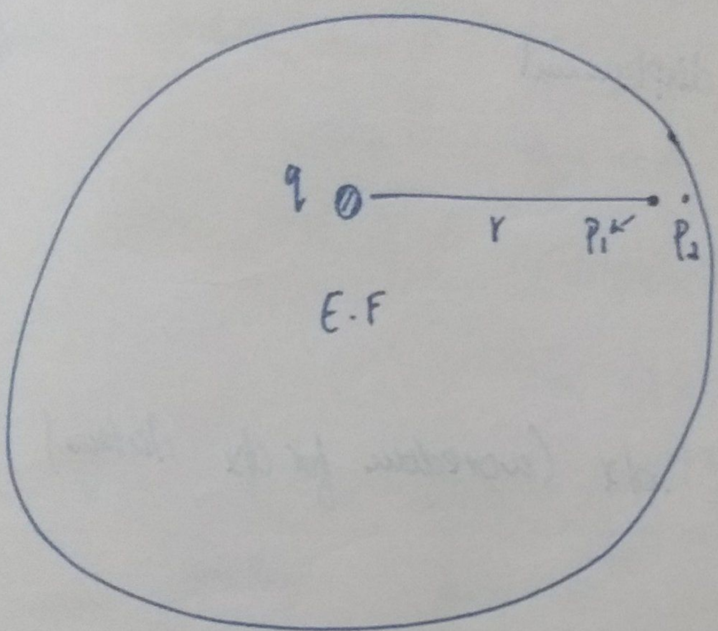
Electrostatic potential and Capacitance

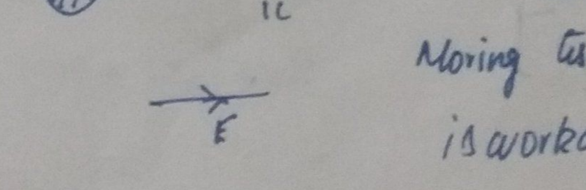
Electrostatic Potential



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

Potential is defined as workdone by moving test charge

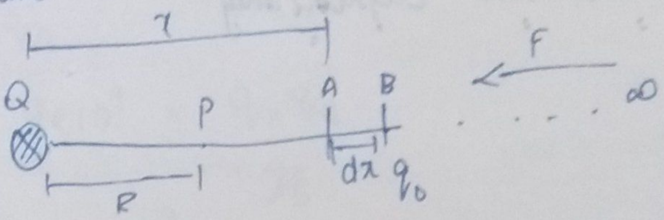
$$= \frac{\text{Workdone}}{\text{Charge (test)}}$$



Moving test charge from ∞ to P is workdone.

The amount of workdone by moving a unit ~~man~~ +ve charge from infinite to a pt against Electrostatic repulsive force.

Derive



workdone = Force $\times$ displacement

$$\text{Force} = k\frac{Qq_0}{x^2}$$

displacement = dx

$$\int dw = -\int_{\infty}^{R} k\frac{Qq_0}{x^2}\,dx \quad \text{(workdone for dx distance)}$$

$$= -kQq_0 \int_{\infty}^{R} x^{-2}\,dx \qquad \frac{x^{-2+1}}{-2+1}$$

$$= \frac{+kQq_0}{+1}\left[x^{-1}\right]_{\infty}^{R} \qquad \Rightarrow \frac{x^{-1}}{-1}$$

$$= kQq_0\left[\frac{1}{x}\right]_{\infty}^{R}$$

$$W = kQq_0\left[\frac{1}{R}\right]$$

$$V = \frac{W}{q_0}$$

$$= \frac{kQ\cancel{q_0} \cdot \frac{1}{R}}{\cancel{q_0}}$$

$$= k\frac{Q}{R}$$

$$\boxed{V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}}$$

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Determine the electric potential at the surface of gold nucleus. The radius of the gold nucleus is 6.6×10^{-15} m atomic number of gold $Z = 79$ charge of proton 1.6×10^{-19} C

$q = ne \quad n = 79$

$= 79 \times 1.6 \times 10^{-19}$ C

$= 126.4 \times 10^{-19}$ C

$$V = \frac{1}{4\pi\varepsilon_0} \frac{126.4 \times 10^{-19}}{6.6 \times 10^{-15}}$$

$$= 9 \times 10^{9} \times \frac{126.4 \times 10^{-4}}{6.6}$$

2.2

$= 57.4 \times 3 \times 10^{5}$

$= 172.2 \times 10^{6}$ Nm/C

$= 1.7 \times 10^{7}$ volt

$22 \times 5 = 110$

$79 \times 16 = 474$, $79 \times$ → 1264

$22 \times 8 = 176$, $22 \times 7 = 154$, $22 \times 4 = 88$

$1264 \div 22 = 57.4$: 110, 164, 154, 100, 88, 12

$57.4 \times 3 = 172.2$

$\frac{N.M}{C}$

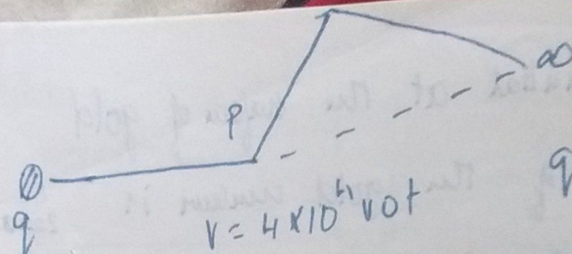
One volt :-

1 Joule of work has to be done by moving 1 coloumb of charge from infinite to a point

$79 \times 16 = 474$, $79 \times$ → 1264

Potential difference is 1volt :

1 Joule of work done by moving 1 coloumb of charge from pt to another pt against electrostatic



$V = 4\times10^{4}$ volt $\qquad q = 4\times10^{-7}$ C

work done = ?

