Handwritten Notes
On
Conductors

29/05/17

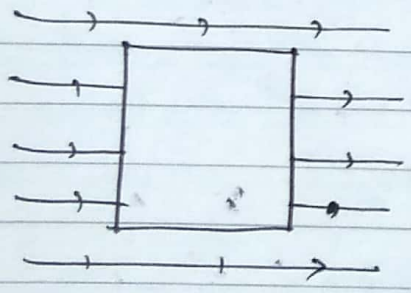
Electrostatic

Conductors

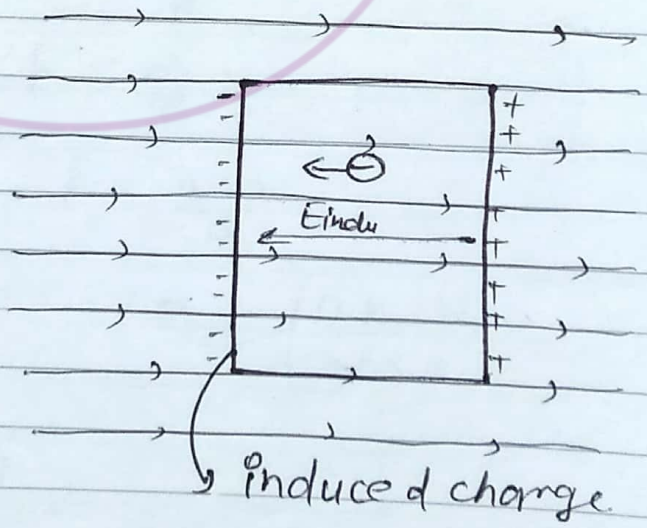
* **Conductors:** (Metal):
These are the substance which have a no. of free electrons and these electron move in the body of conductors

Properties:

1) When a conductor is placed in external electric field then charge induce on the surface of conductor. so that net electric field inside the conductor becomes zero.

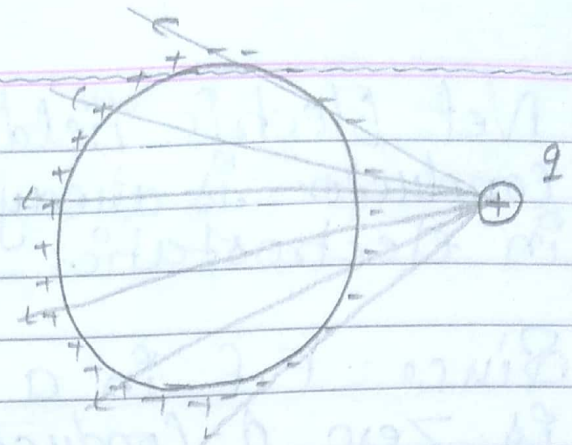


$E_{net} = 0$



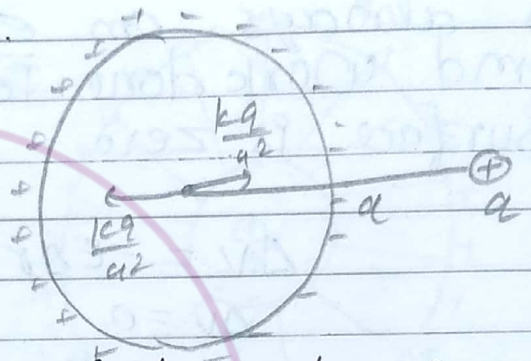
non-conducting → charge is not move

Que:- find net Induce Charge on the sphere.



$Q_{net} = 0$

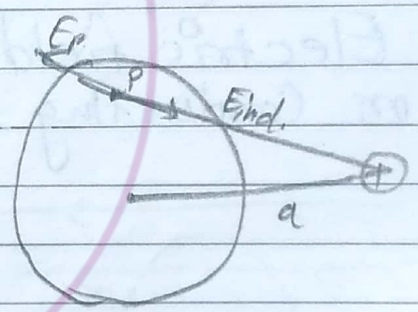
(ii) find Electric field at the Centre due to point charge.



$$E = \frac{kq}{a^2}$$

(ii) find E.F at centre due to induce charge

$E_{net} = 0$

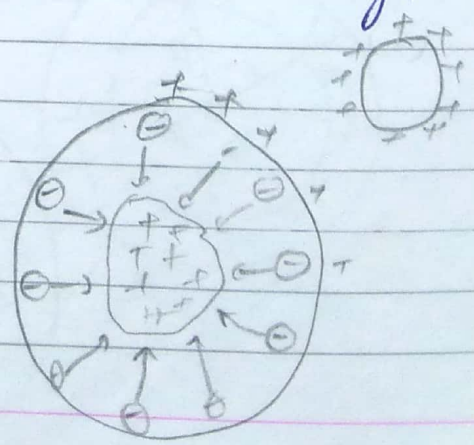


(iv) find E.F due to point charge

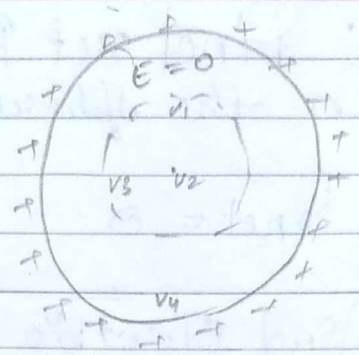
$$E_{point} = \frac{kq}{r^2}$$

$$E_{induced} = \frac{kq}{r^2}$$

(Q) Any Extra charge given to a conductor always appear on its Surface.



