ELECTRIC FIELDS IN MATERIAL SPACE

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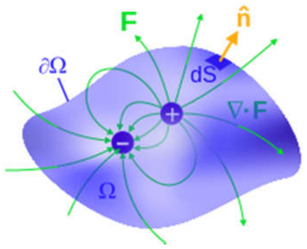
Electric Fields in Material Space

So far, electrostatics in “vacuum.”

Now we consider electric phenomena in material space.

Derived formulas need modifications.



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Materials

Materials are classified in terms of conductivity.

Conductors: metals → $\sigma \gg 1$

Nonconductors: Also called insulators or dielectrics → $\sigma \ll 1$

Conductivity changes with temperature!

Current

Current $I = \dfrac{dQ}{dt}$

$$J_n = \frac{\Delta I}{\Delta S} \Rightarrow \Delta I = J_n \Delta S$$

If current density is not normal to the surface

$$\Delta I = \vec{J} \cdot \Delta\vec{S} \Rightarrow I = \int_S \vec{J} \cdot d\vec{S}$$

Current

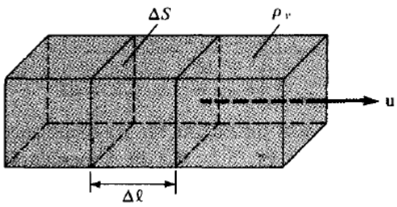
$$\vec{u} = u_y \hat{a}_y$$

$$\Delta I = \frac{\Delta Q}{\Delta t} = \rho_v \, \Delta S \frac{\Delta l}{\Delta t} = \rho_v \, \Delta S \, u_y$$

The current density at a given point is the current through a unit normal area at that point.

$$J_y = \frac{\Delta I}{\Delta S} = \rho_v u_y$$

In general, $\vec{J} = \rho_v \vec{u}$



Conductivity

$$\vec{F} = -e\vec{E}$$

$$\frac{m\vec{u}}{\tau} = -e\vec{E} \Rightarrow \vec{u} = -\frac{e\tau}{m}\vec{E}$$

τ: average time interval between collisions

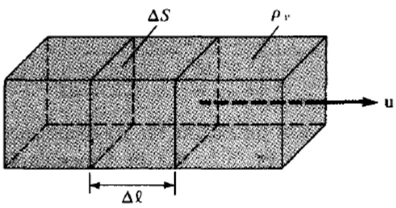
If there are n electrons per unit volume

$$\rho_v = -ne$$

The conduction current density

$$\vec{J} = \rho_v \vec{u} = \frac{ne^2\tau}{m}\vec{E} = \sigma\vec{E}$$

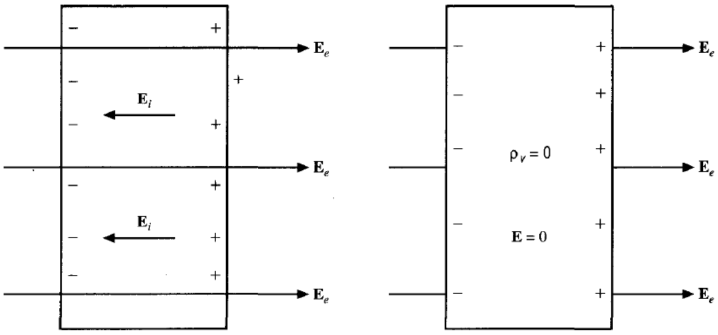
σ: conductivity of the conductor



Conductors

- Abundance of free charge.
- No electric field inside a perfect conductor.
- A perfect conductor is an equipotential body.

$$\vec{E} = -\nabla V = 0$$



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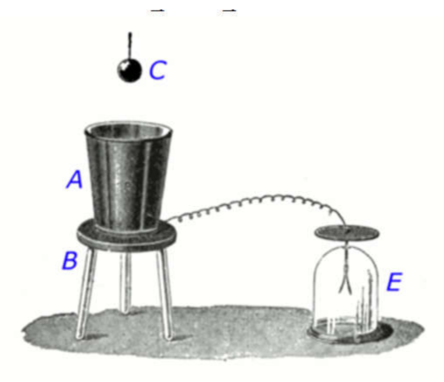
Electrostatic Induction

Faraday's Ice Pail Experiment



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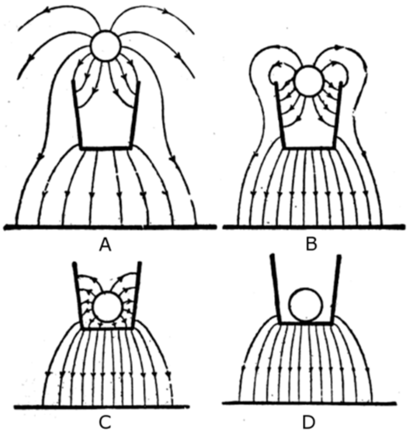
Electrostatic Induction

Faraday's Ice Pail Experiment



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Van de Graaff Generator

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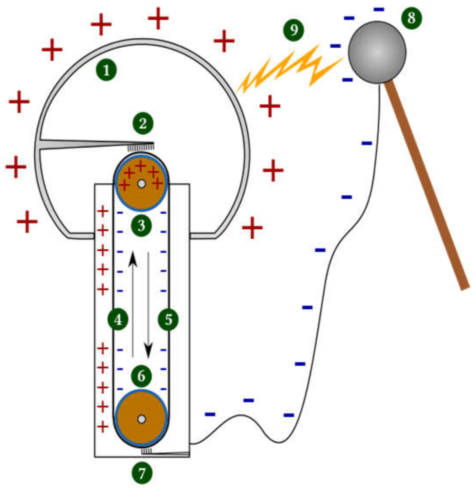
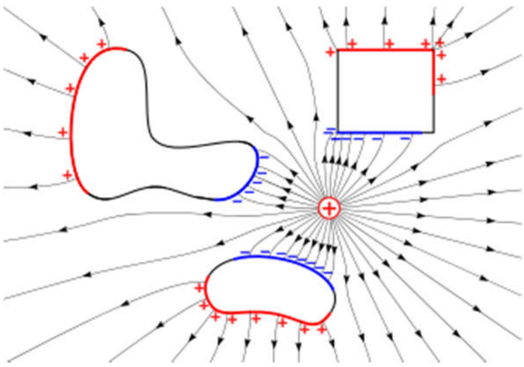
Van de Graaff Generator

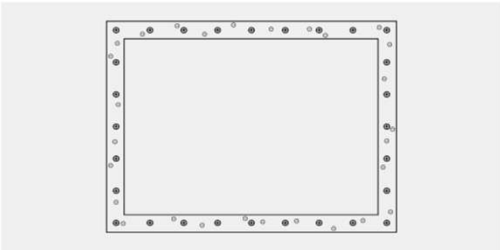


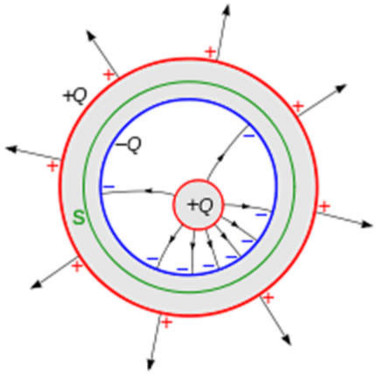
Electrostatic Shielding



- The electrostatic field of a point positive charge causes the mobile charges in metal objects to separate.
- The induced charges create an opposing electric field that exactly cancels the field of the external charge throughout the interior of the metal.

Electrostatic Shielding





Faraday's Cage