PHYS 507
Lecture 5: Electrostatics
Conductors

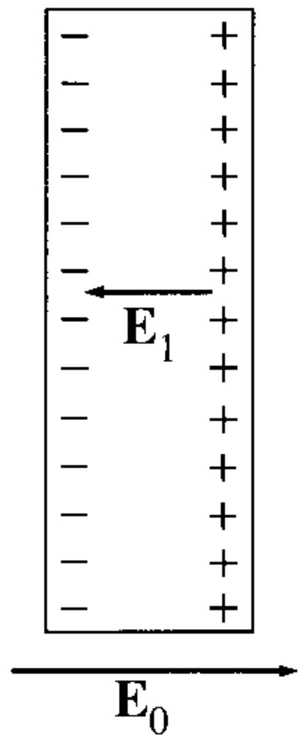
Dr. Vasileios Lempesis

Introduction

- In an **insulator** such as glass or rubber, each electron is attached to particular atom.
- In a metallic **conductor**, by contrast , one or more electrons per atom are free to roam about at will through the material.
- A **perfect** conductor would be a material containing an **unlimited** supply of completely free charges. This is an ideal case.
- From this definition we can have the following properties for ideal conductors.

Properties of ideal conductors-a

- **(i) E=0 inside a conductor.** If you expose a conductor in an external electric field $\mathbf{E}_0$ then this will force the free electrons to move at opposite sides. This process generates an internal field $\mathbf{E}_1$ opposite to $\mathbf{E}_0$. The motion of free electrons goes on until the internal field to compensate the external one. In this case there is **no net electric field** inside the conductor.



Properties of ideal conductors-b

- **(ii) ρ=0 inside a conductor.** This follows from Gauss' Law.

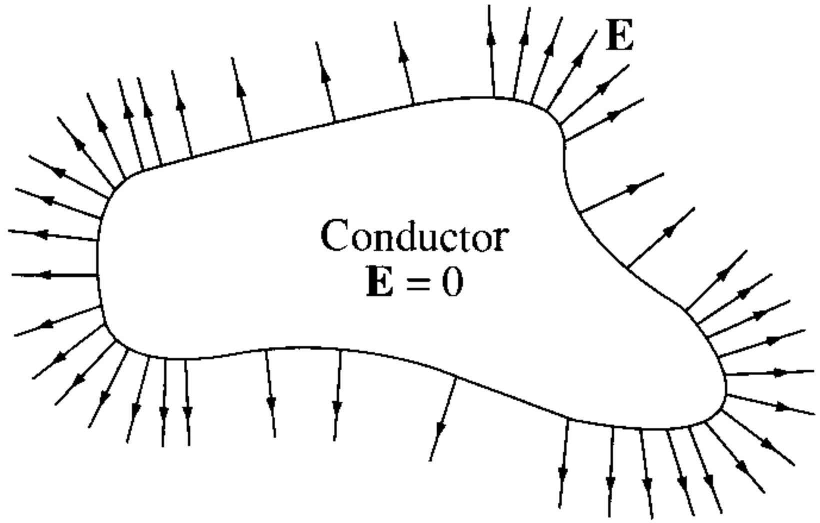
$$\nabla \cdot \mathbf{E} = \rho / \varepsilon_0 \underset{\mathbf{E}=0}{\Rightarrow} \rho = 0$$

- **(iii) Any net charge resides on the surface.** Because this is the only place it can be.
- **(iv) A conductor is an equipotential surface.** For any two points **a** and **b** on the conductor:

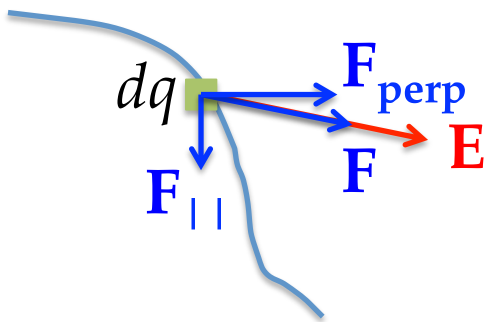
$$V(\mathbf{b}) - V(\mathbf{a}) = -\int_{\mathbf{a}}^{\mathbf{b}} \mathbf{E} \cdot d\mathbf{l} \underset{\mathbf{E}=0}{=} 0 \Rightarrow V(\mathbf{b}) = V(\mathbf{a})$$

Properties of ideal conductors-c

- **(v) E is perpendicular to the surface, just outside the conductor.**

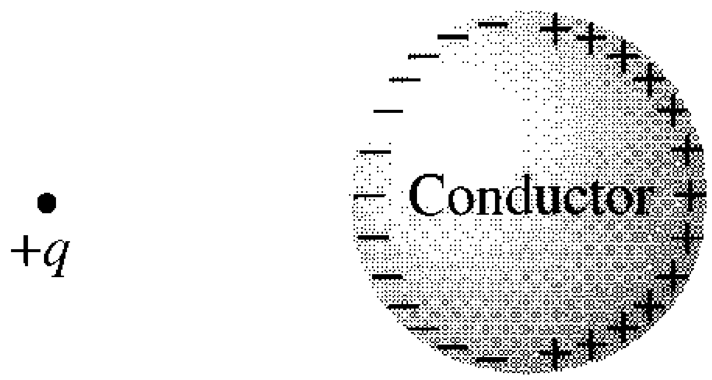


- Otherwise the charge would flow tangential to the surface.