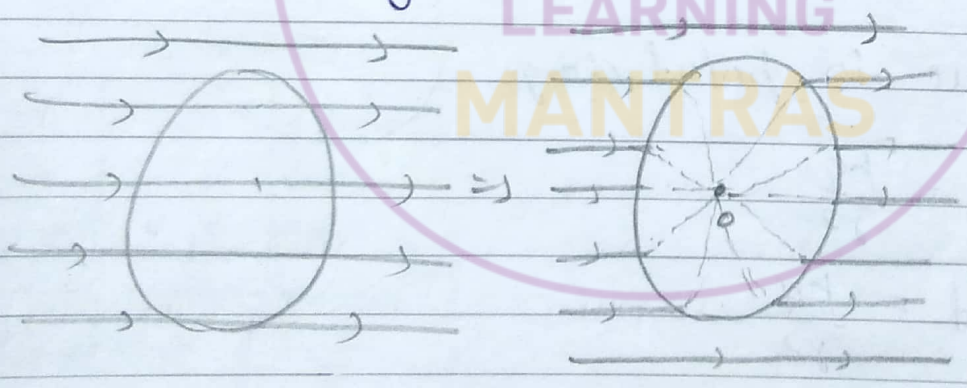
* Net Electric field inside a conductor is always zero in electrostatics



Since E.f in a conductor is zero & Conducting Surface is always an equipotential Surface and work done to move a charge on Conducting Surface is zero

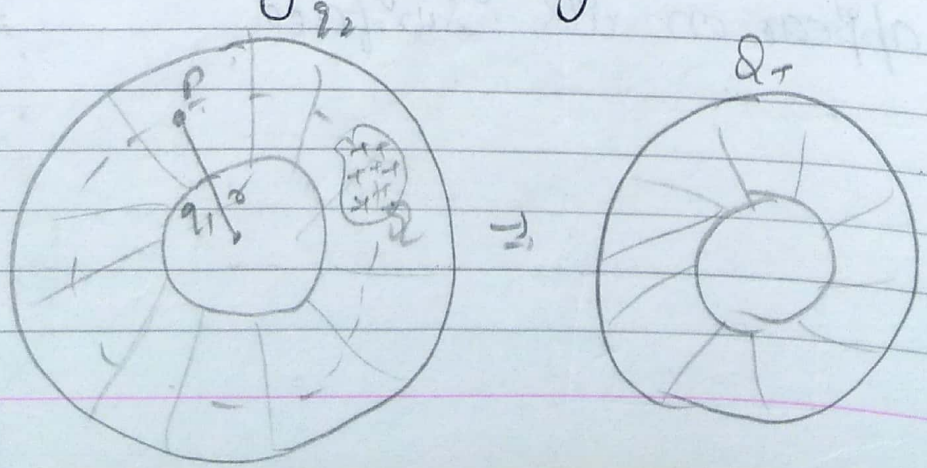
$$\Delta V = -E\Delta r \qquad V_1 = V_2 = V_3 = V_4 - - -$$
$$\Delta V = 0$$
$$W = q\Delta V = 0$$

3) Electric field lines always meet perpendicularly on Conducting Surface.



* Conductors having a Cavity:-

(i)



$q_1 + q_2 = Q$

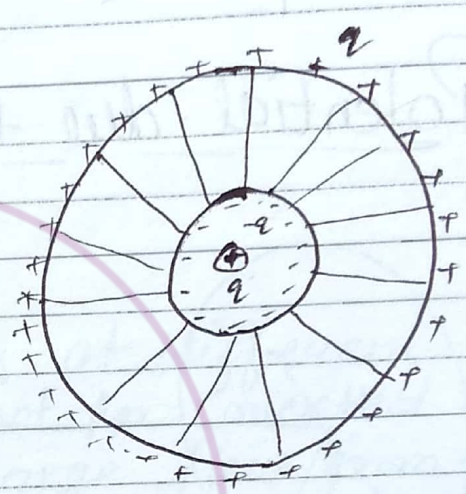
$E_P = 0$

$E 4\pi r^2 = \frac{q_{in}}{\varepsilon_0}$

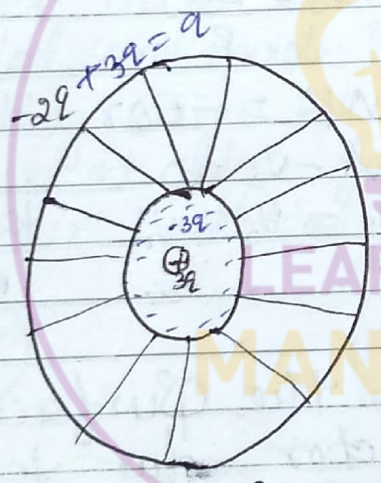
$E = \frac{q_1}{4\pi r^2 \varepsilon_0} = 0$

$q_1 = 0$

(ii)



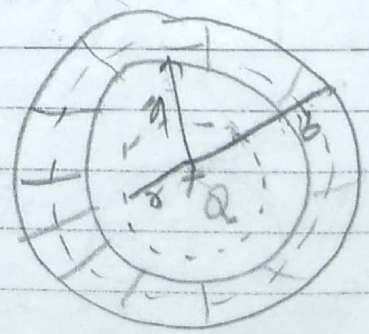
Ques



Conductor is given charge $-2q$ then $+3q$ charge is placed at the centre of cavity. Find charge on Inner and Outer surface.

