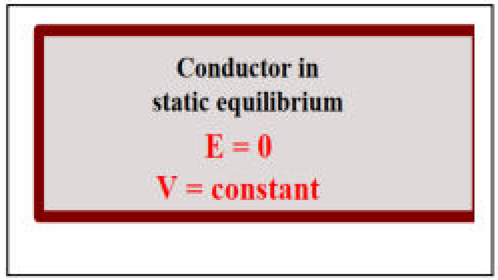
CHAPTER 04: Conductors, capacitors

4.1. Definition of a conductor: A conductor is a body in which free charges (positive or negative) exist that can be set in motion under the action of an electric field, within the volume of the material. The best known conductors are metals (Examples: copper, silver, aluminum, gold).

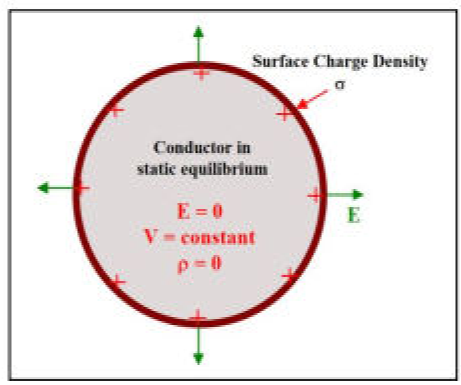
4.2. Conductor in Static Equilibrium: When the charge distribution on a conductor reaches static equilibrium (i.e. implying the immobility of the charges contained inside this conductor), the net electric field witching the conducting material is exactly zero (and the electric potential is constant).



Indeed, by applying Gauss' theorem to any closed surface S included in the volume, we see that the sum of the charges internal to this surface is zero. In this case the excess charges can only be distributed on the surface of the conductor. Since the field is zero, the flow is then given by:

$$\phi = \oiint_{S_G} \vec{E}.d\vec{S} = 0 = \frac{q_{\text{int}}}{\varepsilon_0}$$

4.3. Properties of a Conductor in Electrostatic Equilibrium:



1. The electric field is zero inside a conductor $\vec{E} = \vec{0}$, because the charges do not move and $\vec{F} = \vec{0}$.

2. Just outside a conductor, the electric field lines are perpendicular to its surface, ending or beginning on charges on the surface, and has a magnitude $E = \sigma / \varepsilon_0$ where σ is the surface charge density (i.e. charge per unit area) and the net charge on the conductor is $Q = \int_{Surface} \sigma dS$.

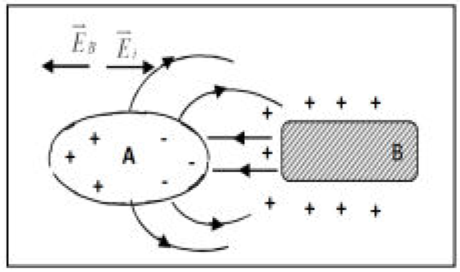
3. All excess charges are located on the surface (or surfaces) of the conductor.

4.The potential is constant inside the conductor. It is an equipotential volume. We say that the conductor is equipotential.

$$\vec{E}(r)=\vec{0} \Rightarrow \vec{E}(r)=-\vec{\nabla}V(r)=\vec{0} \Rightarrow V(r)=Cte$$

4.4. Influence phenomenon

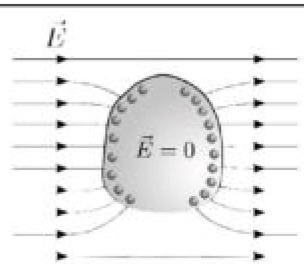
4.4.1 partial Electrostatic influence



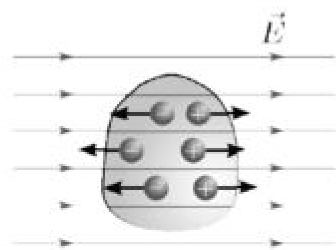
Consider an electrically neutral conductor A. We approach the latter with a positively charged conductor B as shown in the figure.

* The free electrons of conductor A will migrate towards conductor B under the action of the electrostatic field which results from electrification by **influence**, which contributes to the creation of an electric field inside the conductor. Electrostatic influence divides the charge inside the conductor. This phenomenon is called **partial influence**.

Explanations: Conductor has tons of free electrons and under the influence of E_{ext} they will run to the left surface leaving positive charges near the right surface and creating $E_{internal}$. The electrons will keep moving until the internal field cancels out the external field inside the conductor.



equilibrium

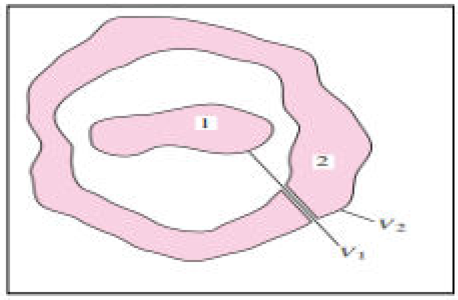


out of equilibrium

4.5. Capacitors

4.5.1. Definition of a capacitor

We will say that two conductors form a capacitor when one of the conductors surrounds the other. They are then in total influence. One of the conductors will be the external plate of the capacitor while the other will be the internal plate. The conductors are called plates. If the conductors carry charges of equal magnitude and opposite sign, a potential difference ΔV exists between them. Experimentally when we vary the charge of a conductor, we see that its potential varies so that the Q/V ratio remains constant. This ratio is called the conductor capacity and is denoted C (in Farad)



$$\frac{Q_1}{V_1} = \frac{Q_2}{V_2} = \dots\dots\dots = \frac{Q_n}{V_n} \Rightarrow C = \frac{Q}{V}$$

milifarad	microfarad	nanofarad	picofarad
$1mF = 10^{-3} F$	$1\mu F = 10^{-6} F$	$1nF = 10^{-9} F$	$1pF = 10^{-12} F$

The capacitance C of a capacitor is defined as the ratio of the magnitude of the charge on either conductor to the magnitude of the potential difference between the conductors: $C = \frac{Q}{\Delta V}$

4.5.1.1 Example01: Capacitance of a spherical conductor

Consider a conductor A of radius R containing a charge Q. Its potential V is written: $V = \frac{KQ}{R}$

The capacity is given by: $C = \frac{Q}{V} \Rightarrow C = \frac{Q}{KQ / R} = \frac{R}{K} \Rightarrow C = 4\pi\varepsilon_0 R$