Note: Ac को shock → attractive @ AA

D.C. को shock → repulsive

Electrostatics

- charge or electron
- at rest

→ Charge
- +ve → Deficiency of electron in neutral matter
- −ve → Excessive of e^- in neutral matter

$ne = np$

└ elec. neutral

Q. If the matter is +vely charged, then its mass :— (e^- defic.)

(a) ↑es (b) ↓es (c) unchanged (d) none

−vely charged → ↑es

A+ < B−

└ mass less └ mass more

Q. If a ~~soap~~ soap bubble is +vely charged, then its radius :—

(a) ↑es (b) ↓es (d) unchanged (d) Fluctuate



surface tension → decreases.

Note :- If the bubble is −vely charged then also radius ↑es.

- Like charge → Repel
- Unlike charge → Attract
- charged body & neutral body → Attract

Q. ~~Force betw~~ Two like charged body :—

(a) always attract (b) always repel

(c) may repel or attract (d) None

like charge को repulsive force लाई inductive force ले cancel गर्‍यो



↓ so, attract.

Two like charged body may attract each other.
but two like charge always repel.

Q. Sure test of electrification is :-
(a) attraction (b) repulsion (c) both (d) Induction
↳ may be +ve, -ve & neutral (all).
↳ either +ve by +ve or -ve by -ve.

→ Charge at rest → produces electric field only.
→ charge in motion → uniform motion ($a=0$) → E & B only.
↳ accelerated motion → E, B & EM radiation (radiated electric field & mag. field.)

→ current carrying conductor produces only magnetic field.

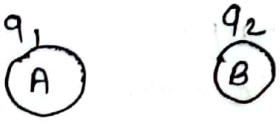
Conservation of charge → neither be created nor be destroyed. always constant or conserved.

→ 

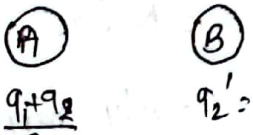
Before contact



After contact



r = same before contact.



$q_1' = \frac{q_1+q_2}{2}$ $q_2' = \frac{q_1+q_2}{2}$
after contact

$V_1 = V_2$

$\frac{q_1' q}{4\pi\varepsilon_0 r} = \frac{q_2'}{4\pi\varepsilon_0 R}$ or, $\frac{Q-q_2'}{r} = \frac{q_2}{R}$

$q_2 = \left(\frac{QR}{R+r}\right)$

$q_1' = \frac{Qr}{R+r}$ $q_2' = \frac{QR}{R+r}$

$Q = q_1 + q_2$

charge after contact = $\frac{\text{Total charge} \times \text{own rad.}}{\text{sum of radii}}$

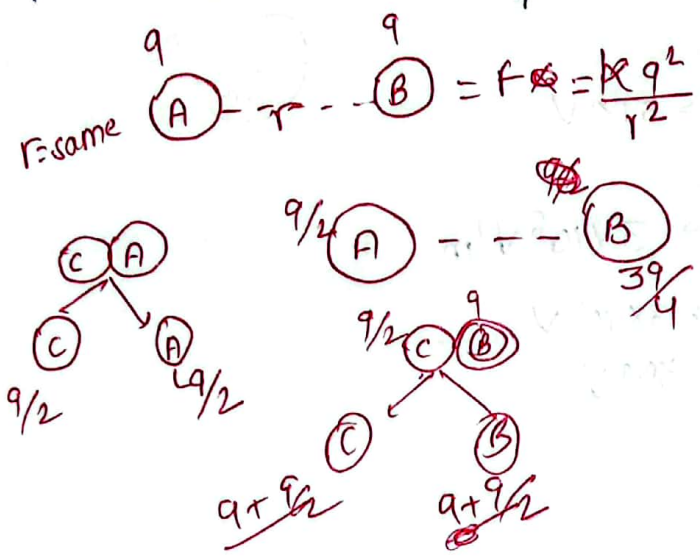
Q. 

⇒ after contact, charge in the sphere of radius (a) is :-

$$q = q\frac{a}{a+b}$$

Q. Two charged spheres A and B of equal radius carrying equal like charge (q) are placed at a certain distance apart & act F force. Third identical uncharged sphere C is first touched with A & then with B. What is the new force btw A & B?

(a) F (b) 2F (c) $\frac{3}{4}F$ (d) $\frac{3}{8}F$



$F' = \frac{3}{8}\frac{Kq^2}{r^2}$

$\therefore F = \frac{3}{8}F$

Quantization of charge

$Q = \pm ne$

$n = 1, 2, 3, 4, \ldots$

Quanta → (bundle or packet or whole)

[e loss → (+ve)
e gain → (-ve)]

[Basic of fundamental value of charge in any body is one electron.]

No. of electrons in 1C charge =

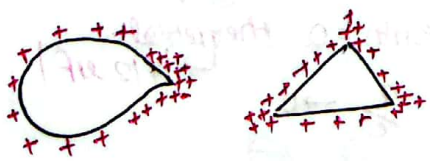
$n = \frac{Q}{e} = \frac{1C}{1.6\times10^{-19}C} = 6.25\times10^{18}$



→ In conductor, charge only resides on outer surface of the body.

r=same

So, both holds equal amount of charge.

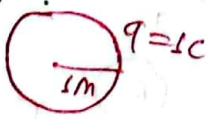


• Surface charge density (σ) = q/A.

pointed region → more charge.

Q. Can a sphere of radius of 1m holds 1C charge in air?

→ $V = \frac{Kq}{r} = \frac{9\times10^9\times1}{1}$



$= 9\times10^9 V >> 3MV$.

so, it can't hold.

Dielectric strength of air → 3×10^6 V/m.

• Deadline potential of air → 3×10^6 V

कति वेला सम्म store गर्न सक्छ।

= 3MV

Action of point

→ Leakage of charge from pointed region of the conductor due to air is called action of point.

→ also called corona discharge.

Q. A cube of side 6cm stores 36μC charge. Find σ.

→ $\sigma = \frac{q}{A} = \frac{36\times10^{-6}}{6\times6\times6\times10^{-4}} = \frac{10^{-2}}{6} = \frac{1}{600}$

$A = 6l^2$

sides l^2

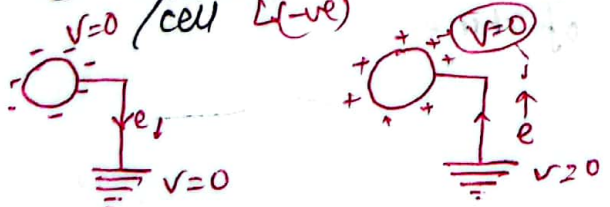
$= \frac{10}{6}\times10^{-3} = 1.6\times10^{-3}$ C/m²

charging of body

- Friction → By rubbing
- conduction → By contact or touch → higher V to lower V.
- Induction → Induce गर्ने।

Q. During the process of earthing charge flow from:-

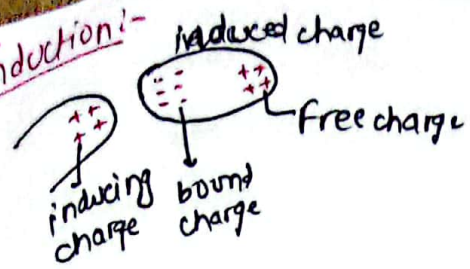
(a) conductor to earth (b) earth to cell (c) both a & b (d) none



C of earth = 0 theoretical (712 μF)

$V = \frac{q}{C} \to 0$

→ Induction:-



• In friction, conduction & induction.
↳ most prefarable step.
bcz no charge & mass change
↳ charge loss & also mass change

→ In induction, potential of moving body decreases.

Note:- Electrophorous → device used to store the unlimited charge produced by induction.

Electroscope → device used to detect the presence of charge and nature of charge.

2 types
→ Gold leaf electroscope
→ pith ball electroscope

• Unit of charge → coloumb (SI)
stat coloumb (CGS)

$1C = 3 \times 10^9$ stat columb.

Coloumb's law

→ sepr between 2 charge (r) is must be greater than 10^{-15} m (1 Fermi)

q_1 - - - r - - - q_2

Nucleus → 10^{-15} m.

→ charge should be point stationery.

$F_a = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$ → in air

$\frac{1}{4\pi\varepsilon_0}$ → $9 \times 10^9 \, Nm^2/C^2$ (SI)
→ 1 in CGS.

ε_0 → permittivity of free space or air
→ $8.85 \times 10^{-12} \, C^2/Nm^2$

Force in medium

$F_m = \frac{1}{4\pi\varepsilon} \frac{q_1 q_2}{r^2}$

Relative permittivity or dielectric const. $(\varepsilon_r \text{ or } k) = \frac{\varepsilon}{\varepsilon_0}$

$\boxed{F_m = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{q_1 q_2}{r^2}}$

$\boxed{\varepsilon = \varepsilon_0 \varepsilon_r}$

$\boxed{\frac{F_a}{F_m} = \varepsilon_r \text{ or } k}$ $\boxed{F_m \propto \frac{1}{r}}$

for conductor, $K = \infty$

for insulator, $K > 1$

for air, $K = \approx 1.0006$

for vacuum, $K = 1$.

Q. Force between any two charges in air is f. What will be the Force between them if air in space betw them is completely exhaus

(a) slightly less than f (b) slightly more than f

(c) equal to f (d) zero

$f_a = f$. then, $f_v \propto \frac{1}{K}$ so, f_v = more than f.

but if air is replaced by any other medium, then force decr and becomes $\frac{1}{K}$ times of the force in air.

e.g. $f_a = 50$, $K = 5$

so, $f_m = \frac{1}{5} \times 50 = 10N$.

Q. Force between 2 charges in air at separation 'r' is f. What is the distance between them in any medium of dielectric constant K to exert same force as in air?

