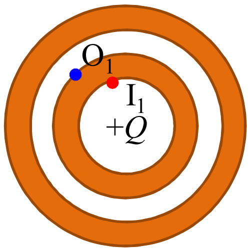
ELECTRIC FIELD IN MATERIAL SPACE

1

Concept Question: Hollow Conductors

A point charge $+Q$ is placed at the center of the conductors. The potential at O_1 is

1. Higher than at I_1
2. Lower than at I_1
3. The same as at I_1

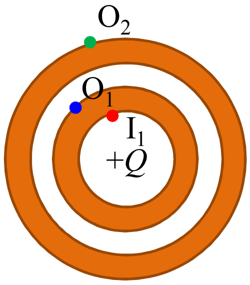


2

Concept Question: Hollow Conductors

A point charge $+Q$ is placed at the center of the conductors. The potential at O_2 is

1. Higher than at I_1
2. Lower than at I_1
3. The same as at I_1

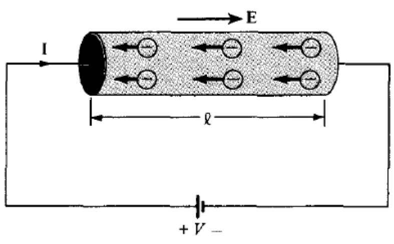


Conductors: Non-equilibrium

Consider a conductor whose ends are at a potential difference V.

In this case $\vec{E} \neq 0 \rightarrow$ no static equilibrium.

Moving electrons encounter damping forces called **resistance**.

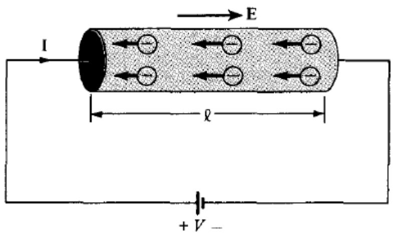


Resistance

For uniform electric field

$$E = \frac{V}{l} \qquad J = \frac{I}{S} = \sigma E = \sigma \frac{V}{l}$$

$$R = \frac{V}{I} = \frac{l}{\sigma S} = \frac{\rho_c l}{S} \qquad R = \frac{V}{I} = \frac{-\int \vec{E} \cdot d\vec{l}}{\int \sigma \vec{E} \cdot d\vec{S}}$$



Joule's Law

Power *P*

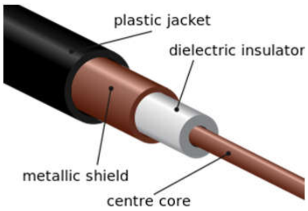
$$P = \int \rho_v \, dv \, \vec{E} \cdot \vec{u} = \int \vec{E} \cdot \rho_v \vec{u} \, dv$$

$$P = \int \vec{E} \cdot \vec{J} \, dv = VI$$

Power density w_P

$$w_P = \frac{dP}{dv} = \vec{E} \cdot \vec{J} = \sigma |\vec{E}|^2$$

Conductance of Coaxial Cable



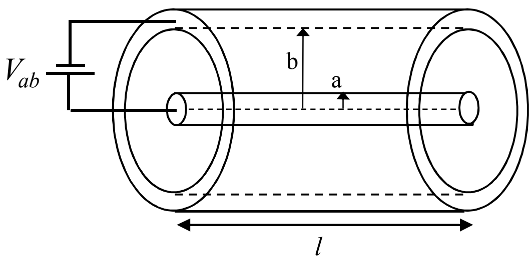
$$R = ?$$

Insulation Resistance

At any radial distance ρ

$$\vec{J} = \hat{a}_\rho \frac{I}{S} = \hat{a}_\rho \frac{I}{2\pi\rho l}$$

$$\vec{J} = \sigma\vec{E} \Rightarrow \vec{E} = \hat{a}_\rho \frac{I}{2\pi\sigma\rho l}$$



$$V_{ab} = -\int_b^a \vec{E}\cdot d\vec{l} = -\int_b^a \frac{I}{2\pi\sigma l}\frac{\hat{a}_\rho \cdot \hat{a}_\rho \, d\rho}{\rho}$$
$$= \frac{I}{2\pi\sigma l}\ln\left(\frac{b}{a}\right)$$

