Sec 2.8 : PE in an external Electric field.

- → PE of a single charge in an external field
- → PE of a system of 2 charges " "
- → PE of a "Dipole" in an external field

General: → In previous sections, we have dealt with the field produced by charges. Now, we calculate PE of ~~system~~ of charges in a given external field.

→ We have already obtained an expression for PE of a ~~system of~~ charges. In this case, the source of the electric field i.e. charges and their locations were specified.

→ We now have to determine PE of a charge (or system of charges) in a given external electric field, which is not produced by the given charges whose PE we have to calculate. The sources that produce external field $\vec{E}$ is often unknown and they are of no interest to us.

PE of a single charge in an external field.

The external electric field $\vec{E}$ and the corresponding potential V may change from point to point. If $V(\vec{r})$ is the external potential at any point P of position vector $\vec{r}$, then by definition, work done in bringing a unit positive charge from ∞ to the point P is equal to V.

∴ Work done in bringing a charge q from ∞ to point P in an "External" field $= q \cdot V(\vec{r})$

⟹ This work is stored in the charged particle in the form of its PE

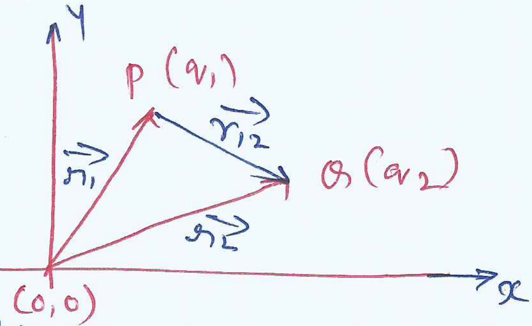
∴ PE of a single charge q at $\vec{r}$ in an external field $= q\,V(\vec{r})$

Thus if electron with charge $q = e = 1.6\times10^{-19}C$ is accelerated by a ~~PE~~ potential difference of $\Delta V = 1$ volt, it would gain energy of $q\Delta V = 1.6\times10^{-19}J$

∴ $1eV = 1.6\times10^{-19}J$ → eV unit is used most commonly in atomic, nuclear and particle physics.

32-

PE of a system of 2 charges in an "External field"



- Suppose q_1, q_2 are 2 point charges at positions vectors $\vec{r_1}$ and $\vec{r_2}$ respectively, in a uniform external electric field of intensity $\vec{E}$. To find the PE of a system of these 2 charges in the external field, we find that

→ Work done in bringing q_1 from ∞ to P is $W_1 = q_1 V(\vec{r_1})$ where $V(\vec{r_1})$ is potential at P due to external field (IMP)

→ IIIly work done in bringing q_2 from ∞ to Q is $W_2 = q_2 V(\vec{r_2})$ where $V(\vec{r_2})$ is potential at Q due to external field (IMP)

→ IMP In addition, there is one more work done which is due to field by charge q_1 when q_2 is brought from ∞ to Q.

$\therefore W_3 = \dfrac{q_1 q_2}{4\pi\epsilon_0 r_{12}}$; r_{12} is the distance betn q_1 and q_2

$\therefore$ So there are 3 terms, ~~one~~ "two" work done due to "external field" and 1 term is work done by field of the given charge

$\therefore W = W_1 + W_2 + W_3$

$$\boxed{U = q_1 V_1(\vec{r_1}) + q_2 V_2(\vec{r_2}) + \frac{q_1 q_2}{4\pi\epsilon_0 r_{12}}}$$

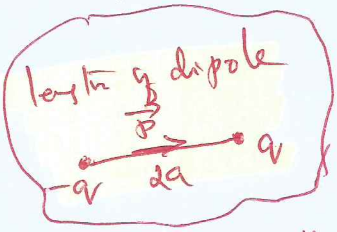
Sec 2.8.3: PE of a "DIPOLE" in an "External field"

* In the previous case of PE of a system of 2 charges in an "external electric field", if we consider two charges as $+q$ and $-q$, ~~the eqn~~ the eqn boils down to ~~eq~~ expression for PE of a dipole in an exter. field.

From previous section $U' = q_1 V_1(\vec{r}_1) + q_2 V_2(\vec{r}_2) + \frac{q_1 q_2}{4\pi\epsilon_0 r_{12}}$

if we consider opposite charges $+q$ and $-q$, then

$$U'(\theta) = q\left[V(\vec{r}_1) - V(\vec{r}_2)\right] - \frac{q^2}{4\pi\epsilon_0 \times 2a}$$



- $\vec{r}_1$ and $\vec{r}_2$ are position vectors of $+q$ and $-q$.
- potential difference (PD) betn positions $\vec{r}_1$ and $\vec{r}_2$ equals the "work done" in ~~bringing~~ bringing a unit positive charge against field from $\vec{r}_2$ to $\vec{r}_1$.
- The displacement parallel to the force $= 2a\cos\theta$