(a) $r\sqrt{K}$ (b) $r/\sqrt{K}$ (c) $K\sqrt{r}$ (d) $K/\sqrt{r}$

$q_1 \longleftarrow r \longrightarrow q_2$

q_1 [K] q_2 → $f_m = f$

r'

$f_a = f_m$

$$\frac{q_1 q_2}{4\pi\varepsilon_0 r^2} = \frac{q_1 q_2}{4\pi\varepsilon_0 \varepsilon_r r'^2}$$

$\varepsilon_0 r'^2 = r^2$

$\therefore r' = \frac{r}{\sqrt{K}}$

$K=4, r' = \frac{10}{\sqrt{4}} = 5cm.$

q_1 —— $r=10cm$ —— q_2 $f_a = 80N$ (air)

q_1 | $K=4$ | q_2 $f_m = 20N$ (medium)

$\leftarrow r \rightarrow$ = 5cm

→ 4 dielectric constant वाको medium को 5cm distance is equivalent to 10cm distance in air.

$5cm \times \sqrt{4} = 10cm$

(5cm: med. को distance; $\sqrt{4}$: diel. constant of medium को; 10cm: air को distance)

q_1 | K | q_2 ⇒ $f_m = f$

$\leftarrow t \rightarrow$

q_1 — — — — q_2 = $f_a = f$

$\boxed{r_a = t\sqrt{K}}$

Force in partial medium

q_1 — — — — — — q_2 → q_1 — | K | — — q_2

$\leftarrow r \rightarrow$; $\leftarrow t \rightarrow$

- हावा distance = $r - t$
- t thickness को medium को air equivalent distance = $t\sqrt{K}$. $(r_a)_{eq.dist.} =$

$$\boxed{r_a = r - t + t\sqrt{K}}$$

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r_a^2} = \frac{q_1 q_2}{4\pi\varepsilon_0 (r - t + t\sqrt{K})^2}$$

Q. Force between any 2 charges in air is F. What will be the new force between them if a medium of K=25 is placed in between them upto half separation?

ⓐ F/5 ⓑ F/3 ~~ⓒ F/9~~ ⓓ F

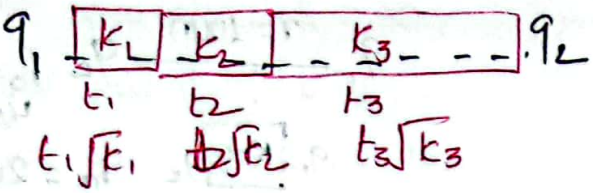
q_1 — r — — q_2 = $f_a = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

q_1 | $K=25$ | q_2 = $f' = ?$

$\leftarrow t = r/2 \rightarrow$

$$F' = \frac{q_1 q_2}{4\pi\varepsilon_0 \left(r - \frac{r}{2} + \frac{r}{2}\times 5\right)^2}$$

$$= \frac{q_1 q_2}{4\pi\varepsilon_0 (3r)^2} = \frac{q_1 q_2}{4\pi\varepsilon_0 9r^2} = F/9$$



$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 (t_1\sqrt{K_1} + t_2\sqrt{K_2} + \dots)^2}$$

Q. Force between any 2 charges is F. What will be the new force between them if 2 different medium of $K_1 = 4$ & $K_2 = 9$ having equal thickness placed completely in between these 2 charges?

$$F' = \frac{q_1 q_2}{4\pi\varepsilon_0 (t_1\sqrt{K_1} + t_2\sqrt{K_2})^2} \quad \because t_1 = t_2 = t = r/2$$

$$= \frac{q_1 q_2}{4\pi\varepsilon_0 t^2 (2+3)^2}$$

$$f = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

$$= \frac{q_1 q_2}{4\pi\varepsilon_0 \frac{r^2}{2^2} 5^2}$$

$$= \frac{q_1 q_2}{4\pi\varepsilon_0 r^2 \frac{25}{4}} = \frac{4}{25} F$$

$$\therefore F' = \frac{4}{25} F$$

Q. Any two charges 1μC & 3μC are placed at a certain distance apart. what is the ratio of Force between them?—

(a) 1:3 (b) 3:1 (c) 1:1 (d) None



$F_2 = \frac{K 1 \times 3}{r^2}$

$\therefore \frac{F_1}{F_2} = 1:1$

[charge equal लगाए fi. force equal & opposite

1. Find the ... of rest two vertices!

$F' = 2F\cos\frac{\theta}{2}$ $(\theta = 60^\circ)$

$= 2F\cos 30^\circ$

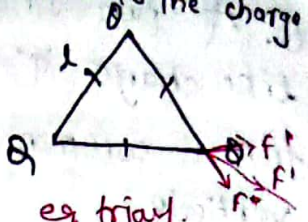
$= \sqrt{3}F$

$= \sqrt{3}\frac{q^2}{4\pi\varepsilon_0 l^2}$

$A = B$

$R = \sqrt{A^2+A^2+2A\cos\theta}$

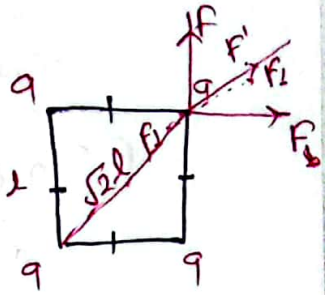
$= 2A\cos\frac{\theta}{2}$



2. (equal) $F' = 2F\cos\frac{\theta}{2}$ $(\theta = 90^\circ)$

$= 2F\cos 45^\circ$

$= \sqrt{2}f = \sqrt{2}\frac{Kq^2}{l^2}$



$F_1 = \frac{Kq^2}{(\sqrt{2}l)^2} = \frac{Kq^2}{2l^2}$

$F_{net} = F' + F_1$

$= \sqrt{2}\frac{Kq^2}{l^2} + \frac{Kq^2}{2l^2}$

$F_{net} = \frac{Kq^2}{l^2}\left(\sqrt{2}+\frac{1}{2}\right)$

Q. What is the ratio of electrostatic force to gravitational force for any two ~~ed~~ electrons placed at a certain distance apart?

(a) 10^{42} (b) 10^{39} (c) 10^{36} (d) 1

e —r— e

$\frac{F_e = \frac{Ke^2}{r^2}}{F_g = \frac{Gmemc}{r^2}} = \frac{9\times10^5(1.6\times10^{-19})^2}{6.67\times10^{-11}\times(9.1\times10^{-31})^2}$

$= 10^{42}$

$\therefore \boxed{\frac{F_e}{F_g} = 10^{42}}$ $\boxed{\frac{F_g}{F_e} = 10^{-42}}$

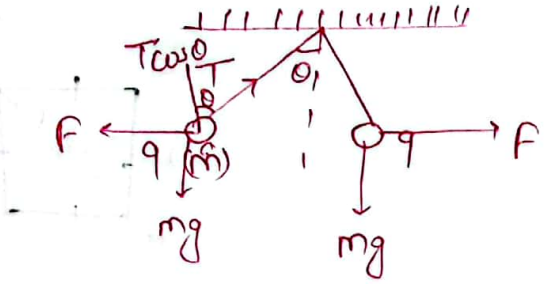
e —r— p $\frac{F_e}{F_g} = 10^{39}$

p —r— p $\Rightarrow \frac{F_e}{F_g} = 10^{36}$

CamScanner

Q. A two small metal ball each of mass (m) carrying equal like charge 'q' are suspended by insulated string of equal length 'l' from a common point. What is the angle made by each ball with vertical?

(a) $\tan^{-1}\frac{mg}{q\varepsilon}$ (b) $\tan^{-1}\frac{q\varepsilon}{mg}$ (c) 180° (d) 0°



$T\sin\theta = F = q\varepsilon$

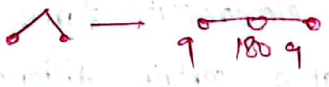
$T\cos\theta = mg$

$\therefore \theta = \tan^{-1}\left(\frac{q\varepsilon}{mg}\right)$

$\tan\theta = \frac{q\varepsilon}{mg}$

(ii) What is the angle between these two balls if this arrangement is taken into space?

(a) 0° (b) 90° (c) 180° (d) 45°



Position of Equilibrium

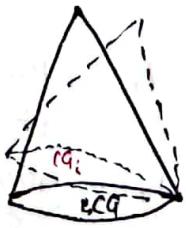




unstable eqm

↓

P.E → (max^m)



stable eqm

Electric Field

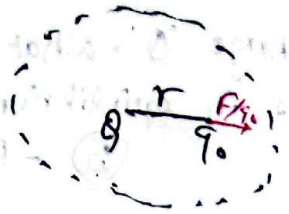
- space or region to experience electric charge.

Electric field intensity (E)

$E = \frac{F}{q_0}$ (force experienced by unit +ve test charge)

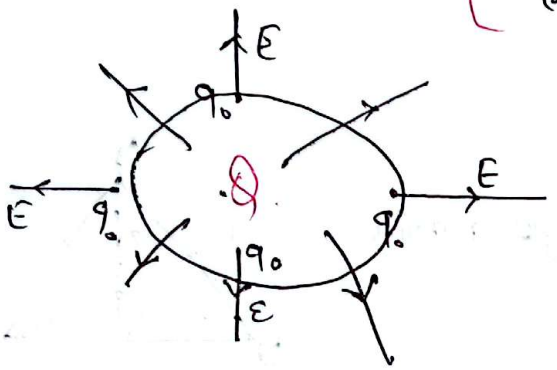
$= \frac{K Q \frac{q_0}{r^2}}{q_0}$

$\boxed{E = \frac{KQ}{r^2}}$

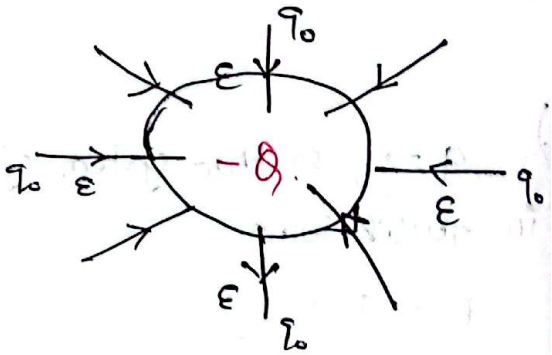


q_0 = unit +ve test charge

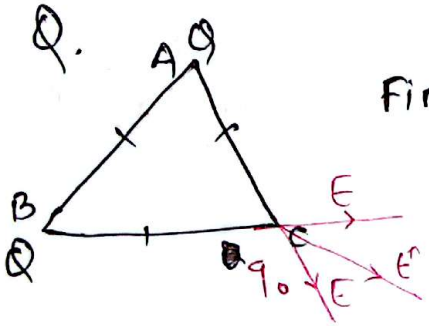
- जहाँ E निकालनु छ त्यो ठाउँमा q_0 राख्ने
- q_0 मा लाग्ने force E हो, जता force लाग्छ त्यो direction हो।



Radially away



Radially inward

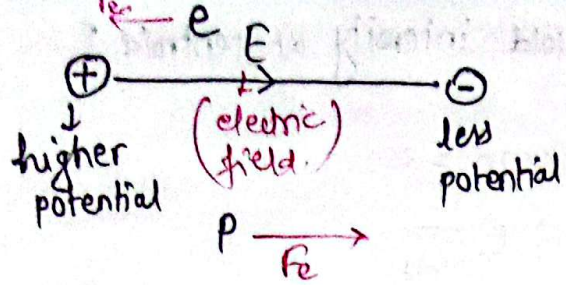
Q. 

