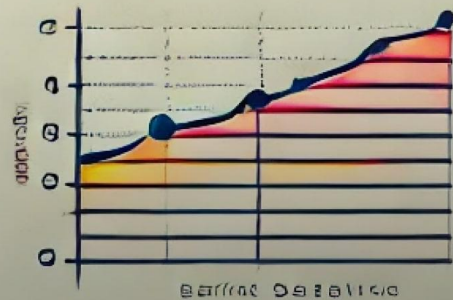
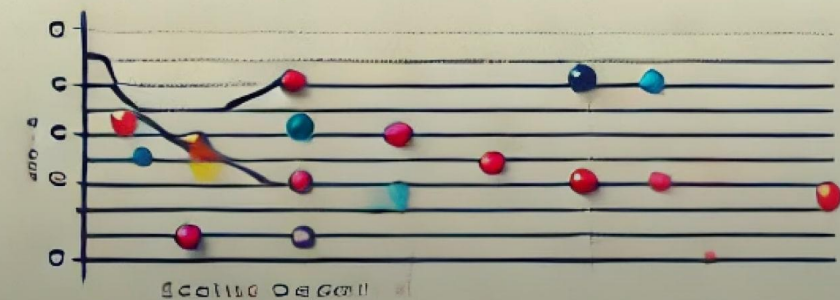




Electric Potential

point charge

Electric potential

Electric field

potential charge

stores charge

Electric Potential & Capacitance

Capacitance

Capacitance

12.0V

22.2

1V

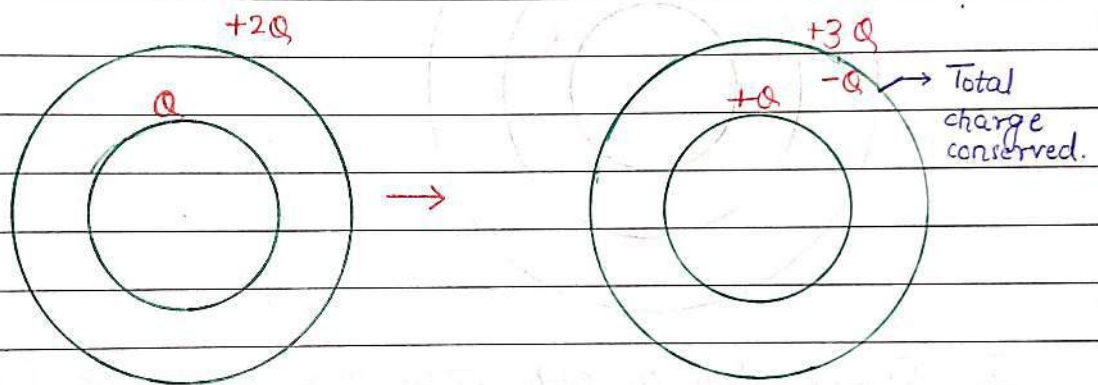
1V

ELECTROSTATIC POTENTIAL

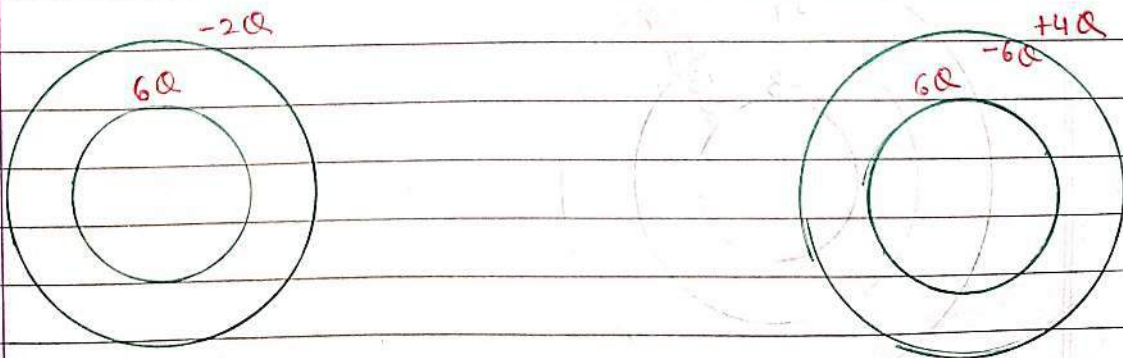
AND CAPACITANCE

Final charge distribution on concentric conducting spheres due to induction

Charge given to inner sphere is Q and $2Q$ on outer sphere



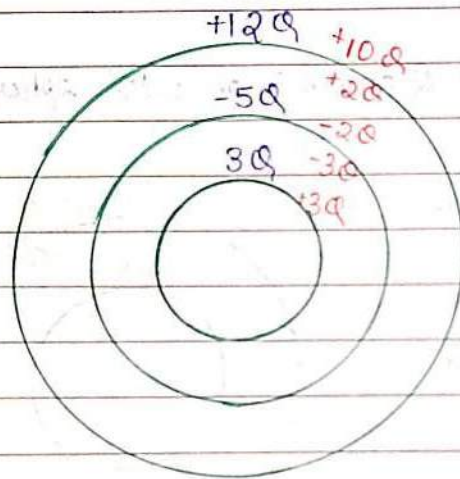
Q Charge given on the sphere shown in figure, then find charge after redistribution.



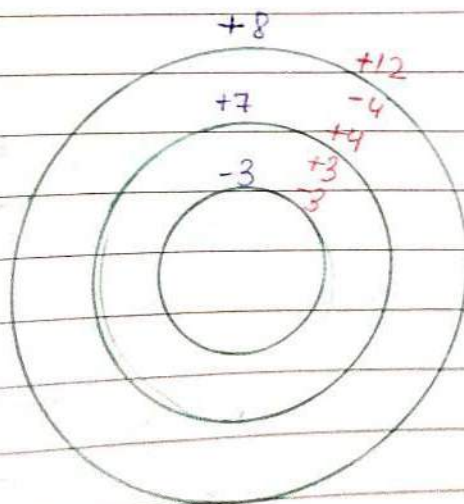
- 1) Total charge conserved.
- 2) Equal and opposite charge on facing surface
- 3) Charge on outer surface = Sum total of charge on each surface of the inner sphere

Q Charge given on sphere is shown in figure, then find final charge on each sphere

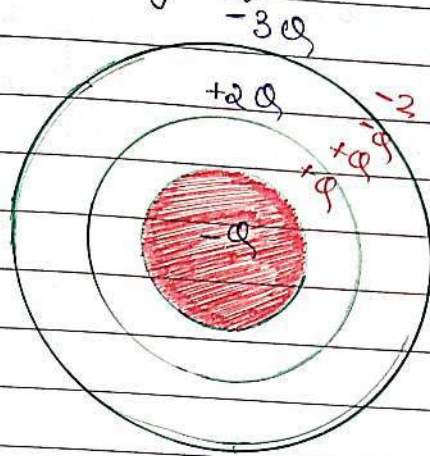
Ans



Q Charge given on each sphere is shown in fig. Find final charge after redistribution.

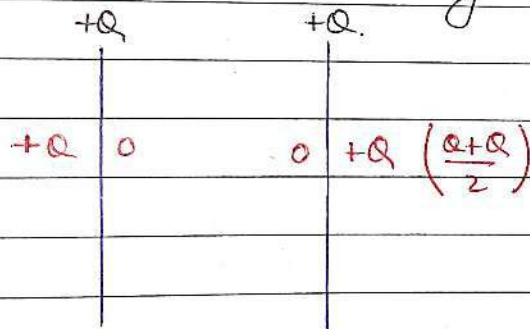


Q Find final charge after redistribution

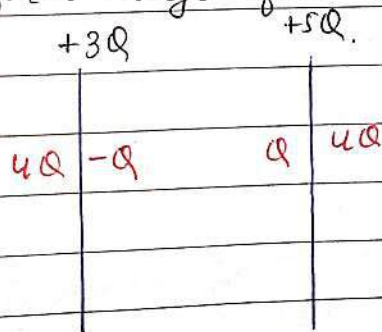


- 1) Charge on outer surface is half of total charge
- 2) Charge on facing area is equal and opposite
- 3) ^{Total} Charge conserved

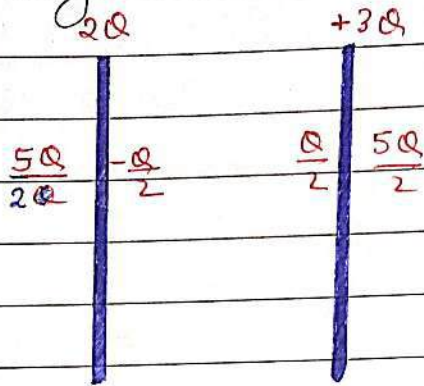
Q Charge distribution on conducting sheet.



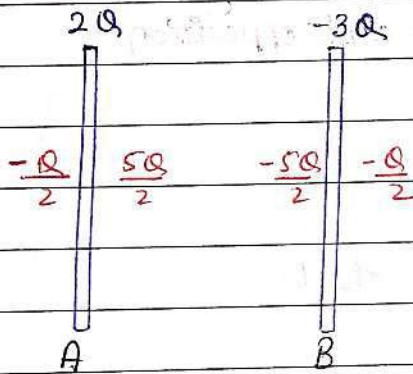
Q Find final charge after redistribution

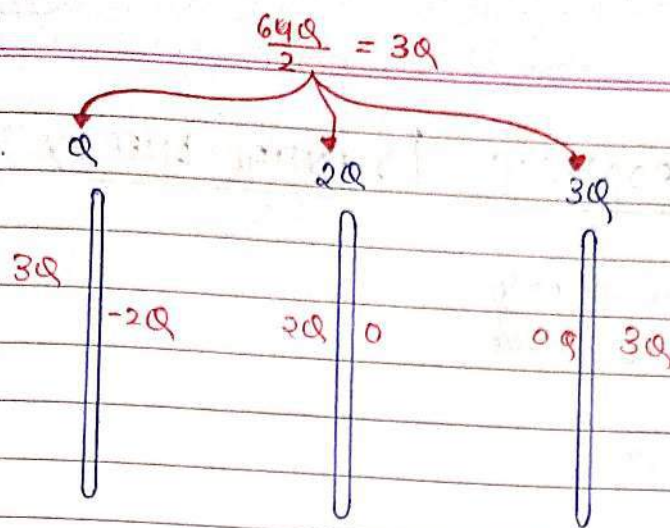


Q Find charge on both surface of each plate



Q

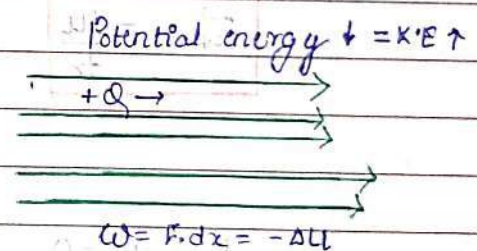
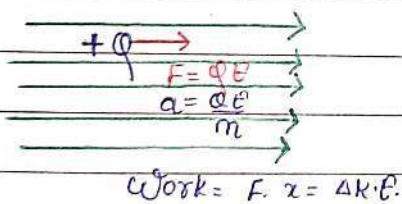




ELECTRIC POTENTIAL AND CAPACITANCE

Kisi bhi phenomenon ko explain karne ke do method hote hai.

- 1) Force method / Field method
- 2) Potential Energy method / Potential method



Work Energy theorem

Work done by all forces = $\Delta K \cdot E$
always valid

Mechanical Energy theorem

$$(K \cdot E + U)_i = (K \cdot E + U)_f$$

Not always valid

Valid when $W_{N.C.F} = 0$

Work by conservative force

Work done by conservative force = $-\Delta U$

Always valid.

Work by non conservative force = ΔU .

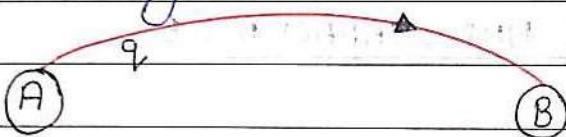
Not always valid.

Valid when $K \cdot E$ is constant and N.C.F is acting against conservative force.

ELECTROSTATIC POTENTIAL ENERGY

- Is not a physical quantity
- does not have unique value
- Not defined at all.
- Depends on reference

→ Change in electric potential Energy is defined.
 $-W_{\text{by electric force}} = \Delta U$



$$U_B - U_A = -W_{A \rightarrow B} \text{ (By electric force)}$$

$$U_B - U_A = - \int_{r_A}^{r_B} \vec{F} \cdot d\vec{r}$$

$$\vec{F}_{e.f.} = - \frac{dU}{dr}$$

→ If $U_A = 0$

$$U_B = - \int_{r_A}^{r_B} \vec{F} \cdot d\vec{r}$$

↑
Potential

Energy at B

- * Negative work done in bringing q charge from infinity to the point by electric field is called Potential energy stored in charge q .

$$U_p - U_\infty = -W_{\text{electric force}}$$

$$U_p = -W_{\text{electric force}}$$

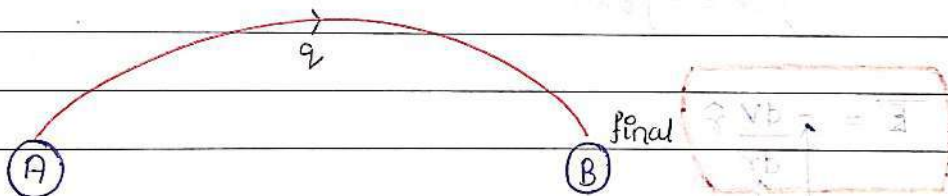
Infinity

$$r = \infty$$

$$U_\infty = 0$$

- * Work done ^{by electric force external agent} in bringing q charge from infinity to the point slowly without change in K.E. in electric field is called Potential energy.

ELECTRIC POTENTIAL DIFFERENCE



$$U_B - U_A = W_{\text{ext force}}$$

divide by q both side

$$\frac{U_B}{q} - \frac{U_A}{q} = \frac{W_{\text{ext force}}}{q}$$

Potential $\leftarrow V_B - V_A$ Work done per unit charge

change in potential.

$$U_B - U_A = -W_{\text{electric force}}$$

divide by q both side.

$$\frac{U_B}{q} - \frac{U_A}{q} = \frac{-W_{\text{electric}}}{q}$$

- positive
- * Work done in bringing unit charge from infinity to the point without change in k.E. is called electric potential.
 - * Negative work done by electric force in bringing unit positive charge from infinity to the point is called electric potential.

$$\Delta U = -W_{c.f} = -\int \vec{F} \cdot d\vec{r}$$

divide by q on both side

$$\Delta V = \frac{-W_{c.f}}{q} = -\int \vec{E} \cdot d\vec{r}$$

$$\Delta U = -W_{c.f}$$

$$\Delta V = -\int \vec{E} \cdot d\vec{r}$$

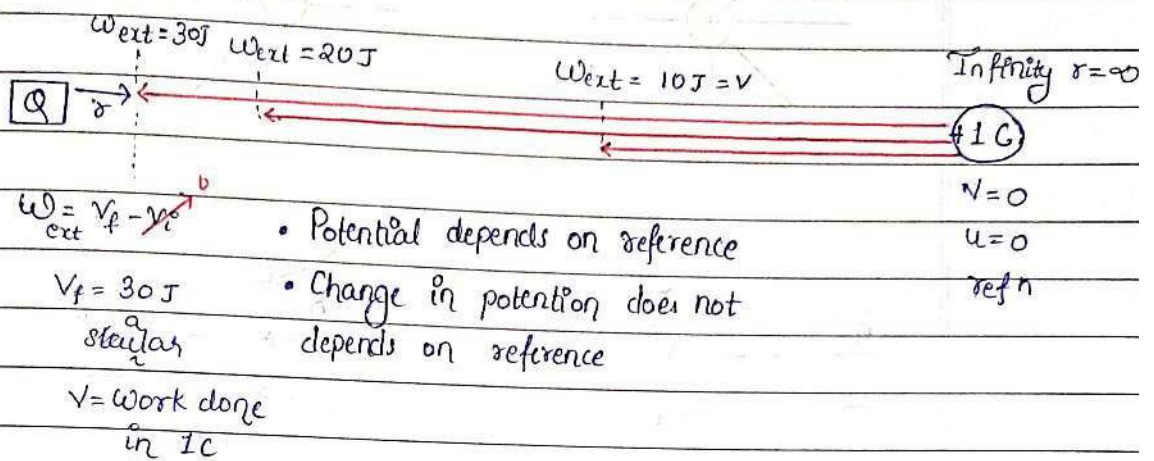
$$\int dV = -\int \vec{E} \cdot d\vec{r}$$

$$\vec{E} = -\frac{dV}{dr} \hat{r}$$

Potential gradient

because potential is decreasing along Electric field

CONTINUANCE OF ELECTRIC POTENTIAL



* Positive charge always moves from region high potential to low potential.

* Along electric field potential decreases.

* Perpendicular to electric field remains same

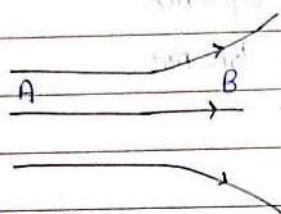
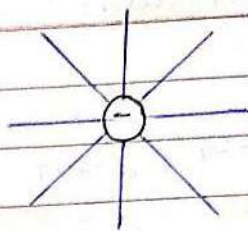
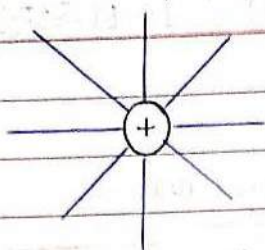
* +ve charge moves from high potential to lower potential by itself.

* -ve charge moves from low to high potential.

* Scalar quantity.

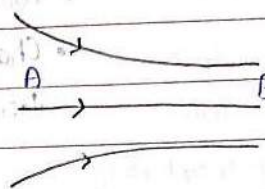
$$\vec{E} = -\frac{dV}{dr}$$

$$\vec{E} = -\left[\left(\frac{\partial V}{\partial x}\right)\hat{i} + \left(\frac{\partial V}{\partial y}\right)\hat{j} + \left(\frac{\partial V}{\partial z}\right)\hat{k}\right]$$



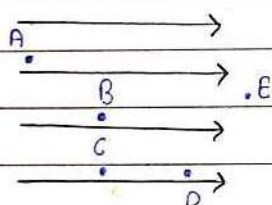
$$E_A > E_B$$

$$V_A > V_B$$



$$E_B > E_A$$

$$V_A > V_B$$



$$V_A > V_B = V_C > V_D > V_E$$

$$E = \text{constant}$$

Q A particle of mass m and positive charge q is released from point A. Its speed is found to be v when it passes through a point B. Which of the following two points is at higher potential? What is the potential difference between the points?

Ans

$$V_B < V_A$$

$$W = \Delta U = -q\Delta V = \frac{1}{2}mv^2 = \Delta U$$

$$q\Delta V = \frac{1}{2}mv^2 - 0$$

$$\Delta V = V_B - V_A = -\frac{mv^2}{2q}$$

Q A proton is accelerated from rest through a potential of 500 volts. Its final K.E. is.

- a) 50 eV ~~b) 500 eV~~
c) 1000 eV d) 2000 eV.

Ans $\Delta U = -q\Delta V = \Delta K.E$

$$\Delta K.E = K.E_f - K.E_i = e\Delta V$$

$$K.E_f = 500 \text{ eV.}$$

Q A particle A has charge q and particle B has charge $+4q$ with each of them having the same mass m . When allowed to fall from rest through the same electric potential difference the ratio of their speeds V_A/V_B will become.

- ~~a) 1:2~~ (b) 2:1
c) 1:4 d) 4:1

Ans $\frac{1}{2}mv^2 = -qE$
 $v \propto \sqrt{q}$

$$\frac{V_A}{V_B} = \sqrt{\frac{1}{4}} = \frac{V_A}{V_B} = 1:2$$

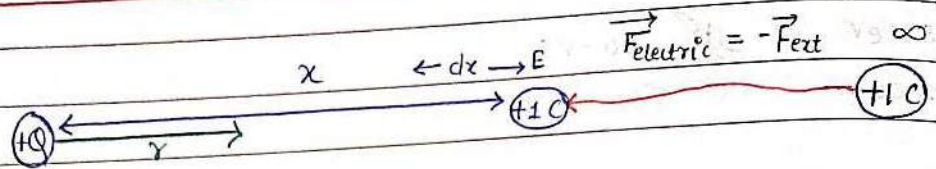
Q An alpha particle (charge = $+2e$) is accelerated from rest through a potential difference of 500 volts. Its final kinetic energy is.

- a) 50 eV (b) 500 eV
~~c) 1000 eV~~ d) 2000 eV

Ans $\frac{1}{2}mv^2 = q\Delta V$
 $\Rightarrow 2e \times 500 \text{ V}$

$$\Rightarrow 1000 \text{ eV Ans}$$

ELECTRIC POTENTIAL DUE TO POINT CHARGE



$$\Delta U = - \int \vec{E} \cdot d\vec{x}$$

$$\Delta V = - \int \frac{kQ}{x^2} \cdot dx \cos 180^\circ$$

here x is decreasing

$$\Delta V = - \int_{\infty}^r \frac{kQ}{x^2} dx$$

$$\Delta V = -kQ \int_{\infty}^r x^{-2} dx$$

$$\Delta V = -kQ \int_{\infty}^r \frac{x^{-1}}{-1} dx$$

$$\Delta V = +kQ \left[\frac{1}{x} \right]_{\infty}^r$$

$$\Delta V = kQ \left[\frac{1}{r} - \cancel{\frac{1}{\infty}} \right]$$

$$\Delta V = V_f - V_i = \frac{kQ}{r}$$

$$V_f = \frac{kQ}{r}$$

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

$+Q$

r

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

$-Q$

r

$$V = -\frac{kQ}{r}$$

Does not have direction

Q Here potential must be $\frac{kQ}{r}$ False

only true when potential at infinity is zero.

Q Two charges $-10C$ and $+10C$ are placed 10 cm apart. Potential at the centre of the line joining of the two charges is.

- ~~a) Zero~~ (b) $2V$
c) $3V$ (d) None of these.

but here answer may be non zero

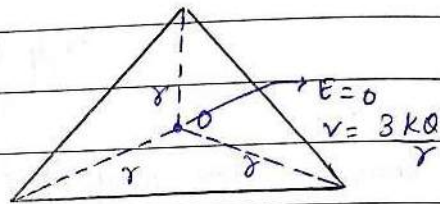
Doubt

Q The potential at a point 0.1 m from an isolated point charge is $+100\text{ volt}$. The nature of the point charge is.

