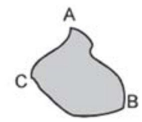
PROPERTIES OF CONDUCTOR

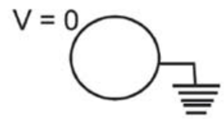
Conductor and it's properties [For electrostatic condition]

1. Conductors are substances that possess a substantial quantity of free electrons capable of moving unrestrictedly within the material.
2. In the realm of electrostatics, conductors consistently manifest as equipotential surfaces.
3. The presence of charge on a conductor is invariably confined to its outer surface.
4. In the event of a cavity within the conductor devoid of any charge, the charge distribution remains exclusively on the outer surface of the conductor.
5. The electric field consistently maintains a perpendicular orientation to the conducting surface.
6. Conductors prevent the penetration of electric lines of force into their interiors.
7. The formula for the electric field intensity near the conducting surface is provided by



$$\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$$

$$\vec{E_A} = \frac{\sigma_A}{\varepsilon_0}\hat{n};\ \vec{E_B} = \frac{\sigma_B}{\varepsilon_0}\hat{n} \text{ and } \vec{E_C} = \frac{\sigma_C}{\varepsilon_0}\hat{n}$$



8. Grounding a conductor results in its potential being reduced to zero.
9. Grounding an isolated conductor causes its charge to be nullified.
10. Upon connecting two conductors, there will be a flow of charge until their potentials are equalized.
11. Electric pressure at the surface of a conductor can be determined using the formula

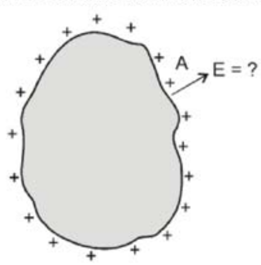
$$P = \frac{\sigma^2}{2\varepsilon_0}, \text{ where } \sigma \text{ is the local surface charge density.}$$

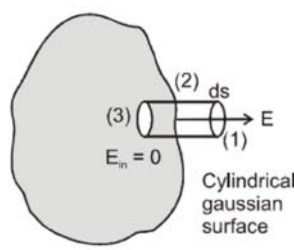
E-Field Just Outside The Charged Conductor

Let's consider a conductor with a local surface charge density of σ at point 'A'. Our objective is to determine the electric field immediately outside the surface of the conductor.

To achieve this, let's examine a small cylindrical Gaussian surface depicted in the figure, with a portion inside and a portion outside the conductor surface.

It has a small cross section area ds and negligible height.





Applying Gauss's theorem for this surface

$$\phi_{net} = \frac{q_n}{\varepsilon_0} = \frac{\sigma ds}{\varepsilon_0}$$

Flux through surface (1)	Flux through surface (2)	Flux through surface (3)
$\phi_1 = Eds$	$\phi_2 = 0$	$\phi_3 = 0$
(Because $\vec{E}$ is normal to the surface of conductor)	($\vec{E}$ is normal to curved Gaussian surface)	(As E inside the conductor=0)

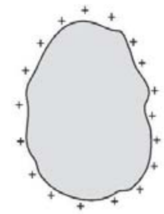
$$Eds = \frac{\sigma ds}{\varepsilon_0} \Rightarrow E = \frac{\sigma}{\varepsilon_0}$$

Electric field just outside the surface of conductor :

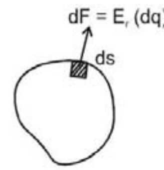
$E = \frac{\sigma}{\varepsilon_0}$ (direction will be normal to the surface) in vector form: $\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$

(Here, $\hat{n} =$ unit vector normal to the conductor surface)

Electrostatic pressure at the surface of the conductor



Imagine a conductor is imparted with some charge. As a result of repulsion, all the charges will distribute themselves across the surface of the conductor. However, the mutual repulsion between these charges persists, leading to an outward force experienced by each charge due to the others. This force gives rise to a pressure at the surface, termed electrostatic pressure. To calculate this pressure, let's consider a small surface element with an area 'ds'. The force acting on this element is due to the presence of the remaining charges.



$$dF = \begin{pmatrix}\text{electric field at} \\ \text{That place due to} \\ \text{remainig charges}\end{pmatrix}\begin{pmatrix}\text{charge of} \\ \text{the small} \\ \text{element}\end{pmatrix}$$

Let electric field at that point due to the remaining charges $= E_r$

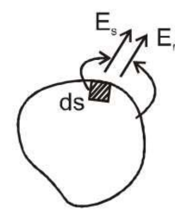
and charge of the small element $= dq = \sigma ds$

$$dF = (E_r)(dq) = (E_r)(\sigma ds)$$

So, pressure on this small element

$$P = \frac{dF}{ds} = \frac{(E_r)(\sigma ds)}{ds}$$

$$P = (E_r)(\sigma) \qquad \text{... (1)}$$



To determine the pressure, it is necessary to calculate the electric field (E_r) at the specific position resulting from the remaining charges. Let's assume:

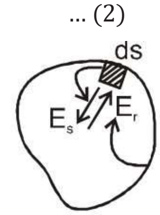
The electric field due to the small element near the surface is denoted as E_s.

The electric field due to the remaining part near the surface is represented as E_r.

At a location just outside the surface, the electric field due to the small element (E_s) and the electric field from the remaining part (E_r) will both exhibit an outward normal orientation.

So Net electric field just outside the surface $= E_s + E_r$ and we have proved that electric field just outside the conductor surface $= \frac{\sigma}{\varepsilon_0}$

$$E_s + E_r = \frac{\sigma}{\varepsilon_o} \qquad \text{... (2)}$$



Now, consider the electric field just within the metal surface. In this scenario, the electric field resulting from the remaining charges (E_r) will maintain the same direction (normally outward). However, the electric field due to the small element will be in the opposite direction (normally inward). Consequently, the net electric field just inside the metal surface is given by E_r - E_s. It is important to note that the electric field inside a conductor is known to be zero.

$$E_r - E_s = 0 \Rightarrow E_r = E_s \qquad \text{... (3)}$$

from eqn. (2) and eqn. (3), we can say that

$$2E_r = \frac{\sigma}{\varepsilon_o} \Rightarrow E_r = \frac{\sigma}{2\varepsilon_o}$$

Now, we can easily find the pressure from eqn. (1)

$$P = (E_r)(\sigma) = \frac{\sigma}{2\varepsilon_o}(\sigma) = \frac{\sigma^2}{2\varepsilon_o}$$

So, electrostatic pressure at the surface of the conductor $P = \frac{\sigma^2}{2\varepsilon_0}$

where, $\sigma =$ local surface charge density