Find the electric field intensity at vertex C?

$E' = 2E\cos\theta/2$

$= 2E\cos 60/2$

$= \sqrt{3}E = \frac{\sqrt{3}KQ}{l^2}$

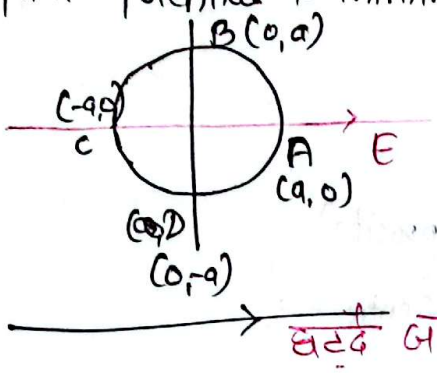


→ In case of +ve charge, direction of force is along the direction of field.

→ In case of -ve charge, direction of force is antiparallel to the direction of field.

→ Electron moves from lower V to higher V.

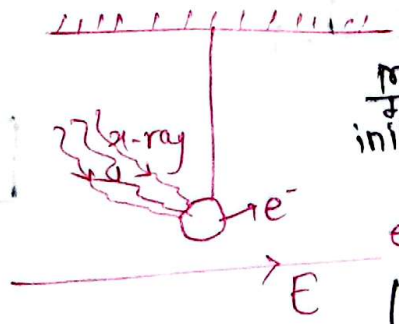
Q. In which point potential is minimum?



ઘટ્ટે જાન્હે. So, E is minimum at (A)

Q. A metal ball is suspended in the region of uniform electric field by the help of an insulated string. If X-ray beam falls on the ball then the ball will deflect –

(a) along the direction of field.
(b) opposite to the direction of field
(c) doesnot deflect
(d) Fly to infinity.



metal ball
↓
initially neutral
($n_e = n_p$)
electron ejecte
↓
(ball +vely cha
metal ball
↓
Force along

Position of null point or neutral point

(Net field = 0) → equal & opposite field.

① In case of two equal like charge :→



→ Null point lies at the centre of line joining of these two charges

② In case of two unequal like charge



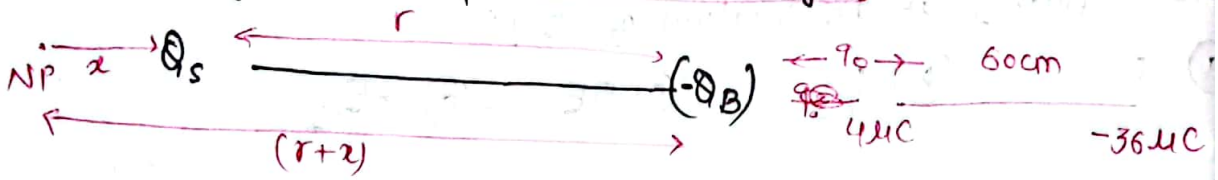
→ Null point lies in between them nearer from smaller charge

Position of null point,

$$x = \frac{r}{\sqrt{\frac{Q_B}{Q_s}} + 1} \quad \text{from } Q_s$$

→ r-x, from Q_B

③ In case of two unequal unlike charge



Position of N.P,

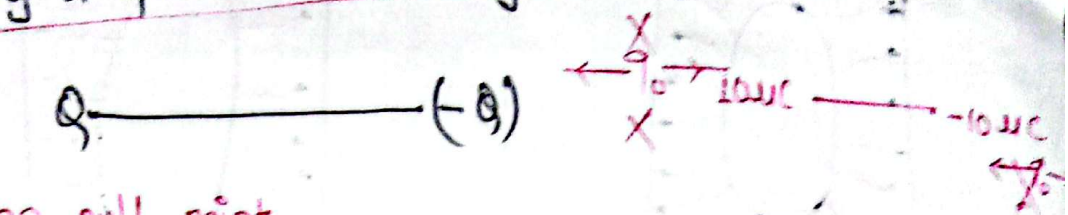
$$x = \frac{r}{\sqrt{\frac{Q_B}{Q_s}} - 1} \quad \text{from } Q_s$$

→ (r+x) from Q_B.

$$x = \frac{60}{\sqrt{\frac{36}{4}} - 1} = 30\text{ cm from } Q_s$$

∴ Q_B से → 60+30 = 90 cm

④ In case of 2 equal unlike charges

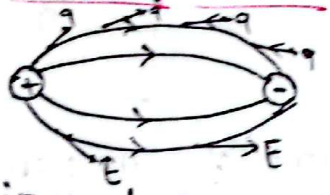


- no null point
- Neutral point doesnot exist.

Conclusion

- equal like → midpoint
- unequal like → in between nearer from smaller
- unequal unlike → outside nearer from smaller.
- equal unlike → doesnot exist.

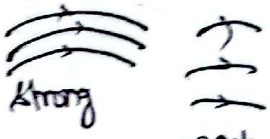
Electric lines of force



→ Two lines of force never intersect each other.

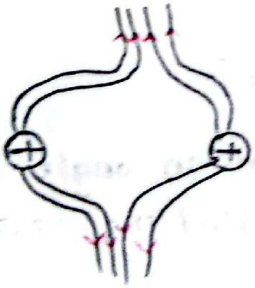
→ lines of force एकदम नजिक छ → strong field.

टाढा छ → weak field.



- In uniform field, lines of force are equidistanant & parallel.

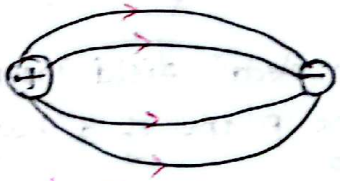
→



Lateral pressure

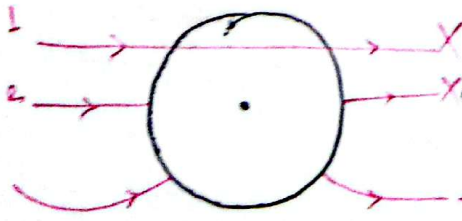
when two like charges are nearer to eachother.

(+,+) or (-,-)

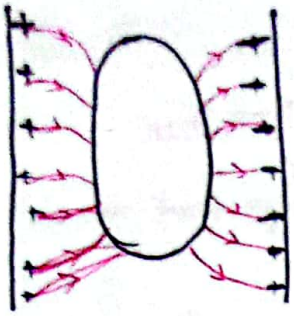


Longitudinal contration

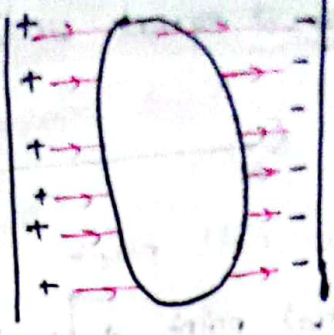
when two unlike charges are nearer to each other.



(goes from centre) normally act हुन्छ



(correct)
(surface संग normally act हुन पर्यो।)



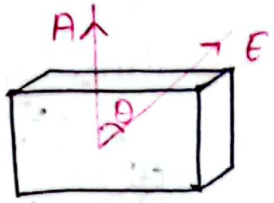
incorrect

Electric Flux

→ Total no. of lines of force passing normaly through the unit surface area.

$$\phi = \vec{E} \cdot \vec{A}$$

$$\boxed{\phi = EA\cos\theta}$$



'θ' → angle made by $\vec{E}$ with the normal of surface area.

If $\theta = 0°$,

$\phi = EA$ (maximum)

→ lines of force are passing perpendicular to the surface area or parallel to the normal of surface are

If $\theta = 90°$,

$\phi = 0$ (parallel to the surface area)

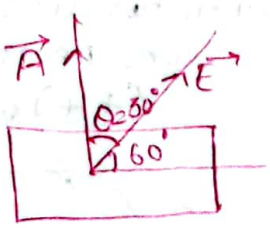
Q. The electric field intensity 50N/c is acting at an angle 60° with the plane of a body having area 10m². Find the electric flux?