Ans: $charge_{inner}$ $-2q + 3q = q$ Ans

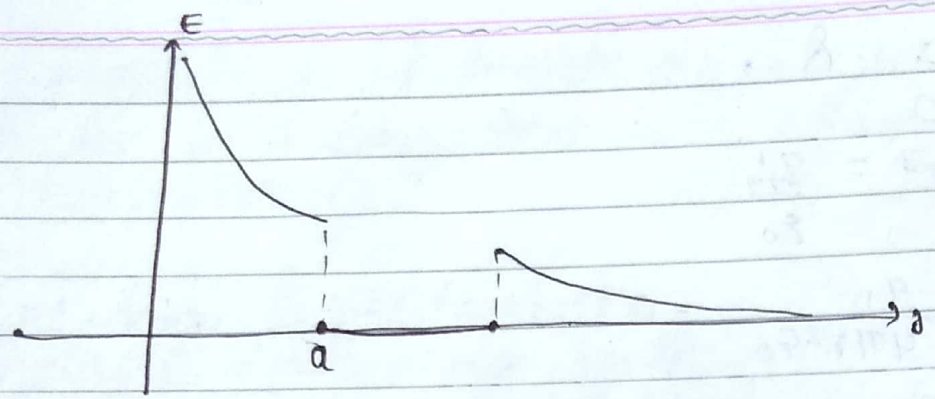
Que: Find E.P at distance r from the centre of cavity of



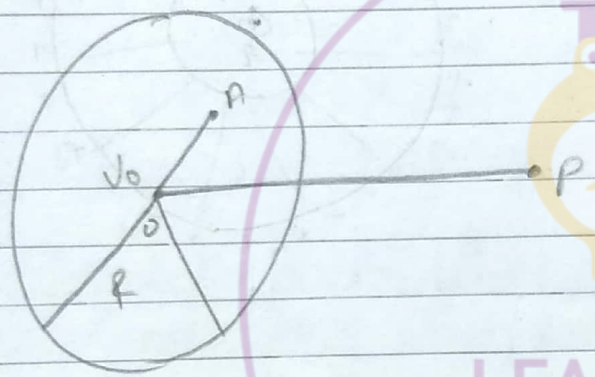
(i) $r < a$ $\quad E = \frac{KQ}{r^2}$

(ii) $a > r > a$ $\quad E = 0$

(iii) $r > b$ $\quad \frac{KQ}{r^2}$



* Potential due to a Conducting Sphere:



$V_P = \frac{KQ}{r}$

$V_S = \frac{KQ}{R}$

$E_{inside} = 0$

$E_{out} = \frac{KQ}{r^2}$

$\Delta V = -E\Delta r$

$V_S - V_0 = 0$

$V_S = V_0 = V_A = \boxed{\frac{KQ}{R}}$

(4) charge distribution on the surface of an irregular shape conductor. due to shape of conductor charge distribution is not uniform on its surface

$V_1 = \frac{Kq_1}{r_1}$, $V_2 = \frac{Kq_2}{r_2}$

$V_3 = \frac{Kq_3}{r_3}$

$V_1 + V_2 + V_3 + V_4 - \text{———}$

$\frac{q_1}{r_1} = \frac{q_2}{r_2} = \frac{q_3}{r_3} = \frac{q_4}{r_4}$

$\frac{q}{r} = \text{constant}$ $\boxed{q \propto r}$

H.W: JA = 1, 2, 3, 5, 11, 12, 15, 20, 26, 28, 31 meter

Isolated / not intered each other

$q \cdot 1:2$

$\frac{22}{3} \cdot \frac{Q}{3}$

* Charge density :

$$\sigma = \frac{q}{A} = \frac{q}{4\pi r^2}$$

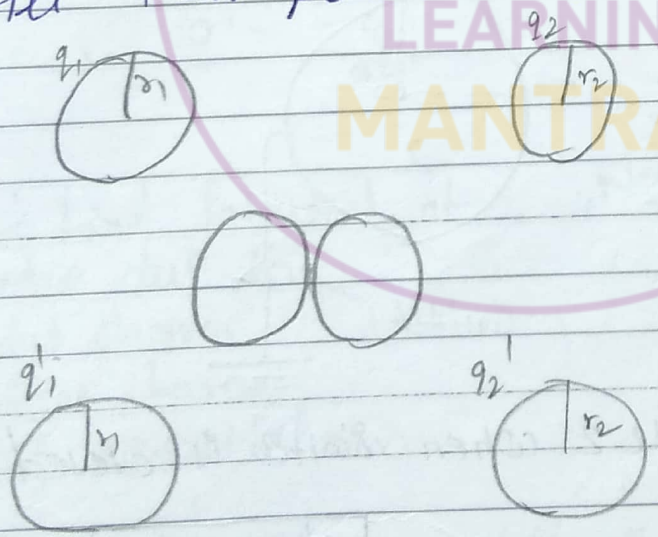
$$q = \sigma 4\pi r^2$$

$$\frac{q}{r} = \text{Constant} \qquad \frac{\sigma 4\pi r^2}{r} = \text{Constant}$$

$$\sigma r = \text{Constant}$$

$$\boxed{\sigma \propto \frac{1}{r}}$$

5] When two Conductors at different Potential are made in contact for Conected by a Conducting wire then charge flow from the Conductor at high potential to low potential till their potential becomes equal.