- a) Positive (b) Negative
c) Zero ~~d) Either positive or zero or negative.~~

Q Three isolated equal charges are placed at the three corners of an equilateral triangle as shown in figure. The statement which is true for net electric potential V and net electric field intensity E at the centre of the triangle is

- i) $E=0, V=0$ b) $E \neq 0, V=0$
~~c) $V \neq 0, E=0$~~ d) $V \neq 0, E \neq 0$



- Q
- 1) Electric potential depends on reference point. True
 - 2) Not have a unique value of a point True
 - 3) Scalar physical quantity True
 - 4) Change in potential does not depends on reference True
 - 5) Unit $\rightarrow$ J/C or volt or Nm/C True
 - 6) Potential gradient is vector. True

Q The potential in a electric field $V = \frac{x^3}{3} + 4$ then find electric field at $(2, -4, 3)$

Ans $E = -\frac{dV}{dx}$

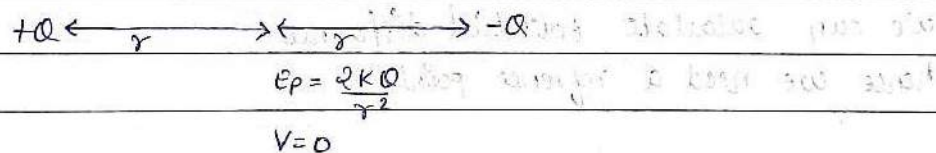
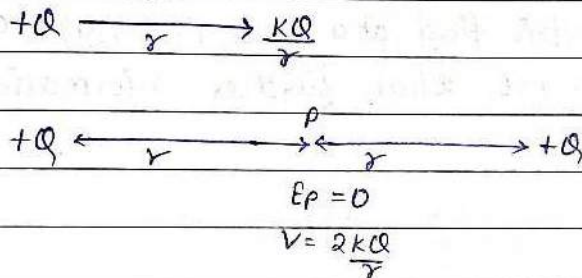
$$E = -\frac{3x^2}{3}$$

$$E = -4\hat{i} \text{ Ans}$$

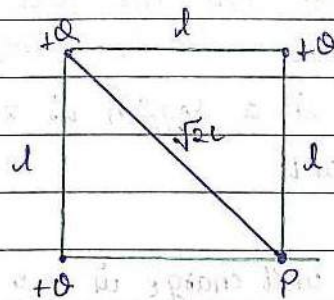
* TRUE OR FALSE

- 1) The electric field is zero at a point then V must be zero at that point. **False**
- 2) If electric field is constant then potential must be constant. **False**
- 3) If potential is constant then electric field must be zero. **True**
- 4) If potential is non zero then electric field must be non zero. **False**
- 5) Electric field is zero then potential may be zero. **True**
- 6) Potential is constant then electric field may be zero. **False**

Q Electric potential due to a point charge and combination of point charge.

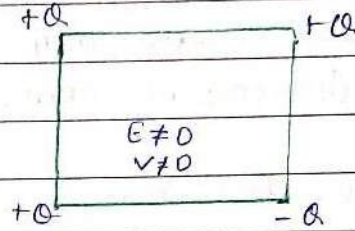
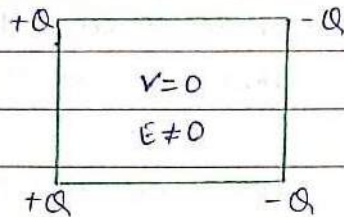
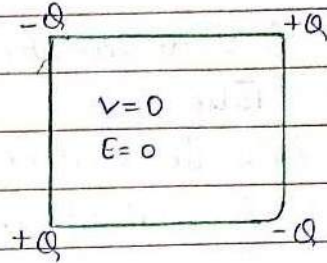
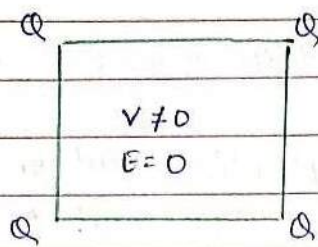


Q Find potential at P.



$$V_P = \frac{2kQ}{l} + \frac{kQ}{\sqrt{2}l} = \frac{2kQ}{l} + \frac{kQ}{\sqrt{2}l}$$

Q Find electric field and potential at centre.



★ Q If you know the electric field at a given point, you can calculate V at that point? If not, what further information do you need?

Ans No, we cannot

$$dV = -\vec{E} \cdot d\vec{r}$$

We can calculate potential difference
hence we need a reference point.

★ Q How can you ensure that the electric potential in a given region of space will be a constant value?

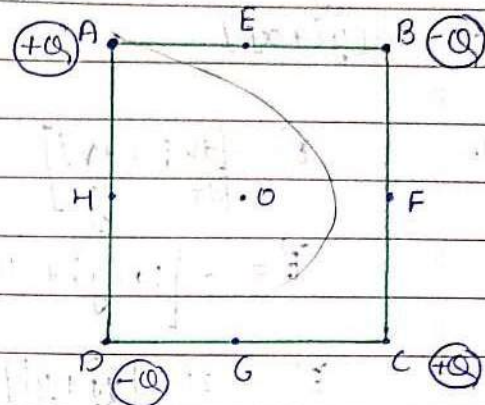
Ans If electric field in a region is zero then electric potential is constant

If work done per unit charge is zero then electric potential is constant.

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

Q Four Four charges $Q, -Q, Q, -Q$ are placed at the corners of a square as shown. The potential is zero at points.

- (a) E, F, G, H, O
 (b) E, O, G only
 (c) H, O, F only
 (d) O only.



Q Find electric potential at point.

	$+Q$	$+Q$	$+Q$	$+Q$	$+Q$
(0,0)	(1,0)	(2,0)	(4,0)	(8,0)	(16,0)

$$V = \frac{kQ}{1} + \frac{kQ}{2} + \frac{kQ}{4} + \frac{kQ}{8} + \frac{kQ}{16} \dots$$

$$V = kQ \left[1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} \dots \right]$$

$$V = kQ \frac{1}{1 - \frac{1}{2}}$$

$$V = 2kQ$$

Q The electric potential V at a point (x, y, z) in space is given by $V = 4x^2$ volt. Electric field at a point $(1, 0, 2)$ in V/m is

- (a) 8 along -ve x axis (b) 8 along +ve x axis
 (c) 16 along -ve x axis (d) 16 along +ve x axis.

Ans $E = -\frac{dV}{dx} = -8x$

$E_{at 1m} = -8 \hat{i}$

Q. Determine the electric field strength vector if the potential of this field depends on x, y coordinates as $V = 10axy$

a) $10a[y\hat{i} + x\hat{j}]$

~~b) $-10a[y\hat{i} + x\hat{j}]$~~

c) $-a[y\hat{i} + x\hat{j}]$

d) $-10a[x\hat{i} + y\hat{j}]$

Ans

$$\vec{E} = -\left[\frac{dV}{dx}\hat{i} + \frac{dV}{dy}\hat{j}\right]$$

$$\vec{E} = -[10ay\hat{i} + 10ax\hat{j}]$$

$$\vec{E} = -10a[x\hat{j} + y\hat{i}]$$

$$\vec{E} = -10a[y\hat{i} + x\hat{j}]$$

Q. If potential $V = xy\hat{i} + yz\hat{j} + xz\hat{k}$
find electric field at $(1,1,1)$

Wrong question

Q. $V = 6x - 8xy - 8y + 6yz$
then find force on 2C at $(1,1,1)$

Solution $\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$

$$\vec{E} = -(6-8y)\hat{i} + (-8x-8+6z)\hat{j} + 6y\hat{k}$$

$$\vec{E} = -(6-8)\hat{i} + (-10)\hat{j} + 6\hat{k}$$

$$\vec{E} = 2\hat{i} + 10\hat{j} + 6\hat{k}$$

$$|\vec{E}| = \sqrt{4+100+36}$$

$$E = \sqrt{140}$$

$$F = qE = 2\sqrt{140} \text{ N} \quad \text{Ans}$$

* Q The electric field in a certain region is given by $E = 5\hat{i} - 3\hat{j}$ V/m. The potential difference $V_B - V_A$ between points A and B, having coordinates (4, 0, 3) m and (10, 3, 0) m respectively is.

- a) 21 kV ~~b) -21 kV~~
 c) 39 kV d) -39 kV

Ans

$$dV = -\int E \cdot dx$$

$$dV = -\int_4^{10} 5 \cdot dx$$

$$dV = -[5x]_4^{10} = -50 + 20 = -30$$

$$dV = -\int E \cdot dy$$

$$dV = -\int_0^3 3 \cdot dy$$

$$dV = +[3y]_0^3$$

$$= 9$$

$$V_{\text{net}} = -30 + 9 = -21 \text{ kV} \text{ Ans}$$

Q If work done in moving 2C charge from A to B is 24J then find potential at A if potential at B is 4 Volt.

Ans

$$W_{\text{ext}} = q\Delta V$$

$$\frac{W_{\text{ext}}}{q} = \Delta V = V_B - V_A$$

$$12 = V_B - V_A$$

$$V_B = 4$$

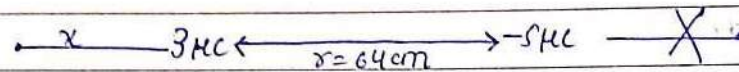
$$V_A = -8 \text{ Volt.}$$

Q A charge Q is placed at each corner of a cube of side a . The potential at the centre of the cube is.

- a) $\frac{8Q}{\pi\epsilon_0 a}$ b) $\frac{4Q}{4\pi\epsilon_0 a}$ ~~c) $\frac{4Q}{\sqrt{3}\pi\epsilon_0 a}$~~ d) $\frac{2Q}{\pi\epsilon_0 a}$

Q Two point charges $-5 \mu\text{C}$ and $+3 \mu\text{C}$ are placed 64 cm apart. At what point on the line joining the two charges is the electric potential zero. Assume the potential at infinity to be zero.

Ans



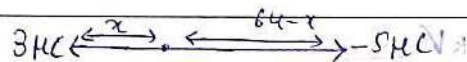
$$\frac{-5 \mu\text{C}}{64+x} + \frac{3 \mu\text{C}}{x} = 0$$

$$\frac{-5 \mu\text{C}}{64+x} = \frac{-3 \mu\text{C}}{x}$$

$$5x = 192 + 3x$$

$$192 = 2x$$

$$x = 96 \text{ cm}$$



$$\frac{3 \mu\text{C}}{x} + \frac{-5 \mu\text{C}}{64-x} = 0$$

$$\frac{3 \mu\text{C}}{x} = \frac{5 \mu\text{C}}{64-x}$$

$$192 - 3x = 5x$$

$$8x = 192 \quad x = 24 \text{ cm}$$

★ Q Two charges $+6 \mu\text{C}$ and $-4 \mu\text{C}$ are placed 15 cm apart as shown. At what distance from A to its right, the electrostatic potential is zero (distance in cm).

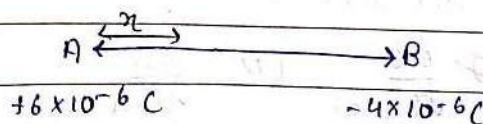
a) 4, 9, 60

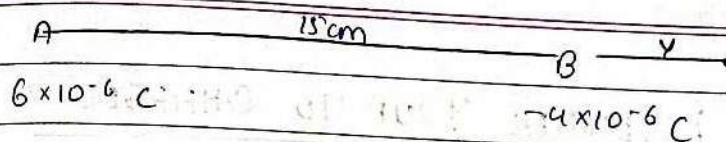
b) 9, 45, infinity

3) 20, 45, infinity

c) 9, 15, 45 cm

Ans





$$\frac{K6K}{15+y} = \frac{4K}{y}$$

$$6y = 60 + 4y$$

$$2y = 60$$

$$y = 30 \text{ cm} = 45 \text{ cm from A}$$

Q Three charged particles having charges q , $-2q$ and q are placed in a line at point $(-a, 0)$, $(0, 0)$ and $(a, 0)$ respectively. The expression for electric potential at $P(x, 0)$ for $x \gg a$ is.

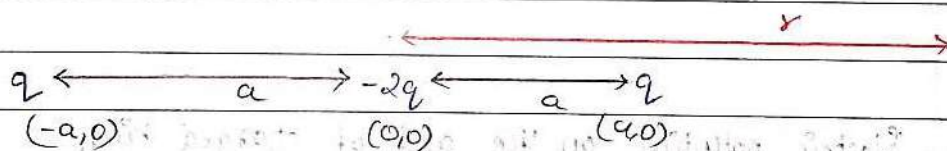
a) $\frac{1}{4\pi\epsilon_0} \frac{qa^2}{x^4}$

(2) $\frac{1}{4\pi\epsilon_0} \frac{2qa^2}{x^3}$

c) $\frac{1}{4\pi\epsilon_0} \frac{4qa^2}{x^2}$

4) $\frac{1}{4\pi\epsilon_0} \frac{8qa^2}{x}$

Ans



$$V = \frac{kq}{x+a} + \frac{kq}{x-a} - \frac{2qk}{x}$$

$$V = \frac{kq(x-a)x + kq(x+a)x - (x+a)(x-a)2}{x(x^2-a^2)}$$

$$V = \frac{kq(x^2 - xa + x^2 + xa - 2x^2 + 2a^2)}{x(x^2-a^2)}$$

$$V = \frac{kq(-2a^2 + 2a^2)}{x(x^2-a^2)} = \frac{kq(2a^2)}{x(x^2-a^2)}$$

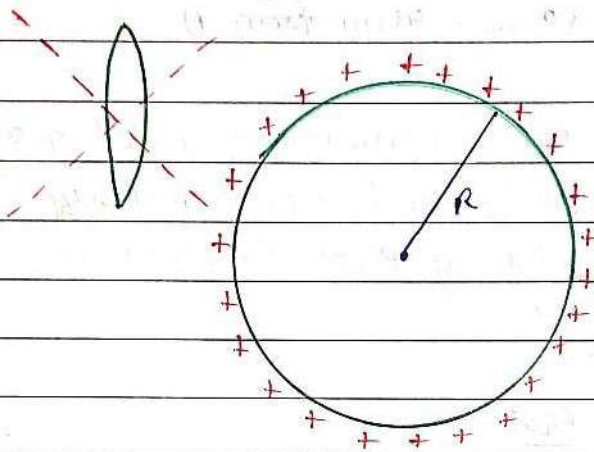
as $x \gg a$

$$\therefore V = \frac{2Kqa^2}{x^3} = \frac{1}{4\pi\epsilon_0} \frac{2qa^2}{x^3} \text{ Ans}$$

ELECTRIC POTENTIAL DUE TO CHARGED

RING

- (i) Electric potential at the centre of a ring having charge Q .

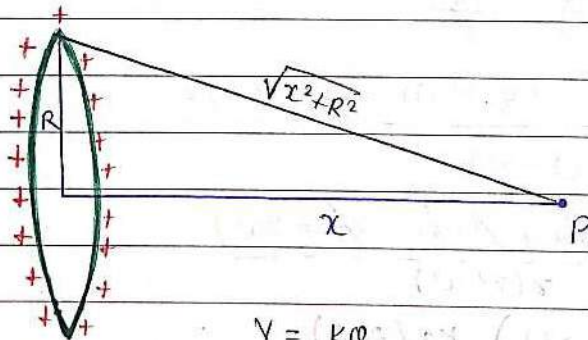


$$dV = \frac{k dq}{R}$$

$$V = \frac{k}{R} \int dq$$

$$V = \frac{kQ}{R}$$

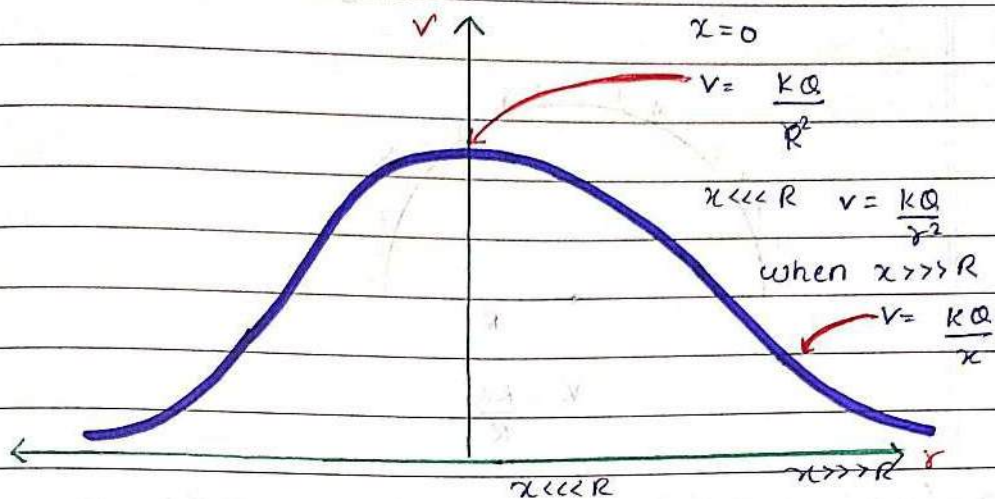
- (ii) Electric potential on the axis of charged ring.



$$V = \frac{kQ}{\sqrt{R^2 + x^2}}$$

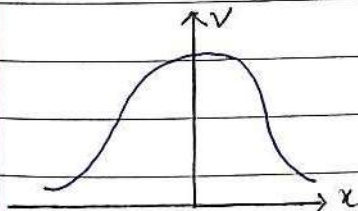
If $x = 0$

then $V = \frac{kQ}{R}$

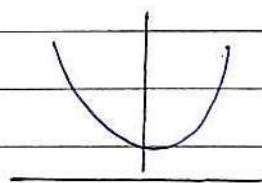


★ Q Two identical positive charges are placed on the y -axis at $y = -a$ and $y = +a$. The variation of V (electric potential) along x -axis is shown by graph.

~~A~~



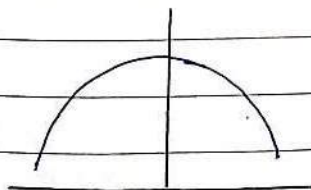
(b)



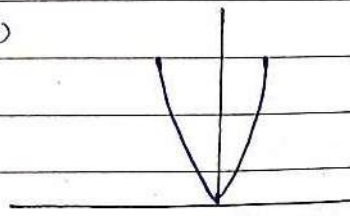
$$V = \frac{2kQ}{\sqrt{x^2 + R^2}}$$

$$V_{\text{centre}} = \frac{2kQ}{R}$$

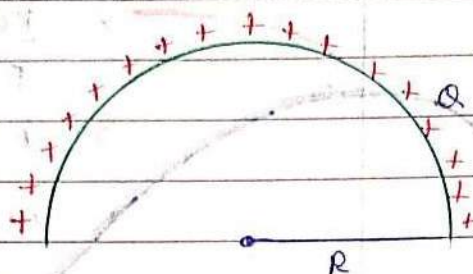
(c)



(d)

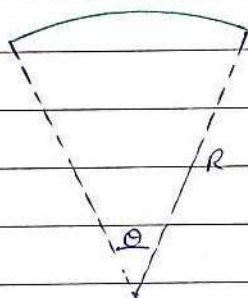


(iii) Electric potential due to half ring, at its centre



$$V_o = \frac{kQ}{R}$$

(iv) Electric potential at the centre of circular arc



$$\lambda = \frac{Q}{R\theta}$$

$$Q = \lambda R\theta$$

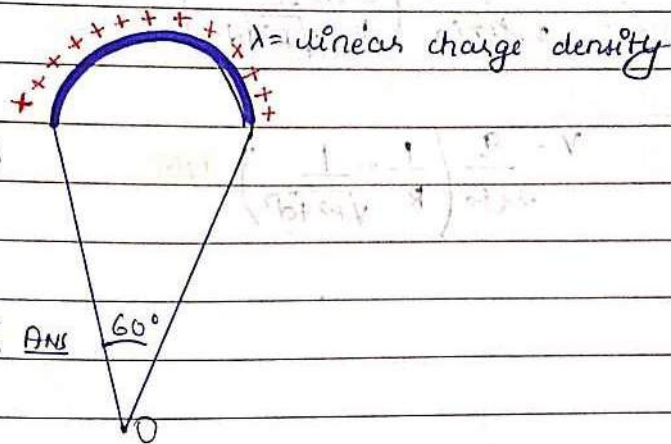
$$V = \frac{k\lambda R\theta}{R} = k\lambda\theta$$

Q Find potential at 'O'.

$$V_0 = \frac{Q \lambda R \theta}{R} = Q K \theta \lambda$$

$$V_0 = \lambda K \theta$$

$$= \lambda K \frac{\pi}{3} = \frac{\lambda K \pi}{3} \text{ Ans}$$



Q Two thin wires rings each of radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are $+q$ and $-q$. The potential difference b/w the centres of two rings is.