(a) 500 Vm (b) 250 Vm (c) $250\sqrt{3}$ Vm (d) 0

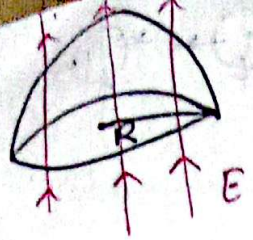
$\phi = EA\cos 30°$

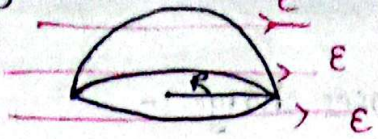
$= 50 \times 10 \times \sqrt{3}/2$

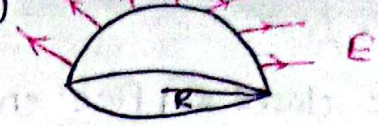
$= 250\sqrt{3}$ Vm or (weber)



Q. (1)







$\vec{E}$ र $\vec{A}$ बिचको angle 0° or 180° or 90° वाला लिने

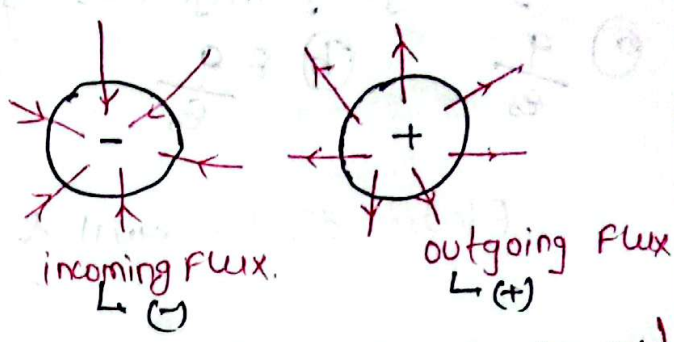
$$\phi_{net} = \phi_{cs} + \phi_{ps}$$

no enclosed charge; so, $\phi = 0$

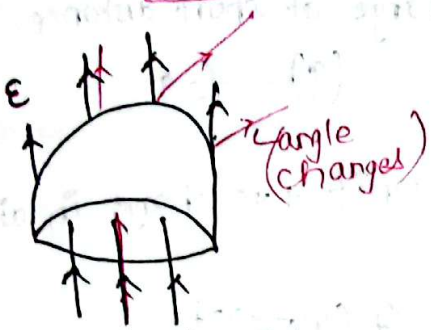
cs → hemispherical curve surface
ps → circular plane surface

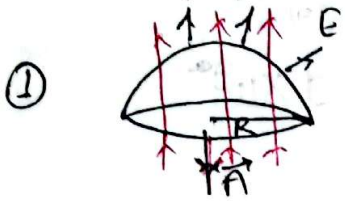
$$\therefore 0 = \phi_{cs} + \phi_{ps}$$

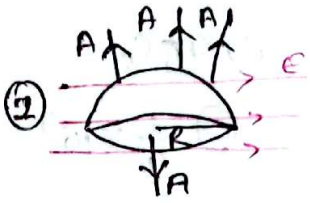
or, $\boxed{\phi_{cs} = -\phi_{ps}}$

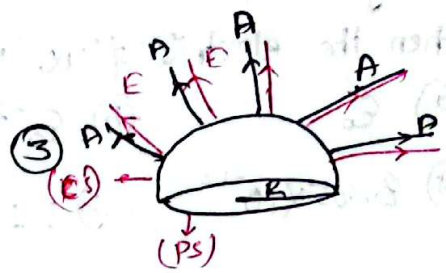


(surface area लिदा outward going wala लिने)









$$\phi_{ps} = EA\cos 180^\circ$$
$$= -EA = -E\pi R^2$$

((−) → incoming flux)

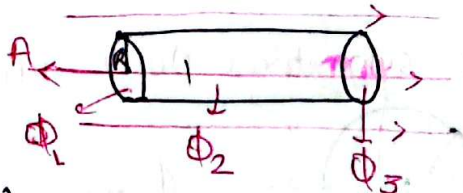
$$\therefore \phi_{cs} = -\phi_{ps}$$
$$= EA$$
$$\boxed{\phi_{cs} = E\pi R^2}$$

$$\phi_{ps} = EA\cos 90^\circ$$
$$= 0.$$
$$\therefore \boxed{\phi_{cs} = 0}$$

$$\phi_{cs} = EA\cos 0^\circ$$
$$= EA$$
$$= E2\pi R^2$$

$$\therefore \boxed{\phi_{ps} = -\phi_{cs} = -2\pi R^2 E}$$

Q.



$$\phi_1 = EA\cos 180^\circ$$
$$= -EA.$$
$$= -\pi R^2 E$$

$$\phi_2 = 0 \ (\theta = 90^\circ)$$

$$\phi_3 = EA\cos 0^\circ$$
$$\boxed{\phi_3 = \pi R^2 E}$$

$$\therefore \boxed{\phi_{net} = 0}$$

Guass's law



→ If the closed surface encloses charge :-

$$\phi = \frac{1}{\varepsilon_0}(\text{total charge enclosed})$$

(q)

$$\phi = \frac{1}{\varepsilon_0}(q) = \frac{q}{\varepsilon_0}$$

Q) If a cubical closed surface encloses eight dipoles, each dipole having charge of magnitude q, then the total electric flux is:-

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{8q}{\varepsilon_0}$ (c) $\frac{q}{8\varepsilon_0}$ (d) 0

Electric dipole → equal & opposite charge at short distance.

(q)——(-q)

Q. If a spherical closed surface encloses unit +ve charge in air then the electric flux is:-

(a) ε_0 (b) ε_0^{-1} (c) $4\pi\varepsilon_0$ (d) $(4\pi\varepsilon_0)^{-1}$

(a) 8.85×10^{-12} (b) 1.1×10^{11} (c) $\frac{1}{9}\times10^{9}$ (d) 9×10^{9}

$$\phi = \frac{1}{\varepsilon_0}(1C) = \frac{1}{\varepsilon_0} = \frac{1}{8.85\times10^{-12}} = 1.1\times10^{11}$$

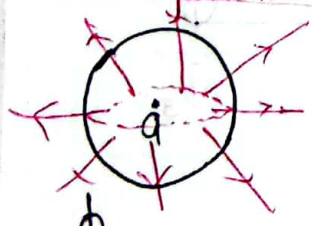
may be (+ve), (-ve) or (0)



$\phi = q/\varepsilon$ $\phi = q/\varepsilon$ $\phi = q/\varepsilon$

→ doesnot depend on shape & size.

* For symmetrical closed surface



$\phi_{sphere} = \frac{q}{\varepsilon_0}$

$\phi_{hemisphere} = ?$ So, $\phi_{hemisphere} = \frac{q}{2\varepsilon_0}$

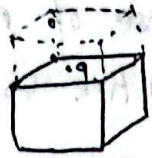


charge 'q' is enclosed at the centre of a cube, the flux contributed by each face?

$$\Phi_{cube} = q/\varepsilon_0 \quad \left.\right\} \text{ (6 faces in cube)}$$
$$\Phi_{face} = q/6\varepsilon_0 \quad \left.\right\}$$

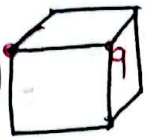
* charge 'q' is at the centre of anyone face of a cube,

$$\Phi_{2cube} = q/\varepsilon_0 \quad \text{(2 cube to midpoint)}$$



$$\Phi_{cube} = q/2\varepsilon_0 \quad \text{(each)}$$

* If charge 'q' is at anyone ~~en~~corner of a cube



$$\Phi_{8cube} = q/\varepsilon_0 \quad \text{(8 cube to make it in midpoint)}$$

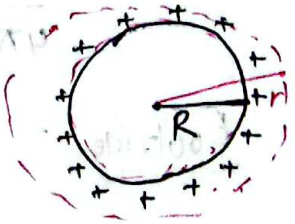
$$\Phi_{cube} = q/8\varepsilon_0 \quad \text{(each)}$$

Application of Guass law

① To find the electric field intensity for a spherical charged conductor.

~~$E_{surface}$~~ =

$E_{inside} = 0$ [no enclosed charge ($q=0$)]



$$E_{surface} = \frac{q}{4\pi\varepsilon_0 R^2} \quad A = 4\pi R^2$$

maximum

$\Phi = EA$ & $\Phi = q/\varepsilon_0$

$\therefore E = q/\varepsilon_0 A$.

$$E_{outside} = \frac{q}{4\pi\varepsilon_0 r^2} \quad (r > R)$$

(goes on decreasing)

Q. A spherical conductor of radius 20cm has electric field intensity 50N/c at its surface. What is the electric field intensity at 15cm?

(a) 32N/c (b) 50N/c (c) 72N/c (d) 0

R = 20cm (r=15) inside = 0.

Q. What is electric field intensity at 5cm outside from surface

(a) 32N/C (b) 50N/C (c) 36 N/C (d) 0

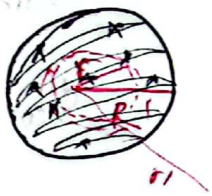
$$\frac{E_R}{E_r} = \frac{\frac{Q}{4\pi\varepsilon_0 R^2}}{\frac{Q}{4\pi\varepsilon_0 r^2}} = \left(\frac{r}{R}\right)^2$$

$r = 5 + 20 = 25cm$

$$\frac{50}{E_r} = \left(\frac{25}{20}\right)^2 \quad \therefore E_r = 32N/C.$$

(2) Electric field intensity for spherical charged solid non conductor

In case of non-conductor, charge is distributed in entire volume;



- $E_{inside} = \frac{q'}{4\pi\varepsilon_0 r^2}$ $(q > q')$ $(r < R)$

whole volume को charge.

small 'r' radius को Gaussian surface भित्र को charge.

$$= \frac{q\,r}{4\pi\varepsilon_0 R^3}$$

$\frac{4}{3}\pi R^3 \longrightarrow q$

$\frac{4}{3}\pi r^3 \longrightarrow \frac{q}{\frac{4\pi R^3}{3}} \times \frac{4}{3}\pi r^3$

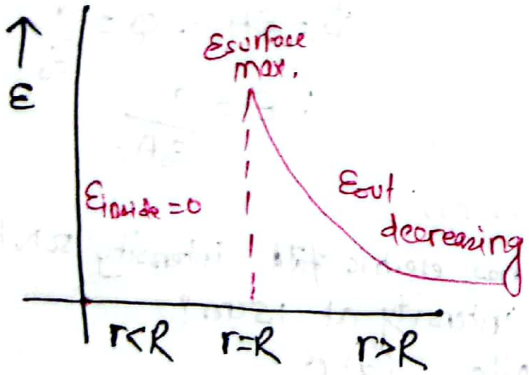
$$\boxed{q' = q\left(\frac{r}{R}\right)^3}$$