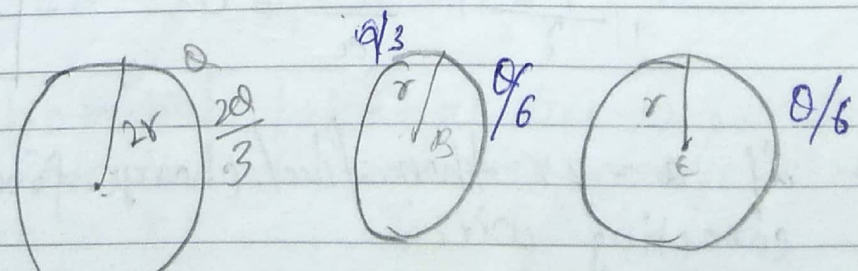


$$q_1' + q_2' = q_1 + q_2$$

$$\frac{kq_1'}{r_1} = \frac{kq_2'}{r_2}$$

$$\boxed{\frac{q_1'}{q_2'} = \frac{r_1}{r_2}}$$

Que :-
Initially A and B are touch and Separated them B and C are in made in Contact and separated find final charge on each sphere



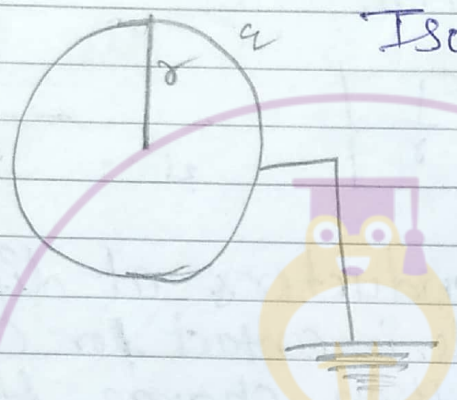
$\frac{kq_1}{2r}$

* Earthing of a Conductor:

Earth is a very large conductor which can exchange any amount of charge and its potential is assumed to be zero. Hence when a conductor is earth potential ~~becomes~~ of conductor also becomes zero.

Isolated sphere

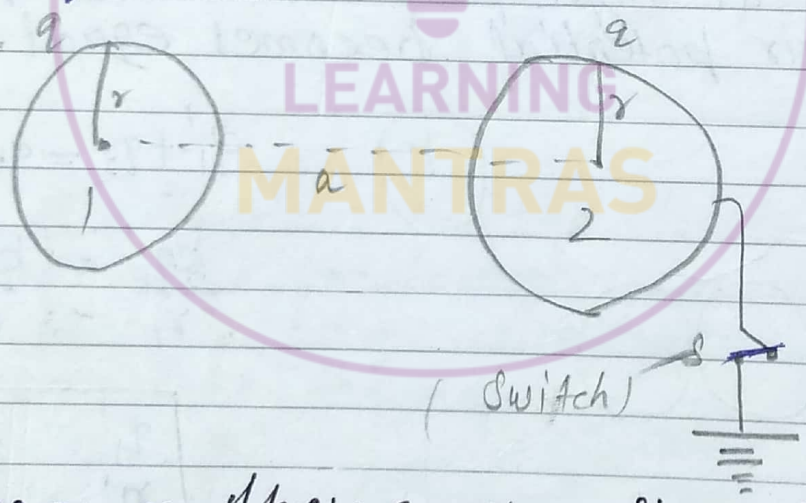
$V = \frac{kq}{r}$



$\frac{kq'}{r} = 0$

$q' = 0$

Que:



⇒ Find charge on sphere 2 when switch is closed

$$\frac{kq'}{r} + \frac{kq}{a} = 0 \quad \Rightarrow \boxed{q' = -\frac{qr}{a}}$$

(ii) if $a = 2r$ then find charge flowing throw the connecting wire

$q' = -\frac{qr}{a} = \frac{-q}{2}$

if $a = 2r$: $q_{final} - q_{initial}$

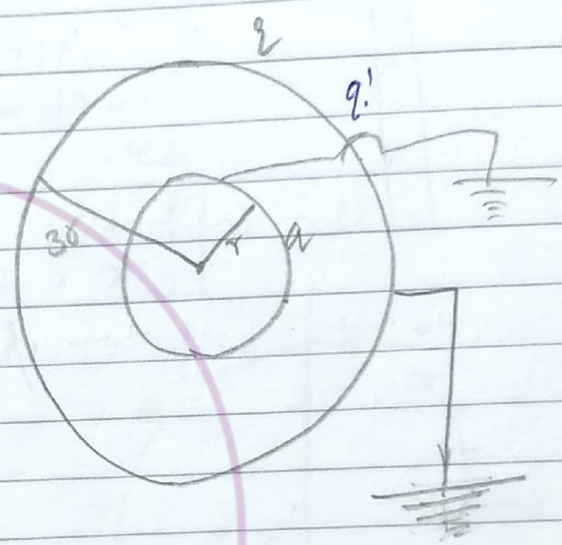
$-\frac{q}{2} - q = -\frac{3q}{2}$

$\frac{pq}{4\pi r^2}$

Que:

Ans: $\frac{kq}{3r} + \frac{kq}{3r} = 0$

$q' = -q$

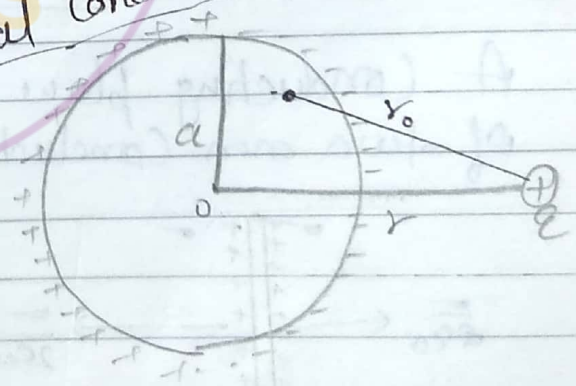


Que: find charge on inner sphere.