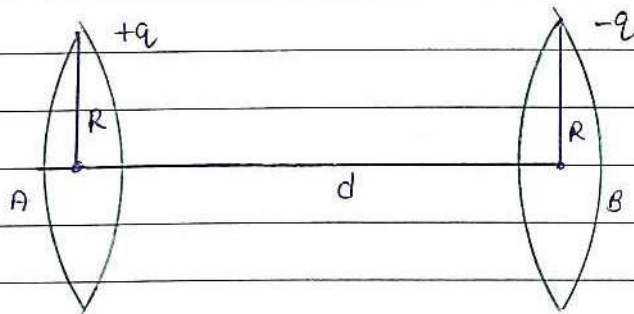
Ans i) Zero

c) $\frac{qR}{4\pi\epsilon_0 d^2}$

b) $\frac{q}{4\pi\epsilon_0} \left[\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}} \right]$

~~d)~~ $\frac{q}{2\pi\epsilon_0} \left(\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}} \right)$

→



$$V_A = \frac{kq}{R} - \frac{kq}{\sqrt{R^2+d^2}}$$

$$V_B - V_A = \frac{2kq}{R} - \frac{2kq}{\sqrt{R^2+d^2}}$$

$$V_B = -\frac{kq}{R} + \frac{kq}{\sqrt{R^2+d^2}}$$

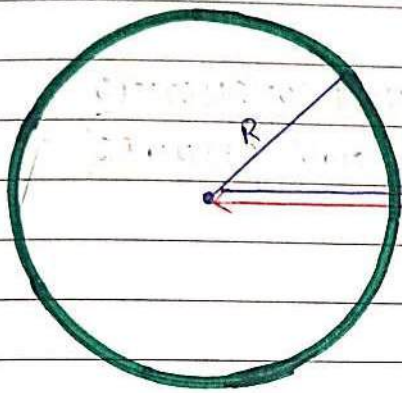
$$2kq \left(\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}} \right)$$

$$\frac{1 \times 2q}{4\pi\epsilon_0} \left(\frac{1}{R} - \frac{1}{\sqrt{R^2+d^2}} \right)$$

$$V = \frac{Q}{2\pi\epsilon_0} \left(\frac{1}{R} - \frac{1}{\sqrt{R^2 + d^2}} \right)$$

$$V = \frac{Q}{2\pi\epsilon_0} \left(\frac{1}{R} - \frac{1}{\sqrt{R^2 + d^2}} \right) \text{ Ans}$$

ELECTRIC POTENTIAL DUE TO HOLLOW / SOLID CONDUCTING CHARGED SPHERE OR NON CONDUCTING HOLLOW SPHERE OR SHELL.



$$r = \infty$$

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

$$+1C$$

$$V = 0$$

ref'n

$$\Delta V = - \int E \cdot dr$$

$$\Delta V = - \int \frac{kq}{x^2} dx \cos 180^\circ$$

$$\Delta V = - \int_{\infty}^x \frac{kq}{x^2} dx$$

$$\Delta V = -kq \frac{x^{-1}}{-1} = \frac{kq}{x} = \frac{kq}{r}$$

$$V_{\text{surface}} = \frac{kq}{R}$$

$V_{\text{inside}} = \frac{kq}{R}$ as inside sphere electric field is zero $\therefore$ No work is done

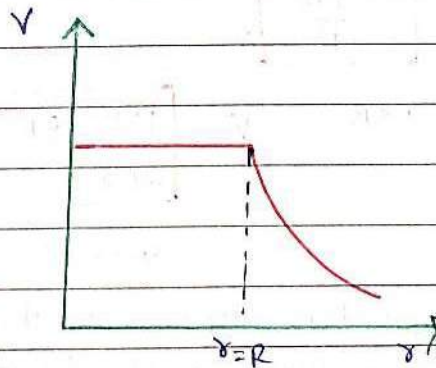
$$V_x - V_{\infty} = \frac{kq}{x}$$

$$V_x = \frac{kq}{x}$$

$$V_x = \frac{kq}{x} = \frac{kq}{r}$$

$$V_{\text{surface}} = \frac{kq}{R}$$

$$V_{\text{inside}} = \frac{kq}{R}$$

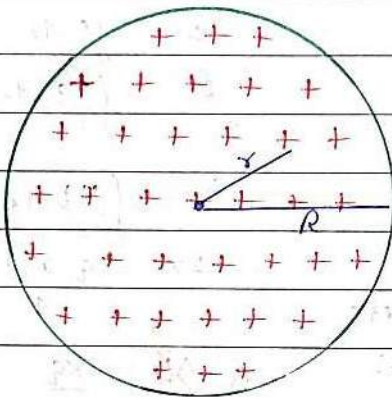


Q A hollow sphere conductor of radius r potential of 100V at its outer surface. The potential inside the hollow at a distance $r/2$ from the centre is.

(a) 100V
(c) 200V

(b) 50V
(d) zero.

ELECTRIC POTENTIAL DUE TO NON CONDUCTING SOLID SPHERE (DERIVATION NOT REQUIRED)



When $r > R$

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

When $r = R$

$$V = \frac{kQ}{R}$$

When $r < R$

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

$$V \propto -r^2$$

When $r = 0$

$$V = \frac{3kQ}{2R}$$

When $r = R$

$$V = \frac{kQ}{R}$$

Q

Which graph best represents the variation of electric potential as a function of distance from the centre of a uniformly charged solid sphere of charge of radius R

POTENTIAL DUE TO AN ELECTRIC DIPOLE

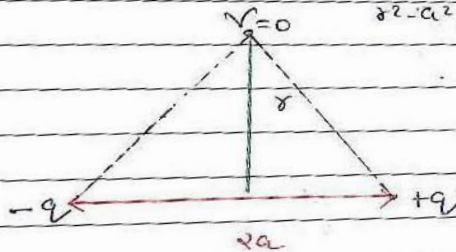


$$V_P = -\frac{kq}{r+a} + \frac{kq}{r-a}$$

$$V_P = \frac{kq}{r-a} - \frac{kq}{r+a}$$

$$V_P = kq \left[\frac{r+a - r-a}{r^2 - a^2} \right]$$

$$V_P = \frac{k2qa}{r^2 - a^2} = \frac{kP}{r^2 - a^2} \quad \text{ANS}$$



If small dipole

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

* Potential on the equatorial line of dipole is zero

Q

An electric dipole consists of two charges of equal magnitude and opposite sign separated by distance $2a$, as shown in the figure. The dipole is along the x-axis and is centered at origin.

- Electric potential at distance r from centre at an angle θ from dipole.

$$r_2 = r - a \cos \theta$$

$$r_1 = r + a \cos \theta$$

$$V_p = \frac{kq}{r - a \cos \theta} - \frac{kq}{r + a \cos \theta}$$

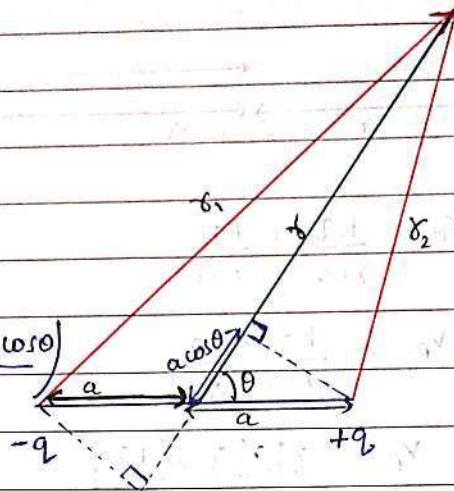
$$V_p = kq \left(\frac{r + a \cos \theta - r + a \cos \theta}{r^2 - a^2 \cos^2 \theta} \right)$$

$$V_p = \frac{2kqa \cos \theta}{r^2 - a^2 \cos^2 \theta}$$

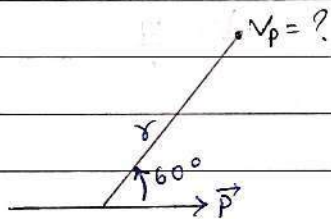
$$V_p = \frac{Kp \cos \theta}{r^2 - a^2 \cos^2 \theta}$$

for short dipole

$$V_p = \frac{Kp \cos \theta}{r^2}$$

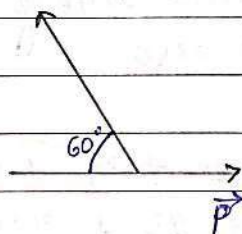


Q



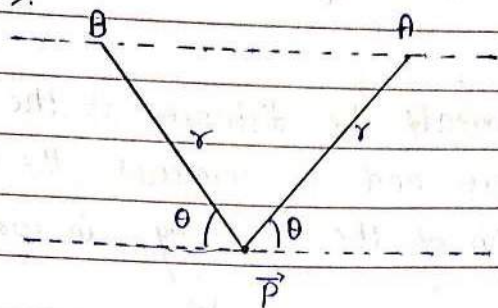
$$V_p = \frac{Kp \cos 60^\circ}{r^2} = \frac{Kp}{2r^2}$$

Q



$$V_p = \frac{Kp \cos 120^\circ}{r^2} = \frac{-Kp}{2r^2}$$

Q A charge q is moved from A to B in the region of a fixed ideal dipole $\vec{p}$. Find work done on the charge (Assume gravity free space).



Ans

$$(\text{Work done})_{\text{ext}} = \Delta U$$

$$= U_B - U_A$$

$$= \frac{qkp \cos(180^\circ - \theta)}{r^2} - \frac{qkp \cos \theta}{r^2}$$

$$= \frac{qkp}{r^2} [-\cos \theta - \cos \theta]$$

$$= -\frac{2qkp \cos \theta}{r^2} \quad \text{Ans}$$

ELECTRIC POTENTIAL DUE TO GROUP OF CONCENTRIC SHELLS.

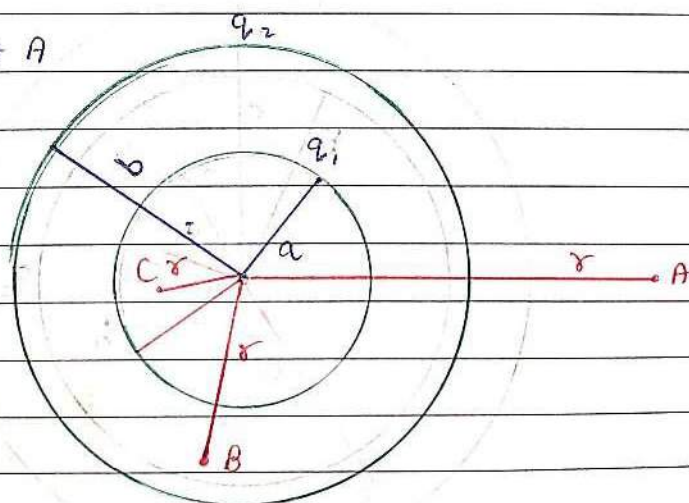
Find potential at A

$$\rightarrow \frac{kq_2}{r} + \frac{kq_1}{r}$$

$$V_A = \frac{k(q_1 + q_2)}{r}$$

Find potential at B

$$\rightarrow V_B = \frac{kq_2}{b} + \frac{kq_1}{r}$$

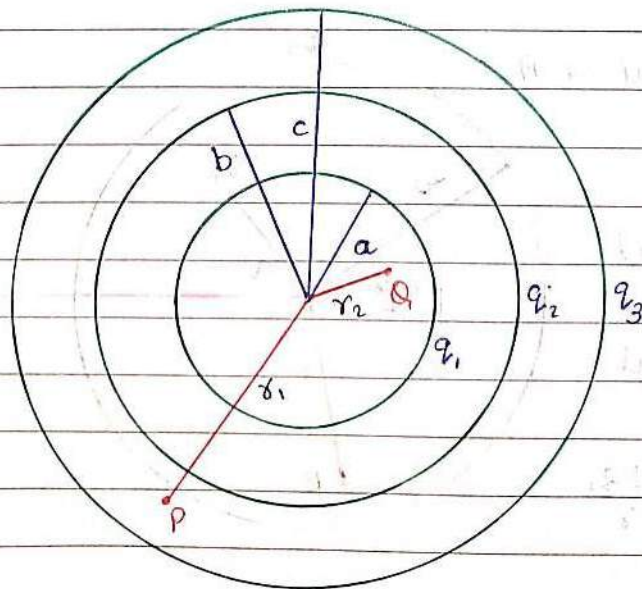


Find potential at C

$$\rightarrow \frac{kq_2}{b} + \frac{kq_1}{a}$$

Q If 'r' represents the distance at the point from the centre of the sphere and 'R' represents the radius of the sphere, then which of the following is correct.

- Electric field for $r > R$ is the same as it would be for an equal charge placed at the centre in case of conducting sphere.
- Potential for $r > R$ is the same as it would be for an equal charge placed at the centre in case of conducting sphere.
- Potential for $r < R$ is the same as it would be for an equal charge placed at the centre of the sphere in case of uniformly charge solid non-conducting sphere.
- Both (1) and (2)



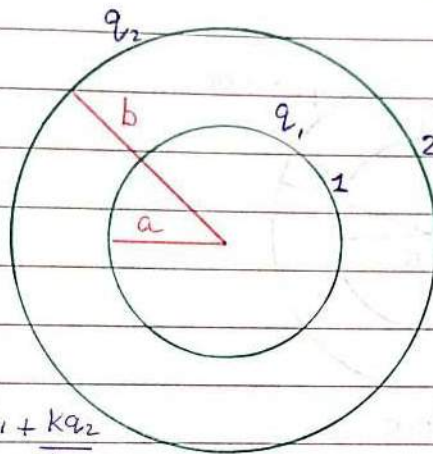
Potential at P

$$\rightarrow \frac{kq_3}{c} + \frac{kq_2}{r_1} + \frac{kq_1}{r_1}$$

Potential at Q

$$\rightarrow \frac{kq_1}{a} + \frac{kq_2}{b} + \frac{kq_3}{c}$$

Find potential difference b/w the surface of concentric shells.



$$V_1 = \frac{kq_1}{a} + \frac{kq_2}{b}$$

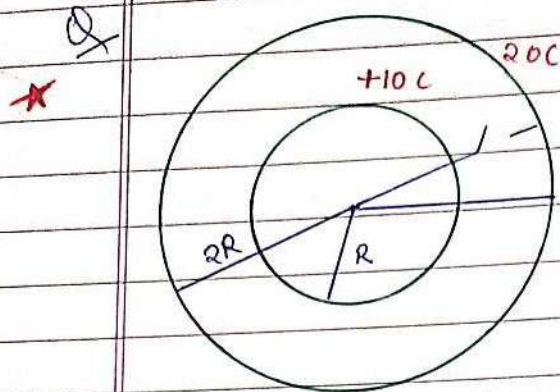
$$V_2 = \frac{kq_2}{b} + \frac{kq_1}{b}$$

$$V_1 - V_2 = \frac{kq_1}{a} + \frac{kq_2}{b} - \frac{kq_2}{b} - \frac{kq_1}{b}$$

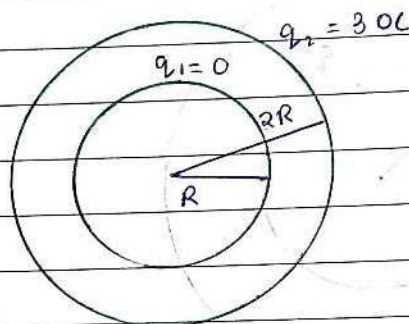
$$= \frac{kq_1}{a} - \frac{kq_1}{b} = kq_1 \left(\frac{1}{a} - \frac{1}{b} \right)$$

$$\Delta V = kq_1 \left(\frac{1}{a} - \frac{1}{b} \right)$$

Potential difference
does not depend on outer
surface.



Q Find final charge on each sphere after wire is connected



Here charge will flow until and unless potential on both the surface is same

$$\Delta V = 0$$

$$\Delta V = kq_1 \left(\frac{1}{a} - \frac{1}{b} \right)$$

$$\Delta V = 0 \therefore q_1 = 0$$

Q Two concentric conducting spheres of radii R and $2R$ are carrying charges Q and $-2Q$ respectively. If the charge on inner sphere is doubled, the potential difference b/w the two spheres will.

- a) Becomes two times b) Becomes four times
 c) Becomes halved d) Remain same.

$\Delta V \propto$ Charge on inner sphere.

* Q A hollow charged metal sphere has radius r . If the potential difference between its surface and a point at a distance $3r$ from the centre is V , then the electric field intensity at distance $3r$ from the centre is.

a) $\frac{V}{3r}$ b) $\frac{V}{4r}$

~~c) $\frac{V}{6r}$~~ d) $\frac{V}{2r}$

Ans

$$\Delta V = -\left(\frac{kq_1}{3r} - \frac{kq_1}{r}\right)$$

$$E = \frac{kQ}{(3r)^2} = \frac{kQ}{9r^2}$$

$$\Delta V = \frac{kq}{r} - \frac{kq}{3r}$$

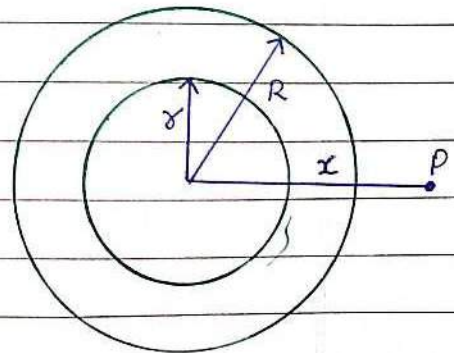
$$E = \frac{kQ}{3r \cdot 3r} = \frac{V}{2 \times 3r} = \frac{V}{6r}$$

$$\Delta V = \frac{2kq}{3r} = V = \frac{2kQ}{3r}$$

Q Two concentric hollow conducting spheres of radius r and R are shown. The charge on outer shell is Q . What charge should be given to inner sphere so that the potential at any point P outside the outer sphere is zero.

a) $-\frac{Qr}{R}$ b) $-\frac{QR}{r}$ ~~c) $-Q$~~ d) $-\frac{2QR}{r}$

Ans $V_P = 0 = \frac{kq}{x} + \frac{kQ}{x} = 0$
 $q = -Q$



ELECTRIC POTENTIAL DIFFERENCE BETWEEN TWO POINT CHARGE DUE TO INFINITE LINE CHARGE DENSITY λ

$$dV = -\vec{E} \cdot d\vec{r}$$

$$\int_{V_2}^{V_1} dV = - \int_{r_2}^{r_1} \frac{2k\lambda}{r} dr$$

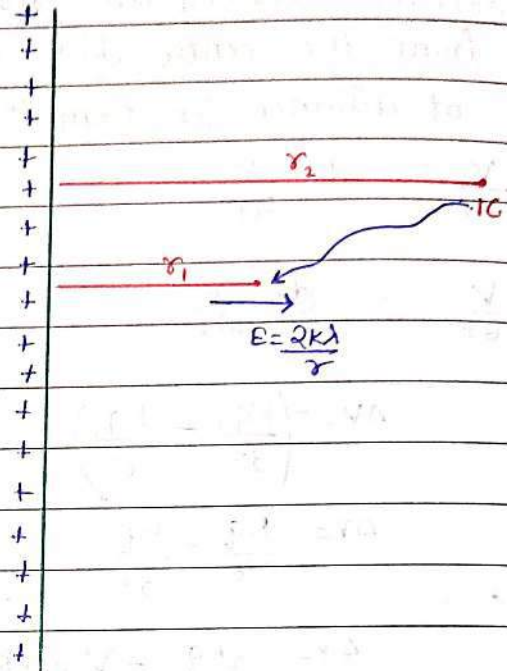
$$V_1 - V_2 = -2k\lambda (\log r)_2^1$$

$$V_1 - V_2 = -2k\lambda (\log r_1 - \log r_2)$$

$$V_1 - V_2 = 2k\lambda (\log r_2 - \log r_1)$$

$$V_1 - V_2 = 2k\lambda \left(\log \frac{r_2}{r_1} \right)$$

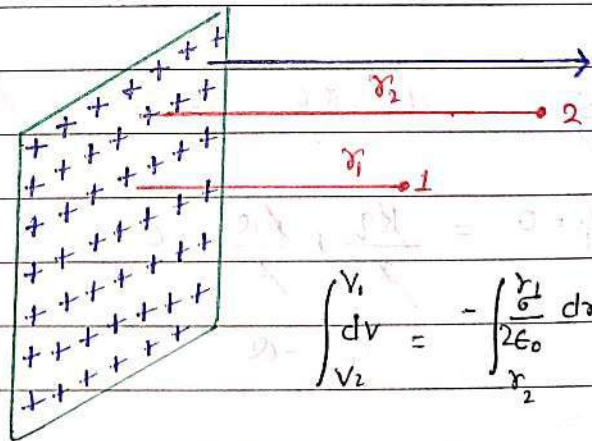
$$V_1 - V_2 = 2k\lambda \log_e \frac{r_2}{r_1}$$



ELECTRIC POTENTIAL DIFFERENCE BETWEEN TWO POINT CHARGE DUE TO THIN INFINITE CHARGE SHEET

Non conducting

$$E = \frac{\sigma}{2\epsilon_0} \text{ (uniform)}$$



$$\int_{V_2}^{V_1} dV = - \int_{r_2}^{r_1} \frac{\sigma}{2\epsilon_0} dr$$

$$V_1 - V_2 = -\frac{\sigma}{2\epsilon_0} (r)_2^1$$

$$V_1 - V_2 = \frac{\sigma}{2\epsilon_0} (r_2 - r_1)$$

Q An infinite conducting sheet has surface charge density σ .
The distance between two equipotential surface is r .
The potential difference between these two surfaces is.

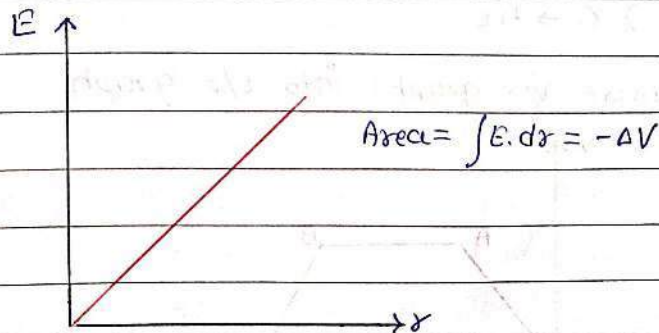
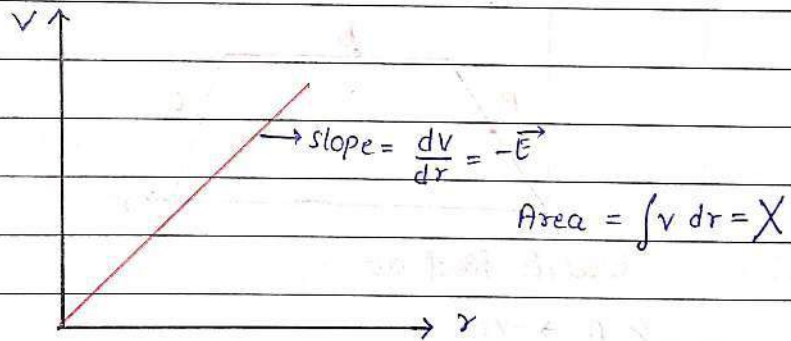
- 1) $\frac{\sigma}{\epsilon_0}$ ~~b) $\frac{\sigma r}{\epsilon_0}$~~ c) $\frac{\sigma}{\epsilon_0 r}$ d) $\frac{\sigma}{2\epsilon_0 r}$

Q A spherical conductor having charge q and radius r is placed at the centre of a spherical shell of radius R and having charge Q ($R > r$). The potential difference b/w the two is.

- a) Proportional to Q
~~b) Proportional to q~~
c) Dependent on both Q & q
d) Independent of both Q and q .