$\therefore \left[V(\vec{r}_1) - V(\vec{r}_2)\right] = -E \times 2a\cos\theta$, we thus obtain

$$U'(\theta) = -pE\cos\theta - \frac{q^2}{4\pi\epsilon_0 \times 2a} = -\vec{p}\cdot\vec{E} - \frac{q^2}{4\pi\epsilon_0 \times 2a}$$

This term is extra but it is constant is insignificant for PE calculation. So we can drop this term

$$U'(\theta) = -\vec{p}\cdot\vec{E}$$

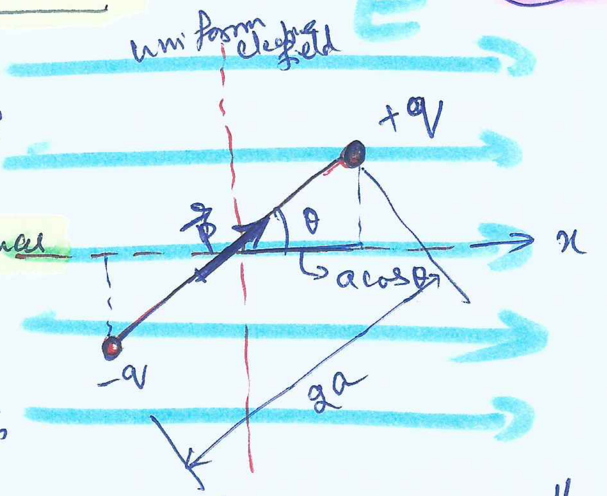
The above analysis is deducing from previous case for finding P.E. of a dipole in an external field.

Next page, we will derive taking this dipole case as independent case $\longrightarrow$

P.T.O

IMP.X

PE of a dipole in an external field :



When an electric dipole of moment ~~$\vec{p}$~~ $\vec{p}$ is placed in a uniform electric field $\vec{E}$ making an ~~eg~~ angle θ with the field, a restoring torque $\vec{\gamma}$ acts upon the dipole (dipole experiences no net force, but experiences torque) which tends to align the dipole in the direction of the field. The magnitude of this torque is

$$\gamma = pE\sin\theta$$

If we rotate the dipole further from this position thro' an infinitesimally small angle $d\theta$, the work done (torque × angular displacement) would be

$$dW = \gamma\, d\theta = pE\sin\theta\, d\theta$$

∴ Hence, the work done in rotating the dipole thro' an angle θ from its equilibrium position is

$$W = \int_0^\theta pE\sin\theta\, d\theta = pE\left[-\cos\theta\right]_0^\theta = pE\left[\cos\theta\right]_\theta^0$$

$$\boxed{W = pE(1-\cos\theta)}$$

This is the formula for the work done in rotating an electric dipole in a uniform external electric field thro' an angle θ from the direction of the field (equilibrium position)

→ If the dipole be rotated thro' 90° from the direction of the field, then the work done will be

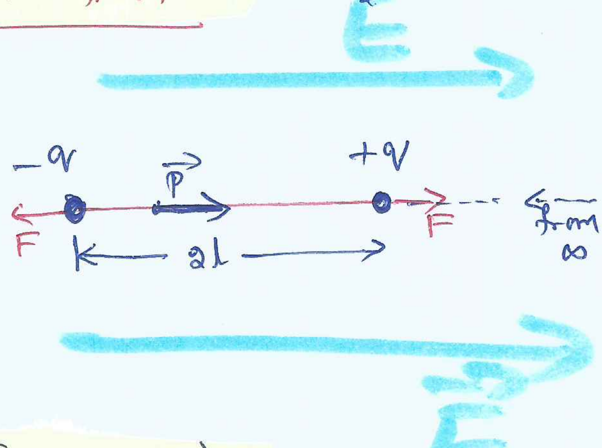
$$W = pE(1-\cos 90^\circ) = pE(1-0) = pE$$

→ IIIly if dipole is rotated thro' 180° from the direction of the field, then the work done will be

$$W = pE(1-\cos 180^\circ) = pE(1-(-1)) = 2pE$$

$\boxed{\cos 180^\circ = -1}$

PE of an electric dipole in an External Electric field :



The PE of an electric dipole in an external electric field is equal to the work done in bringing the dipole from ∞ to inside the field $\vec{E}$

P.T.O →

From pre. figure, an electric dipole is brought from ∞ to a uniform external electric field $\vec{E}$ in such a way that the dipole moment $\vec{p}$ is always in the direction of $\vec{E}$. (See fig)

→ Due to field $\vec{E}$, a force $\vec{F} = (q\vec{E})$ acts on the charge $+q$ in the direction of the field, and an equal force $\vec{F}(=q\vec{E})$ on the charge $-q$ in the opposite direction (to $\vec{E}$)

→ Hence, in bringing the dipole into the field, work will be done on the charge $+q$ by an external agent, while work will be done by the "external field" itself on the charge $-q$.