$\boxed{E_{inside} \propto r}$

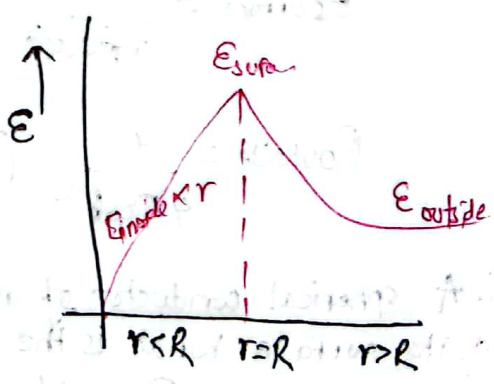
$\boxed{E_{centre} = 0}$ $(\because r = 0)$

$$E_{surface} = \frac{q}{4\pi\varepsilon_0 R^2}$$

$$E_{outside} = \frac{q}{4\pi\varepsilon_0 r^2} \quad (\because r' > R)$$



Conductor



Non-conductor

- Magnetic field intensity for → Hollow cylinder
- Electric field intensity → spherical charged conductor
- Gravitational field intensity → Hollow sphere

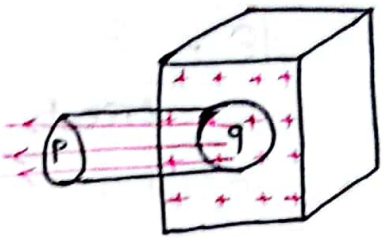
} inside = 0, surface = max., outside → gas on earth

- Magnetic field intensity → solid cylinder rod
- Electric " " → Solid non-conducting sphere.
- Gravitational " " → Solid sphere

} centre = 0, inside = (E ∝ r), surface → max., outside → gas or liquid

③ Electric field intensity for uniformly charged plane conductor

$$\phi = EA, \quad \phi = \frac{q}{\varepsilon_0}$$



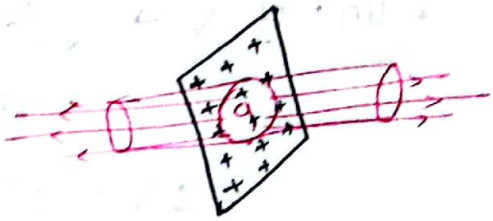
$$\therefore EA = \frac{q}{\varepsilon_0}$$

$$E = \frac{q}{\varepsilon_0 A} = \frac{\sigma}{\varepsilon_0} \quad \left(\frac{q}{A} = \sigma\right)$$

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

④ Electric field intensity for uniformly charged thin sheet or plane non-conductor

$$\phi = EA + EA = 2EA$$



$$\phi = \frac{q}{\varepsilon_0}$$

$$2EA = \frac{q}{\varepsilon_0}$$

$$\boxed{E = \frac{q}{2\varepsilon_0 A} = \frac{\sigma}{2\varepsilon_0}}$$

$$\therefore \boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

⑤ Electric field intensity due to the uniformly charged linear rod



$\Phi = \oint E A$

$= E \cdot 2\pi R l$

$\Phi = \frac{q}{\epsilon_0}$

$E \cdot 2\pi R l = \frac{q}{\epsilon_0}$

$\frac{q}{l} = \lambda$ Linear charge density

$E = \frac{q}{2\pi\epsilon_0 R l}$

$\therefore \boxed{E = \frac{\lambda}{2\pi\epsilon_0 R}}$

Electric Potential

q_0

$V_A = \frac{W_{\infty A}}{q_0}$

$\boxed{V_A = \frac{q}{4\pi\epsilon_0 r} = \frac{Kq}{r}}$

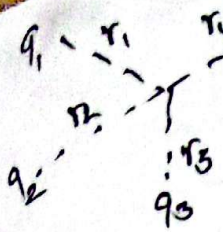
* unit of V → J/C or volt (SI)

stat volt or esu volt (CGS)

$\therefore 1\,V = 1\,J/C = \frac{10^7 \text{ erg}}{300 \times 10^9 \text{ stat coul.}} = \frac{1}{300}$ stat volt.

$\therefore \boxed{1 \text{ Volt} = \frac{1}{300} \text{ stat volt}}$

→ It is scalar quantity.

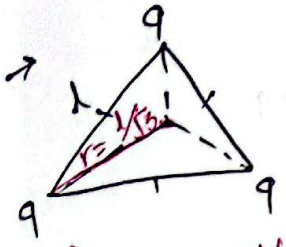


$$V = \frac{Kq_1}{r_1} + \frac{Kq_2}{r_2} + \frac{Kq_3}{r_3} + \dots$$

$$V = V_1 + V_2 + V_3 + \dots$$

$$K = \frac{1}{4\pi\varepsilon_0}$$

(Solve algebraically)



$E_{centre} = 0$.

$V_{centre} = \frac{3V}{} = \frac{3\sqrt{3}KQ}{l}$.

$V = \frac{Kq}{l/\sqrt{3}}$

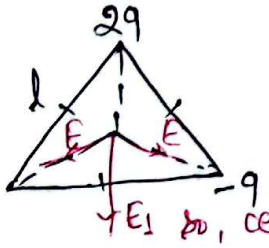
Q. Which is correct at its centroid?

(a) $E=0$ & $V=0$

(b) $E \neq 0$ & $V \neq 0$

(c) $E \neq 0$, $V=0$

(d) $E=0$ & $V \neq 0$



Q. Which is correct at its centroid?

$V_{centroid} = \frac{-Kq}{l/\sqrt{3}} + \frac{Kq}{l/\sqrt{3}} + \frac{Kq}{l/\sqrt{3}} = 0$

(a) $E=0$ & $V \neq 0$

(b) $E \neq 0$, $V \neq 0$

(c) $E=0$, $V=0$

(d) $E \neq 0$, $V=0$

Q. Which of the following is correct?

(a) If $E=0$, then V must be 0.

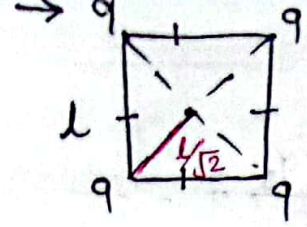
(b) If $E \neq 0$, then V can't be 0.

(c) If $V=0$, then E must be 0.

(d) If $V \neq 0$, then E can't be 0.

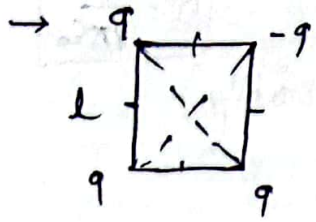
(e) All of above.

(f) None of above



$E_{centre} = 0$

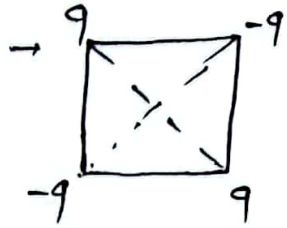
$V_{centre} = \frac{KQ}{l/\sqrt{2}} \times 4 = \frac{4\sqrt{2}\,Kq}{l}$.



$E_{centre} \neq 0$

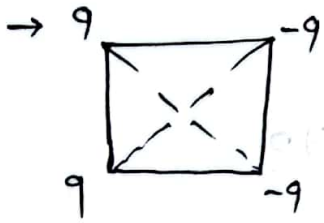
$V_{centre} = 2V$ $\quad (q+q+q-q) = 2q$.

$= 2\,\frac{KQ}{l/\sqrt{2}} = \frac{2\sqrt{2}\,KQ}{l}$.



$E_{centre} = 0$

$V_{centre} = 0$ $\quad (q + -q) = 0$.



$E_{centre} \neq 0$

$V_{centre} = 0$ $\quad ((q-q) = 0)$

Q. Identical charges 'q' are placed at all corners of a cube of side 'l'. What is the net potential at its centre?

→

$V = \frac{KQ}{\sqrt{3}l/2}$ (8 corner in cube)



$V_{net} = 8V$

$= 8\,\frac{Kq}{\sqrt{3}l/2}$

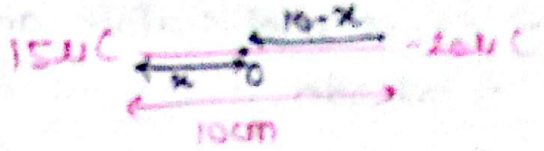
$= \frac{16\,Kq}{\sqrt{3}l} = \frac{16q}{4\pi\varepsilon_0\sqrt{3}l} = \frac{4q}{\sqrt{3}\pi\varepsilon_0 l}$

In equilateral Δ of side 'l'
vertex to centre = $l/\sqrt{3}$
In square of side 'l'
vertex to centre = $l/\sqrt{2}$
In cube of side 'l'
corner to cube = $\sqrt{3}l/2$

CamScanner

Q. Any two charges 15μC & -20μC are at separation of 10cm apart what distance in between them from 15μC charge the potential is zero?

→



$$V_{net} = \frac{K \times 15 \times 10^{-6}}{x} - \frac{K \times 20 \times 10^{-6}}{10-x}$$

$$\therefore \frac{15}{x} = \frac{20}{10-x}$$

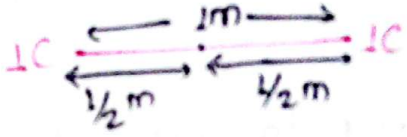
a. $150 - 15x = 20x$

$150 = 35x$

or, $x = 4.28\,cm$ from 15μC

Q. Two unit positive charge are at unit separation. Find net potential at their mid point?

→



$$V_{net} = \frac{K \times 1}{1/2} + \frac{K \times 1}{1/2}$$

$$= 4K = 4 \times 9 \times 10^9$$

$$= 36 \times 10^9 V$$

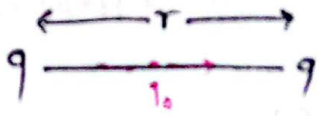
→



$E \neq 0$

$V = 0$.

→

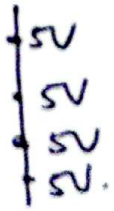


$E = 0$

$V \neq 0$

Equipotential surface

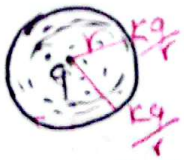
- Locus of the point having constant potential.