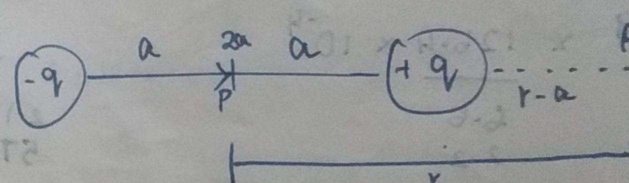
$r = 9$

$V = 2$

$q_0 = 2\times10^{-9}$

Potential due to dipole

(i) On axial line



Let the potential at 'p' to +q charge

$$V_{+q} = \frac{kq}{(r-a)} \quad -(1)$$

||'y the potential at 'p' to -q charge

$$V_{-q} = \frac{-kq}{(r+a)} \quad -(2)$$

$$V_{net} = V_{+q} + V_{-q}$$

$$= kq\left(\frac{1}{(r-a)} - \frac{1}{(r+a)}\right)$$

$$= kq\left(\frac{r+a-r+a}{r^2-a^2}\right)$$

$$V_{net} = kq\left(\frac{2a}{r^2 - a^2}\right)$$

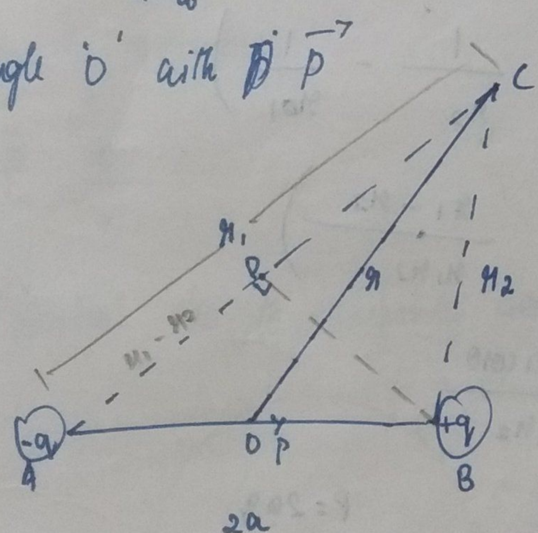
$$= \frac{k\,P}{r^2-a^2} \qquad P = 2a \times q$$

$$V_{net} = \frac{1}{4\pi\varepsilon_0} \times \frac{P}{r^2 - a^2}$$

if $r >> a$

$$V_{net} = \frac{1}{4\pi\varepsilon_0} \times \frac{P}{r^2}$$

(ii) On angle 'θ' with $\vec{P}$



$r_1 > r_2$

$AC = r_1 \quad DC = BC = r_2 \quad AD = r_1 - r_2$

In ABD

$$\cos\theta = \frac{AD}{AB}$$

$$\cos\theta = \frac{AD}{2a}$$

$AD = 2a\cos\theta$

Let us consider a potential at a point "c" due to '-q' is

$$V_{-q} = -\frac{kq}{r_1}$$

||ly

$$V_{+q} = \frac{kq}{r_2}$$

$$V_{net} = V_{+q} + V_{-q}$$

$$= \frac{kq}{r_2} - \frac{kq}{r_1}$$

$$= kq\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

$$= kq\left(\frac{r_1 - r_2}{r_1 r_2}\right)$$

$$= kq\frac{2a\cos\theta}{r_1 r_2}$$

$$= \frac{kP\cos\theta}{r_1 r_2} \qquad P = 2aq$$

$r_1 \approx r_2 \approx r$

$$= \frac{kP\cos\theta}{r^2}$$

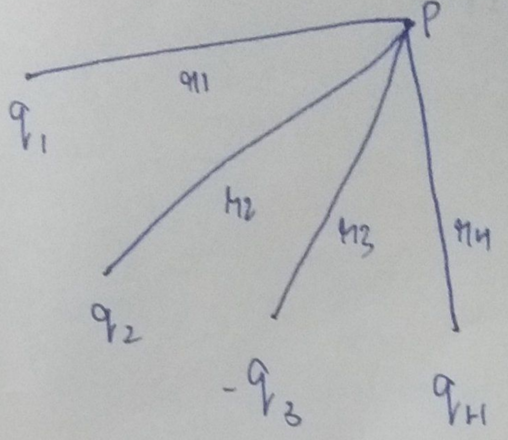
$$\boxed{V_{net} = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}}$$

$\theta = 90°$ $V = 0$

$\theta = 0$ $V = \frac{kP}{r^2}$

$\theta = 180°$ $V = -\frac{kP}{r^2}$

Potential due to system of charges



$$V_1 = \frac{kq_1}{r_1} \qquad V_4 = \frac{kq_4}{r_4}$$

$$V_2 = \frac{kq_2}{r_2}$$

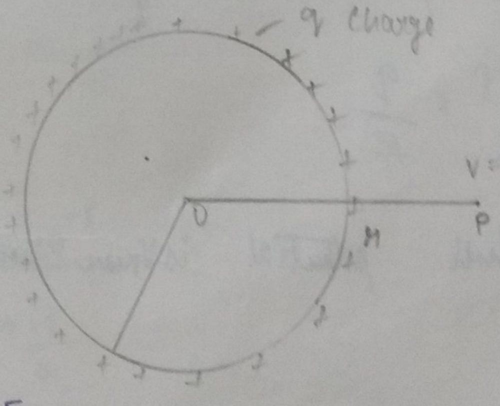
$$V_3 = \frac{-kq_3}{r_3}$$

$$V_{net} = k\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} - \frac{q_3}{r_3} + \frac{q_4}{r_4}\right]$$

for n no. of q charges

$$V_{net} = k\sum_{i=1}^{n} \frac{q_i}{r_i}$$

Electric Potential due to uniformly charged spherical shell



$$E = \frac{F}{q} \qquad q = 1$$

$$E = F$$

$$\text{Work done} = F \cdot dr$$

$$W = E \cdot r$$

$$E = \frac{1}{4\pi\epsilon_0} \times \frac{q}{r^2}$$

$$V = \frac{W}{q} \qquad q = 1$$

$$V = E \cdot r$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} \times r$$