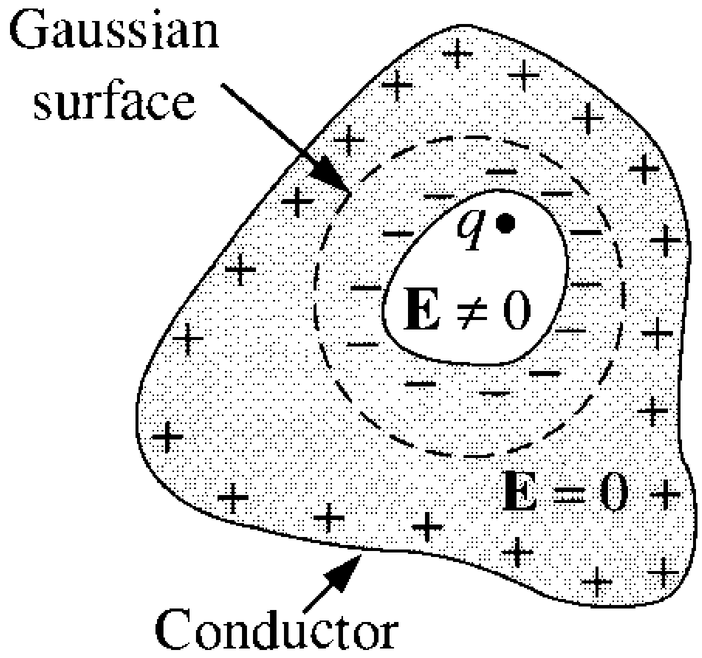
Induced charges in a conductor-a

- If you hold a charge $+q$ near an uncharged conductor, the two will attract each other. The reason for this is that q will pull minus charges over to the near side and repel plus charges to the far side.



Induced charges in a conductor-b

- If there is some cavity in the conductor, and within the cavity there is some charge, then the field in the cavity will not be zero.
- But in a remarkable way the cavity and its contents are electrically isolated from the outside world.
- **No external fields penetrate the conductor**!

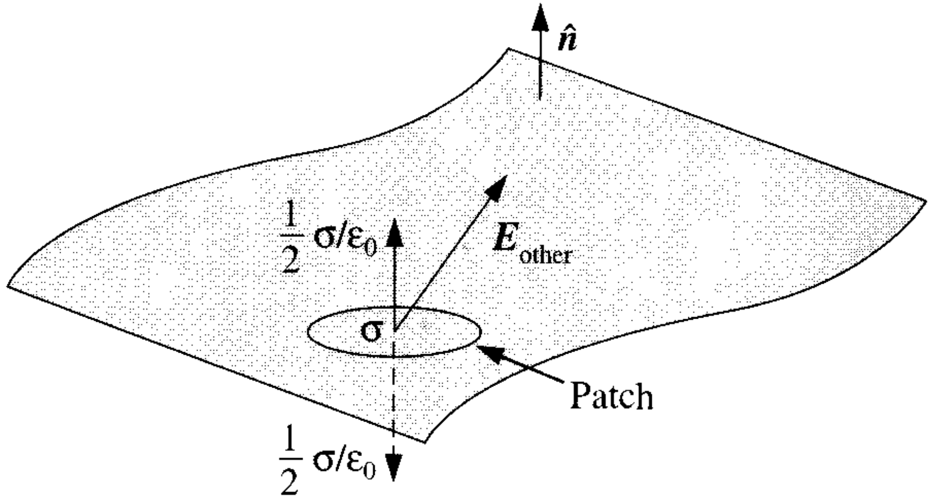


Surface Charge & Force on a Conductor

- We can show that in the presence of electric field the surface of a conductor experiences a force per unit area:

$$\mathbf{f} = \frac{1}{2\varepsilon_0}\sigma^2\hat{\mathbf{n}}$$

- This force tends to draw the conductor into the field, regardless the sign of σ.



Capacitors

- A system of two conductors with charges +*Q* and –*Q* respectively maintained at a potential difference *V* is called a capacitor.
- A capacitor is characterized by the **capacitance *C***.
- Capacitance is a purely geometrical quantity determines by sizes, shapes and separation of two conductors

$$C = \frac{Q}{V}$$

The capacitance is measured in Farad (1F=1V/C). Since this is a large value we normally use 1 μF, 1nF and 1pF.

Energy of a Capacitor

- Capacitors are used to store electric energy. The energy stored in a capacitor is given by:

$$W = \frac{1}{2}QV \qquad W = \frac{1}{2}CV^2 \qquad W = \frac{1}{2}\frac{Q^2}{C}$$