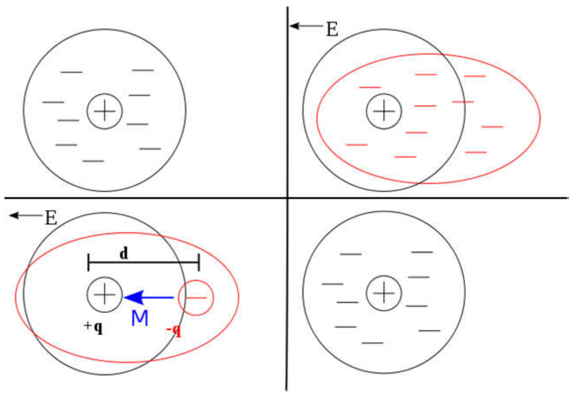
$$R = \frac{V}{I} = \frac{1}{2\pi\sigma l}\ln\left(\frac{b}{a}\right)$$

POLARIZATION IN DIELECTRICS

9

Dielectrics

- A dielectric is a non-conductor or insulator, e.g., rubber, glass.
- When a dielectric is placed in an electric field, charges do not flow as they do in a conductor, but only slightly shift from their average equilibrium positions causing **dielectric polarization**.



10

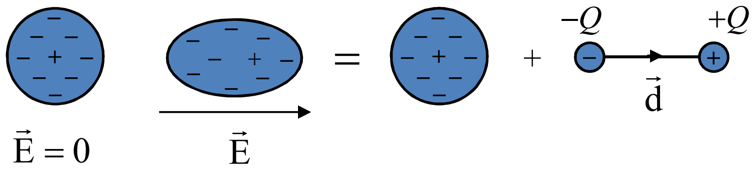
Polarization in Dielectrics

The distorted charge distribution is equivalent to the original distribution plus a dipole whose moment is

$$\vec{p} = Q\vec{d}$$

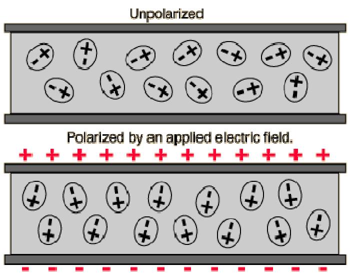
For N dipoles

$$Q_1\vec{d}_1 + Q_2\vec{d}_2 + \cdots + Q_N\vec{d}_N = \sum_{k=1}^{N} Q_k\vec{d}_k$$



11

Polarization in Dielectrics

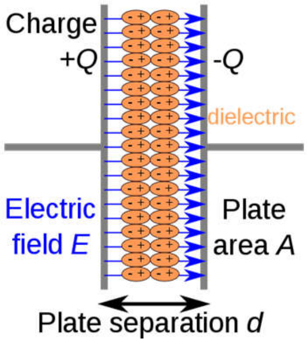


$\vec{P}$: Intensity of polarization, $\quad \vec{P} = \lim_{\Delta v \to 0} \dfrac{\sum_{k=1}^{N} Q_k\vec{d}_k}{\Delta v}$

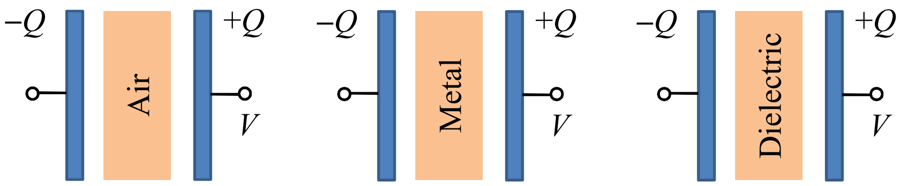
The effect of electric field $\vec{E}$ on a dielectric is the creation of dipole moments that align themselves in the direction of $\vec{E}$.