$$\boxed{V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}}$$

when the point 'p' lies out side of the shell at 'r' distance

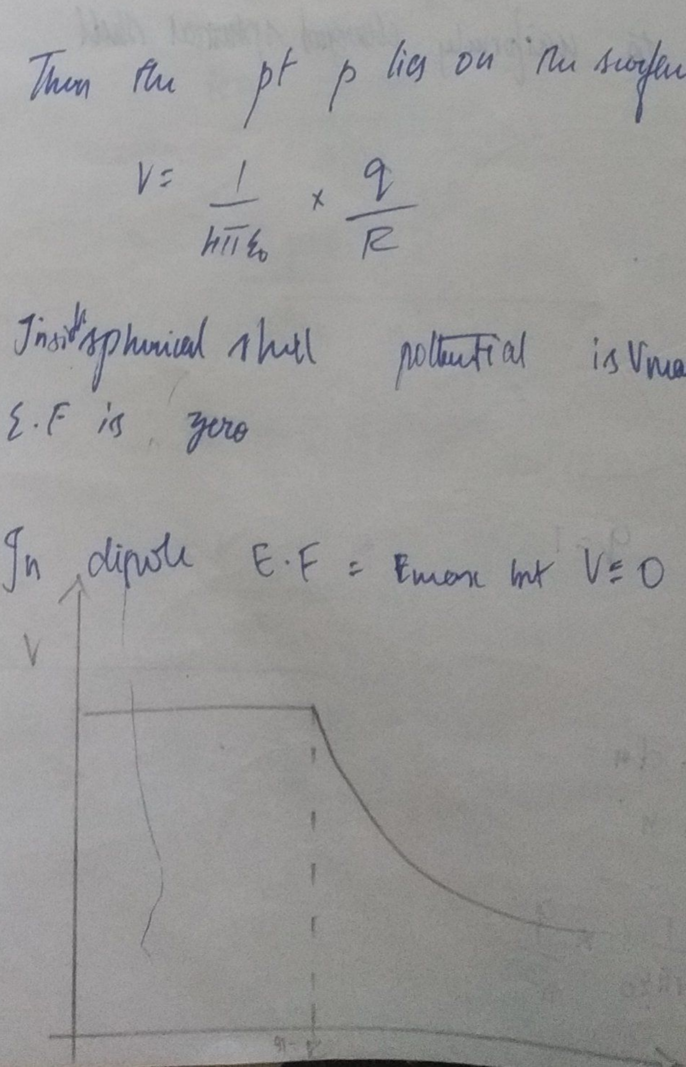
$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

Then the pt p lies on the surface

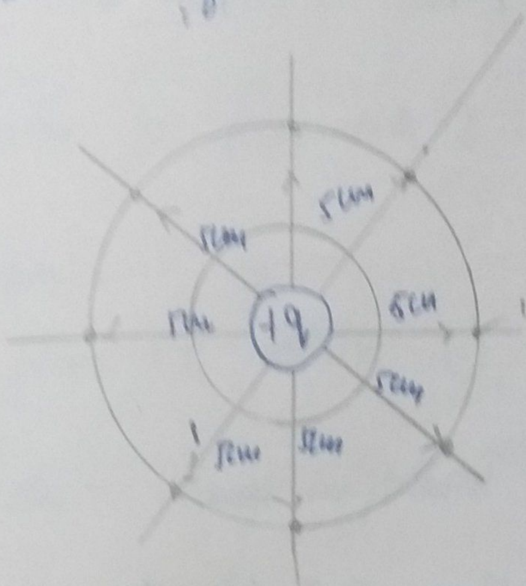
$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{R}$$

Inside spherical shell potential is V_{max} and E.F is zero

In dipole E.F = E_{max} but V = 0

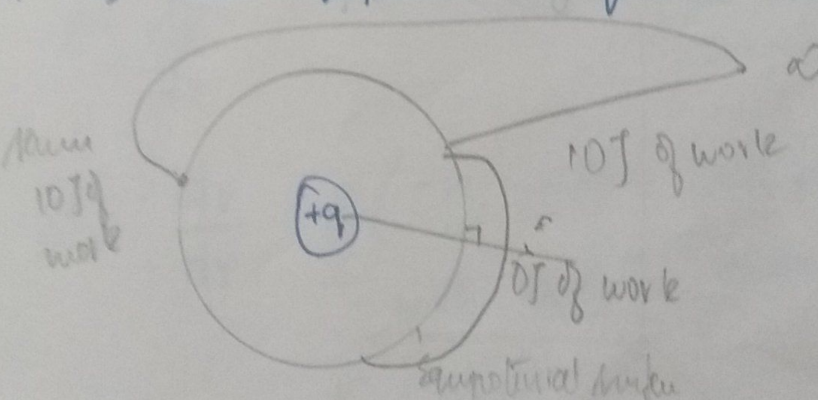


Equipotential Surface



Any surface which has same potential at every point is called equipotential.

Any surface that has same electric potential at every point on it is called equipotential surface.



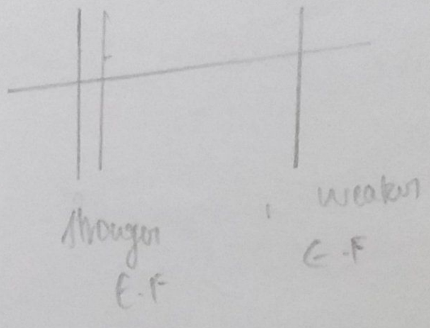
$$V = \frac{W}{q}$$

$$\boxed{W = V \cdot q}$$

Properties :-

(i) No work has to be done by moving a charge from 1 pt to another pt in same equipotential surface

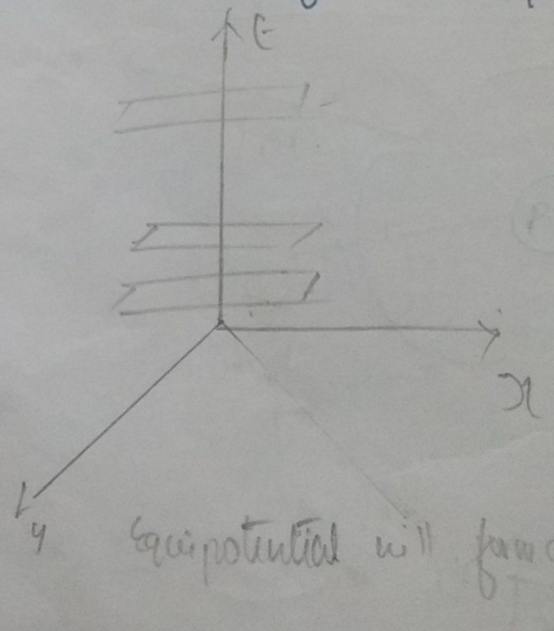
(ii) Electric field is always ~~perpen~~ normal or perpendicular to Equipotential surface.