For point charge,

↓

equipotential surface is spherical in shape.



→ Infinite in number.

→ Two equipotential surface of an isolated charge, never intersect each other.

→ No work is done to move charge from one point in equipotential surface.

→ Equipotential surface and electric field intensity are perpendicular to each other.

* for Linear charge



- equipotential surface is cylindrical.
- infinite in number.
- Two equipotential surface never intersect each other.
- W = 0, Lines of force → radially. (perpendicular).

- For infinite source charge, For point or Linear
  └ equipotential surface is plane.

→ Equipotential surface for a point homogenous charge → spherical.

→ If the point charge or linear charge is at infinite large distance → eq. surface is plane.

Potential difference

Q. V_A (A) = 15V, V_B (B) = 10V

$$\Delta V = V_A - V_B = \frac{W_{BA}}{q_0}$$

$$\therefore \boxed{\Delta V = \frac{W_{BA}}{q_0}}$$

$$\boxed{W_{BA} = q_0 \Delta V}$$

$$\boxed{W_{BA} = q_0 (V_A - V_B)}$$

Q. 20eV energy is supplied to move the charge 0.2μC from one point to another. Find the potential difference between these two points?

→ $W = 20eV$

$= 20 \times 1.6 \times 10^{-19} J$

$q = 0.2 \times 10^{-6} C.$

$\Delta V = \frac{W}{q} = \frac{20 \times 1.6 \times 10^{-19}}{0.2 \times 10^{-6}}$

$= 160 \times 10^{-13} VAm$

Q. An extra electron from infinity is added to a soap bubble having 40 electron charge. What is the work done? (has radius r)

(a) $\frac{40e}{4\pi\varepsilon_0 r}$ (b) $\frac{e}{4\pi\varepsilon_0 r}$ (c) $\frac{40e^2}{4\pi\varepsilon_0 r}$ (d) 0

(r) $q = 40e$ ---------- e

$V_A = \frac{40e}{4\pi\varepsilon_0 r}$ $V_\infty = 0$

$W_{\infty A} = e(V_A - V_\infty)$

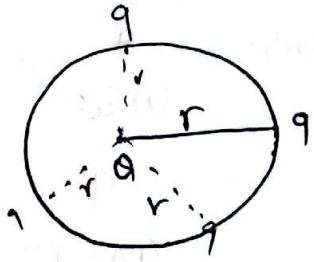
$= e\left(\frac{40e}{4\pi\varepsilon_0 r} - 0\right)$

$= \frac{40e^2}{4\pi\varepsilon_0 r}$

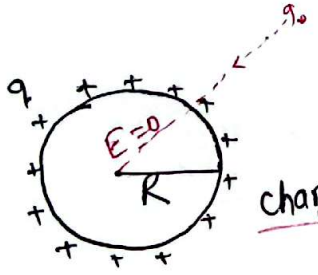
→ In equipotential surface, $V_A = V_B$

$\Delta V = 0.$

$\therefore \boxed{W_{BA} = 0}$



$\therefore W = 0$



charged conductor

- $V_{inside} = V_{surface} = \frac{q}{4\pi\varepsilon_0 R} = \frac{Kq}{R}$ $K = \left(\frac{1}{4\pi\varepsilon_0}\right)$

- $V_{outside} = \frac{q}{4\pi\varepsilon_0 r}$ $(r > R)$

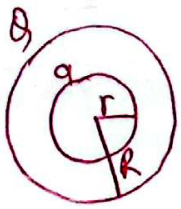
Q. Two spherical concentric conductors having radii R & r (R>r) carrying charge Q and q respectively. What is the pot. difference between their surfaces?

(a) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}-\frac{Q}{R}\right)$

(b) $\frac{Q}{4\pi\varepsilon_0 Q}\left(\frac{1}{R}-\frac{1}{r}\right)$

(c) $\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{R}\right)$

(d) 0



$V_{\text{सानो}} = \frac{q}{4\pi\varepsilon_0 r} + \frac{Q}{4\pi\varepsilon_0 R}$

$V_{\text{ठुलो}} = \frac{Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$

$\Delta V = V_{\text{सानो}} - V_{\text{ठुलो}}$

$= \frac{q}{4\pi\varepsilon_0 r} - \frac{q}{4\pi\varepsilon_0 R}$

$= \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{R}\right)$

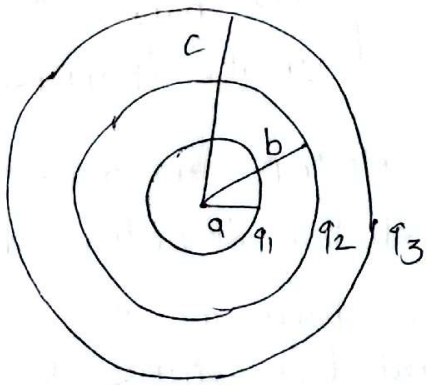
* In case of concentric conductors, the pot. difference between their surface doesnot depend upon charge present in outer sphere. (Q doesn't exist).

→

$V_a = \frac{Kq_1}{a} + \frac{Kq_2}{b} + \frac{Kq_3}{c}$

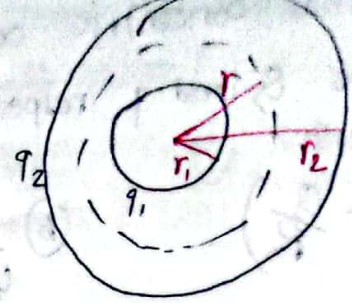
$V_b = \frac{Kq_1}{b} + \frac{Kq_2}{b} + \frac{Kq_3}{c}$

$V_c = \frac{Kq_1}{c} + \frac{Kq_2}{c} + \frac{Kq_3}{c}$

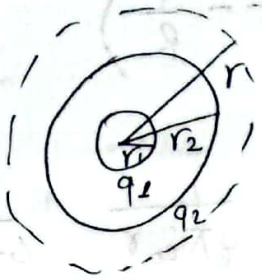


CamScanner

→ $V_r = \frac{Kq_1}{r} + \frac{Kq_2}{r_2}$



→ $V_r = \frac{Kq_1}{r} + \frac{Kq_2}{r}$



Electric potential energy

$q_1 \longleftarrow r \longrightarrow q_2$

$U = \frac{q_1 q_2}{4\pi\varepsilon_0 r}$ +ve ↑es.

$q_1 \longleftarrow r \longrightarrow -q_2$

$U = \frac{-q_1 q_2}{4\pi\varepsilon_0 r}$ −ve, ↓es

Q. When two charges are brought nearer to each other, then electric potential energy of system,
may be like or unlike.

(a) ↑es (b) ↓es (c) may ↑es or ↓es (d) None

(Like charge → ↑es.
unlike charges → ↓es)

— Two electrons are moved towards each other, U ↑es.

— An electron & proton are moved towards each other, then U ↓es.

Q. Third charge 'q' is placed at the centre of line joining of two equal like charges Q. What is 'q' so that P.E of that system is zero?

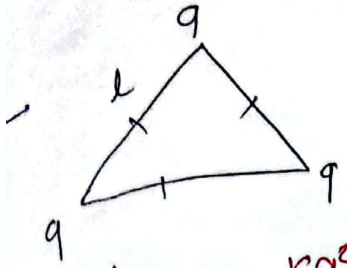
→ $U_{system} = \frac{KQq}{r/2} + \frac{KQq}{r/2} + \frac{KQ^2}{r}$

$Q \longleftarrow r/2 \longleftarrow q \longrightarrow r/2 \longrightarrow Q$

$0 = \frac{4KQq}{r} + \frac{KQ^2}{r}$ ∴ $\frac{4KQq}{r} = \frac{KQ^2}{r}$ ∴ $q = -Q/4$

→ If the P.E of system is zero → system of charges remains in eqm.

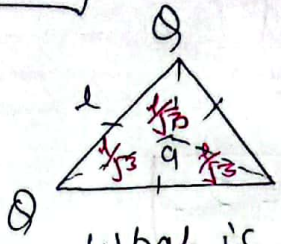
$\frac{n(n-1)}{2}$ (n = no. of charges)



$U_{system} = \frac{Kq^2}{l} + \frac{Kq^2}{l} + \frac{Kq^2}{l}$

$= \frac{3Kq^2}{l}$

Q.



$\frac{2 \times 4 \times 3}{2} = 6$.

What is 'q' so that P.E. of the system is zero?

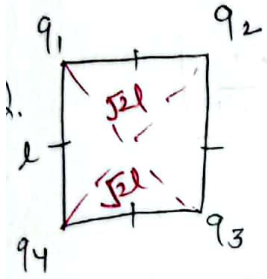
→ $U_{system} = \frac{3KQ^2}{l} + 3\frac{KQq}{l/\sqrt{3}}$

If, $U_{sy} = 0$.