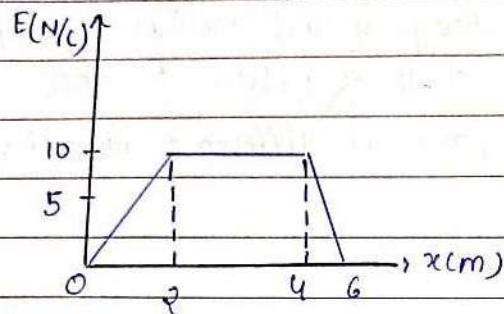
QUESTIONS ON GRAPHS.

$$\vec{E} = -\frac{dV}{dr}$$



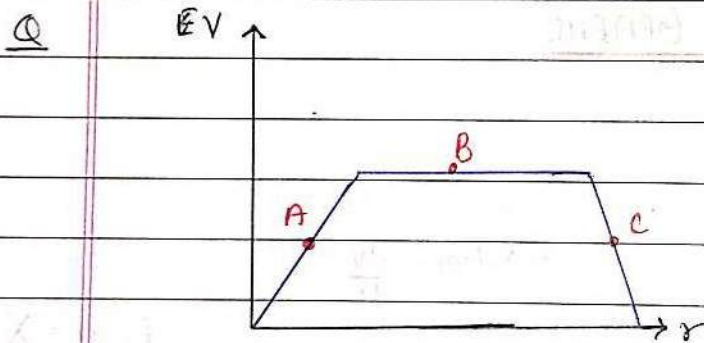
Q Figure shows the variation of electric field intensity E versus distance x . What is the potential difference between the points at $x=2$ and at $x=6$ m from O ?

- a) 30V b) 60V
c) 40V d) 80V



$$\text{Area} = -\Delta V$$

$$= 2 \times 10 + \frac{1}{2} \times 4 \times 10 = 30V \text{ Ans}$$



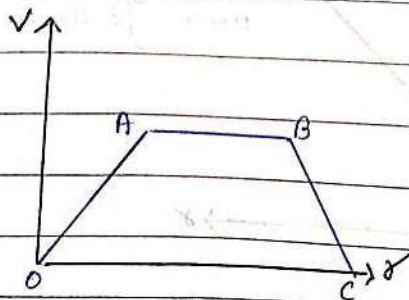
Electric field at

➤ A → -ve

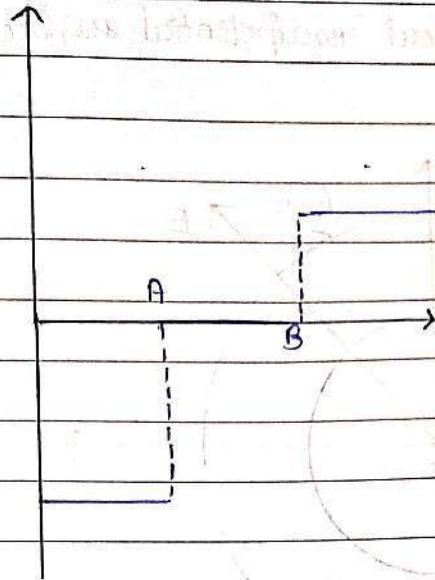
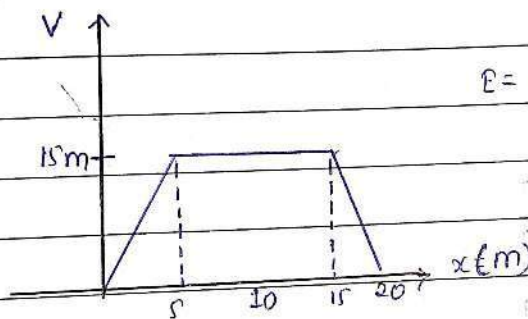
➤ B → 0

➤ C → +ve

Q Convert V/r graph into E/r graph.



ANS

Q Find electric field at $x = 17 \text{ m}$?

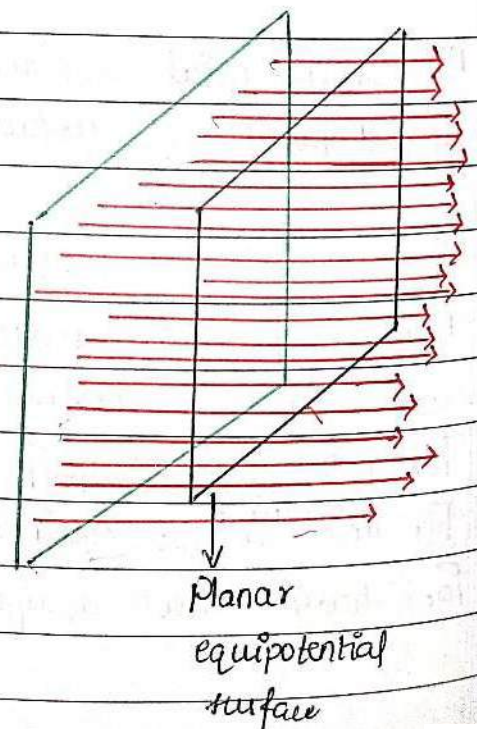
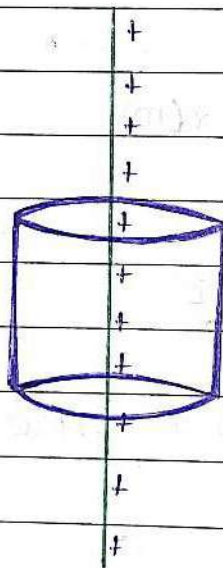
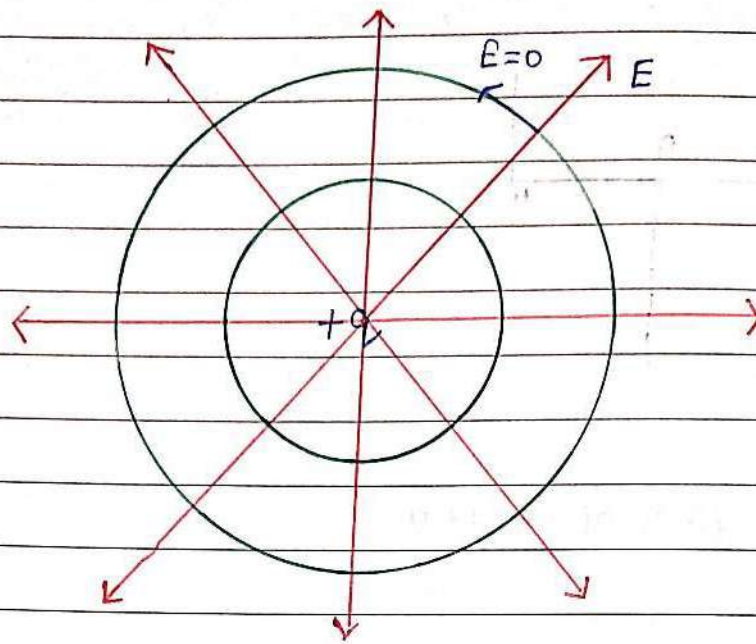
$$E = -\frac{dV}{dx} = -\left(\frac{15}{5}\right) = +3 \text{ N/C} \text{ } \underline{\text{ANS}}$$

EQUIPOTENTIAL SURFACE

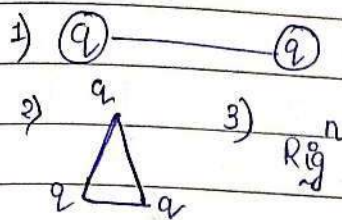
An equipotential surface is a surface with a constant potential at all points of surface

- Electric field is perpendicular to surface
- Along equipotential surface electric field must be zero.
- Work done in moving any charge on that surface is zero.
- For point charge equipotential surface is spherical
- For line ^{infinite} charge equipotential surface is cylindrical
- For charge sheet _{infinite} equipotential surface is sheet.

• spherical charge $\rightarrow$ spherical equipotential surface.

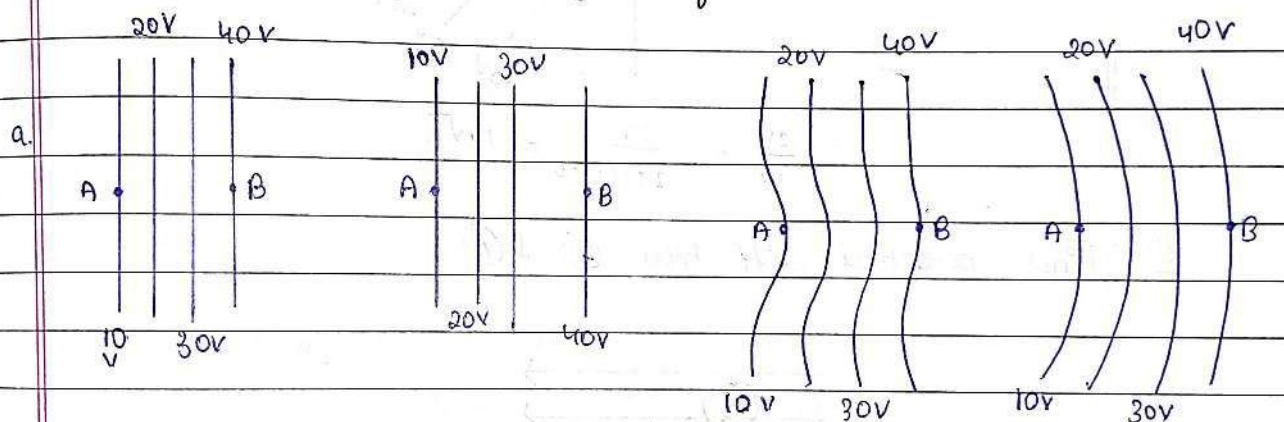


Q Equipotential surface due to some non zero combination / distribution of charge at very large distance



→ ANSWER Spherical as all these would behave as point charge at very large distance.

Q The diagrams below show regions of equipotentials.



A positive charge q is moved from A to B in each diagram

1) Maximum work is required to move q in figure (c).

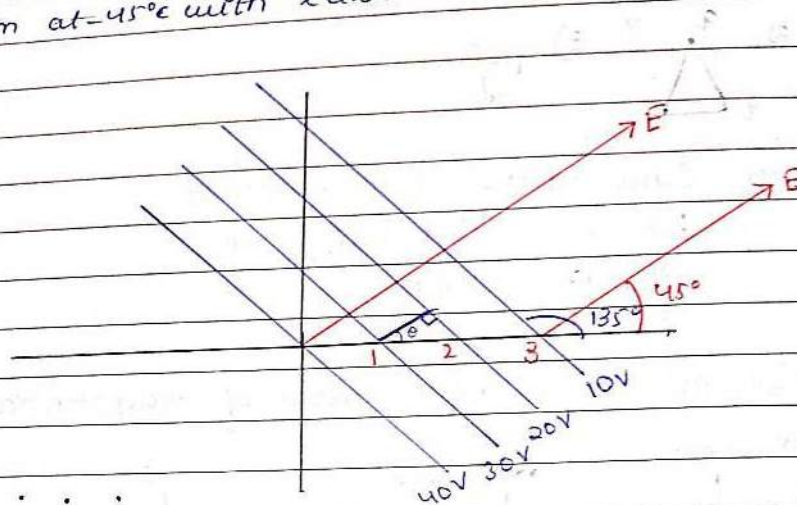
2) In all cases the work done is same

c) Minimum work is required to move q in fig (a)

d) Maximum work is required to move q in fig (b)

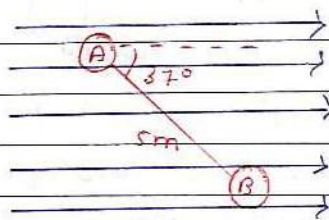
★ Q Figure shows a set of equipotential surfaces. The magnitude and direction of electric field that exists in the region is.

- a) $10\sqrt{2}$ V/m at 45° with x axis
 b) $10\sqrt{2}$ V/m at -45° with x axis
 c) $10\sqrt{2}$ V/m at 45° with x axis
 d) $10\sqrt{2}$ V/m at -45° with x axis.



$$E = -\frac{\Delta V}{\Delta r} = \frac{10}{1 \cos 45^\circ} = 10\sqrt{2}$$

Q Find potential diff b/w (A) & (B)

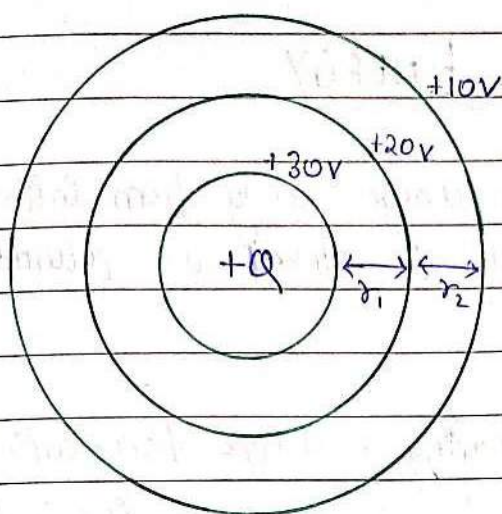


$$5 \cos 37^\circ = \Delta x$$

$$E = -\frac{\Delta V}{\Delta x} = -\frac{\Delta V}{4}$$

$$\Delta V = -4E$$

* Q



Some equipotential surface due to point charge are drawn as shown in figure then which of the following is correct

a) $r_1 > r_2$

~~b) $r_1 < r_2$~~

c) $r_1 = r_2$

Ans

$$\frac{-\Delta V}{\Delta x} = \Delta E$$

as $\Delta V = \text{same} = \text{constant}$

and ΔE goes on decreasing
as distance from point charge
increases

$\therefore \Delta x$ is more where ΔE is less

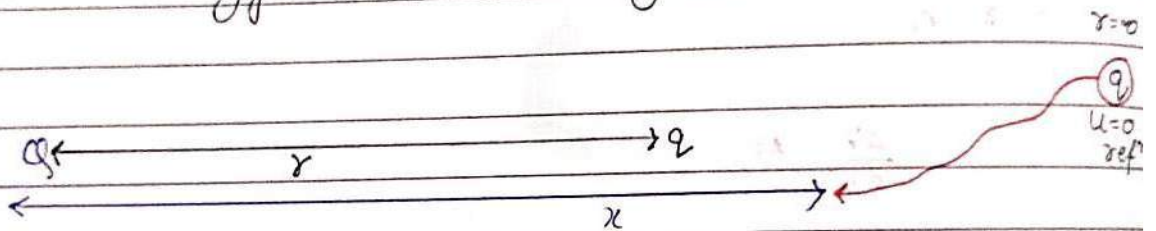
$$\therefore r_2 > r_1$$

POTENTIAL ENERGY

- Work done in bringing q charge slowly from infinity to the point in electric field is stored as a potential energy in that charge.
- Negative work done in moving q charge from infinity to the point in electric field by electric force is called potential energy.

POTENTIAL ENERGY OF A SYSTEM OF CHARGES

(i) Potential energy of two points charge.



$$U_r - U_{\infty} = - \int_{\infty}^r \vec{F} \cdot d\vec{x}$$

$$U_r - U_{\infty} = - KQq \int_{\infty}^r \frac{1}{x^2} dx \cos 180^\circ$$

$$U_r - U_{\infty} = - KQq \left[\frac{x^{-2+1}}{-2+1} \right]_{\infty}^r$$

$$U_r - U_{\infty} = KQq \left[\frac{1}{x} \right]_{\infty}^r$$

$$U_r - U_{\infty} = KQq \left[\frac{1}{r} - \frac{1}{\infty} \right]$$

$$U_r - U_{\infty} = \frac{KQq}{r}$$

$$U = \frac{kQq}{r}$$

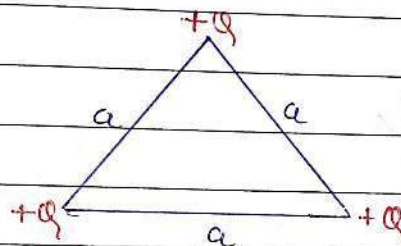
$+Q \leftarrow r \rightarrow q$
fixed $U = \frac{kQq}{r}$ ANS

$Q \leftarrow r \rightarrow q$
 $U = \frac{kQq}{r}$
↑

$+Q \leftarrow r \rightarrow q$
 $U = \frac{kQq}{r}$ ANS fixed

Stored potential energy in the system of two charge.

Q Find potential energy of the given system.



$$U = \frac{kQ^2}{a} + \frac{kQ^2}{a} + \frac{kQ^2}{a}$$

$$U = \frac{3kQ^2}{a}$$
 ANS

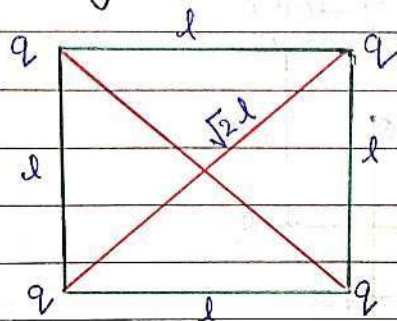
* Total no. of terms of potential energy
For N charge $= \frac{N(N-1)}{2}$

For 1 charge pair = 0

For 3 charges pair = 3

For 4 charges pair = 6

Q Find potential energy of the given system.



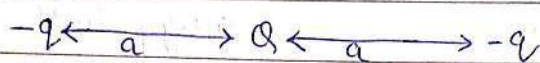
pair = 6

then $\frac{4kQ^2}{l} + \frac{2kQ^2}{\sqrt{2}l}$

Q Three charges $-q$, Q , and $-q$ are placed respectively at equal distances on a straight line. If the potential energy of the system is zero then find the ratio of $Q:q$.

- (a) 1:4 (b) 4:1
(c) 1:3 (d) 1:2

Ans



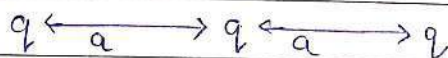
Total pairs = 3

$$-\frac{kQq}{a} - \frac{kQq}{a} + \frac{kq^2}{2a} = 0$$

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

$$\frac{Q}{q} = \frac{1}{4}$$

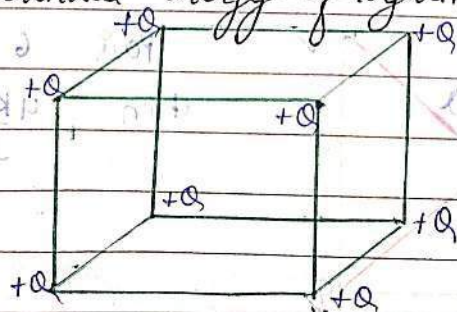
Q Find potential energy of the system.



$$\rightarrow \frac{2kq^2}{a} + \frac{kq^2}{2a}$$

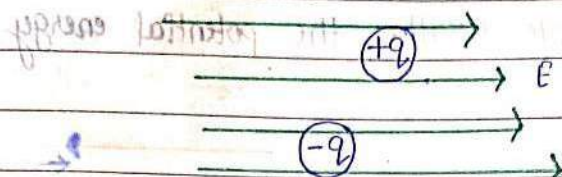
$$= \frac{5kq^2}{2a}$$

Q Find potential energy of system.



Ans $\frac{12 k Q^2}{l} + \frac{12 k Q^2}{\sqrt{2} l} + \frac{4 k Q^2}{\sqrt{3} l}$

Q Two point charges are released then potential energy will



Positive charge

$$\rightarrow \Delta U = q(\Delta V) \downarrow$$

$$\Delta U \downarrow$$

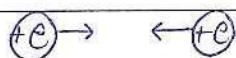
Negative charge

$$\Delta U = -q(\Delta V) \uparrow$$

$$\text{but } \Delta U \downarrow$$

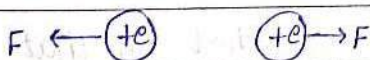
Generalised $\rightarrow$ All natural phenomenon statement undergo to that direction where potential energy decreases.

Q Two protons are moving towards each other then potential energy of system??



Potential energy increase as it is against natural phenomenon.

Exp-2



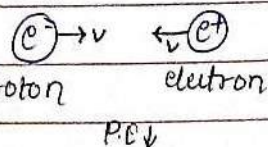
$$K.E \downarrow$$

$$U \uparrow$$

Q Two electrons are moving towards each other then potential energy of the system.

→ increase

Q



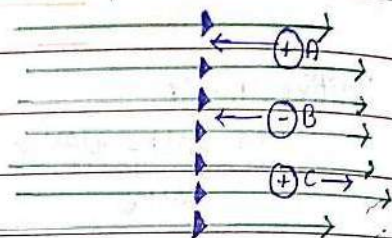
Q

Three charged particles (their sign are shown) move along the path in a uniform electric field as shown. In each of the three cases state whether the potential energy increases or decreases.

A → Increase

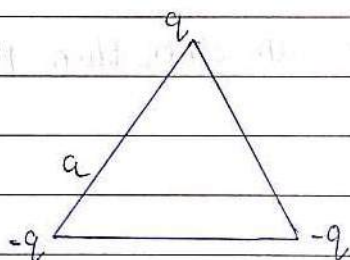
B → decrease

C → decrease



Q

Find potential energy of system.

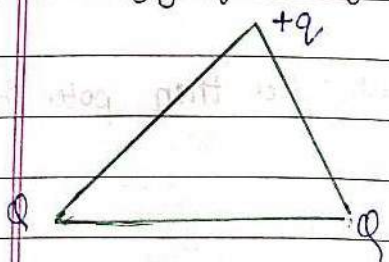


$$U = \frac{-kq^2}{a} - \frac{kq^2}{a} + \frac{kq^2}{a}$$

$$U = \frac{-kq^2}{a} \text{ Ans}$$

Q

Find relation between q and Q so that so that potential energy of the system is zero



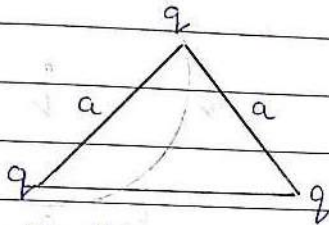
$$\frac{kqQ}{a} + \frac{kQq}{a} + \frac{kQ^2}{2a} = 0$$

$$\frac{kQ^2}{2a} = -\frac{2kQq}{a}$$

$$Q = -2q$$

Q Calculate the work done to make an arrangement of three particles each having a charge $+q$ such that the particles lie at the vertices of an equilateral triangle of side a .

Ans



Initially the 3 charges are at infinity then $U_i = 0$

$$W_{ext} = U_f - U_i$$

$$U_f = \frac{3kq^2}{a} \quad U_i = 0$$

$$W_{ext} = \frac{3kq^2}{a} \quad \text{Ans}$$

Q The work which is required to be done to make an arrangement of four particles each having a charge $+q$ such that the particles lie at the four corners of a square of side a is.