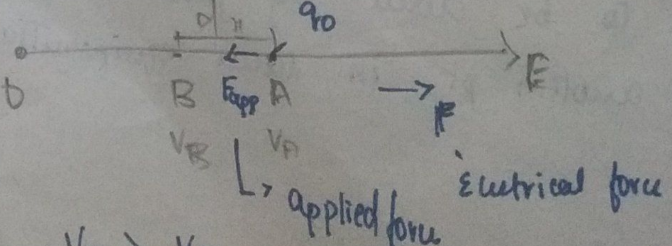
~~Where~~ ~~Equi~~ When 2 Equipotential surface are closer then, stronger E.F and If its is far away then its weaker E.F

No 2 Equipotential surfaces can intersect each other

Relation between Electric field and potential



Equipotential will form at x-y plane



$V_B > V_A$

$dv = (V_B - V_A)$

For moving q_0 from A to B. It needs workdone

workdone = $F \cdot dr$

$dw = -Eq_0 \cdot dr$ — (1)

dw = change in potential × charge —

$dw = dv \times q_0$ — (2) (By $w = \frac{v}{q}$

By (1) & (2)

$-Eq_0 \cdot dr = dv \times \cancel{q_0}$

$-E = \frac{dv}{dr}$

$\therefore E = -\frac{dv}{dr}$ (-ve potential graudient)

with respective distance potential increases.

If $E = 0$

$dv = 0$

v = constant

If the potential in the region of the space around the point $(-1, 2, 3)$ m is given by potential $(10x^2+5y^2-3z^2)$ volt calculate 3 components of E.F

$E_x = ?\quad E_y = ?\quad E_z = ?$

$$E_x = \frac{dv}{dx} = -\left(\frac{dv}{dx} + \frac{dv}{dy} + \frac{dv}{dz}\right)$$

~~$V = E/x$~~

~~$10x^2 = E/-1$~~

~~$E_x = -10x^2$~~

$$E_x = -\frac{dv}{dx}$$

$$= \frac{-d(10x^2)}{dx} = -10(-2)$$

$$= 20\ V/m$$

$$E_y = \frac{-d}{dy}(5y^2)$$

$$= -10y$$

$$= -10(2)$$

$$= -20\ V/m$$

$$E_z = \frac{d(3z^2)}{dz}$$

$$= -6z$$

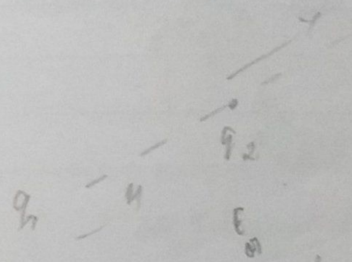
$$= -6(3)$$

$$= -18\ V/m$$

Electric potential Energy for system of charges:

$w_1 = 0$ (q_1 from ∞)

$w_2 = \frac{k q_1 q_2}{r}$ (q_2 from ∞)



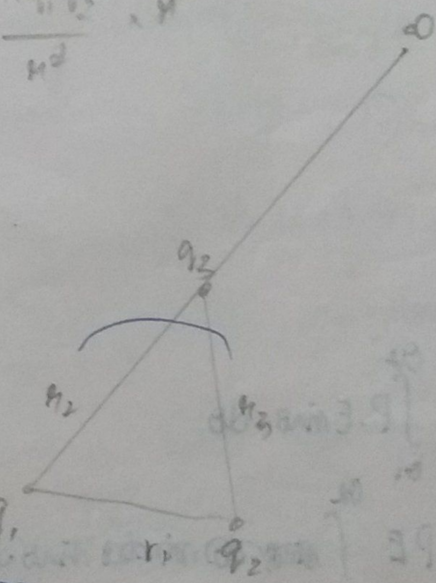
$E = \frac{F}{q}$

$E = \frac{F}{+1}$

$\therefore E = F$

$w_2 = \vec{F} \cdot disp$

$= \frac{k q_1 q_2}{r^2} \times r$



$W_3 = (V_1 + V_2) q_3$

$= \left(\frac{k q_1}{r_2} + \frac{k q_2}{r_3} \right) q_3$

$= \frac{k q_3 q_3}{r_2} + \frac{k q_2 q_3}{r_3}$

$W = w_1 + w_2 + w_3$

$= 0 + \frac{k q_1 q_2}{r_1} + \frac{k q_1 q_3}{r_2} + \frac{k q_2 q_3}{r_3}$

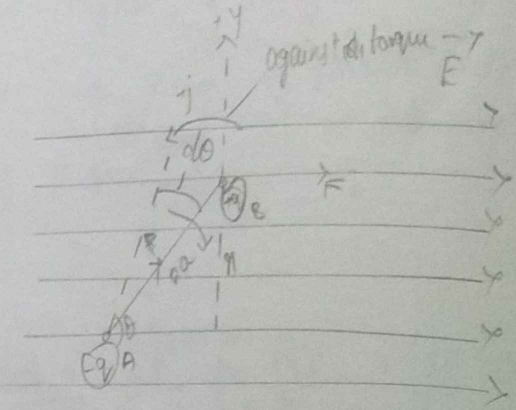
No. of terms $= \frac{n(n-1)}{2}$

for N terms $= k \sum_{i,j=1}^{n} \frac{q_i q_j}{r_{ij}}$

Potential Energy of a dipole in an uniform E.F

$\vec{\tau} = \vec{p} \times \vec{E}$

$-\hat{k} = \hat{j} \times \hat{i}$



$dw = F.ds$

$dw = \tau . d\theta$

The work done by rotating a dipole against the torque

$dw = \tau . d\theta$ -(1)

$\tau = P.E \sin\theta$ -(2)

sub (2) in (1)

$dw = P.E \sin\theta . d\theta$

By integrating

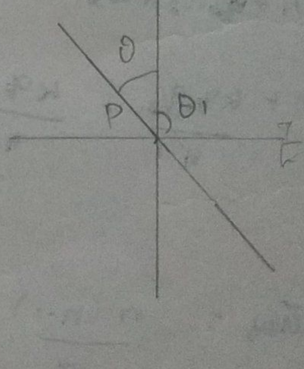
$$\int dw = \int_{\theta_1}^{\theta_2} P.E \sin\theta . d\theta$$

$$W = PE \int_{\theta_1}^{\theta_2} \sin\theta \, d\theta$$

$$= P.E \left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$W = -P.E \left[\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$= -P.E\left[\cos\theta_2 - \cos\theta_1\right]$$



$$U = W = P.E\left[\cos\theta_1 - \cos\theta_2\right]$$

Potential energy

Note :-

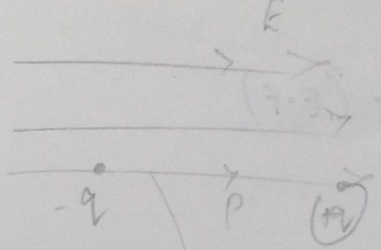
if $\theta_1 = 90^\circ$ $\theta_2 = \theta$

$$U = -P.E \cos\theta$$

(i) when $\theta = 0°$

$U = -P \cdot E$ (stable Equilibrium)

The potential energy of a dipole is minimum when its dipole moment is ~~par~~ parallel of external field



$\theta = 0$

$F_{net} = 0$

$\tau = 0$

Electron energy = -13.6 eV

when $\theta = 90°$

$U = 0$

when $\theta = 180°$

$U = P \cdot E$ (unstable Equilibrium)

Energy value - max

Behaviour of conductor in Electrostatic field.