→ But, as is clear from fig (pre. page), as the dipole is brought from ∞ into the field, the charge $-q$ covers $2l$ distance more than the charge $+q$. Hence, "net" work done on $-q$ will be greater.

→ ∴ Work done in bringing the dipole from ∞ into the field is force on charge $(-q)$ × additional dist. moved

$= -qE \times 2l = -pE$

where $p = q \times 2l$ is the moment of the electric dipole. This work is the potential Energy U_0 of the electric dipole placed in the electric field parallel to it:

$$U_0 = -pE$$

→ In this position, the electric dipole is in "stable equilibrium" inside the field.

→ Now if we rotate the dipole in the field thro' an angle θ, then work will have to be done on the dipole. This work is given by $W = pE(1-\cos\theta)$

→ This will result in an increase in the PE of the dipole. Hence the PE of the dipole in the position θ will be given by

$$U_\theta = U_0 + W = -pE + pE(1-\cos\theta)$$

$$\therefore \boxed{U_\theta = -pE\cos\theta}$$ This is the general eqn of the PE of the electric dipole.

→ In Vector notation $\boxed{U_\theta = -\vec{p}\cdot\vec{E}}$ → (1)

Case (1): If dipole is ⊥r to field $\theta = 90°$, $\cos 90° = 0$ ∴ $U_{90} = 0$. In this position, the PE of dipole is zero. ⟹ If we keep the dipole ⊥r to $\vec{E}$ while bringing it from ∞ into the field, then the work done on $+q$ by an external agent = work done on $-q$ by the field. Thus, net work done on the dipole will be zero and hence the PE of the dipole will also be zero.

Case (2): → If dipole is rotated thro' 180° from the position of stable equilibrium, then the potential energy in the new position will be $U_{180} = -pE\cos 180 = +pE$.

In this position, the dipole will be in "unstable" equilibrium.

36 X. Electric potential due to a spherically symmetric distribution of charge (not in Syllabus)

Let us consider a spherical ~~sheet~~ shell of radius R carrying a charge q, distributed uniformly on its surface. We can determine electric potential outside the shell, on the surface of the shell and inside the shell.

① At an external point : From Gauss's law, electric field at a distance $r\,(> R)$ from the centre of the charged shell is given by $E = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r^2}$

If V be the electric potential at this point, then by potential gradient, we have

$$E = -\frac{dV}{dr} \qquad \text{Integrating } V = -\int_\infty^r E\,dr = -\frac{q}{4\pi\epsilon_0}\int_\infty^r \frac{dr}{r^2} = -\frac{q}{4\pi\epsilon_0}\left[-\frac{1}{r}\right]_\infty^r$$

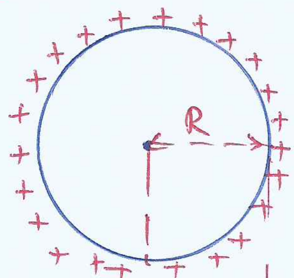
$$\text{or } \boxed{V = \frac{1}{4\pi\epsilon_0}\cdot\frac{q}{r}} \longrightarrow ①$$

We see that electric potential outside a charged spherical shell varies inversely with distance r from the centre of the shell.

② ~~At the~~ At the Surface of spherical shell : For a point on the surface of the shell $r = R$. Therefore, by eqn ①, we have

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\,\frac{q}{R}}$$

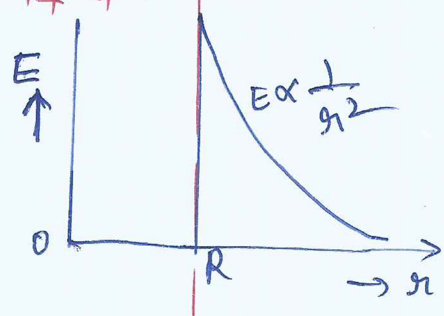
Thus, electric potential on the surface of the shell is same everywhere.



③ At an internal point : Again by Gauss' theorem, the field at any point inside ~~the~~ a charged shell is zero. $\Longrightarrow \quad E = 0$

But $E = -\dfrac{dV}{dr} \quad \therefore \quad -\dfrac{dV}{dr} = 0$

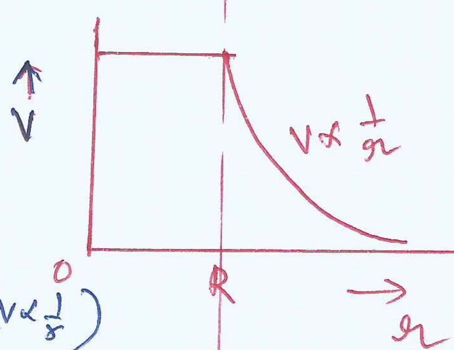
$$\therefore \boxed{V = \text{constant}}$$



Thus, inside the ~~shell~~ charged shell, the potential at all points is same and its value is equal to that on the surface, that is

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\,\frac{q}{R}}$$

∴ Therefore, if we take any other charge from one point to another inside a charged spherical shell, then no work will be done.