$\frac{kq'}{r} + \frac{kq}{3r} = 0$

$q' = -\frac{q}{3}$

Neutral Conducting sphere



Que: find Potential at centre due to
i) Point charge
ii) Induce charge
iii) Net potential at O

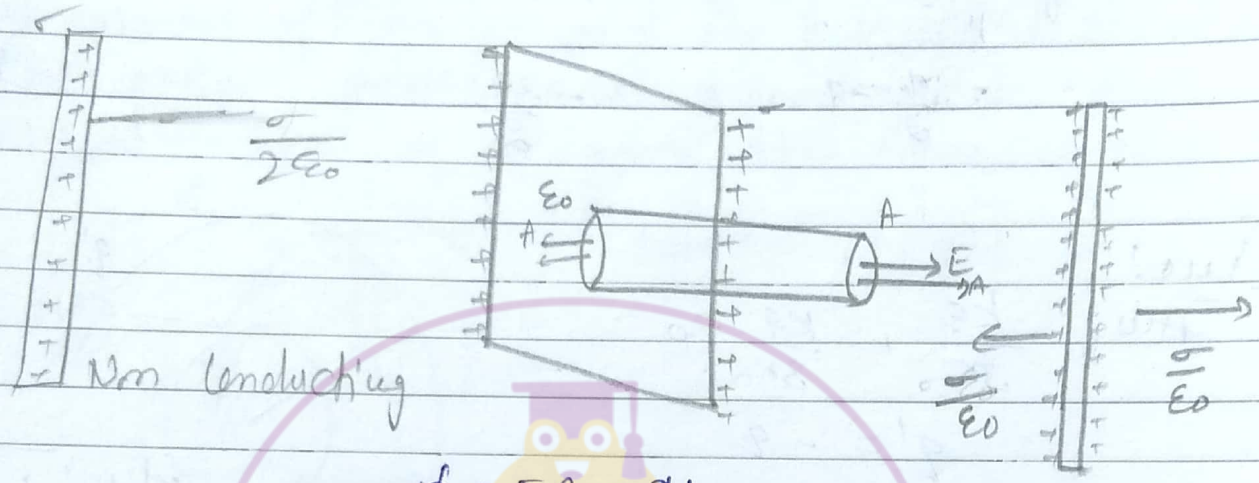
i) $V_{induce} = 0$, $V_{point} = \frac{kq}{r}$, $V_{O(Net)} = \frac{kq}{r}$.

Que: find Net potential, potential due to point charge and Potential due to induce charge at A.

Ans: $(V_A)_{Net} = \frac{kq}{r}$, $V_p = \frac{kQ}{r_0}$

V_{induce}: $\frac{kq}{r} - \frac{kq}{r_0}$, A

* Electric field due to uniformly Charged large Conducting plane :



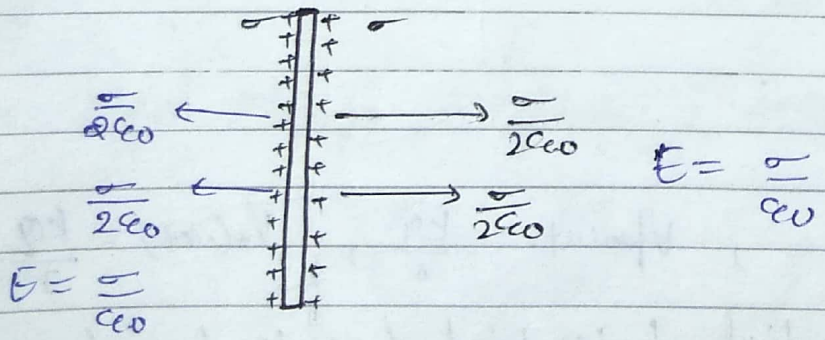
$$\phi = EA = \frac{q_{in}}{\varepsilon_0}$$

$$EA = \frac{\sigma A}{\varepsilon_0}$$

$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$

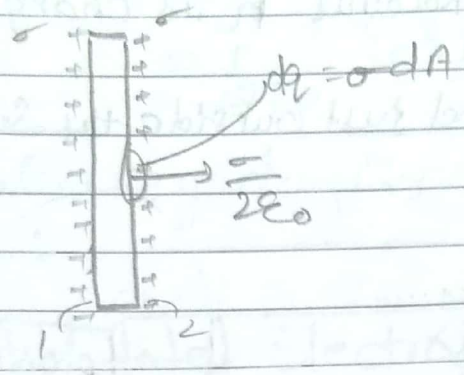
* Alternate Method

A Conducting plane can be assume as a Combination of two non Conducting plates



H.W: Ex: 5-1: 19, 21, 22,
O.H: 62 to 78.

* Electrostatics Pressure:



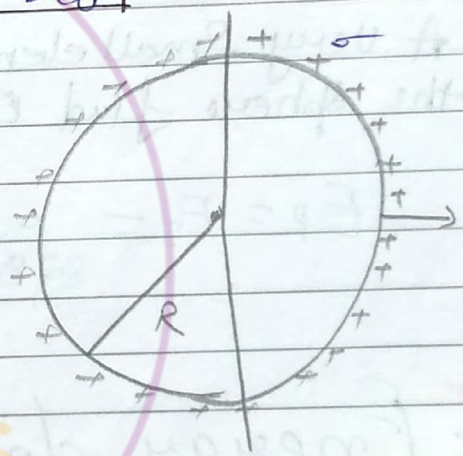
$\frac{\sigma}{2\varepsilon_0} = E_1$

$df = dq E_1$

$df = \sigma dA \frac{\sigma}{2\varepsilon_0}$

$\frac{df}{dA} = \frac{\sigma^2}{2\varepsilon_0}$ $\boxed{P_{elect} = \frac{\sigma^2}{2\varepsilon_0}}$

Que: find force applied by Left half on Right half.