(i) the potential is constant within and on the surface of the conductor.

why: $E = -\frac{dv}{dr}$ The E.F inside the charged spherical shell is zero

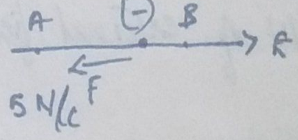
$0 = \frac{-dv}{dr}$

$\therefore dv =$ constant (uniform potential)

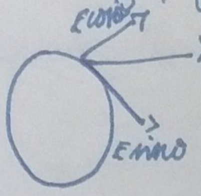
(ii) E.F is always normal to the charged conductor

why: If it not $\perp r$. It can be divided in components

$E\cos\theta$ and $E\sin\theta$ (one of the component is tangential to surface)



B → less than 5 (E.F)



it causes movement of e^- that

If it is tangential ~~it will immediately~~ it causes current which is voilation of current electricity

(iii) The net charge interior of the conductor is zero. so charges are resides only on the outer surface

why: ~~A charged body~~ In conductor (inside) the net charge = 0.

(iv) The potential ~~is uniform~~ on the surface is ~~zero~~ constant for a charged body the surface is equipotential

(v) for a charged body

Electrostatic shielding

E K Nandha kumar 83

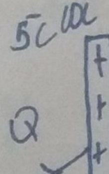
The phenomenon of making a region free from any Electric field is called as Electrostatic shielding.

Capacitance of conductor

The ability to hold the charges.

5C 10C — 10 volt 5 volt

Q — V



If it is holding ability is less than the supplied It will attain leakage of 'q' (1C+q) get ionized with air molecule)

$Q \propto V$

$Q = \underbrace{C V}_{}\rightarrow$ capacitance

$C = \dfrac{Q}{V}$ unit : farad

mF $\times 10^{-3}$ F

μF $\times 10^{-6}$ F

nF $\times 10^{-9}$ F

pF $\times 10^{-12}$ F

It is the ratio

charge given to conductor to develop 1 volt.

It depends on :- (i) Shape and size of the conductor (dimension

2) Medium in which it is placed (surrounding)

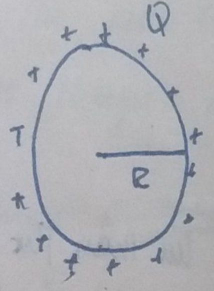
3) Proximity of the other conductor placed nearby

One farad:-

1 coulomb of charges given to conductor to develop potential difference of 1 volt

Spherical capacitor → To store electrical energy and charge

Let us consider the charge given to spherical conductor of radius 'R' is Q coulomb



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

The potential developed is V volt

$$V = \frac{kQ}{R} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$$C = \frac{Q}{V} = \frac{\cancel{Q}}{\frac{\cancel{Q}}{4\pi\varepsilon_0 R}}$$

$$\boxed{C = 4\pi\varepsilon_0 R}$$

eg $c = 100 \mu C$

$C = 4\pi \varepsilon_0 \varepsilon_r R$ (for other outside medium)

$$\boxed{C = 4\pi\varepsilon R}$$

Principle of Parallel Plate Capacitor

Let us consider a charged plate A is 'Q' coloumb given to the, hence the potential developed v volt then the capacity of the conductor ~~C = 4πε₀r~~

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

$V \to$ changes (decreases) (S_1)

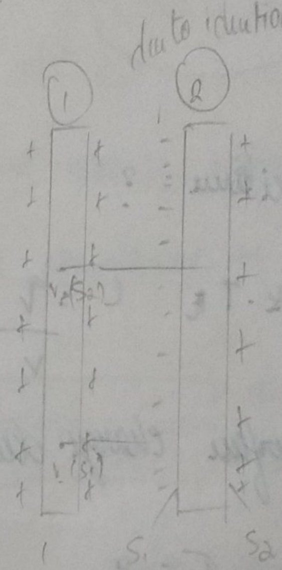
$C \to$ increases (S_1) ∴ It happens maximum

$V \to$ increases (S_2)

$C \to$ decreases (S_2)

If the S_2 is connected to ⏚

then the +ve q will get neutralize.



1st → It alone gets +v (potential)

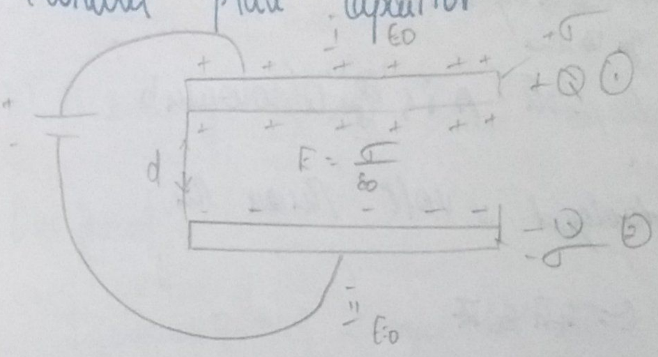
2nd → after 2nd plate (due to induction) it will form -ve charge on one side ∴ It will form -v (potential)

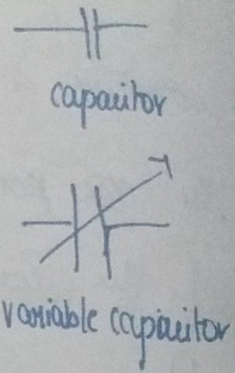
$V_{net} = V_+ - V_-$

In S_2 +ve q will form. It produce +v (potential) (S_2) which will increase the V.

$V_{net} = V_2(S_2) - V_1(S_1)$

Parallel plate capacitor





Capacitance = ?