12

Capacitors

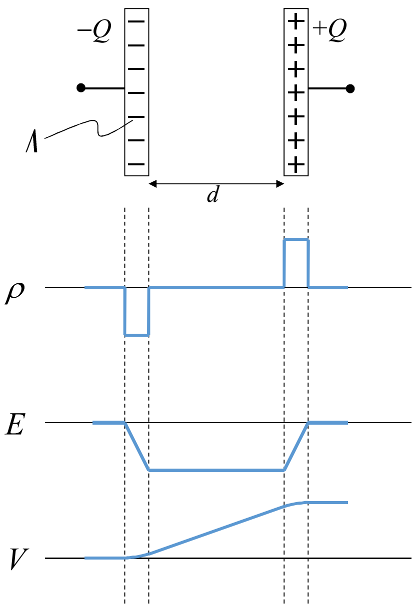


- What happens when we place air, metal, and dielectric between the plates of a charged capacitor?
- What is the effect on potential V?



13

Air Between Charged Plates



$$CV = Q$$

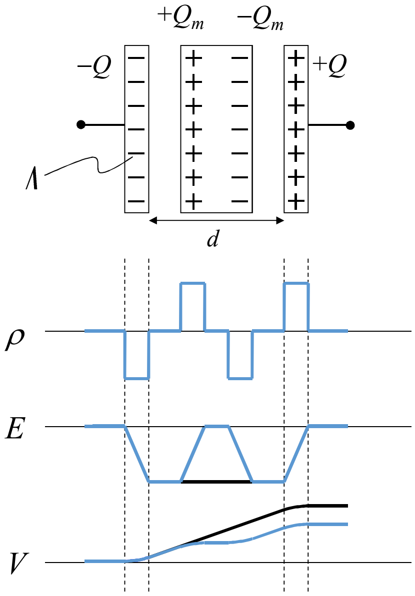
$$\varepsilon_0 \frac{A}{d} V = Q$$

$$\frac{V}{d} = E = \frac{Q}{\varepsilon_0 A}$$

$$V = -\int \vec{E} \cdot d\vec{l}$$

14

Metal Between Charged Plates



$$CV = Q$$

$$\varepsilon_m \frac{A}{d} V = Q$$

$$\frac{V}{d} = E = \frac{Q}{\varepsilon_m A}, \ \varepsilon_m > \varepsilon$$

Since Q remains same, V decreases.

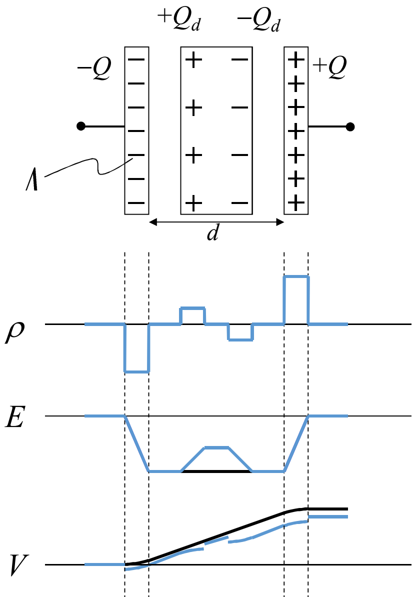
$$Q = Q_m$$

$$V = -\int \vec{E} \cdot d\vec{l}$$

Since E decreases, V decreases.

15

Dielectric Between Charged Plates



$$CV = Q$$

$$\varepsilon_d \frac{A}{d} V = Q$$

$$\frac{V}{d} = E = \frac{Q}{\varepsilon_d A}, \ \varepsilon_d > \varepsilon$$

Since Q remains same, V decreases.

$$Q \geq Q_d$$

$$V = -\int \vec{E} \cdot d\vec{l}$$

Since E decreases, V decreases.

16