The variation of $\vec{E}$ and $\vec{V}$ with r is shown in figure →

$\vec{E}$ is zero everywhere inside the shell from ($r = 0$ to $r = R$), and V is constant and uniform.

Outside the shell, both E and V decrease with distance, E decreases rapidly ($\propto 1/r^2$) while V decreases slowly ($V \propto \frac{1}{r}$)

The above result hold also for a "conducting" charged sphere whose charge lies entirely on its outer surface.

Further →

→ Electrostatics of conductors

→ Dielectrics and polarization

→ Capacitors and Capacitance

→ The parallel plate capacitor

→ Effects of Dielectric on capacitance

→ Combination of capacitors < Series / parallel

→ Energy stored in a capacitor

Connected with Capacitors.

→ Van de Graaff Generator.

Electric properties of an Isolated charged conductor.

Imp PYQ

Under electrostatic conditions, charged "conductors" have the following electric properties.

(1) The electric potential at all points inside and on the surface of ~~the~~ a charged conductor is same. → When we charge an isolated conductor, then this charge produces 'momentarily' an electric field inside the material of the conductor. Immediately, the free electrons inside the conductor move from the points at lower potential to the points at higher potential until the potential becomes same at every point. In other words, charge given to the conductor distributes itself on the surface such that all points of the conductor, whether on the surface or inside, come to the same potential. In particular, the surface of a charged conductor is an equipotential surface.

(2) The electric field "inside" a charged conductor is zero everywhere. Because there is no variation of potential inside a charged conductor, the electric field $\vec{E}$ is zero ($E = -\frac{dV}{dr} = 0$ because V is ~~constant~~ constant)

→ The absence of electric field inside charged conductors enables conductors to act as electrostatic shields. To save an electrical instrument from external electric fields, the instrument may be covered by a hollow conductor. This is why during thunderstorm accompanied by lightning, it is safest to sit inside a car, rather than standing near a tree on open ground.

(3) The 'total' charge of a charged conductor lies at the outer surface of the conductor. The electric field inside ~~the~~ a conductor is zero. It is possible only when there is no charge inside the conductor. Hence the total charge given ~~to~~ to the conductor is distributed on its outer surface.

(4) The surface charge density is high where the radius of curvature of the surface of the conductor is small. → The distribution of charge at different places on the surface of a conductor takes place according to the radii of curvature of those places. If the whole surface is of the same radius of curvature (as plane and spherical surfaces), then the distribution of charge on the surface is uniform. If radius of curvature is not same, then more charge is accumulated at the place of smaller radius of curvature. In other words, the surface density of charges at the places of smaller radii of curvature is higher than that at the places of larger radii of curvature. If a part of the surface of the conductor is "pointed" surface-density of charge is very high in that part. Glow discharges from sharp points during thunderstorms are an example. The lightning conductor acts in a ~~way~~ way to neutralize charged clouds and thus saves from lightning strokes.

(5) The electric field at a point on the surface of a charged conductor or just outside it is ⊥ to the surface → This is so because the surface of a charged conductor is an equipotential surface. If the electric field were not ⊥, it would have a component tangential to the surface which would at once cause flow of charges on the surface until the electric field due to the charges cancels the tangential component. The ⊥ component remains as such because charge cannot flow ⊥ to the surface.

Info only

IMP

From NCERT book (Sec 2.9)

Electrostatics of conductors:

Introduction: Electrically, most of the materials can be placed in one of the 2 classes : Conductors and Insulators (or dielectrics)

Conductors: Conductors are those thro' which electric charge can easily flow. Metals, human body, earth, mercury and electrolytes are conductors of electricity.

→ • In metals, only the –ve charge is free to move, positive charge is immobile. The actual charge-carriers in metals are "free electrons". In metals, the (valence) electrons of the outermost orbit of the atoms leave the atoms and become 'free' to move throughout the volume of the metal. These free electrons constantly collide ~~with~~ among themselves and with the residual (positive) ions (The residual +ve ions in the metal are made up of the nuclei and the bound electrons of atoms), in the metal and move randomly in different directions. They have practically no affinity with their parent atoms. In an external electric field, they drift against the direction of the field. The residual ions remain fixed in their positions (donot move).

→ In electrolyte conductors, the charge-carriers are both positive and negative ions. When an external electric field is applied across the ends of a conductor, a force acts upon the free electrons which get accelerated. There is a net drift of electrons in the conductor against the direction of the field. As the intensity of the field is increased, more and more free electrons cross through the section of the conductor.