$0 = \frac{3KQ^2}{l} + \frac{3KQq}{l/\sqrt{3}}$

$\frac{3KQ^2}{l} = -\frac{\sqrt{3} \times 3Kq}{l}$

$\therefore \boxed{q = -Q/\sqrt{3}}$



$U_{system} = \frac{Kq_1q_2}{l} + \frac{Kq_2q_3}{l} + \frac{Kq_3q_4}{l} + \frac{Kq_4q_1}{l} + \frac{Kq_1q_3}{\sqrt{2}l} + \frac{Kq_2q_4}{\sqrt{2}l}$

If $q_1 = q_2 = q_3 = q_4 = q$,

$\boxed{U_{system} = \frac{4KQq^2}{l} + \frac{2Kq^2}{\sqrt{2}l}}$

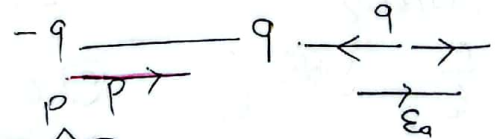
Electric Dipole

Electric field intensity due to a dipole

① In axial line

→ P || E_a

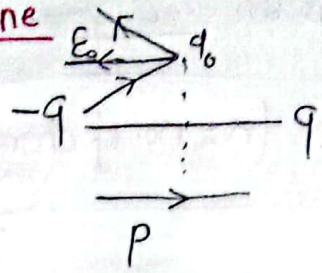
$E_a = \frac{2KP}{r^3}$



$B_a = \frac{\mu_0}{4\pi} \frac{2M}{r^3}$

(1) In perpendicular bisectoral line

→ Pantill E_b (180°)

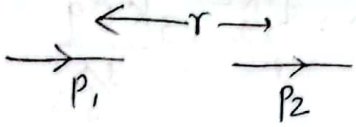


$$E_b = \frac{KP}{r^3}$$

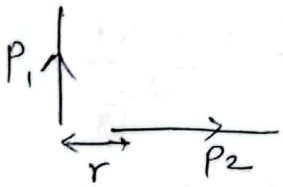
$$E_a : E_b = 2:1$$

$$E \propto \frac{1}{r^3}$$

Dipole-Dipole interaction



$$F_0 = \frac{K6 P_1 P_2}{r^4}$$



$$F_1 = \frac{K3 P_1 P_2}{r^4}$$

$$F \propto \frac{1}{r^4}$$

$$W = PE(\cos\theta_1 - \cos\theta_2)$$

$$\tau = PE\sin\theta$$

$m \longleftrightarrow q$

$M \longleftrightarrow P$

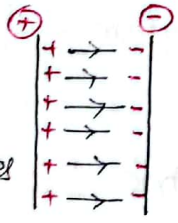
$\frac{\mu_0}{4\pi} \longleftrightarrow \frac{1}{4\pi\varepsilon_0} = k.$

$B \longleftrightarrow E$

Capacitor

→ Net charge in capacitor is zero.

→ Capacitor stores energy in space between two plates in the form of electrical potential energy.

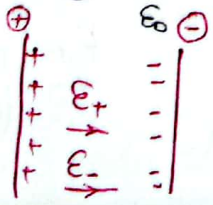


→ Capacitor is the source of instantenous energy.

Capacitor stores:-
- energy (1st prij)
- charge (2nd prij)
- both

Q. Electric field intensity in space between the plates?

(a) $\frac{\sigma}{2\varepsilon_0}$ (b) $\frac{\sigma}{\varepsilon_0}$ (c) 0 (d) $\frac{2\sigma}{\varepsilon_0}$



E_{net} inside the plates $= E_+ + E_-$

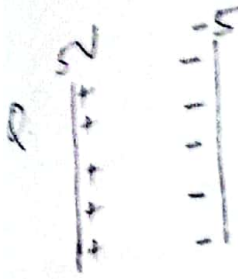
$= \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon} = \frac{\sigma}{\varepsilon_0}$

outside the plates;

$E_{net} = E_+ - E_-$

$= 0$





pd = 5 − (−5)

diff. = 10 V.



pd = 20V.

diff.

- $\boxed{Q \propto V}$

$Q = CV$

$\boxed{C = Q/V}$

* unit of C (capacitance) → $\frac{coul}{volt}$ = farad (SI)

- stat farad (CGS)

1 Farad = $1\ C/V$

1 stat farad = $\frac{1 \text{ stat volt}}{300} = \frac{3 \times 10^9 \text{ stat coul}}{1/300 \text{ stat V}}$

→ C doesn't depend upon Q & V both.

Q $C = \frac{Q\uparrow}{V\uparrow}$ - factor constant ∴ $\boxed{1 \text{ Farad} = 9 \times 10^{11} \text{ stat farad.}}$

Types of capacitors

① Capacitance of an isolated spherical conductor:-



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

∴ $\boxed{C = 4\pi\varepsilon_0 R}$

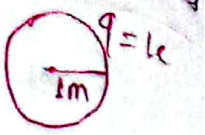
$\boxed{C_{medium} = 4\pi\varepsilon_0 K R}$

'C' depends upon → shape & size of conductor

→ Nature of surrounding medium

→ Area of the conductor

Q. If a conductor of radius is 1m. Find capacitance of its sphere 1C charge?



→

$$C = 4\pi\varepsilon_0 R$$

$$= 4\pi\varepsilon_0$$

$$= \frac{1}{9}\times 10^{-9} = \frac{10}{9}\times 10^{-10}$$

$$= 1.1\times 10^{-10} \text{ Farad.}$$

Q. 64 identical drops each having capacitance 2 μf are combined to form a single bigger drop. find the capacitance of bigger.

(a) 2 μf (b) 4 μf (c) 8 μf (d) 1 μf



$\longrightarrow$ (R) Q

$Q = nq$

$Q/q = n.$

$$n\,\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$\frac{R}{r} = n^{1/3}$$

$$\frac{C_{bigger}}{C_{smaller}} = \frac{R}{r} = n^{1/3}$$

$(V = Q/C)$

$$\frac{V_{bigger}}{V_{smaller}} = \frac{Q}{q}\cdot\frac{C_{smaller}}{C_{bigger}} = n\cdot n^{-1/3} = n^{2/3}$$

$$\frac{E_{bigger}}{E_{smaller}} = \frac{Q}{q}\left(\frac{r}{R}\right)^2 = n\cdot\left(\frac{1}{n}\right)^{2/3} = n^{1/3} \qquad \left(E = \frac{Q}{4\pi\varepsilon_0 r^2}\right)$$

Ele. field intensity

$$\frac{\sigma_{bigger}}{\sigma_{smaller}} = \frac{Q}{q}\left(\frac{r}{R}\right)^2 = n^{1/3}. \qquad \sigma = \frac{Q}{4\pi R^2}$$

$$\frac{U_{bigger}}{U_{smaller}} = \frac{Q}{q}\cdot\frac{V_B}{V_b} = n\cdot n^{2/3} = n^{5/3}$$

① $\frac{Q}{q} = n$ ② $\frac{C_B}{C_S} = n^{1/3}$ ③ $\frac{V_B}{V_S} = n^{2/3}$

④ $\frac{E_B}{E_S} = n^{1/3}$ ⑤ $\frac{U_B}{U_S} = n^{5/3}$ ⑥ $R/r = n^{1/3}$.

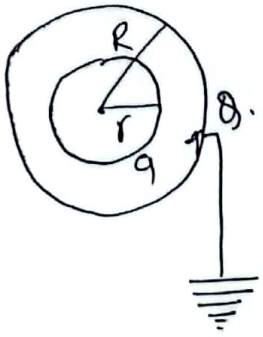
- $C_S = 2\mu F$, $n = 64$.

$C_B = (64)^{1/3} \times C_S$

$= 8\mu F$.

1) Capacitance of two concentric spherical conductors

outer space is earthing



$$V = \Delta V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{R}\right)$$

$$C = \frac{q}{V} = \frac{4\pi\varepsilon_0 Rr}{R-r}$$

$$\therefore \boxed{C = \frac{4\pi\varepsilon_0 Rr}{R-r}}$$

$$C = \frac{4\pi\varepsilon_0 r}{1 - \frac{r}{R}}$$

i) If $R >> r$, so, $r/R = 0$.

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

[single conductor is a capacitance. another ↓ equal -ve charge storing plate is at infinity]

→ If $R >> r$, inner sphere act as isolated ~~sphere~~ capacitor.

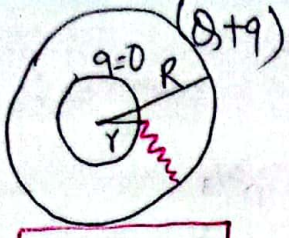
ii) If R & r are very large

$R \cdot R \approx R^2$

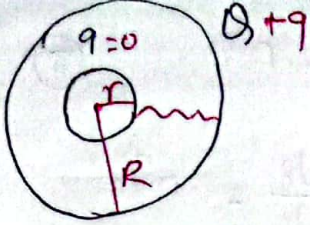
$R - r \approx d$

$$C = \frac{4\pi\varepsilon_0 R^2}{d} = \frac{\varepsilon_0 A}{d}$$

→ If R act are very large, then concentric spherical conductor act as parallel plate capacitor.

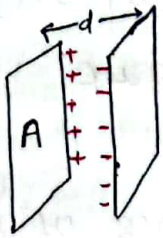


$C = 4\pi\varepsilon_0 R$



$C = 4\pi\varepsilon_0 R$

Parallel plate capacitor :-



$C_a = \frac{\varepsilon_0 A}{d}$ in air

$C_m = \frac{K\varepsilon_0 A}{d}$ in medium

K = dielectric constant

$\therefore C_m = K C_a$

$\frac{C_m}{C_a} = \frac{K}{1}$

$\therefore C_m : C_a = K : 1$ $\quad C \propto K$

$\therefore f_a : f_m = K : 1$ $\quad f \propto \frac{1}{K}$

Q. $C_a = 50\,\mu F$, $K = 5$

$C_m = ?$

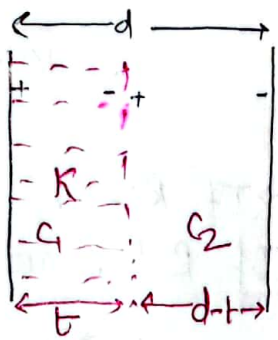
$\therefore C_m = K \times C_a$

$= 5 \times 50 = 250\,\mu F.$

Q. $f_a = 50N$, $K = 5$

$f_m = \frac{f_a}{K} = \frac{50}{5} = 10N.$

Capacitance in partial medium



$C_1 = \frac{K\varepsilon_0 A}{t} = \frac{\varepsilon_0 A}{t/K}$

$C_2 = \frac{\varepsilon_0 A}{d-t}$

in series

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

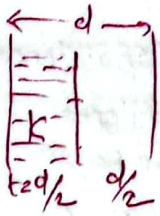
$= \frac{t/K}{\varepsilon_0 A} + \frac{d-t}{\varepsilon_0 A}$

$\therefore \frac{1}{C_{eq}} = \frac{d - t + t/K}{\varepsilon_0 A}$

$$\therefore \boxed{C_{eq} = \frac{\varepsilon_0 A}{d - t + t/K}}$$

Q. Capacitance of parallel plate capacitor in air is 10 μF. What will be the new capacitance if a medium of dielectric constant (K) = 2 is placed in between them upto half separation?