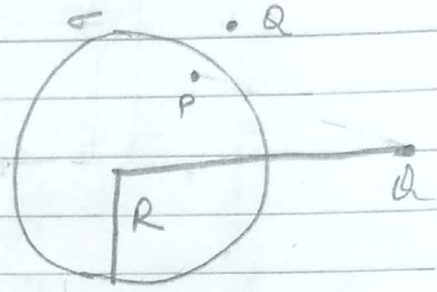
$P_{elect.} = \frac{\sigma^2}{2\varepsilon_0}$

$F = PA$

$= \frac{\sigma^2}{2\varepsilon_0} \pi R^2$

Date: 31/05/17

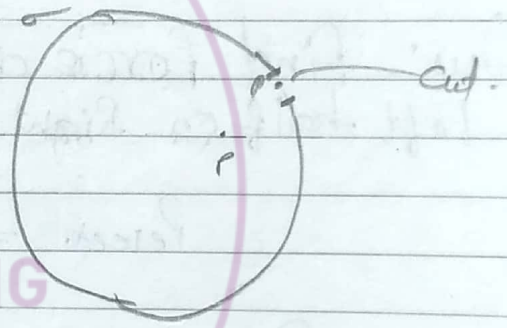
Que: A Conducting Sphere of Radius R is charged with charge density σ.
P and Q are just inside and just outside the Surface. Find E.f at P and Q.



Ans: $E_P = 0$

$$E_Q = \frac{KQ}{R^2} = \frac{Q}{4\pi\varepsilon_0 R^2} = \frac{\sigma}{\varepsilon_0}$$

(ii) A very Small element cut from the sphere find E.f at P.



$$E_P = E_2 = \frac{\sigma}{2\varepsilon_0}.$$

* Energy density:

* If electric field exist in a region it means electrostatic Energy is stored in that region

Electrostatic Energy per unit Volume Called Energy density.

$$\text{Energy density} = \frac{\text{Energy}}{\text{Vol.}} = \frac{\text{work}}{\text{Vol.}} = \frac{f \cdot \cancel{d}}{A \cdot \cancel{d}}$$

$$= \frac{f}{A} = P_{electrostatics}$$

$$\frac{\sigma^2}{2\varepsilon_0}$$

$$E = \frac{\sigma}{\varepsilon_0} \qquad \sigma = \varepsilon_0 E$$

$$= \frac{1}{2\varepsilon_0} \varepsilon_0^2 E^2$$

$$\boxed{\text{Energy density} = \frac{1}{2}\varepsilon_0 E^2}$$

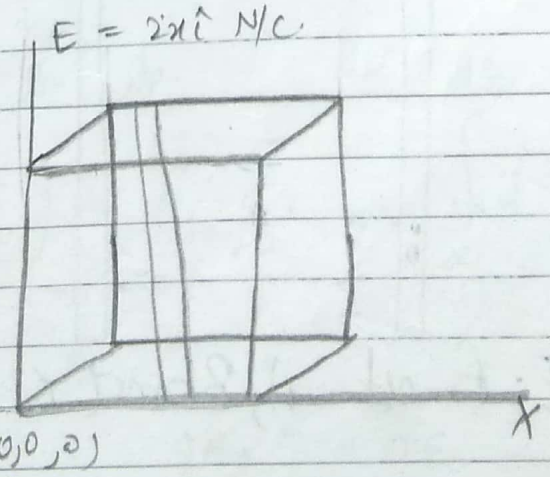
Que: Find total Electrostatics Energy stored in a spherical volume of radius R.

$$E_{sphere} = \frac{1}{2}\varepsilon_0 E^2 \times \frac{4\pi}{3} R^3$$

Cubical Volume of side a

$$\text{Energy} = \frac{1}{2}\varepsilon_0 E^2 a^3$$

Que: $E = 2x\hat{i}$ N/C. Find electric energy in a cube of side a having one corner at origin.



Ans: $dv = a^2 dx$

$$U_E = \frac{1}{2}\varepsilon_0 E^2$$

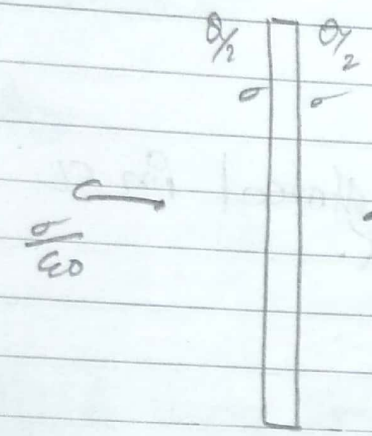
$$\frac{1}{2}\varepsilon_0 E^2 dv$$

$$= \frac{1}{\cancel{2}}\varepsilon_0 \overset{2}{\cancel{4}} x^2 a^2 dx$$

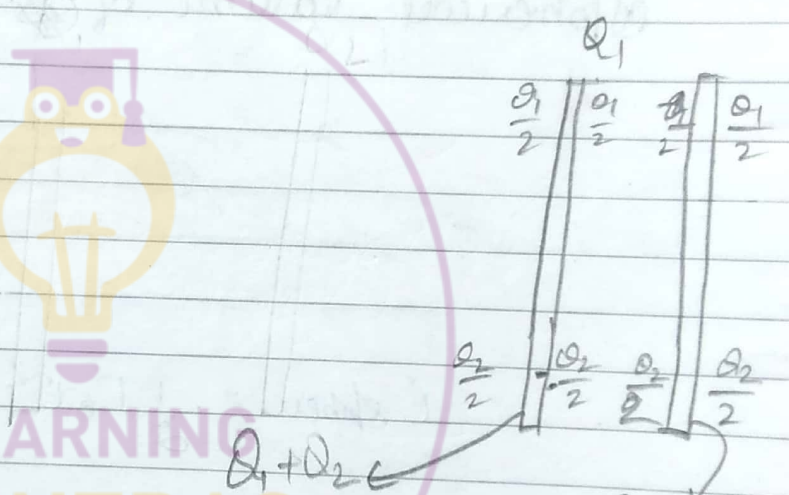
$$= 2\varepsilon_0 a^2 \int_0^a x^2 dx = \frac{2\varepsilon_0 a^5}{3} \text{ Ans}$$