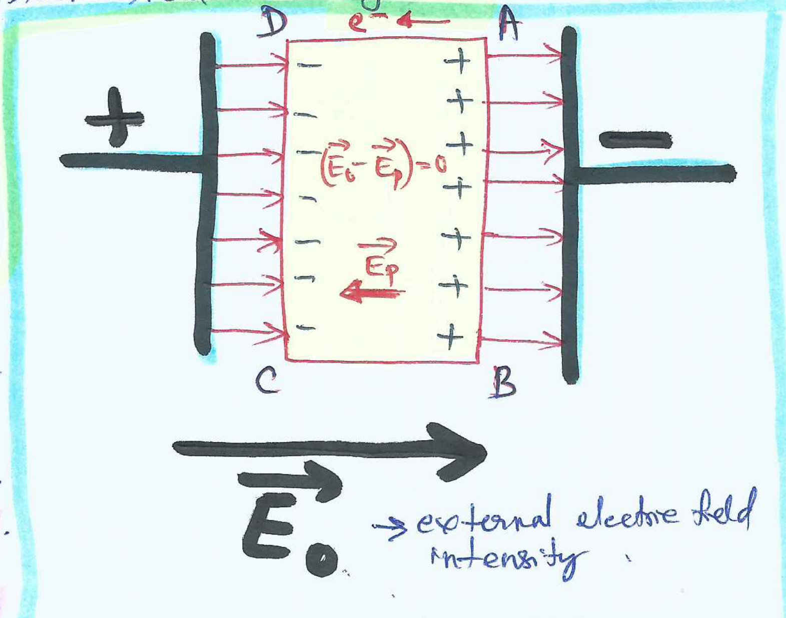
The free electrons, though not bound with any particular atom, are bound with the conductor as a whole and cannot escape from the surface of the conductor unless some external energy is supplied.

Insulators: Insulators are those thro' which electric charge cannot flow. They have negligibly small number of free electrons. Glass, hard-rubber, plastics, ebonite, mica, wax, paper and dry wood are "Insulators". In an insulator, electrons are tightly bound to the nuclei of the atoms. In fact, there are no free electrons to carry current. Thus, Insulators are also called Dielectrics. Dielectrics fail to conduct electricity. However, when an electric field is applied, induced charges appear on the surface of the dielectric. Thus, dielectrics transmit electric effect, but do not conduct electricity.

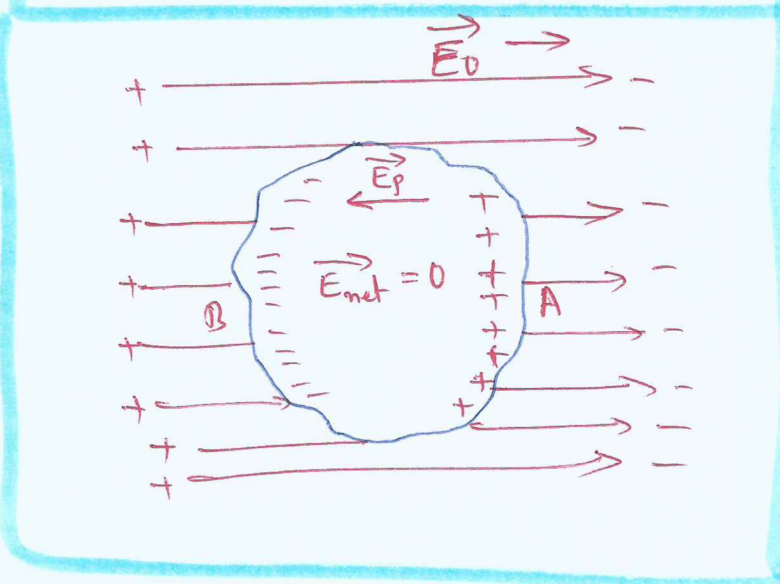
We shall restrict our discussion to metallic Solid Conductors → P.T.O

Behaviour of Conductors in the electrostatic Field

(1) Inside a Conductor, net electrostatic field Intensity is Zero.



- Suppose a conductor ABCD is held in an external electric field of Intensity $\vec{E_0}$. (See fig ⟶)
- Free electrons in the conductor move from AB side to CD side.
- As a result, some net −ve charge appears on CD and an equal +ve charge appears ~~A~~ on AB Side. These are called Induced charges.
- They produce an induced electric field of intensity $\vec{E_p}$ which opposes the flow of electrons from AB to CD.
- The flow of electrons, therefore, stops when $\vec{E_p} = \vec{E_0}$
- As the external electric field $\vec{E_0}$ and induced electric field $\vec{E_p}$ are equal and opposite, therefore, the net electric field in the interior of conductor ~~is Zero~~. placed in the electrostatic field $\vec{E_0}$ is Zero.



