	60,000
Epoxy	4	35,000
Glass (Pyrex)	4.5	90,000
Gutta-percha	4	14,000
Mica	6	60,000
Mineral oil	2.5	20,000
Paraffin	2.2	29,000
Polystyrene	2.6	30,000
Paranol	5	20,000
Porcelain	5	11,000
Quartz (fused)	5	30,000
Rubber	2.5–3	25,000
Transformer oil	2–3	12,000

❖Example D4.3:



For 0 < z < d,

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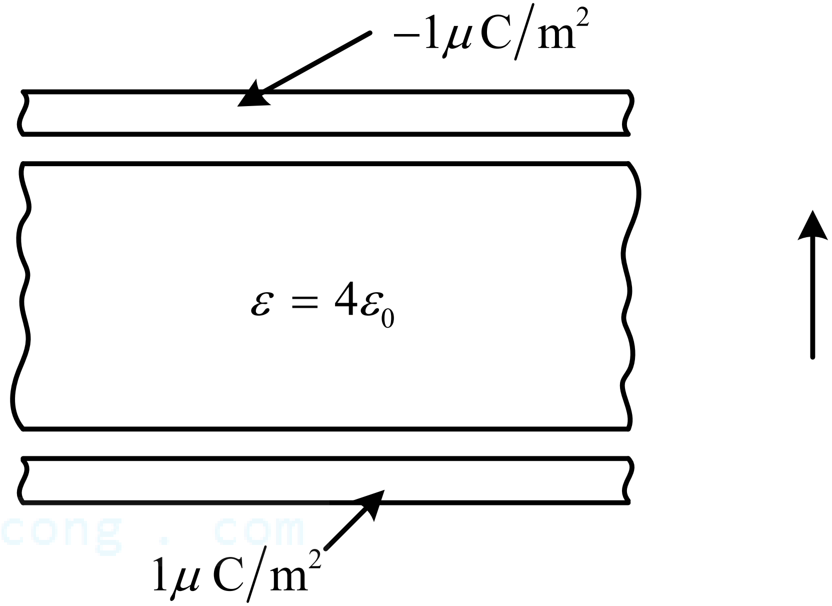
(a) $\vec{\mathbf{D}} = \rho_{S0}\vec{\mathbf{a}}_z = 10^{-6}\vec{\mathbf{a}}_z\ \mathrm{C/m^2}$

❖Example D4.3: (Cont.)



(b) $$\vec{\mathbf{E}} = \frac{\vec{\mathbf{D}}}{\varepsilon} = \frac{1}{4\varepsilon_0}\left(10^{-6}\vec{\mathbf{a}}_z\right)$$

$$= \frac{36\pi}{4\times 10^{-9}} \times 10^{-6}\vec{\mathbf{a}}_z$$

$$= 9000\pi\,\vec{\mathbf{a}}_z \text{ V/m}$$

(c) $$\vec{\mathbf{P}} = \vec{\mathbf{D}} - \varepsilon_0\vec{\mathbf{E}}$$

$$= 10^{-6}\vec{\mathbf{a}}_z - 0.25\times 10^{-6}\vec{\mathbf{a}}_z$$

$$= 0.75\times 10^{-6}\vec{\mathbf{a}}_z \text{ C/m}^2$$