Ans

$$W_{ext} = U_f - U_i$$

$$U_i = 0$$

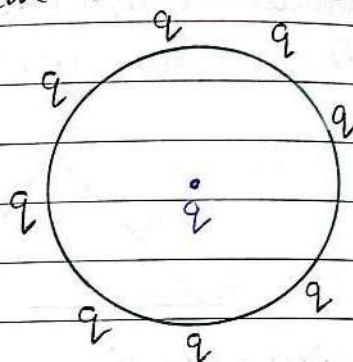
$$U_f = \frac{4kq^2}{a} + \frac{2kq^2}{\sqrt{2}a}$$

$$\frac{(4+\sqrt{2})kq^2}{a} \quad \text{Ans.}$$

Q A point charge q is surrounded by eight identical charges at distance r as shown in figure. How much work is done by the forces of electrostatic repulsion when the point charge at the centre is removed to infinity.

a) Zero ~~(b)~~ $\frac{8q^2}{4\pi\epsilon_0 r}$

c) $\frac{8q}{4\pi\epsilon_0 r}$ (d) $\frac{64q^2}{4\pi\epsilon_0 r}$



ANS ~~Work~~ $= \Delta U$

Work done by electrical force $= -\Delta U$

$= -[U_f - U_i]$

$= U_i - U_f$

$= \frac{8q^2 k}{r} - 0 = \frac{8q^2}{4\pi\epsilon_0 r}$

Q A proton is fixed at origin. Another proton is released from rest, from a point at a distance r from origin. Taking charge of proton as e and mass m find the speed of the proton (i) at a distance $2r$ from origin (ii) at a large distance from origin.

ANS (i) Work done by Non conservative force $= 0$
'COM E'

$U_i + K.E_i = U_f + K.E_f$

$\frac{Ke^2}{r} + 0 = \frac{Ke^2}{2r} + \frac{1}{2}mv^2$

$= \frac{Ke^2}{2r} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{Ke^2}{mr}}$

(ii) COM E

$K.E_i + U_i = K.E_f + U_f$

$= 0 + \frac{Ke^2}{r} = \frac{1}{2}mv^2 + 0$

$v = \sqrt{\frac{2Ke^2}{mr}}$ **ANS**

- Q Two protons is fixed at origin. And are separated by a distance R . What will be the speed of each proton when they reach infinity under their mutual repulsion. released

Ans By COME.

$$KE_i + U_i = KE_f + U_f$$

$$\Rightarrow 0 + \frac{ke^2}{R} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + 0$$

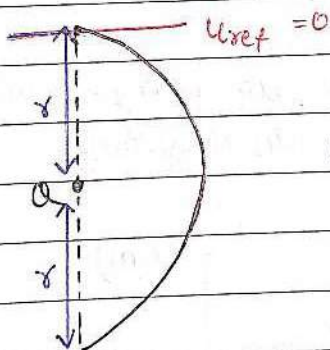
$$\Rightarrow \frac{ke^2}{R} = mv^2$$

$$v = \sqrt{\frac{ke^2}{mR}} \quad \text{ANS}$$

- Q The work done in slowly moving a charge e of electron and mass m from A to B along a semicircular path in vertical plane in the field of charge Q is.

- a) $-2mgr$ b) $-Qe/r$
c) $2mgr + \frac{2Qe}{r}$ d) zero.

Ans



$$W = \Delta U$$

$$= U_f - U_i$$

$$= -mg2r - 0$$

$$= -2mgr \quad (\text{Gravitational field})$$

$$W = \Delta U = q\Delta V$$

$$= e[V_f - V_i]$$

$$W = e\left[\frac{kQ}{r} - \frac{kQ}{r}\right] = 0$$

for electric field

Q The charge q is fired towards another charged particle Q which is fixed with a speed v . It approaches Q upto a closest distance r and then returns. If q were given a speed $2v$, the closest distance of approach would be.

a) r (b) $2r$

c) $r/2$ ~~(d) $r/4$~~

Ans

$$\frac{1}{2}mv^2 = \frac{kQq}{r}$$

$$v \propto \frac{1}{\sqrt{r}} \quad \text{or} \quad r = \frac{1}{v^2}$$

$$\frac{r_1}{r_2} = \frac{v_2^2}{v_1^2}$$

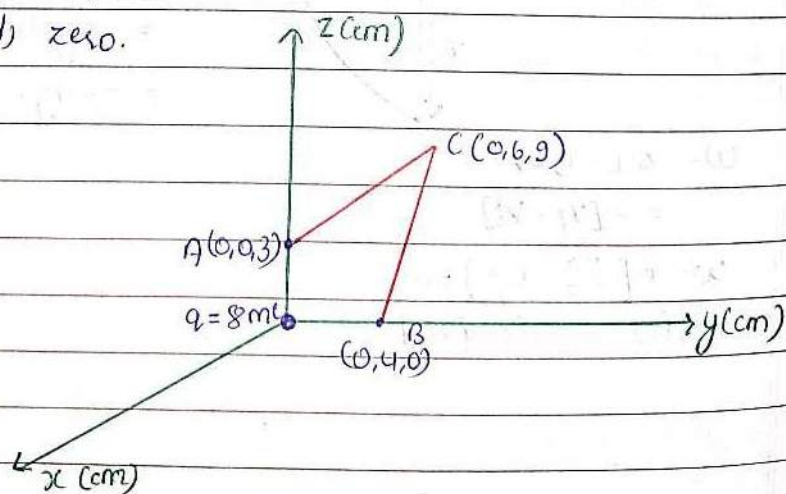
$$\frac{r}{r_2} = \frac{4v^2}{v^2}$$

$$r_2 = r/4 \quad \text{Ans}$$

Q Calculate the work done in taking a charge $-2 \times 10^{-9} \text{C}$ from A to B via C (in diagram).

1) 0.2 joule ~~(b) 1.2 joule~~

3) 2.2 joule (d) zero.



ANS

$$W_{ext} = \Delta U = U_f - U_i$$

$$U_f = -K \times \frac{2 \times 10^{-9} \times 8 \times 10^{-3}}{4 \times 10^{-2}}$$

$$U_i = -K \times \frac{2 \times 10^{-9} \times 8 \times 10^{-3}}{3 \times 10^{-2}}$$

$$U_f - U_i = -K \times 2 \times 10^{-9} \times 8 \times 10^{-3} \left[\frac{1}{4 \times 10^{-2}} - \frac{1}{3 \times 10^{-2}} \right]$$

$$U_f - U_i = -9 \times 10^9 \times 2 \times 10^{-9} \times 8 \times 10^{-3} \times \frac{-1 \times 10^{-2}}{12 \times 10^{-4}} \times 10^{-1}$$

$$U_f - U_i = \frac{144}{12} \times 10^{-1} = 12 \text{ Joule Ans}$$

Q

Two electrons are moving towards each other, each with a velocity of 10^6 m/s. What will be the closest distance of approach b/w them?

- a) $1.53 \times 10^{-8} \text{ m}$ ~~b) $2.53 \times 10^{-10} \text{ m}$~~
 c) $2.53 \times 10^{-6} \text{ m}$ d) Zero

ANS

$$\frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{ke^2}{r}$$

$$\Rightarrow mv^2 = \frac{ke^2}{r}$$

$$r = \frac{ke^2}{mv^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31} \times 10^{12}} \times 10^{-10}$$

$$= 2.56 \times 10^{-10} \text{ m}$$

Q

Three equal charge Q are at the vertices of an equilateral triangle of side $2A$, then how much work done is required in bringing them closer to an equilateral triangle of side A .

Ans $W_{ext} = \Delta U = U_f - U_i$

$$U_f = \frac{3KQ^2}{a}$$

$$U_i = \frac{3KQ^2}{2a}$$

$$U_f - U_i$$

$$= \frac{6KQ^2}{2a} - \frac{3KQ^2}{2a} = \frac{3KQ^2}{2a} \text{ Ans}$$

Q A positively charged ring is in $y-z$ plane with its centre at origin. A positive test charge q_0 , held at the origin is released along x axis, then its speed.

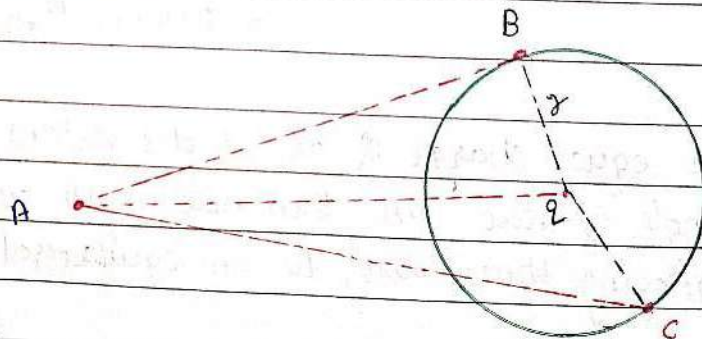
- ~~a) Increases continuously~~ b) Decreases continuously
c) First increases and then decreases d) First decreases then increases

Q A point charge q is held at the centre of a circle of radius r . B, C are two points on the circumference of the circle and A is a point outside the circle. If W_{AB} represents the work done by the electric field in taking a charge q_0 from A to B and W_{AC} represents the work done from A to C, then

a) $W_{AB} > W_{AC}$ b) $W_{AB} < W_{AC}$

~~c) $W_{AB} = W_{AC} = 0$~~

d) $W_{AB} = W_{AC} \neq 0$



$-Q, -q, 2q$, and $2Q$

Q Four point charges are placed one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero is.

a) $Q = q$

b) $Q = 1/q$

~~c) $Q = -q$~~

d) $Q = -1/q$

Ans

$$-\frac{kQ}{r} - \frac{kq}{r} + \frac{2kQ}{r} + \frac{2kq}{r} = 0$$

$$\frac{2kQ}{r} - \frac{kQ}{r} + \frac{2kq}{r} - \frac{kq}{r} = 0$$

$$\frac{kQ}{r} + \frac{kq}{r} = 0$$

$$\cancel{\frac{kQ}{r}} = -\cancel{\frac{kq}{r}}$$

$$Q = -q \text{ Ans}$$

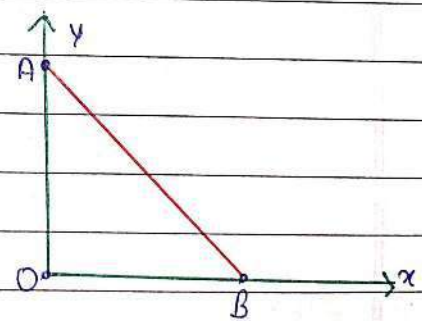
Q As per the diagram a point charge $+q$ is placed at the origin O . Work done in taking another point charge $-Q$ from the point A [coordinates $(0, a)$] to another point B [coordinates $(a, 0)$] along the straight path AB is.

~~a) zero~~

b) $\left(\frac{-qQ}{4\pi\epsilon_0 a^2}\right) \sqrt{2}a$

c) $\left(\frac{qQ}{4\pi\epsilon_0 a}\right) \cdot \frac{1}{\sqrt{2}}$

d) $\left(\frac{qQ}{4\pi\epsilon_0 a^2}\right) \sqrt{2}a$



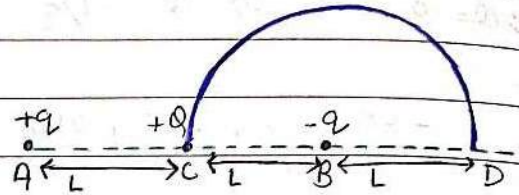
Ans

$$W_{\text{ext}} = \Delta U = U_f - U_i$$

$$\Rightarrow \frac{-kqQ}{a} - \left(-\frac{kqQ}{a}\right) = 0$$

9)

$$(b) \quad \frac{-90}{4\pi \epsilon_0 L}$$



$$(d) \quad \frac{-2Q}{2\pi\epsilon_0 L}$$

$$\Delta V_{DC} = V_D - V_C$$

$$\frac{kq}{3L} - \frac{kq}{L} = -\frac{2kq}{3L}$$

$$W = q \Delta V$$

$$W = -2192$$

$$2 \mu r_0 \times 3L$$

$$= \frac{-900}{6 \times 600}$$

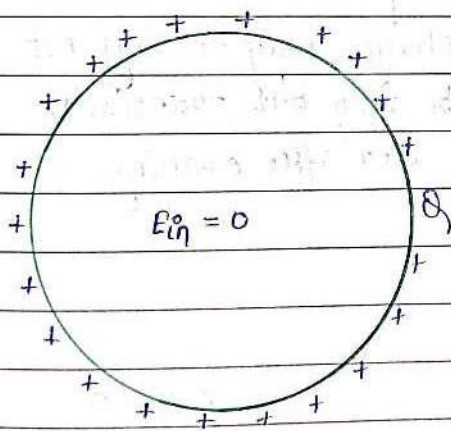
ELECTROSTATICS OF CONDUCTOR

Having large no of e^- are free to move inside conductor where matter is present

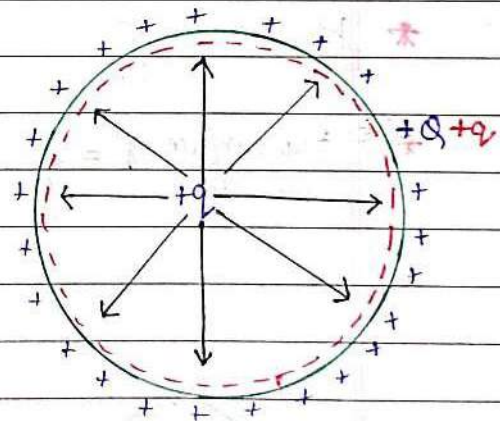
$$\vec{E}(\text{due to free } e^-) = 0$$

Excess charge resides on the surface of conductor.

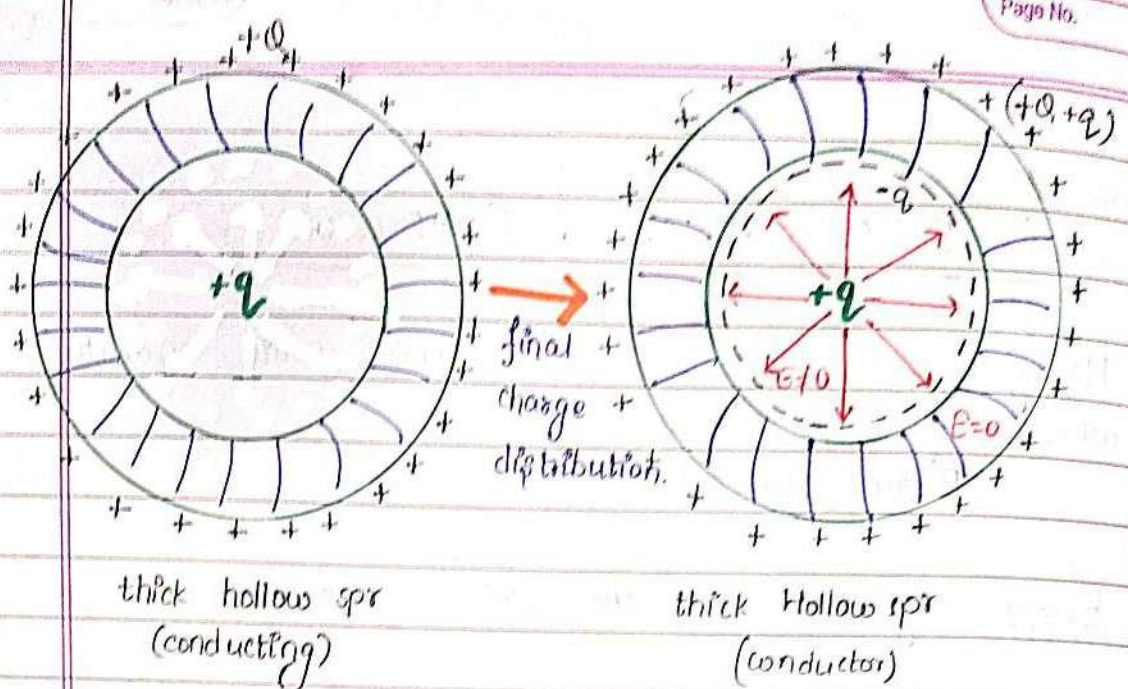
- * Electric field inside conductor is always zero $\rightarrow$ False
- * Electric field inside ^{isolated} conductor is zero, where matter is present. $\rightarrow$ True
- * Electric field inside conductor is zero $\rightarrow$ True
 $\downarrow$
 General statement.



Hollow sphere
(conducting)



Here electric field
inside conductor is
not zero



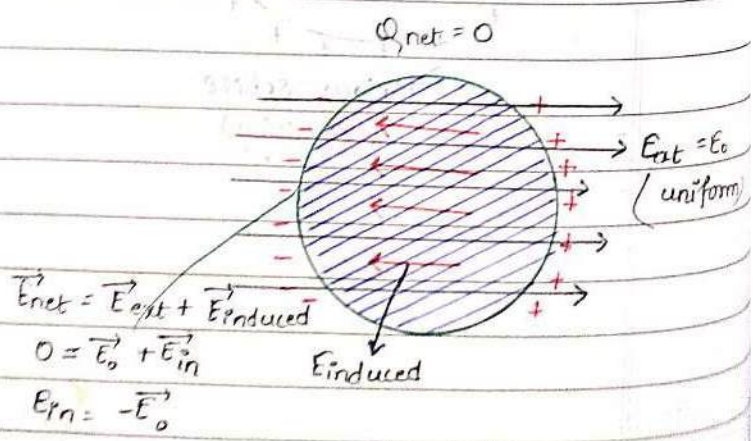
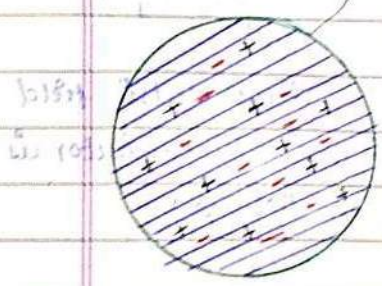
- Conductor creates equipotential region where matter is present.
- Electric field is always $\perp$ to the surface.
- We connect two conductor with wire then their potential becomes same

* If conductor is connected to the earth then its potential becomes zero

* Pressure = $\frac{\sigma^2}{2\epsilon_0}$

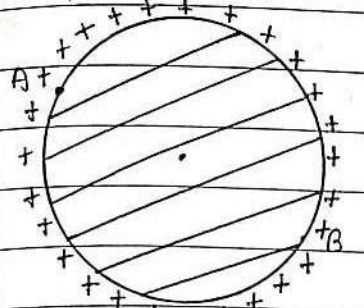
charge may or may not be zero but potential is zero after earthing

Ext surface of conductor = $\frac{\sigma}{\epsilon_0}$



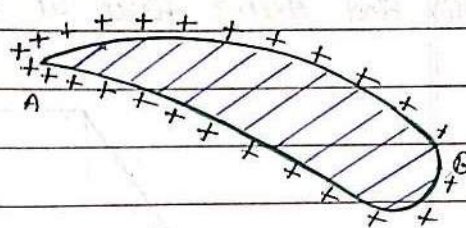
Excess charge given to conductor

(i) Uniform sphere



Excess charge distributed uniformly
 $|\vec{E}_A| = |\vec{E}_B|$
 $V_A = V_B$

(ii) Random shape

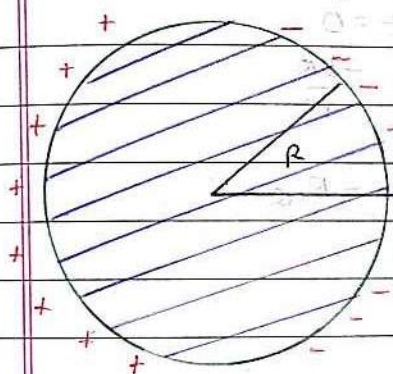


$|\vec{E}_A| > |\vec{E}_B|$ ($\sigma_A > \sigma_B$)

$V_A = V_B$

Conductor creates equipotential region.

* When point charge is placed near to conductor.