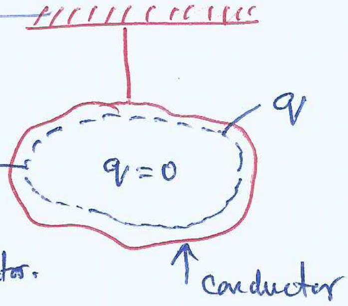
(2) Because of the absence of electric field inside the Conductor:

(i) there will be no electric field lines inside the conductor

(ii) all points just under the surface of the conductor are at same potential.

P.T.O →

(2) Charge resides on the surface of a conductor



Consider a conductor suspended with an insulating thread. Let this conductor be given an excess charge q.

→ Imagine a Gaussian surface (dotted line) which lies *just* inside but near to the surface of the conductor.

→ Since $\vec{E}$ inside conductor is zero, so it must also be zero for all points on the gaussian surface which is also inside the conductor.

→ As per Gauss's law, the net charge inside the Gaussian surface must be zero.

→ If "excess charge" q is not inside the Gaussian surface, then it must lie on the surface of the conductor.

→ Thus, charge cannot reside in the interior of the conductor, it can only reside on the surface of the conductor.

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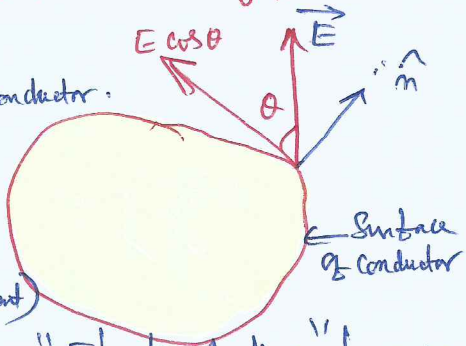
(3) ~~At the sur~~ At the surface of the charged conductor, electrostatic field must be ⊥r to the surface of the conductor at every point.



→ Suppose $\vec{E}$ is not ⊥r to surface of conductor,
Let $\vec{E}$ makes an angle θ with the surface of conductor.

→ then $\vec{E}\cos\theta$ is tangential component of the field.

→ This tangential component of electric field will cause flow of charges i.e. (surface current)

→ But, there must be no surface current in "Electrostatics" because conductor placed in the electrostatic field finally has only "static charges"

→ Thus, electric field just outside the surface can only have a normal component ($\hat{n}$) and no tangential component.

$\Rightarrow E\cos\theta = 0 \xRightarrow{\text{Since } E \neq 0} \cos\theta = 0 \quad \therefore \theta = 90^\circ$ (Note that $E \neq 0$)

which clearly shows $\vec{E}$ just outside a charged conductor is ⊥r to the surface of the conductor at every point

P.T.O →

④ Net charge in the interior of a conductor is zero.

As per Gauss' theorem $\oint_S \vec{E} \cdot \vec{ds} = \frac{q}{\epsilon_0}$

Since $\vec{E} = 0$ inside the conductor, so the net electric charge inside a conductor is zero. $\Rightarrow q = 0$

$\therefore$ Net volume charge density in the interior of conductor is zero.

⑤ "Electric potential" is constant for the entire conductor. (IMP)

We know that $E = -\frac{dV}{dr}$

$\therefore dV = -E\,dr \longrightarrow ①$

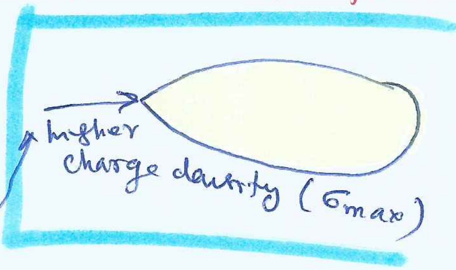
But $\vec{E} = 0$ for all points inside the conductor

$\therefore \frac{dV}{dr} = 0$ $\therefore$ V must be a constant value.

$\Rightarrow$ potential V will be same at the surface as well as whole of the interior of the conductor " placed in an electrostatic field.

⑥ Surface charge ~~density~~ distribution may be different at different points.

Surface charge density $\sigma = \frac{\text{Electric charge } q}{\text{Area } A}$ may be different at different points on the surface of the conductor.



$\rightarrow$ A smaller surface area say conical or pointed portion of the surface of the conductor will have higher charge density.