W.K.T $C = \frac{q}{V}$

The surface charge density $+\sigma$

$$\sigma = \frac{q}{A}$$

$$q = \sigma . A$$

$$|E| = \frac{-dv}{dr} = \frac{V}{d} \text{ for magnitude}$$

$$\therefore V = Ed$$

$$= \frac{\sigma}{\varepsilon_0} \times d$$

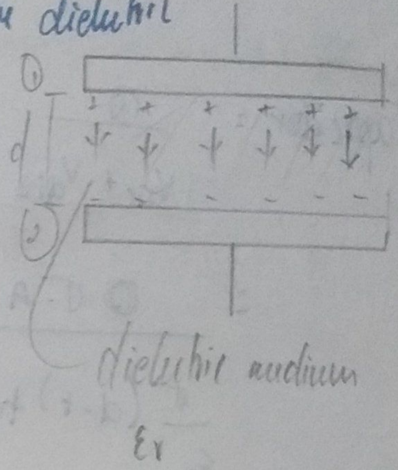
$$C = \frac{q}{V}$$

$$= \frac{\cancel{\sigma} . A}{\frac{\cancel{\sigma} \times d}{\varepsilon_0}}$$

$$\boxed{C = \frac{\varepsilon_0 . A}{d}}$$

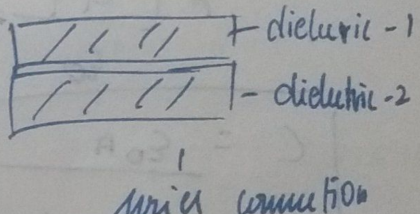
The space b/w the plates is completely filled with dielectric

$$C = \frac{\varepsilon_0 A}{d}$$



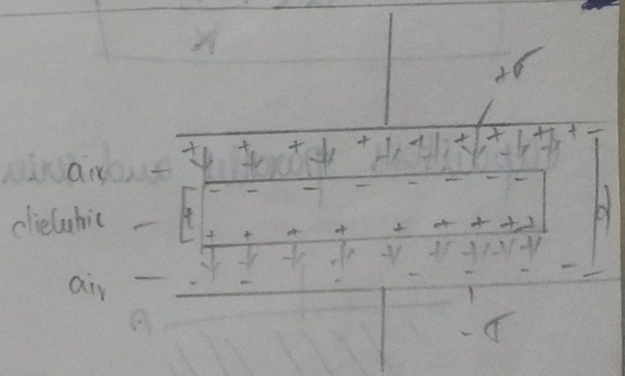
$$C = \frac{\varepsilon_0 A}{d} \times \varepsilon_r$$

If 1/2 region is consider as dielectric and next 1/2 region is air medium then it will be considered as 2 separate capacitor



Partially filled with dielectric

The capacitance of the capacitor is



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

where $Q = \sigma \cdot A$ (1)

$V = E \cdot$ distance

For air medium $V_{air} = E_{air} \times d_{air}$

$$V_{air} = \frac{\sigma}{\varepsilon_0} \times (d-t)$$

For dielectric medium $V_{die} = E_{die} \times d_{die}$

$$= \frac{\sigma}{\varepsilon_0 \varepsilon_r(k)} \times t$$

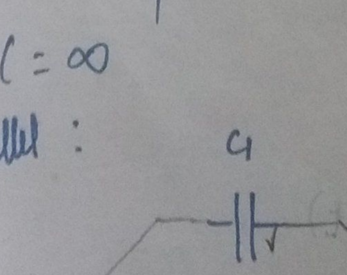
$$\text{Capacitor} = \frac{Q}{V_{air} + V_{die}}$$

$$= \frac{\sigma \cdot A}{\frac{\sigma}{\varepsilon_0}(d-t) + \frac{\sigma \cdot t}{\varepsilon_0 K}}$$

$$= \frac{\cancel{\sigma} \cdot A}{\cancel{\sigma}\left(\frac{d-t}{\varepsilon_0} + \frac{t}{\varepsilon_0 K}\right)}$$

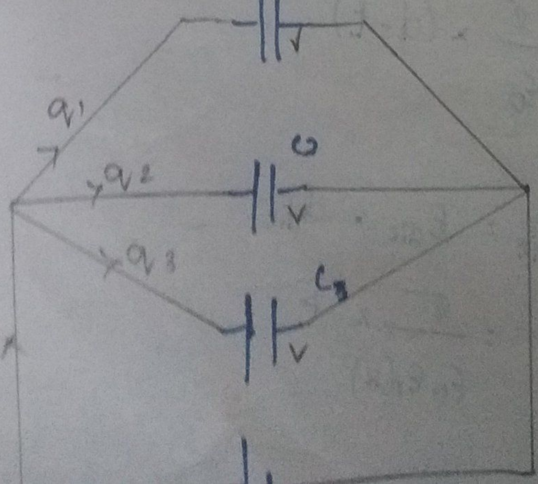
$$\boxed{C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}}$$

Capacitors parallel and series combination



$C = \infty$

(i) parallel:



In $\|^{el}$ the Potential diff. across the capacitors are same

The charge flow across the capacitors varies

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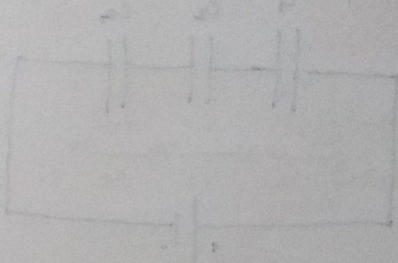
Let us consider 3 capacitor of capacitance C_1, C_2, C_3 are connected in $\parallel^{l}$



$$Q = q_1 + q_2 + q_3 \quad - (1)$$

W.K.T $C = \dfrac{Q}{V}$

$$Q = CV \quad - (2)$$

Across the 1st capacitor

$$q_1 = C_1 V$$

$\parallel^{ly}$

$$q_2 = C_2 V$$

$$q_3 = C_3 V$$

Sub these equ in equ (1)

$$Q = C_1 V + C_2 V + C_3 V$$

$$Q = V(C_1 + C_2 + C_3) \quad - (3)$$

By equ (2) & (3)

$$C_p \cancel{V} = \cancel{V}(C_1 + C_2 + C_3)$$

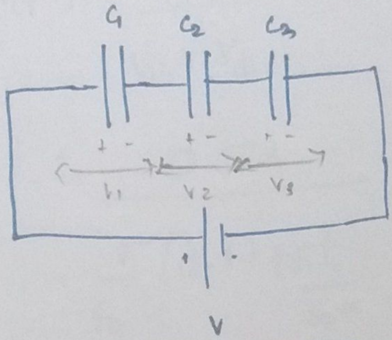
$$\therefore C_p = C_1 + C_2 + C_3$$

~~The efficitive capac~~ ~~is equal to~~ the

net capacitancy in parallel connection is equal to sum of the capacitancy of individual capacitor.