Neutral conductor

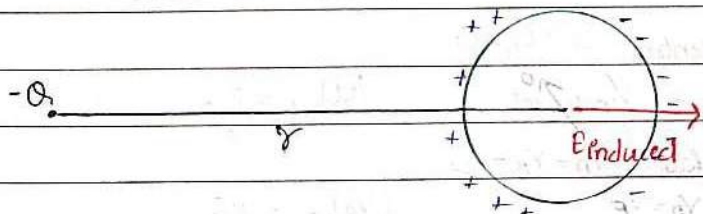
$(\vec{E}_0) = \frac{KQ}{r^2}$
due to +Q charge

$\vec{E}_{net} = 0 = \vec{E}_{induced} + \vec{E}_0$

$0 = \frac{KQ}{r^2} + \vec{E}_{induced}$

$\vec{E}_{induced} = -\frac{KQ}{r^2}$ Ans

Q Find electric field at centre of neutral conductor



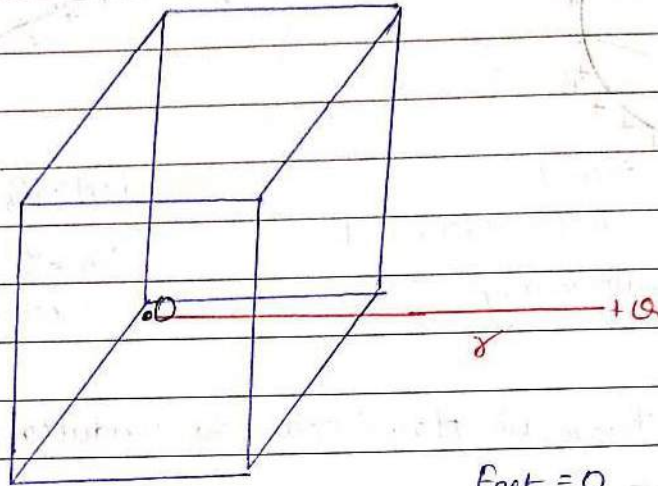
$E_{net} = 0$

$E_{net} = E_0 + E_{induced}$

$E_{induced} = +\frac{KQ}{r^2}$ Ans

direction

- Q (i) Find electric field at O
 (ii) Find electric field due to Induced charge
 (iii) Find electric field at 'O' due to +Q

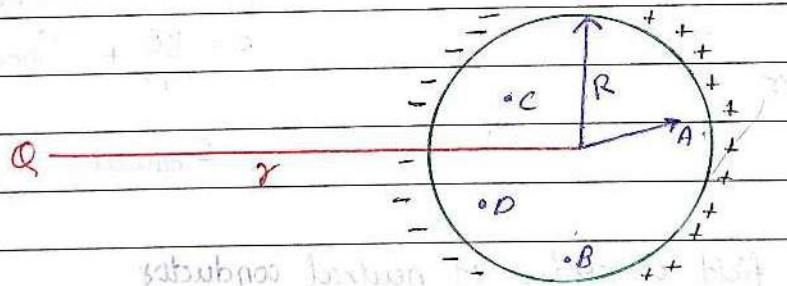


Conducting
neutral cube

$$E_{\text{net}} = 0$$

$$E_{\text{in}} = -\frac{KQ}{r^2}$$

$$E_{\text{in}} = -E_{+Q}$$



Neutral conductor.

$$E_A = E_B = E_{\text{at centre}} = E_C = E_D = 0$$

$$V_{\text{net}} = V_{+Q} + V_{\text{induced}}$$

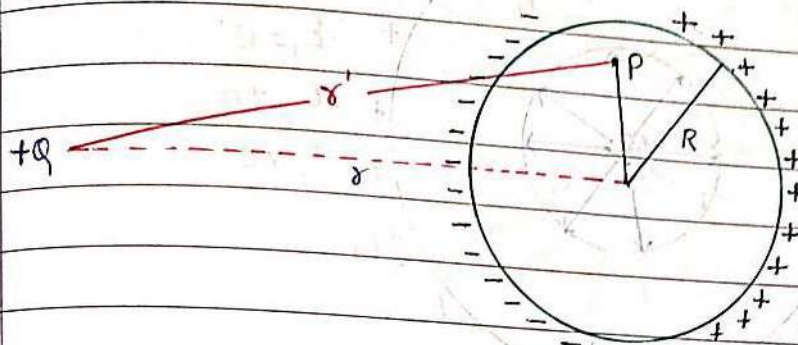
$$(V_0)_{\text{net}} = \frac{KQ}{r}$$

$$V_{\text{centre}} = V_{\text{surface}} = V_A = V_B = V_C =$$

$$V_0 = V_E$$

$$(V_0)_{+Q} = \frac{KQ}{r}$$

$$(V_0)_{\text{induced}} = 0$$

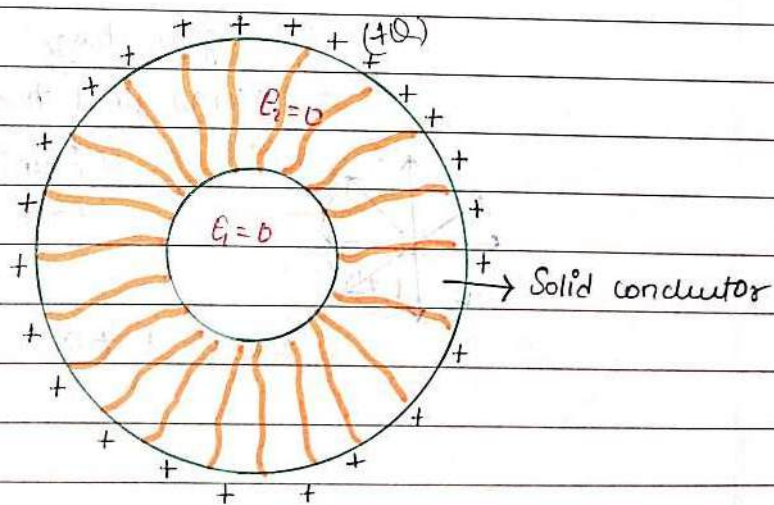


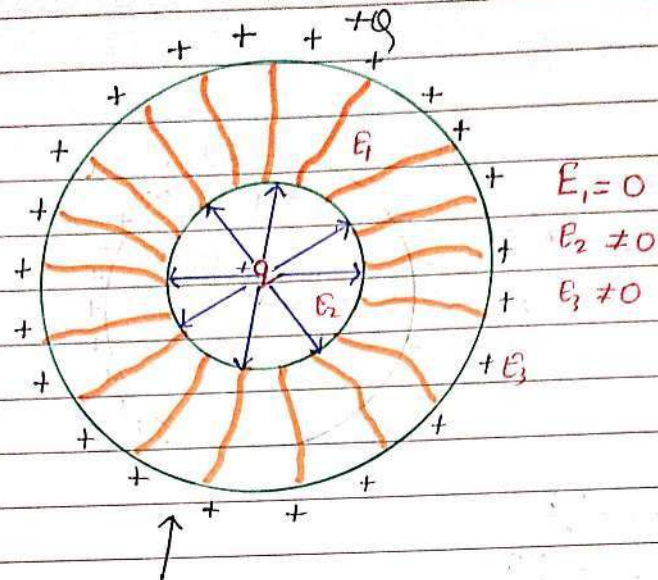
$$(V_p)_{\text{net}} = \frac{kQ}{r}$$

$$(V_p)_{+Q} = \frac{kQ}{r'}$$

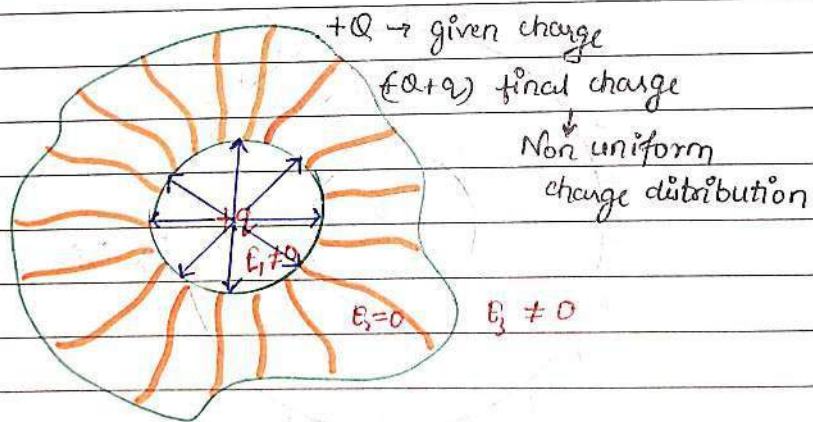
$$(V_p)_{\text{induced}} = \frac{kQ}{r} - \frac{kQ}{r'}$$

CONDUCTOR WITH CAVITY

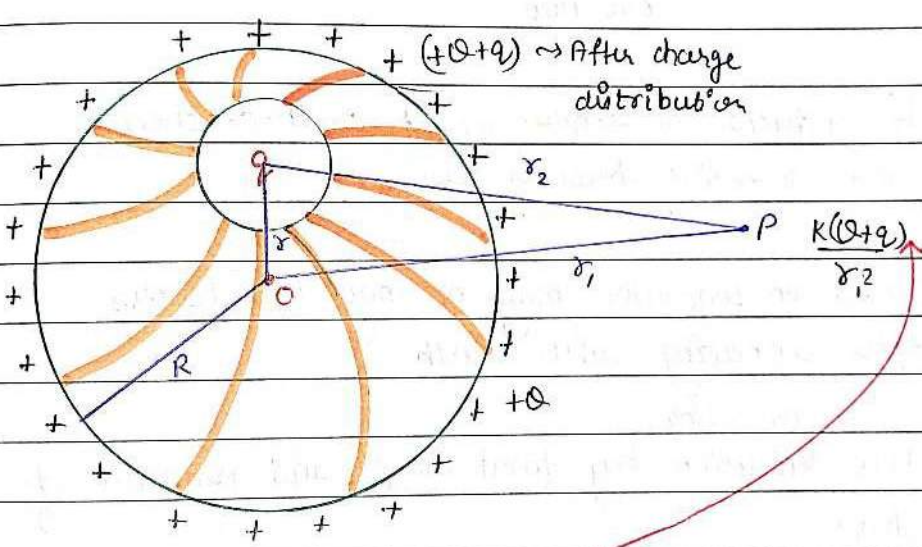
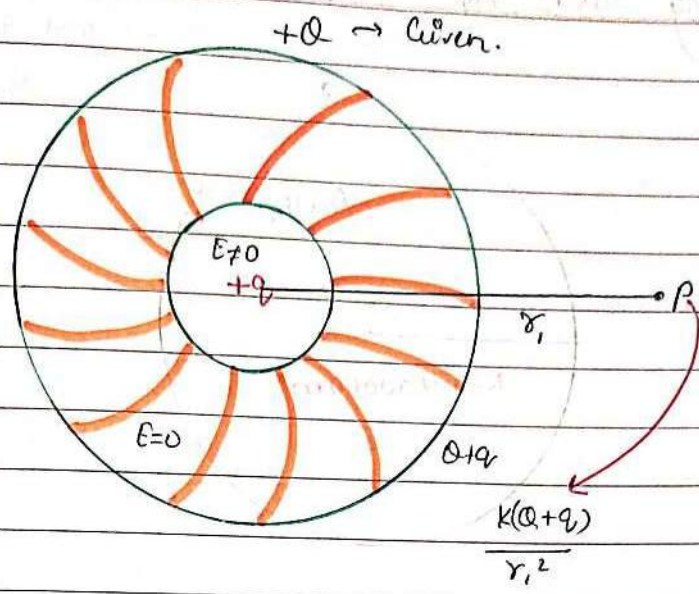




Final net charge $(Q+q)$
on surface
which is uniformly
distributed.



Q Find electric field at 'P'

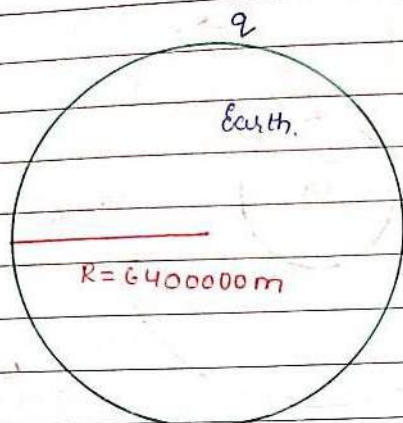


Find electric field at point P

If the question was like a charge q is placed at centre of cavity then electric field at P

$$= \frac{kq}{r_1^2}$$

Why earth has zero potential

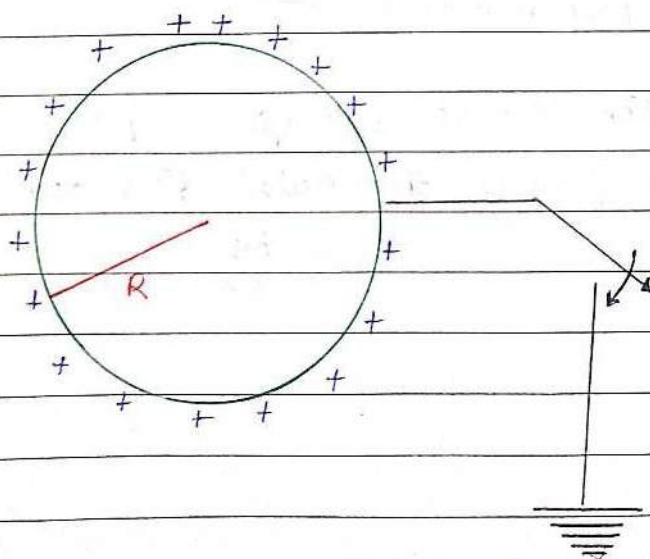


$$V_{\text{surface}} = \frac{kq}{6400000} \xrightarrow{\text{very small}} = \frac{1}{\infty} = 0$$

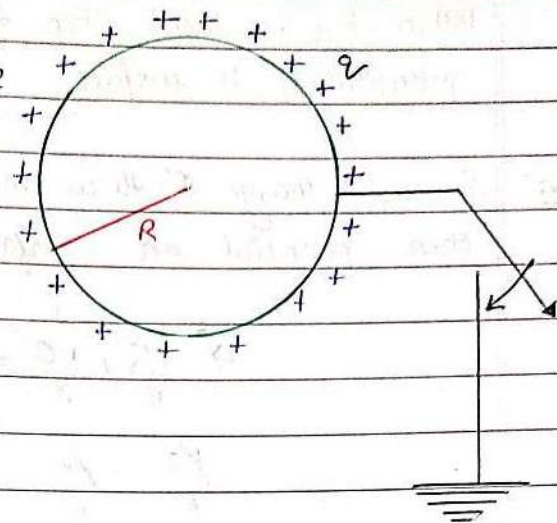
* If conductor is ~~conductor~~ earthed then its potential becomes zero

* Charge on conductor may or may not be zero after connecting with earth.

Q After ^{connecting} connection key final charge and potential of sphere.



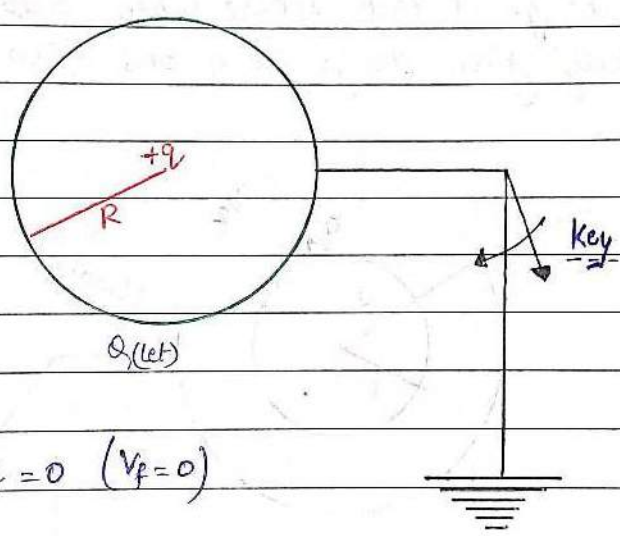
lets suppose a final charge q remains on the surface of conductor after connecting it with earth



$$\frac{kq}{R} = 0$$

$$q = 0$$

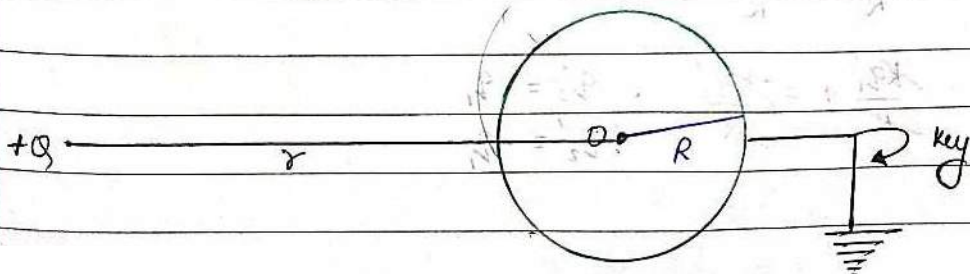
Q $+q$ charge is placed at centre of conductor then find final charge



$$\frac{kQ}{R} + \frac{kq}{R} = 0 \quad (V_f = 0)$$

$$\frac{kQ}{R} = -\frac{kq}{R}$$

$$Q = -q \text{ Ans}$$



When key is closed then find charge on sphere and potential on its surface.

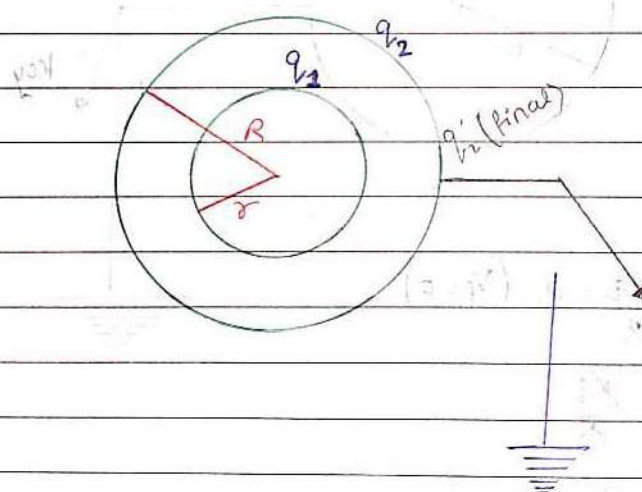
Ans Suppose a charge Q' flows to the surface of sphere then potential on surface

$$\Rightarrow \frac{kQ'}{R} + \frac{kQ}{r} = 0$$

$$\frac{kQ'}{R} = -\frac{kQ}{r}$$

$$Q' = -\frac{QR}{r}$$

Q Find charge on each sphere when outer sphere is earthed initially given charge is q_1 and q_2 as shown in figure.



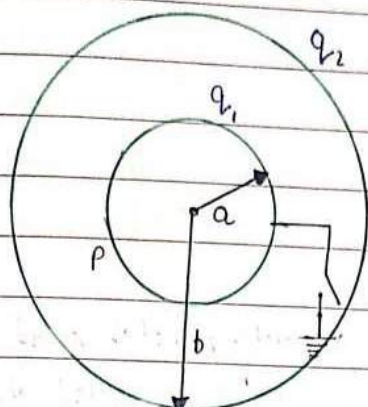
Ans Potential on outer surface should be '0'.

$$\therefore \frac{kq_1}{R} + \frac{kq_2'}{r} = 0$$

$$\frac{kq_1}{R} = -\frac{kq_2'}{r} \quad q_2' = -q_1$$

$$q_2' = -q_1$$

Q Find charge on each sphere when inner sphere is earthed



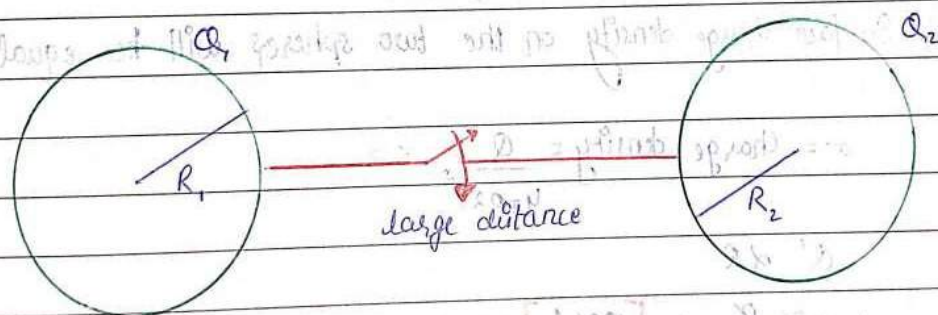
Ans V_0 Potential on inner surface = 0

$$V_p = 0$$

$$\Rightarrow \frac{kq_1}{a} + \frac{kq_2}{b} = 0$$

$$q_1 = -\frac{q_2 a}{b} \quad \text{Ans}$$

Q Find final charge on each sphere when key is closed



Ans After key is closed potential of both sphere is zero

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

$$\frac{kQ_1'}{R_1} = \frac{kQ_2'}{R_2}$$

$$\frac{Q_1'}{R_1} = \frac{Q_2'}{R_2}$$

$$(Q_1 + Q_2) - Q_2' = \frac{Q_2'}{R_2} R_1$$

$$R_2 Q_1 + R_2 Q_2 - R_2 Q_2' = Q_2' R_1$$

$$\frac{R_2(Q_1 + Q_2)}{R_1 + R_2} = Q_2'$$

$$Q_2' = \frac{R_2 (Q_1 + Q_2)}{R_1 + R_2}$$

Similarly

$$Q_1' = \frac{R_1 (Q_1 + Q_2)}{R_1 + R_2}$$

Q Two ~~insulated~~ ^{isolated} charged conducting spheres of radii 20 cm and 15 cm respectively and having equal charge of 10 μC are connected by a copper wire and then they are separated. Hence.

- Both spheres will have equal charges.
- Surface charge density on the 20 cm sphere will be greater than that on the 15 cm sphere.
- ☒ Surface charge density on the 15 cm sphere will be greater than that on the 20 cm sphere.
- Surface charge density on the two spheres will be equal.

Ans $\sigma = \text{charge density} = \frac{Q}{4\pi R^2}$

$$Q \propto R$$

$$\therefore \sigma \propto \frac{R}{R^2} \Rightarrow \left[\sigma \propto \frac{1}{R} \right] \checkmark$$

Q Two spheres of radii R_1 and R_2 respectively are charged and joined by a wire. The ratio of electric field of spheres is.

- $\frac{R_2^2}{R_1^2}$
- $\frac{R_1^2}{R_2^2}$
- ☒ $\frac{R_2}{R_1}$
- $\frac{R_1}{R_2}$

Ans $E = \frac{kQ}{R^2}$

as $Q' \propto R$

$\therefore E \propto \frac{R'}{R^2} = \frac{1}{R}$

$\boxed{E \propto \frac{1}{R}} \Rightarrow$

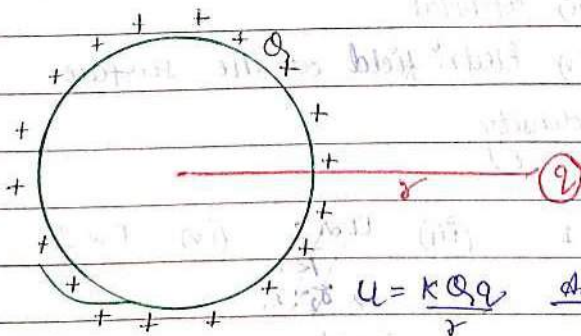
Q A conducting sphere of radius 10 cm is charged with 10 μC . Another uncharged sphere of radius 20 cm is allowed to touch it for some time. After this if the spheres are separated, then surface density of charge on the spheres will be in the ratio of

- 1) 1:1 2) 2:1
3) 1:3 4) 1:4

Ans $\sigma \propto \frac{1}{R} = \frac{20}{10} = 2:1$

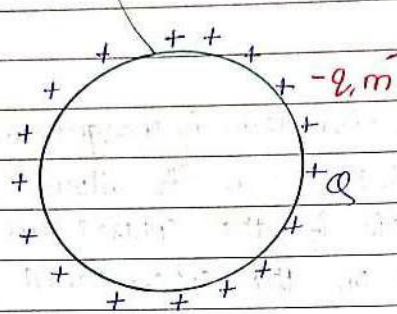
Q Charge Q is placed on surface of hollow conductor of radius R then find potential energy of charge q placed at r ($r > R$) from the centre of sphere.

Ans



$\frac{1}{R} = \frac{10}{20} \quad (\checkmark)$

Q A charge is placed on surface of hollow sphere find speed given to the charge $(-q, m)$ surface of sphere so that it will escape to infinity.