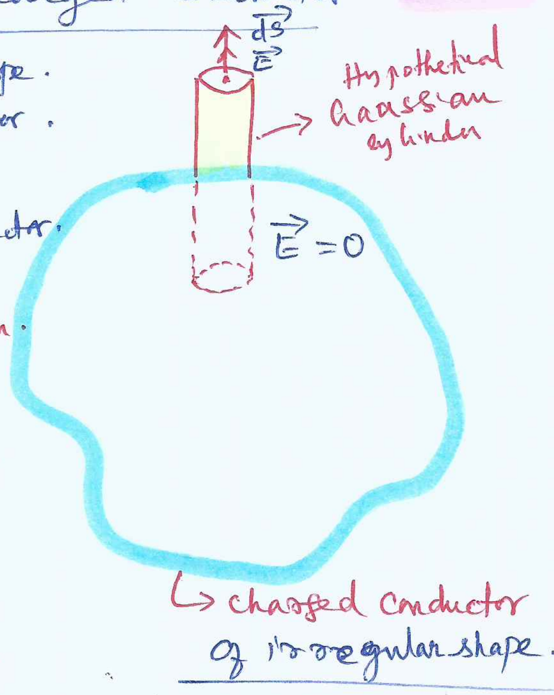
$\rightarrow$ portions of a surface have +ve / −ve charges will have +ve charge density / −ve charge density.

$\rightarrow$

※ Every conductor is an equipotential volume (3-dimensional) rather than just an equipotential surface (2-dimensional).

P.T.O $\longrightarrow$

(7) Electric Field at the surface of a charged conductor



- Consider a charged conductor of irregular shape.
- Let σ be the "Surface charge density" of the conductor.
- Consider a Gaussian surface in the form of a cylinder having some portion lies inside the conductor.

(o) Gaussian cylinder has 3 parts — two circular ends and one curved portion.

→ Since $\vec{E} = 0$ inside the conductor, no electric flux is linked with bottom circular end (inside the conductor)

→ Also, no electric flux is linked with the curved ~~surface~~ portion of cylinder the curved surface. Since $\vec{E}$ is $\perp^r$ to curved surface.

→ So, electric flux passes only thro' the top circular end of area vector $\vec{ds}$ of the Gaussian cylinder (which is outside the conductor)

→ As per Gauss's law

$$\oint \vec{E} \cdot \vec{ds} = \frac{q}{\epsilon_0}$$

$$\oint E \, ds \cos\theta = \frac{q}{\epsilon_0}$$

$\vec{E} \cdot \vec{ds} = E \, ds \cos\theta$

~~Since~~

Since $\theta = 0$

$\cos\theta = 1$

Since $\theta = 0°$

$\cos\theta = 1$

$$\underbrace{E \oint ds}_{\oint ds = ds} = \underbrace{q/\epsilon_0}_{q = \sigma \, ds}$$

Surface charge density $\sigma = \dfrac{q}{ds}$

$$\therefore E \cancel{ds} = \frac{\sigma \cancel{ds}}{\epsilon_0}$$

$$\therefore \boxed{E = \frac{\sigma}{\epsilon_0}}$$

In Vector notation, $\vec{E} = \dfrac{\sigma}{\epsilon_0} \hat{n}$ (Since $\vec{E}$ is $\perp^r$ to surface of conductor).

P.T.O

— 44 —

Consolidation

: In a nutshell, the description in previous pages is consolidated below.

(a) Net $\vec{E}$ inside a conductor placed in electrostatic field is zero.

(b) Electric field just outside the charged conductor is $\perp$r to the surface of the conductor. Thus, electric field lines are $\perp$r to the surface of a charged conductor.

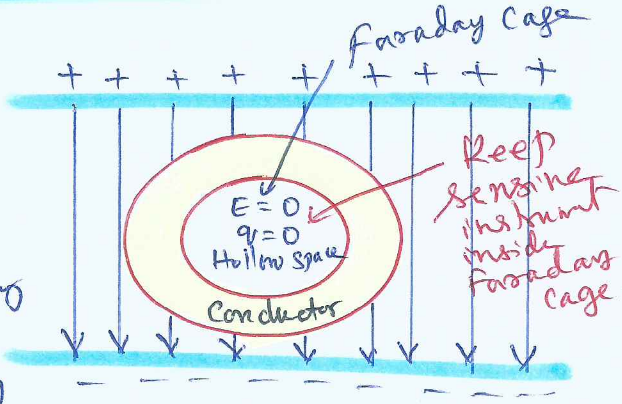
(c) Electric charge resides on the surface of the conductor.

(d) Magnitude of the electric field intensity $|\vec{E}|$ at the surface of a charged conductor is given by

$$|\vec{E}| = \frac{\sigma}{\epsilon_0}$$

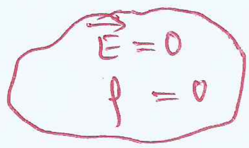
, where σ is the surface charge density.