The net capacitance is always greater than larger individual capacitor.

(ii) ~~parallel~~ : series :



Charges will be same

Let C_1 C_2 & C_3 are 3 capacitor connected in series Then the total potential is divided across individual capacitors

$$V = V_1 + V_2 + V_3 \quad -(1)$$

W.k.T $C = \frac{Q}{V}$

$$V = \frac{Q}{C} \quad -(2)$$

Across 1st capacitor

$$V_1 = \frac{Q}{C_1}$$

$^{||}$ly.

$$V_2 = \frac{Q}{C_2}$$

$$V_3 = \frac{Q}{C_3}$$

Sub all in (1)

$$V_s = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$= Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \quad -(3)$$

Compare (3) and (2)

$$\frac{\cancel{Q}}{C_s} = \cancel{Q}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

$$\frac{C_2+C_1+C_3}{C_1C_2C_3}$$

$$\cancel{C_s = \frac{C_1C_2C_3}{C_1+C_2+C_3}}$$

$$\frac{C_2C_3+C_1C_3+C_1C_2}{C_1C_2C_3}$$

$$C_s = \frac{C_1C_2C_3}{C_2C_3+C_1C_3+C_1C_2}$$

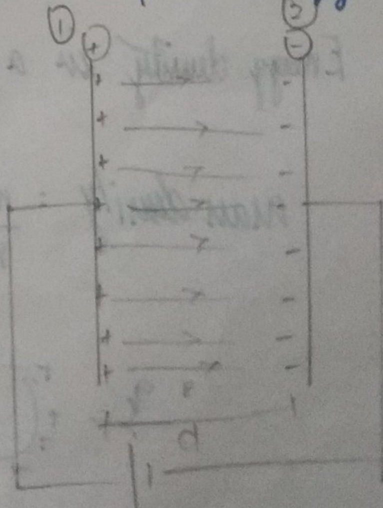
The reciprocal of net capacitance in series connection is equal to reciprocal of individual capacitor.

C_s value will be less the least individual capacitor.

Energy stored in Capacitor

Let us consider 2 plates having distance of separation of 'd'

while charging capacitor dq charge is moved from plate 2 to 1 then the workdone is stored as Electric potential energy



$$dw = F \cdot dx$$

$$= E \cdot dq$$

$$dw = V \cdot dq$$

$$\int dw = \int V \cdot dq$$

$$W = \int_0^Q \frac{Q}{C} \cdot dq$$

$$= \frac{1}{C} \int_0^q Q \cdot dQ$$

$$E = \frac{F}{q}$$

$$E = \frac{F}{q}$$

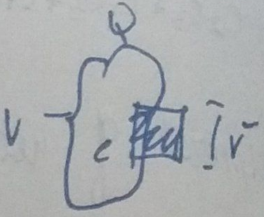
$$E = \frac{\sigma}{\varepsilon_0}$$

$$= \frac{dV}{dr}$$

$$E \cdot dr = dV$$

$$\Rightarrow \frac{1}{C}\left[\frac{Q^2}{2}\right]$$

$$U \Rightarrow \frac{1}{2}\frac{Q^2}{C}$$



$$\boxed{U = \frac{1}{2}\frac{Q^2}{C}} \quad -(1)$$

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

$$Q = CV$$

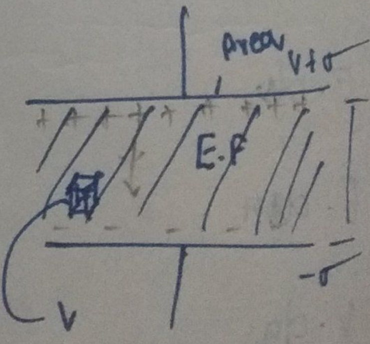
$$U = \frac{1}{2}\frac{(CV)^2}{C}$$

$$\boxed{U = \frac{1}{2}CV^2} \quad -(2)$$

$$U = \frac{1}{2}\frac{Q^2 V}{Q}$$

$$\boxed{U = \frac{1}{2}QV} \quad -(3)$$

Energy density in a capacitor



mass density $= \frac{\text{mass}}{\text{volume}}$

q

Charge density $= \frac{\text{Charge}}{\text{surface area}}$

Energy density $= \frac{U}{\text{Volume}}$ $\qquad$ Volume $= A \times d$

$U = \frac{1}{2}\frac{Q^2}{C}$

$U = \frac{1}{2} C V^2$

$U = \frac{1}{2} Q V$

$E = \frac{V}{d}$ $\qquad$ $U = \frac{1}{2}\frac{Q^2}{C}$

W.K.T capacitance of the capacitor

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

$\sigma = \frac{q}{A}$

E-F b/w the plates $E = \frac{\sigma}{\varepsilon_0}$

$$E = \frac{Q}{A\varepsilon_0}$$

$$\boxed{Q = A\varepsilon_0 E}$$

Energy density $= \dfrac{\frac{1}{2}\frac{Q^2}{C}}{A \times d}$

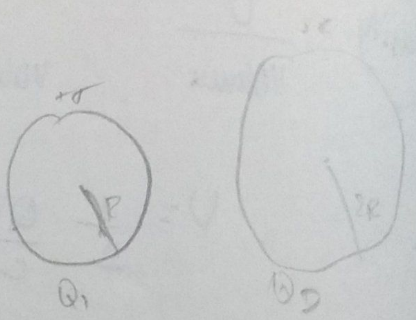
$$u = \dfrac{\frac{1}{2}\dfrac{(A\varepsilon_0 E)^2}{\frac{\varepsilon_0 A}{d}}}{A \times d}$$

$$= \frac{\cancel{A^2} \cdot \varepsilon_0^{\cancel{2}} E^2 \cdot \cancel{d}}{2 \cancel{A} \times \cancel{d}\, \cancel{\varepsilon_0} \cdot \cancel{A} \cdot \cancel{d}}$$