$\vec{E} = 2x\hat{i} + 2y\hat{j} = \Rightarrow \frac{4\varepsilon_0 a^5}{3}$ Ans

* Charge Distributing on Conducting planes :

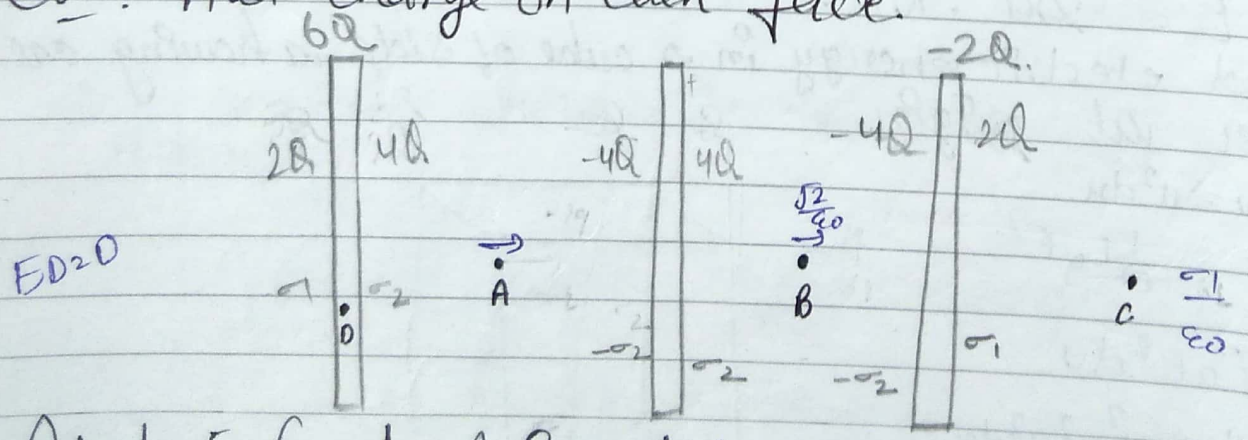


When a Conducting plate is charged then Charge is on both surface. will be equal if plate is isolated.



Charge on each face of each plate. $= \frac{Q_1 + Q_2}{2}$ Ans

Que: find charge on each face.



Find E.F at A, B and C

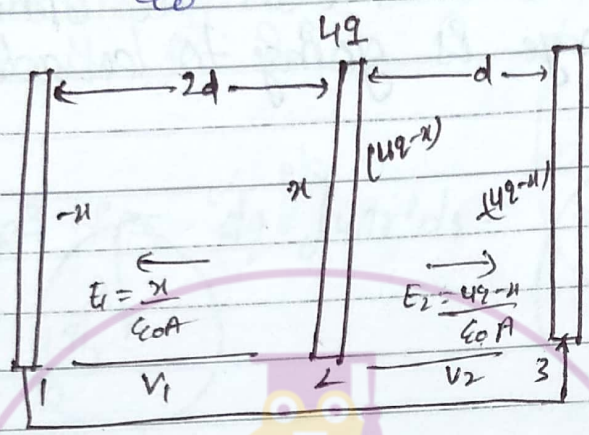
H.W

3-1 20 Ques left.
0-2 32 Complete
(30)

$$E_A = \frac{\sigma_1}{2\varepsilon_0}\hat{i} + \frac{\sigma_2}{2\varepsilon_0}\hat{i} - \frac{\sigma_2}{2\varepsilon_0}\hat{i} - \frac{\sigma_2}{2\varepsilon_0}\hat{i} + \frac{\sigma_2}{2\varepsilon_0}\hat{i} - \frac{\sigma_1}{2\varepsilon_0}\hat{i}$$

$$= \frac{\sigma_2}{\varepsilon_0}\hat{i}$$

Ques:



Find Charge on Each face.

$$\frac{x}{\varepsilon_0 A}\,2d - \frac{4q-x}{\varepsilon_0 A}\,d = 0$$

$$2x - 4q + x = 0$$

$$x = \frac{4q}{3}$$

Ans: 0-2

Date: 01/06/17

(22)

$$\vec{E} = \frac{a(x\hat{i} + y\hat{j} + z\hat{k})}{(x^2+y^2+z^2)^{3/2}}$$

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

$$E = \frac{a\vec{r}}{r^3} = \frac{a}{r^2}\left(\frac{\vec{r}}{r}\right) \qquad E = \frac{q}{r^2} \Rightarrow \int_R^{2R} \frac{1}{2}\varepsilon_0 E^2\, 4\pi r^2\, dr.$$