Ans By COME.

$$-\frac{kQq}{R} + \frac{1}{2}mv^2 = 0$$

$$\frac{1}{2}mv^2 = \frac{kQq}{R}$$

$$v = \sqrt{\frac{2kQq}{mR}} \text{ Ans}$$

Q Two charged metallic spheres of radii r_1 and r_2 are touched and separated. Calculate the ratio of their

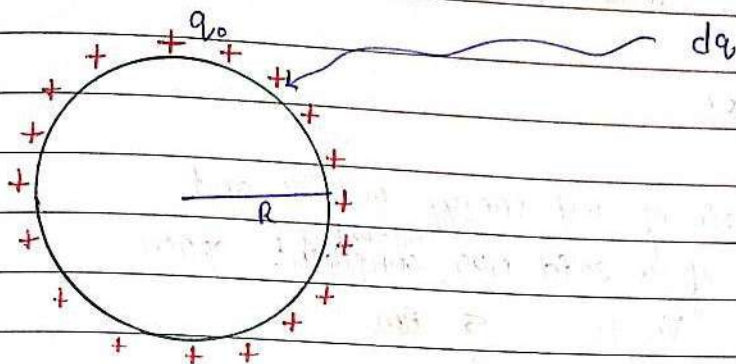
- (i) Charges
- (ii) Potential
- (iii) Self energy
- (iv) Electric field at the surface
- (v) Surface charged density.

Ans (i) $\frac{r_1}{r_2}$ (ii) 1:1 (iii) $U \propto \frac{1}{R}$ (iv) $E \propto \frac{1}{R}$ $\frac{E_1}{E_2} = \frac{r_2}{r_1}$

(v) $\frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}$ $\frac{u_1}{u_2} = \frac{r_1}{r_2}$

Q Find work done in bringing Q charge from infinity to the surface of hollow sphere of radius R (self energy)

Ans



Let any time t charge on sphere is q_0

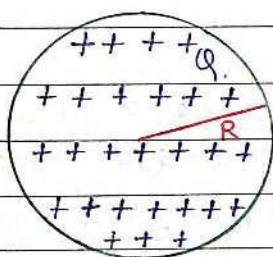
$$dW = \int \frac{k q_0 dq}{R^2}$$

$$W = \frac{k}{R} \left[\frac{q_0^2}{2} \right]_0^Q = \frac{kQ^2}{2R}$$

∴ (self energy) = $\frac{kQ^2}{2R} = 0.5 \frac{kQ^2}{R}$
electrostatic energy

This electrostatic energy is stored from surface to infinity.

Q Self energy of non conducting solid sphere.



∴ $E_{out} \neq 0$
 $E_{in} \neq 0$

Ans $U_E = \frac{0.6 K Q^2}{R} = (0.1 + 0.5) \frac{K Q^2}{R}$

↑ outside
↓ Inside

$U_E = \frac{3 K Q^2}{5 R}$

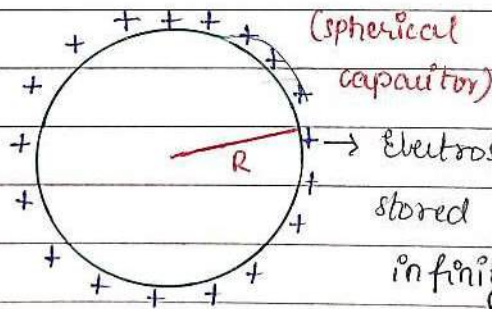
AIIMS Find ratio of self energy outside and inside of a solid non-conducting sphere.

$\frac{V_{\text{outside}}}{V_{\text{inside}}} = \frac{5}{1}$ Ans

✓ $U_{\text{solid non conductor}} = \frac{0.5 K Q^2}{R} + \frac{0.1 K Q^2}{R} = \frac{3 K Q^2}{5 R}$

CAPACITOR

A device which stores electrostatic energy by storing charge.

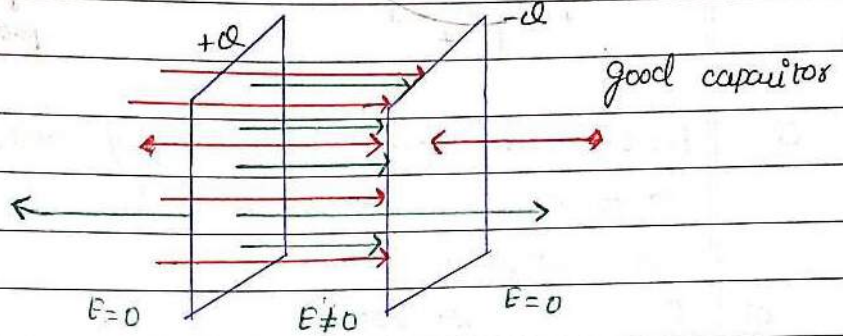
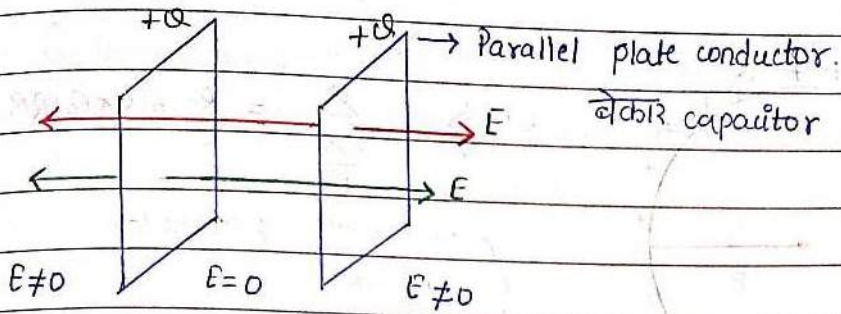


$C = \frac{Q}{V}$ Charge Potential

$C \propto Q$

$C \propto 1/V$

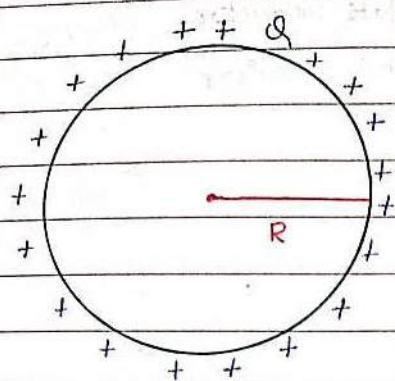
→ Kisi bhi sphere ka potential jitna jyada hoga utna hi jyada apko work karne padega us conductor ko charge karne ke liye.



Capacitor is a combination of two conductor two used to store electrostatic energy by storing charge.

- Any arrangement of two isolated conductors carrying equal and opposite charges can be called as capacitor.
- If $V = V_1 - V_2$ potential difference and charge Q and $-Q$ respectively then capacitance $C = \frac{Q}{V}$
- Scalar quantity
- S.I. unit farad; $1 \text{ Farad} = 1 \text{ C/V} / \text{C}^2/\text{J}$

CAPACITANCE OF ISOLATED SPHERICAL CONDUCTOR.



$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{4\pi\epsilon_0 R}} = \frac{R}{\frac{1}{4\pi\epsilon_0}} = 4\pi\epsilon_0 R$$

→ property of conductor
 $C = 4\pi\epsilon_0 R$
 ↓
 Independent of charge and potential

Q 1000 small water drops each of capacitance C join together to form one large spherical drop. The capacitance of bigger sphere is.

- a) C b) $10C$
 c) $100C$ d) $1000C$

Sol

$$\frac{C'}{C} = \frac{4\pi\epsilon_0 R'}{4\pi\epsilon_0 R} \Rightarrow \frac{C'}{C} = \frac{n^{1/3}}{1} = n^{1/3} = (1000)^{1/3} = 10 \text{ Ans}$$

Ex

Q A bullet of mass 2g is having a charge of 2μC. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s.

- a) 5 kV ~~b) 50 kV~~
c) 5 V (d) 50 V

Ans $W = AK \cdot E$

$$q \Delta V = \frac{1}{2} m v^2$$

$$\Delta V = \frac{1}{2} \times \frac{2 \times 10^{-3} \times 10^5}{2 \times 10^{-6}} = 50 \times 10^3 \text{ V} = 50 \text{ kV} \text{ Ans}$$

Q Two metallic spheres of radii 1 cm and 3 cm are given charges of $-1 \times 10^{-2} \text{ C}$ and $5 \times 10^{-2} \text{ C}$ respectively. If these are connected by a conducting wire, the final charge on the bigger sphere.

- a) $2 \times 10^{-2} \text{ C}$ ~~b) $3 \times 10^{-2} \text{ C}$~~
c) $4 \times 10^{-2} \text{ C}$ (d) $1 \times 10^{-2} \text{ C}$

Ans $Q' = \frac{3}{4} \times (4 \times 10^{-2}) = 3 \times 10^{-2} \text{ C}$

Q Two metallic spheres of radii 1 cm and 2 cm are given charges 10^{-2} C and $5 \times 10^{-2} \text{ C}$ respectively. If they are connected by a conducting wire, the final charge on smaller sphere.

- a) $3 \times 10^{-2} \text{ C}$ (b) $4 \times 10^{-2} \text{ C}$
~~c) $2 \times 10^{-2} \text{ C}$~~ (d) $1 \times 10^{-2} \text{ C}$

Ans $Q' = \frac{1}{3} \times 2 \times 10^{-2}$

★ Q

Two metallic spheres one of radius R and the other of radius $2R$ respectively have the same surface charge density σ . They are brought in contact and separated. What will be the new surface charge densities on them?

a) $\sigma_1 = \frac{5}{6} \sigma, \sigma_2 = \frac{5}{2} \sigma$ (b) $\sigma_1 = \frac{5}{2} \sigma, \sigma_2 = \frac{5}{6} \sigma$

c) $\sigma_1 = \frac{5}{2} \sigma, \sigma_2 = \frac{5}{3} \sigma$ (d) $\sigma_1 = \frac{5}{3} \sigma, \sigma_2 = \frac{5}{6} \sigma$

Ans

By trick $\sigma_1 : \sigma_2 = 2 : 1$

By concept $\sigma = \frac{Q_1}{4\pi R^2} \quad \sigma = \frac{Q_2}{4\pi R^2}$

$$Q_1' = \frac{R(Q_1 + Q_2)}{3R} = \frac{R(\sigma 4\pi R^2 \times 5)}{3R}$$

$$\frac{Q_1'}{4\pi R^2} = \frac{5\sigma}{3} \Rightarrow \sigma_1' = \frac{5}{3} \sigma$$

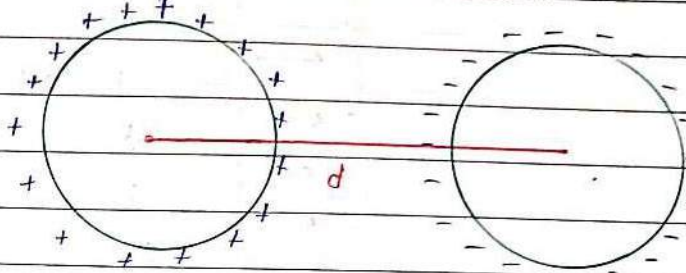
$$Q_2' = \frac{2R(Q_1 + Q_2)}{3R} = \frac{2(\sigma 4\pi R^2 \times 5)}{3}$$

$$Q_2' = \frac{2 \times 2 \times \sigma 4\pi R^2 \times 5}{3 \times 2}$$

$$\frac{Q_2'}{4\pi R^2 \times 4} = \frac{5\sigma}{6} \Rightarrow \sigma_2 = \frac{5}{6} \sigma \quad \text{Ans}$$

Q Two similar conducting balls having charges $+q$ and $-q$ are placed at a separation d from each other in air. The radius of each ball is r and the separation between their centres is $(d \gg r)$. Calculate the capacitance of the two ball system.

- a) $4\pi\epsilon_0 r$ ~~b) $2\pi\epsilon_0 r$~~
c) $4\pi\epsilon_0 \log_e \frac{e_0 r}{d}$ d) $4\pi\epsilon_0 \log_e \frac{r}{d}$



Ans

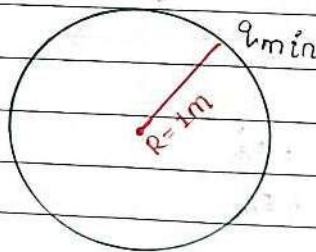
$$C = \frac{Q}{\Delta V}$$

$$\Delta V = \frac{kq}{r} - \left(-\frac{kq}{r} \right)$$

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

$$C = \frac{Q}{\Delta V} = \frac{q}{\frac{2kq}{r}} = \frac{r}{2k} = \frac{r}{2 \times \frac{1}{4\pi\epsilon_0}} = 2\pi\epsilon_0 r$$

- Air is insulator upto certain field, after that it behaves as conductor, that limit is called dielectric strength of air ($3 \times 10^6 \text{ N/C}$)

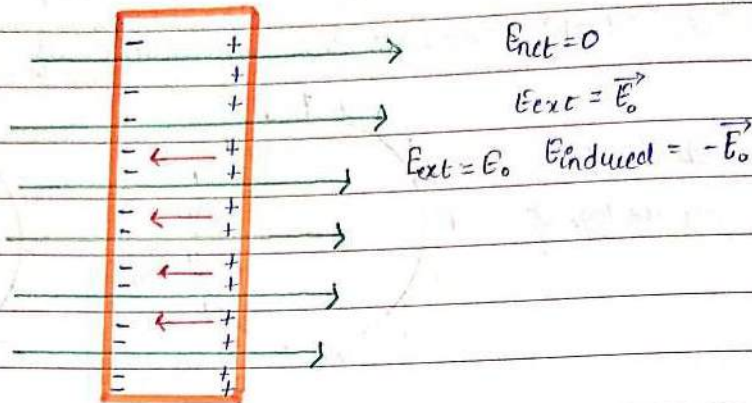


$$E = \frac{kQ}{R^2}$$

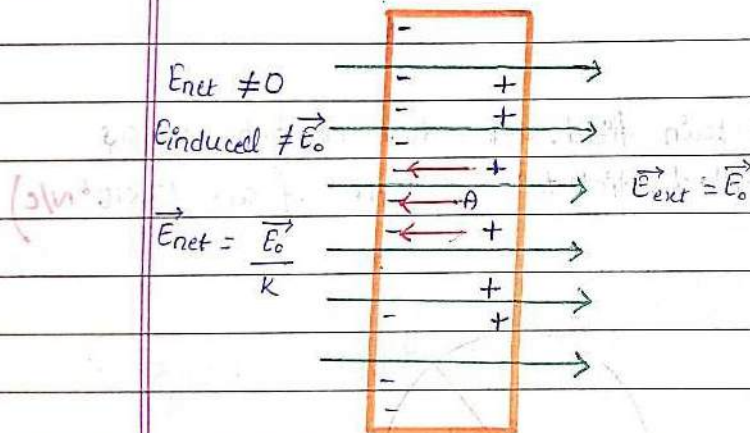
$$3 \times 10^6 = \frac{9 \times 10^9 \times Q}{1}$$

$$Q = 3.33 \times 10^{-4} \text{ C}$$

- When conductor is placed in an electric field.



Dielectric placed in electric field



$$\vec{E}_{net} = \vec{E}_{ext} + \vec{E}_{in}$$

$$\frac{\vec{E}_0}{K} = E_0 + E_{in}$$

$$E_{in} = -E_0 + \frac{E_0}{K}$$

$$E_{in} = -E_0 \left(1 - \frac{1}{K} \right)$$

$$E_{in} = -E_0 \left(1 - \frac{1}{K} \right)$$

For conductor $K = \text{infinite}$
the $E_{in} = -E_0$.

DIMENSION OF CAPACITANCE

$$C = \frac{Q}{V} = \frac{Q^2}{VU} = \frac{(IT)^2}{\frac{ML^2T^{-2}}{ML^2T^{-2}}} = \frac{I^2 T^2}{ML^2T^{-2}} = \boxed{M^{-1}L^{-2}I^2T^4}$$

Q What is capacitance of earth.
 → Earth is a sphere hence its capacitance

$$C = 4\pi\epsilon_0 R$$

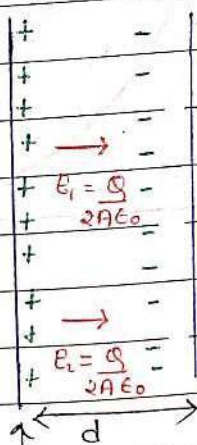
$$C = \frac{1}{9 \times 10^9} \times 6400 \times 10^3 = \boxed{711 \mu F}$$

Potential of earth is zero
 but capacitance does not
 depend on potential.

PARALLEL PLATE CAPACITOR.

(i) Electric field b/w the plate.

+Q -Q



$$E_{net} = \frac{Q}{2A\epsilon_0} + \frac{Q}{2A\epsilon_0}$$

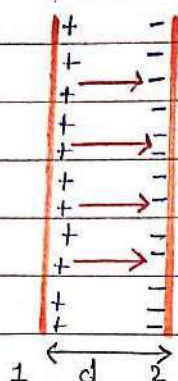
$$= \frac{2Q}{2A\epsilon_0}$$

$$\sigma = \frac{Q}{A} \quad E_{net} = \frac{\sigma}{\epsilon_0} \quad \text{OR} \quad E_{net} = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0}$$

$$\Rightarrow \frac{\sigma}{\epsilon_0}$$

charge is only on
 one surface
 due to attraction
 therefore it will
 behave as non conducting
 plate.

POTENTIAL DIFFERENCE B/W THE PLATE



$$E = \frac{\sigma}{\epsilon_0} \text{ (constant)}$$

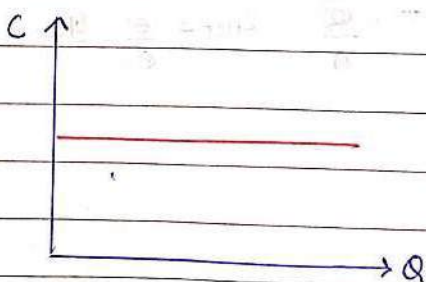
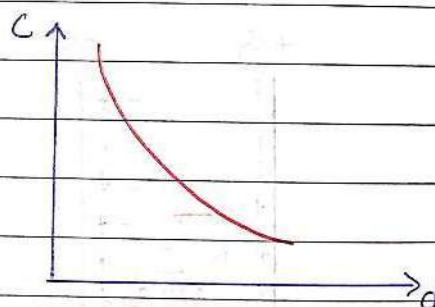
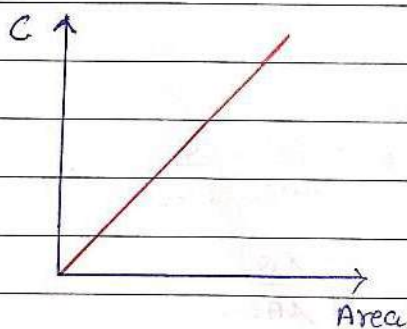
$$E = - \frac{\Delta V}{\Delta r}$$

$$\frac{\sigma}{\epsilon_0} d = V_1 - V_2$$

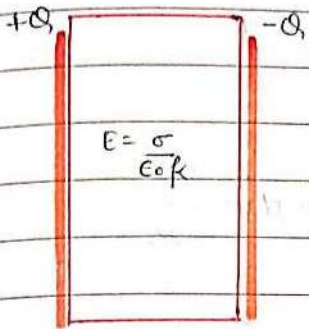
$$V_1 - V_2 = \frac{Qd}{A\epsilon_0}$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{Qd/A\epsilon_0} = \frac{A\epsilon_0}{d} = \frac{\epsilon_0 A}{d} \text{ Ans}$$

$$C = \frac{\epsilon_0 A}{d} \left(\begin{matrix} C \propto \epsilon_0 & C \propto d^{-1} \\ C \propto A \end{matrix} \right)$$



If dielectric medium of dielectric constant $k = \epsilon_r$ is placed between the plate then capacitance will be.



$$\Delta V = Ed$$

$$= \frac{\sigma}{\epsilon_0 k} Ad \quad C = \frac{Q}{\Delta V} = \frac{\epsilon_0 k A}{d}$$

$$C = \frac{\epsilon_0 k A}{d} = C = \frac{\epsilon_m A}{d}$$

Q The capacitance of a parallel plate capacitor with air as medium is $6 \mu\text{F}$. With the introduction of a dielectric medium, the capacitance becomes $30 \mu\text{F}$. The permittivity of the medium is. ($\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$)

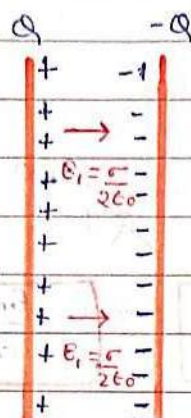
a) $0.44 \times 10^{-13} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ (b) $1.77 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

c) $0.44 \times 10^{-10} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ (d) $5.00 \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

Ans $\frac{6 \mu\text{F}}{d} = \frac{\epsilon_0 A}{d} \Rightarrow \epsilon_m = 5 \epsilon_0$
 $= 0.44 \times 10^{-10} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

$5 \times 30 \mu\text{F} = \frac{\epsilon_m A}{d}$

DUE FORCE ON ONE PLATE TO OTHER / PRESSURE EXPERIENCED BY PLATE



Electric field = $\frac{\sigma}{\epsilon_0}$
b/w plate

Electric field at one plate = $\frac{\sigma}{2\epsilon_0}$

~~$F = q(E_{net})$
 $= Q \frac{\sigma}{\epsilon_0} = \frac{Q\sigma}{\epsilon_0} = \frac{Q^2}{A\epsilon_0}$~~

It is wrong
we should take electric field due to one plate.