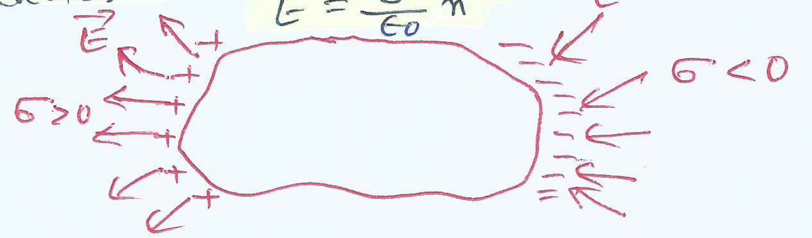
Electrostatic Shielding:

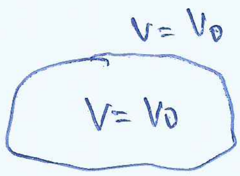


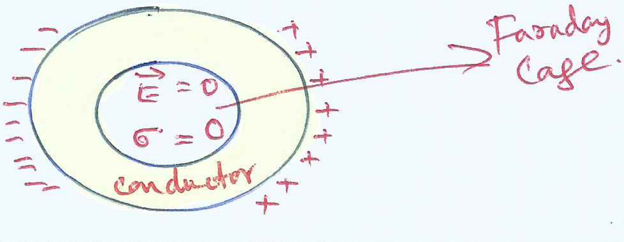
- The method of protecting a region from the effect of electric field is called "electrostatic shielding / screening"
- Sensitive instruments are affected seriously with strong external electric fields. Their working suffers and they may not work properly under the effect of electric fields.
- The electrostatic shielding/screening can be achieved by protecting and enclosing sensitive instruments inside a hollow conductor because inside hollow conductor, the electric field $\vec{E}$ is zero. Such hollow conductors are called Faraday cages.
- The absence of $\vec{E}$ inside the conductor means no electric force acts inside it. Thus, the inner sides of the hollow conductor remains unaffected by the external electric field. $\Rightarrow$ appliances or instruments inside the hollow conductor remain shielded from the external field. It is for this reason that it is safer to sit inside a car during lightning and thunder than to stand under a tree or open ground. The phenomenon is also used in the design and TV cables.

$$E = \frac{\sigma}{\epsilon_0}\hat{n}$$









Dielectrics and polarization.

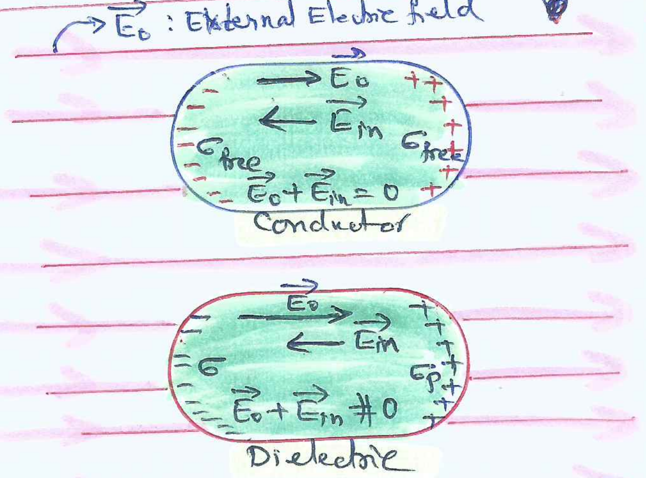
Introduction : Dielectrics → Dielectrics are insulating materials which transmit electric effects without actually conducting electricity. These dielectrics are the non-conducting materials (substances) that donot have (or have negligible number of) free electrons (charge carriers).

Examples : Air, glass, mica, paraffin wax, paper etc..

⟹ In contrast to conductors, these dielectrics have no charge carriers.

⊙ As shown in figure, when a "conductor" is placed in an external electric field, the free charge carriers move and charge distribution in the conductor adjusts itself in such a way that "electric field due to induced charges" ($\vec{E}_{in}$) opposes the external field ($\vec{E}_0$) within the conductor. This happens until, in the static situation, the two fields $\vec{E}_0$ and $\vec{E}_{in}$ cancel each other and the "net electrostatic field" in the "conductor" is zero.

Difference in behaviour of a conductor and a dielectric in an external Electric field.



$\vec{E}_{in}$ = Induced Electric field due to induced surface charge densities.

⊙ In contrast to "conductors", the situation is different in dielectric materials. In dielectric, the free movement of charges is not possible. However, the external field $\vec{E}_0$ induces dipole moment by stretching or re-orienting molecules of the dielectric. The collective effect of all these molecular dipole moments is net charges on the surface of the dielectric which produce a field ~~that opposes~~ $\vec{E}_{in}$ that opposes external field ($\vec{E}_0$).

→ However, unlike in a conductor, the opposing field ($\vec{E}_{in}$) so induced does not ~~cancel~~ exactly cancel the external field ($\vec{E}_0$). It only "reduces" it. The extent of reduction effect depends on the nature of the dielectric. (See figure → $\vec{E}_0 + \vec{E}_{in} \neq 0$)

→ To understand the above effect, we need to look at the "charge distribution of a dielectric material" at the "molecular level"

P.T.O →