(23) $E_0 + \frac{\sigma}{\varepsilon_0} = 5\times10^5$

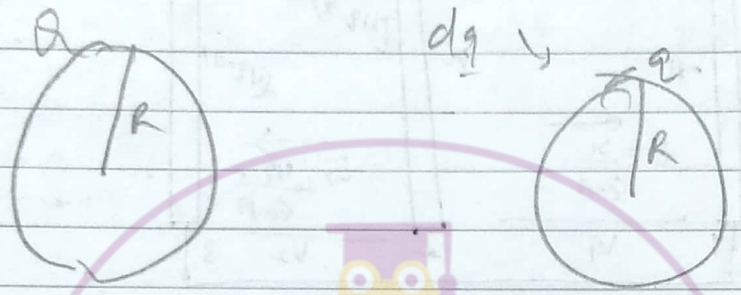
$$\frac{\sigma}{\varepsilon_0} - E_0 = 3\times10^5 \quad \Rightarrow \quad qE_0 = -AE_0 = F.$$

01/06/17

* Self Energy:

It is the Work done to charge an object

Let at any time charge on the sphere is small (q) and dq charge is going to be added on the sphere



(1) Hollow Sphere: $W = \text{charge} \times \Delta V$

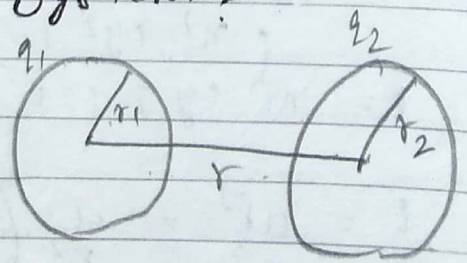
$= dq\,(V_f - V_i)$

$$W = \frac{kq}{R}\,dq \qquad U = \frac{kQ^2}{2R}$$

$$U = \frac{k}{R}\int_0^Q q\,dq$$

$$\boxed{U = \frac{Q^2}{8\pi\varepsilon_0 R}}$$

Que: Find total energy on the system:



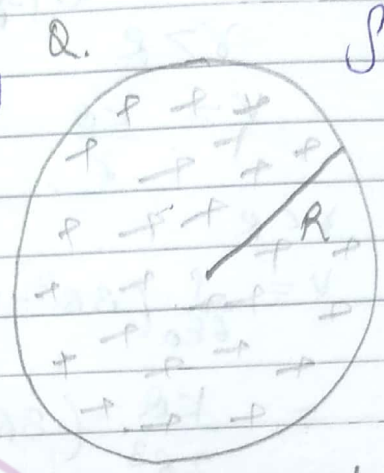
TE = Self Energy + Interaction Energy (PE)

$$\frac{kq_1^2}{2r_1} + \frac{kq_2^2}{2r_2} + \frac{kq_1q_2}{r}$$

$\int r^4 = \frac{r^5}{5}$

iii) Solid Sphere: (Non-Conducting):-

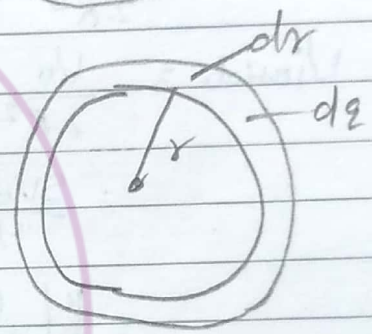
Let at any time radius of sphere is small (r) and charge on it is Q.



$\rho = \frac{Q}{\frac{4\pi}{3}R^3}$

$$\rho = \frac{Q}{\frac{4\pi}{3}R^3} \qquad dq = \rho 4\pi r^2 dr.$$

$$q = \rho \frac{4\pi}{3} r^3$$



$$w = dq\,\Delta V$$

$$w = \frac{kq}{r}\,dq$$

$$w = \frac{kq}{r}\int 4\pi r^2 dr$$

$$U = \int kq\,4\pi \int r\,dr$$

$$U = \int k\,4\pi \int \frac{4\pi}{3} r^3\, r\,dr$$

$$U = \rho^2 \frac{16\pi^2 k}{3}\int r^4 dr$$

$$\boxed{U = \rho^2 \frac{16\pi^2 k R^5}{15}} \Rightarrow \frac{\rho^2 16\pi^2 R^5}{4\pi\varepsilon_0\, 15}$$

$$= \frac{4\pi\rho^2 R^5}{15\varepsilon_0}$$

HAPPY Ending

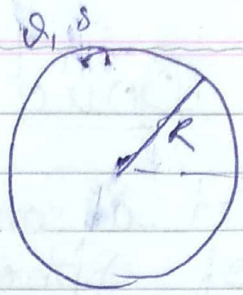
$$\boxed{U = \frac{3Q^2}{20\pi\varepsilon_0 R}}$$

In terms of charge.

$\frac{KQ}{R} = V_0$

J.M.

(22)



$r > R$

$V = \frac{KQ}{r}$ $\quad V_S = \frac{KQ}{R} = V_0$

$r < R$

$V = \frac{\rho}{6\varepsilon_0}(3R^2 - r^2) = \frac{1}{2\times 6\varepsilon_0} \cdot \frac{Q}{\frac{4\pi}{3}R^3}(3R^2 - r^2)$

$= \frac{KQ}{2R^3}(3R^2 - r^2)$

$V_{inside} = \frac{V_0}{2R^2}(3R^2 - r^2)$ $\quad R_1 = 0$

$\frac{5V_0}{4} = \frac{V_0}{2R^2}(3R^2 - R_2)$

$\boxed{O-2}$

Q1)

$V_0 = V_A$

$(V_Q + V_{sheet})_0 = (V_Q + V_{sheet})_0$

$V_{Q_0} + V_{sheet_0} = V_{Q_A} + V_{sheet_A}$

$V_{Q_0} + V_{sheet} - V_{sheet_A} = V_{Q_A}$

$\frac{KQ}{R} = \frac{-R}{4\varepsilon_0} = (V_Q)_A$