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

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

Redistribution of charges



$Q_2 > Q_1$

$\sigma = \frac{q}{A}$

$q = \sigma \cdot A$

$= \sigma \cdot 4\pi R^2$

$q \propto R^2$

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

$C_1 = 4\pi\varepsilon_0 R^2$ $\qquad C_2 > C_1$

$C_2 = 4\pi\varepsilon_0 (2R)^2$

Charge flow ~~is~~ is from high potential to low

In this case the charges are not equal

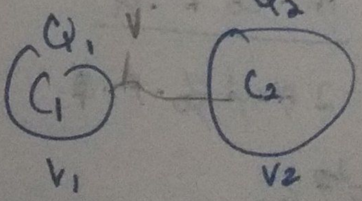
$\therefore V_2 > V_1$

Charge flow is from $V_2 \to V_1$

Common potential = $\dfrac{\text{Total charge}}{\text{Total capacitance}}$

$Q_1 = C_1 V_1$

$Q_2 = C_2 V_2$

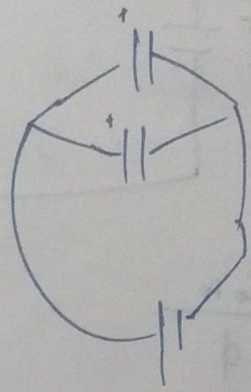


$C = \frac{Q}{V}$

If they are connected

potential is same for both after flow of charge. (v)

$\therefore$ Total capacitance $= C_1 + C_2 = C$



$\therefore$ common potential $=$

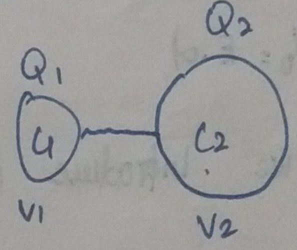
$$\frac{Q_1 + Q_2}{C_1 + C_2}$$

$$V \Rightarrow \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

Energy lost during (discharg of capacitor)

or

(sharing of charge)



Energy stored before connection the capacitor (initial energy U_i) $\Rightarrow \frac{1}{2} C_1 V_1^2 + \frac{1}{2} C_2 V_2^2$

$$\Rightarrow \frac{1}{2}\left(C_1 V_1^2 + C_2 V_2^2\right)$$

$$V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

Energy stored after connecting the capacitor (final energy U_2 $\;\; \frac{1}{2}(C_1 + C_2) \times \left(\frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}\right)^2$

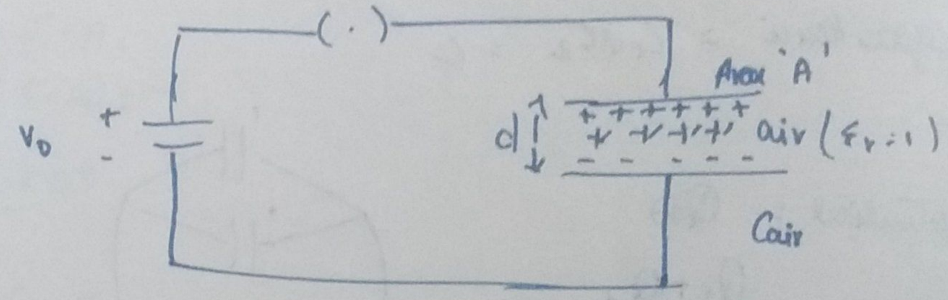
$$U_f = \frac{1}{2}\frac{(C_1 V_1 + C_2 V_2)^2}{C_1 + C_2}$$

heat form while flow of charges

Electro magnetic wave production

Energy lost = $U_i - U_f$

Effect of dielectric on various Parameters



$$C_{air} = \frac{\varepsilon_0 A}{d}$$

$$E = \frac{V_0}{d}$$

$$Q = C_{air} \cdot V_0$$

$$U = \frac{1}{2} \frac{Q^2}{C} \Rightarrow \frac{1}{2} C_0 V_0^2$$

$$V_0 = E \cdot d$$

If we introduce dielectric medium when it is connected to battery

$$C' = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$= k \frac{\varepsilon_0 A}{d}$$

$$\boxed{C' = k\ C_{air}}$$

$$Q' = k\ C_{air}\ V_0$$

$$\boxed{Q' = k \cdot Q}$$

$$\boxed{U' = k \cdot U}$$

$$E = \frac{V_0}{d}$$

$$V_0 = E \cdot d$$

when we disconnect the battery

Q = remain same

$E_0 = \frac{\sigma}{\varepsilon_0}$ $E' = \frac{\sigma}{k\varepsilon_0} = \frac{E_0}{k}$

In before case also it will decrease but battery will compensate the reduced energy

$V' = E' \cdot d$ $\quad V_0 = Ed$ $\quad C = \frac{Q}{V}$

$= \frac{V_0}{k}$

$C' = k \cdot C_{air}$

$U = \frac{1}{2} C' V'^2$

$= \frac{1}{2} k \cdot C_{air} \left(\frac{V_0}{k}\right)^2$

$\therefore U' = \frac{U}{k}$

~~Source of energy lost is~~ final capacitor

$Q = C_{air} \cdot V$

$Q' = k \cdot C_{air} V$

$= 3 \cdot 10^{-6} \cdot 6$

$= 18 \times 10^{-6}$

$=$

$V = E \cdot d$

$= \frac{\sigma}{k \cdot \varepsilon_0} \cdot d$

$V' = \frac{V}{k} = \frac{V}{3}$

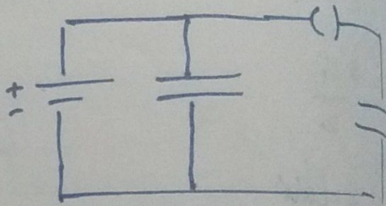
$= \frac{6}{3} = 2$

$E' = \frac{\sigma}{k\varepsilon_0}$

Qa

Figure shows 2 identical capacitors C_1 & C_2 of each 1μF capacitance connected to a battery of 6V. Initial switch 's' is closed. After some time S is left open and dielectric slab of k = 3 is inserted completely in the space btw the plates of capacitors. How will the charge and potential affects after the slab insert

Q. P.d across the capacitor before disconnectic



C_1 — $V = 6V$

C_2 — $V = 6V$

$C = \frac{q}{V}$ $\boxed{q = C \times V}$

$q_1 = 6\mu C$ $q_2 = 6\mu C$

P.d across the capacitor ~~before~~ after disconnecting

$C_1' = k \cdot C_1 = 3\mu F$ $C_2' = k \cdot C_2 = 3\mu F$

$V = 6V$ $V' = \frac{V}{k} \Rightarrow \frac{6}{3} = 2V$

$q' = k \cdot q$ q = remain same

$= 18\mu C$ $= 6\mu C$