→ (a) 20 μF (b) 10 μF (c) 13.3 μF (d) 16.7 μF



$$C_a = \frac{\varepsilon_0 A}{d} = 10\,\mu F$$

$$C_{eq} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}} = \frac{\varepsilon_0 A}{\frac{d}{2}\left(1 + \frac{d}{2}\right)}$$

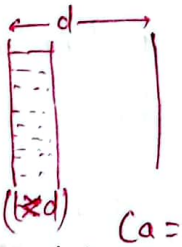
$K \to 2$

$$= \frac{4}{3}\frac{\varepsilon_0 A}{d} = \frac{4}{3} \times 10 = 13.3\,\mu F$$

Q. Capacitance of parallel plate capacitor in air is 100 μF. A medium of K = 5, and thickness (t) (t < d) is placed in between them. The new capacitance will be:— (d is the sepr between plates)

partially (t < d) is the sepr between plates

(a) 100 μF (initial में है) (b) 200 μF so, this option (c) 50 μF less है (d) 500 μF — Fully.



$C_a = 100\,\mu F$

→ If a metal plate of thickness 't' (t < d) is placed in between parallel plate capacitor, then:—

K = ∞ for conductor.

$$\boxed{C_{eq} = \frac{\varepsilon_0 A}{d - t}}$$

→ For metal plate, $\boxed{C_{eq} = \frac{\varepsilon_0 A}{d - t}}$

• if $t \approx 0$, negligable thickness,

$$\boxed{C_{eq} = \frac{\varepsilon A}{d - t} \approx \frac{\varepsilon_0 A}{d} \approx C.}$$

(ii) If $t = d/2$ (half separation)

$$C_{eq} = \frac{\varepsilon_0 A}{d - d/2} = \frac{2\varepsilon_0 A}{d} = 2C.$$

(iii) If $t = d$, (fully)

$$C_{eq} = \frac{\varepsilon_0 A}{d - d} = \infty$$

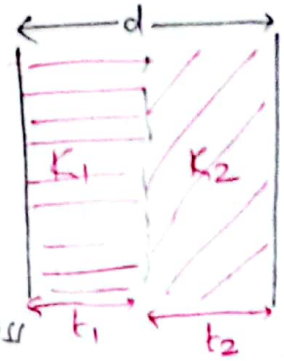
Q. Capacitance of parallel plate capacitor in air is C. A copper plate (negligible) capacitance in between them upto half separation. The new capacitance will be :-

→ (a) C (b) C/2 (c) 2C (d) ∞

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

$$C_{eq} = \frac{\varepsilon A}{d - d/2} = \frac{2\varepsilon_0 A}{d} = 2C.$$

$$\boxed{C_{eq} = \frac{\varepsilon_0 A}{\frac{t_1}{K_1} + \frac{t_2}{K_2}}}$$



Q. Two dielectrics K_1 & K_2 of equal thickness are placed completely in between parallel capacitor in series than equivalent dielectric constant is ?

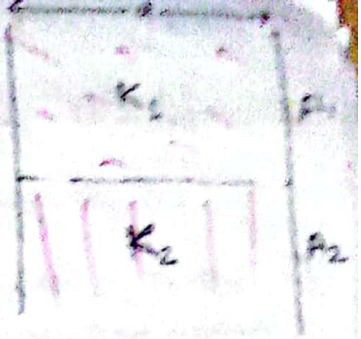
(a) $K_1 + K_2$ (b) $\frac{K_1 + K_2}{2}$ (c) $\frac{2K_1K_2}{K_1 + K_2}$ (d) $\frac{K_1K_2}{K_1 + K_2}$

$$C_{eq} = \frac{\varepsilon_0 A}{d/2K_1 + d/2K_2} = \frac{2K_1K_2}{K_1 + K_2}\frac{\varepsilon_0 A}{d}$$

$$C_{eq} = K_{eq} C_a$$

$$\therefore \boxed{K_{eq} = \frac{2K_1K_2}{K_1 + K_2}}$$

If Dividing area of plates



$$C_{eq} = C_1 + C_2 \quad \text{(in parallel)}$$

$$= \frac{K_1 \varepsilon_0 A_1}{d} + \frac{K_2 \varepsilon_0 A_2}{d}$$

$$= \frac{\varepsilon_0}{d}(K_1 A_1 + K_2 A_2)$$

. If $A_1 = A_2 = A/2$.

$$C_{eq} = \frac{\varepsilon_0}{d}\left(K_1 \frac{A}{2} + K_2 A/2\right)$$

$$= \frac{\varepsilon_0 A}{d\,2}(K_1 + K_2$$

$$\therefore \boxed{C_{eq} = \frac{\varepsilon_0 A}{d}\left(\frac{K_1 + K_2}{2}\right)}$$

→ $K_{eq} = \frac{2K_1K_2}{K_1+K_2}$ (HM) For series ✓

→ $K_{eq} = \frac{K_1+K_2}{2}$ (A.M) For parallel ✓

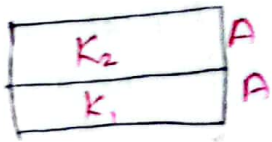
$$\boxed{C_{eq} = K_{eq} C_0 \quad \text{or} \quad \frac{\varepsilon_0 A}{d}}$$

In series (end to end)

- $K_{eq} = \frac{2K_1K_2}{K_1+K_2}$ (Diel. const).
- $K_{eq} = \frac{2K_1K_2}{K_1+K_2}$ (Thermal cond).
- $\sigma_{eq} = \frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (elect. condu)

thermal conductivity:
$K_{eq} = \frac{K_1+K_2}{2}$

eq. elect condu.
$\sigma_{eq} = \frac{\sigma_1+\sigma_2}{2}$



CamScanner

Energy stored in capacitor / Work

$$U = \frac{1}{2}CV^2 = \frac{1}{2}qV = \frac{q^2}{2C}.$$

Q. What is the workdone by an external source while charging a capacitor?

(a) CV^2 (b) $\frac{1}{2}CV^2$ (c) $2CV^2$ (d) zero

energy supplied = qV → $(\frac{1}{2}qV)(50\%)$ stored in capacitor

(rest 50%) energy is lost in the form of heat through resistor

or, workdone by an ext. source.



$$qV = CV.V$$
$$= CV^2.$$

$$\therefore \frac{\text{Energy supplied}}{\text{Energy stored}} = \frac{1}{1/2} = 2:1.$$

$$\therefore \frac{\text{Energy supplied}}{\text{Energy lost}} = 2:1$$

Q. A $4\mu F$ capacitor is charged upto potential 100V by connecting through a wire having $1K\Omega$ resistance. How much heat energy is produced?

→ $U = H = \frac{1}{2}CV^2$

$H = \frac{1}{2} \times 4 \times 100^2 \times 10^{-6}$ $(C = 4\mu F)$

$= 2 \times 10^{-2}$

$= 0.02\,J$

* Efficiency = 50%.

* energy density $(\bar{E}) = \frac{\text{Energy stored}}{\text{volume}}$

$$\bar{E} = \frac{\frac{1}{2}CV^2}{A \times d} = \frac{\frac{1}{2}\frac{\varepsilon_0 A}{d} \times V^2}{A.d} = \frac{1}{2}\frac{\varepsilon_0 V^2}{d^2}$$

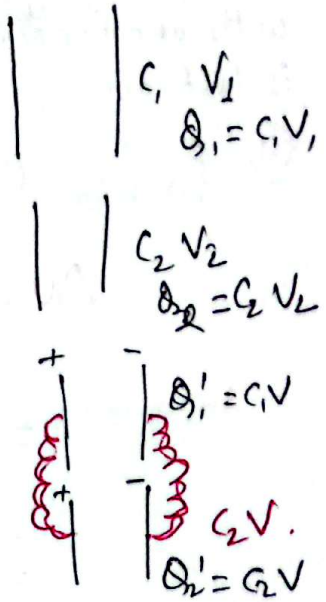
$$= \frac{1}{2}\varepsilon_0 E^2 \quad \left[E = \frac{V}{d}\right].$$

→ $\boxed{\bar{E} = \frac{1}{2}\varepsilon_0 E^2 \text{ in air}}$

→ $\boxed{\bar{E} = \frac{1}{2}K\varepsilon_0 E^2}$ in medium

K = die. constant

Connection of two capacitors by a wire



After connection = before connection

$$Q_1' + Q_2' = Q_1 + Q_2$$

$$C_1V + C_2V = C_1V_1 + C_2V_2$$

$$\boxed{V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}}$$

common pot.

$$\boxed{V_1 = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{\text{Total charge}}{\text{Total capacitance}}}$$

↳ like plate together.

If unlike plate connected by wire:-

$$V = \frac{Q_1 - Q_2}{C_1 + C_2} = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$$

Total energy before connection,

$$U_{initial} = \frac{1}{2}(C_1V_1^2 + C_2V_2^2)$$

Total energy after connection,

$$U_{final} = \frac{1}{2}(C_1+C_2)V^2$$

→ Loss of energy due to connection,

$$\Delta U = U_i - U_f$$

$$\boxed{\Delta U = \frac{C_1C_2}{2(C_1+C_2)}(V_1-V_2)^2}$$ → like plates.

$$\boxed{\Delta U = \frac{C_1C_2}{2(C_1+C_2)}(V_1+V_2)^2}$$ → unlike plates

Q. A charged capacitor stores energy E. If it is allowed to share its charge with another identical capacitor having half of its potential. How much energy is lost due to connection?

(a) E (b) E/4 (c) E/8 (d) E/2

$$\Delta U = \frac{C\cdot C}{2(C+C)}\left(V_0 - \frac{V}{2}\right)^2$$

$$= \frac{C^2}{2\times 2C}\left(\frac{V^2}{4}\right)$$

$$= \frac{1}{16}CV^2$$

$$= \frac{1}{8}\times\frac{1}{2}CV^2$$

$$= \frac{1}{8}\times E.$$