$F = qE$ (electric field due to other plate)

Force on Charge on other plate one plate

$F = \frac{Q\sigma}{2\epsilon_0} = \frac{Q^2}{2A\epsilon_0}$

$P = \frac{F}{A} = \frac{Q^2}{2A^2\epsilon_0} = \frac{\sigma^2}{2\epsilon_0}$

Energy density = $\frac{\text{Energy}}{\text{Volume}} = \frac{\sigma^2}{2\epsilon_0}$

Energy = $\frac{\sigma^2}{2\epsilon_0} \times \text{Volume} = \frac{\sigma^2}{2\epsilon_0} \times Ad = \frac{Q^2}{A^2} \frac{Ad}{2\epsilon_0} = \frac{Q^2 d}{2A\epsilon_0}$

Energy = $\frac{Q^2 d}{2A\epsilon_0} = \frac{Q^2}{2C}$

Energy = $\frac{1}{2} C V^2$ (as $Q = CV$)

Parallel plate capacitor

$$1) E_{net} \Rightarrow \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$$

$$2) AV = \frac{\sigma d}{\epsilon_0} = \frac{Qd}{A\epsilon_0}$$

$$3) G_{ir} = \frac{\epsilon_0 A}{d} = \frac{\epsilon_0 k A}{d}$$

$$4) C_{medium} = \frac{\epsilon_m A}{d} = \frac{\epsilon_0 k A}{d}$$

$$5) \text{Force} = QE = \frac{Q\sigma}{2\epsilon_0} = \frac{Q^2}{2A\epsilon_0}$$

$$6) \text{Pressure} = \frac{F}{A} = \frac{Q^2}{2A^2\epsilon_0} = \frac{\sigma^2}{2\epsilon_0}$$

$$7) \text{Energy density} = \frac{\sigma^2}{2\epsilon_0} = \frac{Q^2}{2A^2\epsilon_0}$$

$$8) \text{Energy} = \frac{1}{2} CV^2 = \frac{Q^2}{2C}$$

Q A parallel plate conductor with oil between the plates (dielectric constant of oil $k=2$) has a capacitance of C . If the oil is removed then the capacitance becomes

a) $C/\sqrt{2}$ b) $2C$

c) $\sqrt{2}C$ ~~d) $C/2$~~

Ans $C' = k C_{air}$

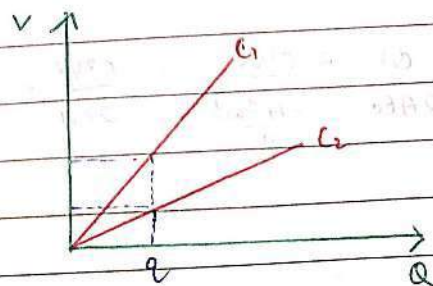
$$C_{air} = \frac{C'}{k} = \frac{C}{2}$$

Q For two conductors capacitors graph between potential and charge is given then which of the following is correct?

a) $C_1 = C_2$

b) $C_1 > C_2$

~~c) $C_1 < C_2$~~



Ans Concept $\rightarrow$ For a charge q voltage is more for $C_1 \therefore C_2 > C_1$

⇒ By formula

$$Q = CV$$

$$\frac{V}{Q} = \frac{1}{C}$$

Slope is more for $C_1 \because C_1 < C_2$

Q The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A , is.

- a) independent of the distance b/w the plate
- b) linearly proportional to the distance b/w the plates
- c) proportional to the square root of the distance b/w the plates.
- d) inversely proportional to the distance b/w the plates.

Ans $F = QE = \frac{Q^2}{2A\epsilon_0}$

Q A parallel plate air capacitor has capacity C , distance of separation between plates is d and potential difference V is applied b/w the plates. Force of attraction b/w the plates of the parallel plate air capacitor.

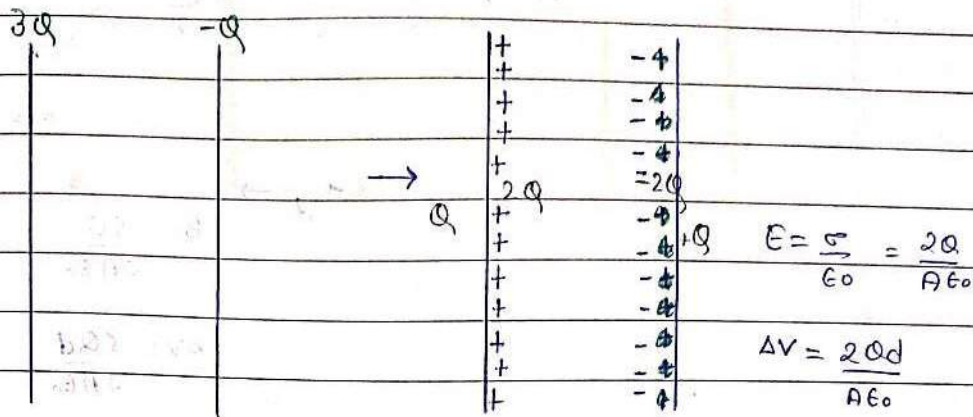
a) $\frac{CV^2}{d}$ b) $\frac{C^2V^2}{2d^2}$

c) $\frac{C^2V^2}{2d}$ ~~c) $\frac{CV^2}{2d}$~~

Ans $F = \frac{Q^2}{2A\epsilon_0} = \frac{C^2V^2}{2A\epsilon_0 d} = \frac{C^2V^2}{2Cd} = \frac{CV^2}{2d}$

Q One plate given charge Q is neutral then find field and potential difference b/w them.

b/w the plate

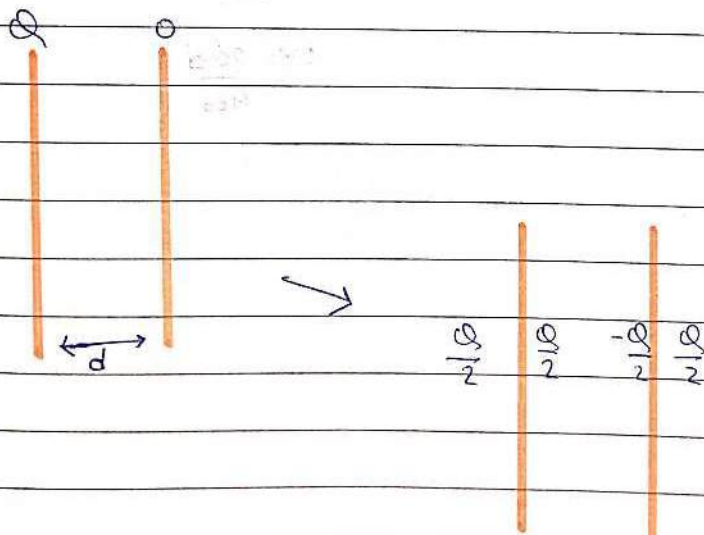


Electric field
& potential diff

is only due to charge
on inner surface

Q One plate of charge Q and other is neutral then find b/w the plate and potential difference.

field



$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{2A\epsilon_0}$$

$$\Delta V = \frac{Qd}{2A\epsilon_0}$$

Q

$3Q$

$-2Q$



$\frac{Q}{2}$

$\frac{5Q}{2}$

$-\frac{5Q}{2}$

$+\frac{Q}{2}$

$$\sigma = \frac{5Q}{2A}$$



$$E = \frac{5Q}{2A\epsilon_0}$$

$$\Delta V = \frac{5Qd}{2A\epsilon_0}$$

Q

$6Q$

$2Q$



$4Q$

$2Q$

$-2Q$

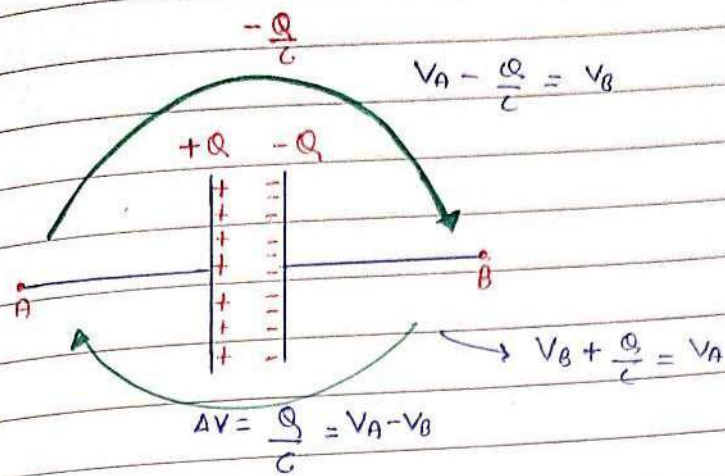
$4Q$

$$E = \frac{2Q}{A\epsilon_0}$$

$$\sigma = \frac{2Q}{A}$$

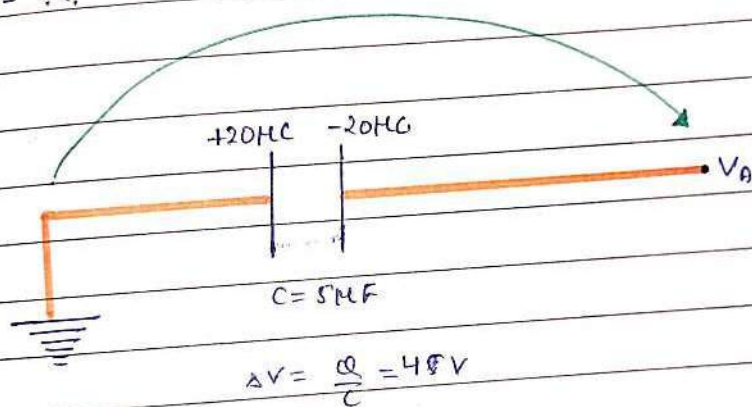
$$\Delta V = \frac{2Qd}{A\epsilon_0}$$

Find $V_A - V_B$



$$V_A - V_B = \frac{Qd}{\epsilon_0 A}$$

Find $V_A = ??$

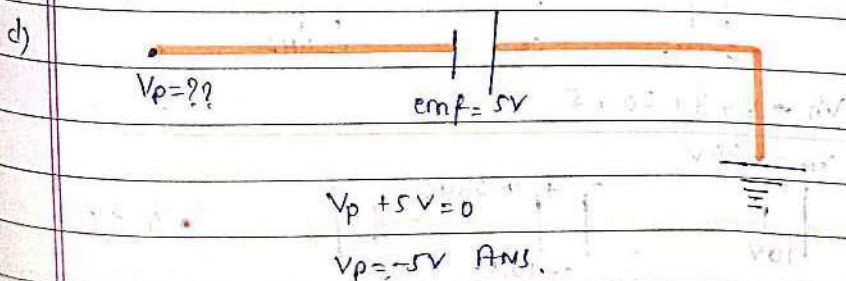
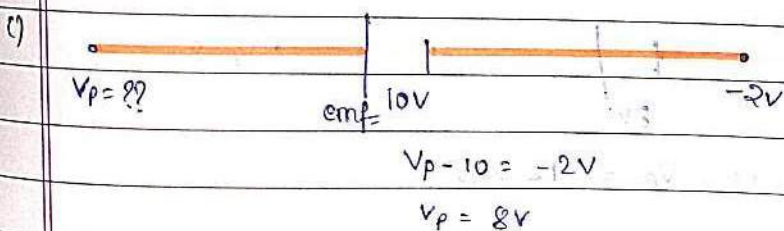
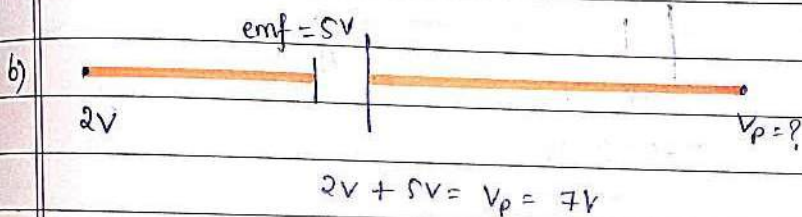
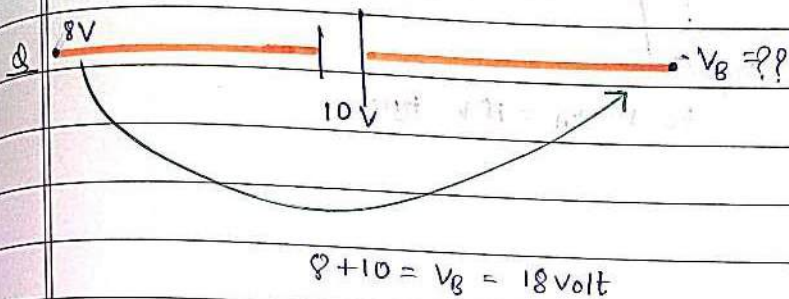


$$0 - 4 = V_A$$

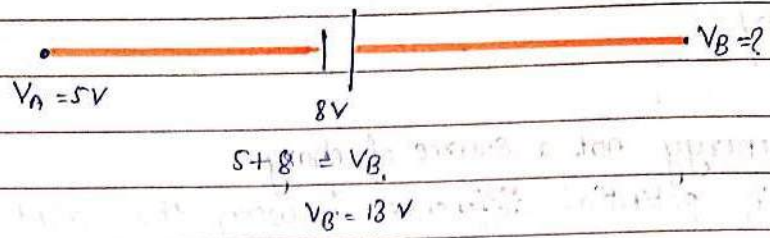
$$V_A = 4 \text{ volt} - 4 \text{ volt}$$

BATTERY

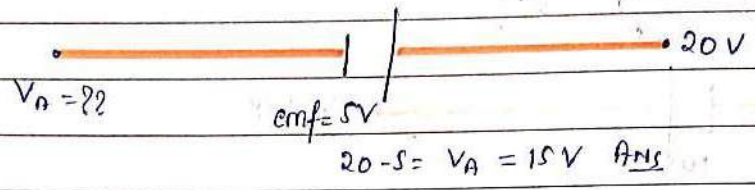
- Source of energy not a source of charge.
- It maintain potential difference between the points where it is connected
- Work done by battery = $q\Delta V$



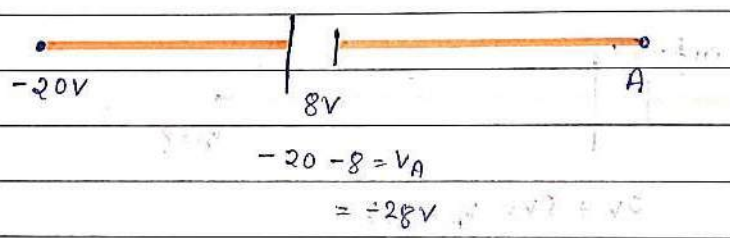
e)



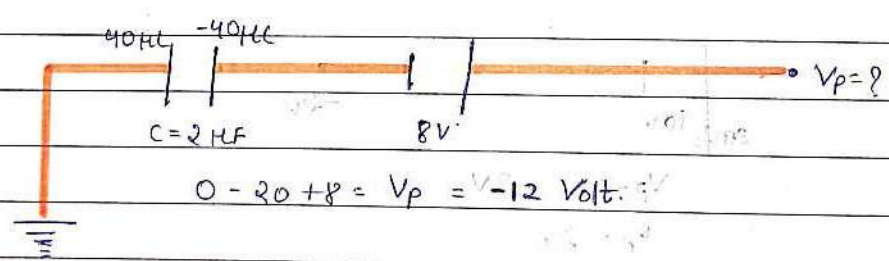
f)



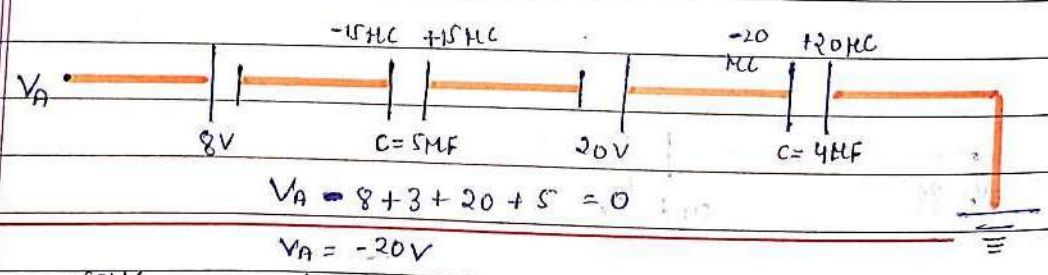
g)



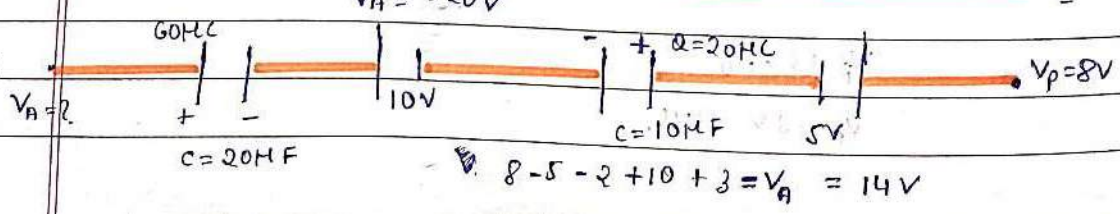
h)



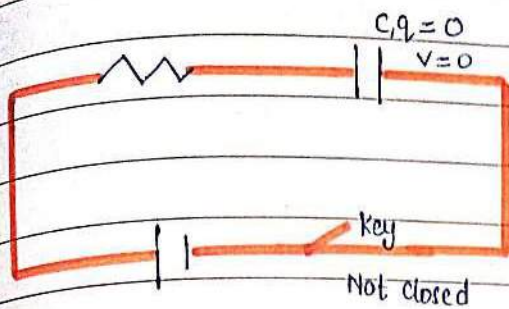
(i)



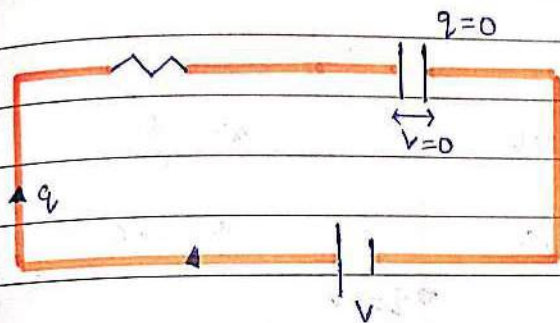
(ii)



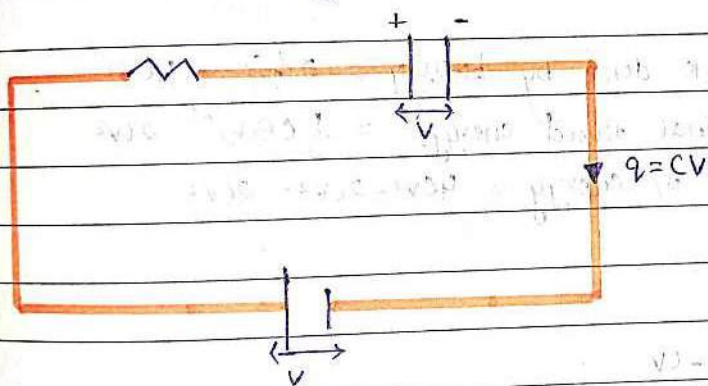
CHARGING OF CAPACITOR (D/C RC circuit)



i) At $t=0$ just after switch is closed.



ii) At time $(t = \infty)$ steady state.

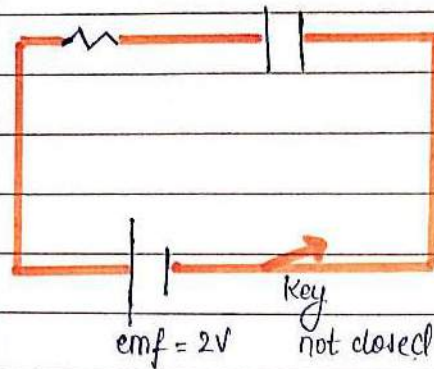


i) Energy stored in capacitor $= \frac{1}{2} CV^2$

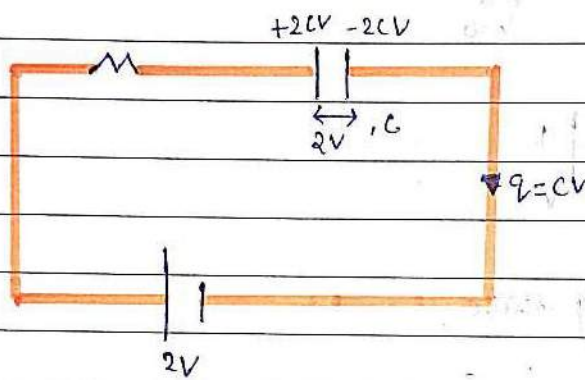
ii) Work done by the battery in charging this capacitor $= qV = CV^2$

iii) Loss in energy $= \frac{1}{2} CV^2$ in charging

Q Find work by battery and U_{loss} .



At steady state.



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

$$Q = 2VC$$

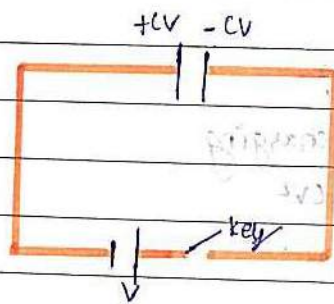
1) Work done by battery = $2CV^2 = 4CV^2$

2) $U_{\text{final stored energy}} = \frac{1}{2}C(2V)^2 = 2CV^2$

3) Loss in energy = $4CV^2 - 2CV^2 = 2CV^2$

Q Find loss in $U_{\text{loss}} =$

Initially

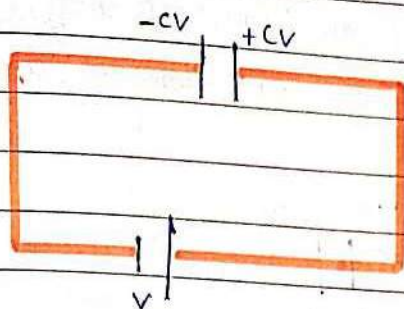


(i)

(ii)

(iii)

Finally



$$q = CV - (-CV) = 2CV$$

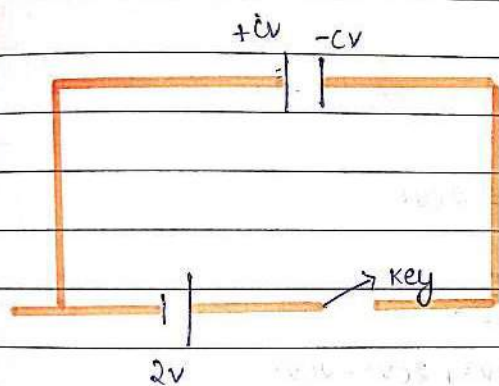
$$\text{work done by battery} = 2CV^2$$

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

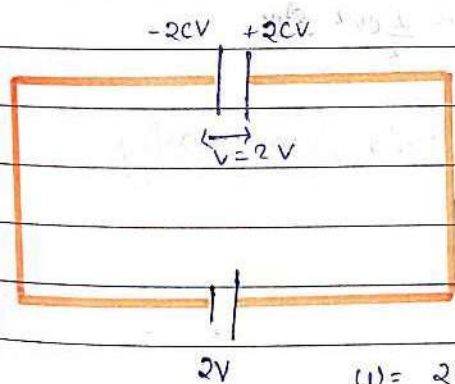
$$U_i = \frac{1}{2}CV^2$$

$$U_{\text{loss}} = 2CV^2$$

Q When key is closed the find loss in energy.



Initially



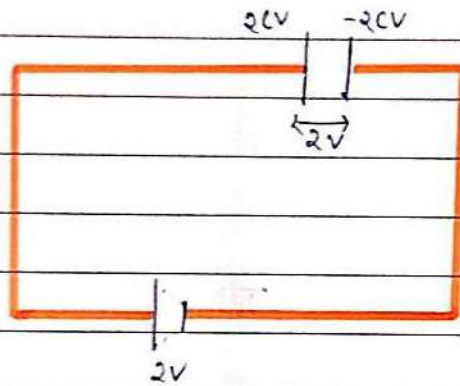
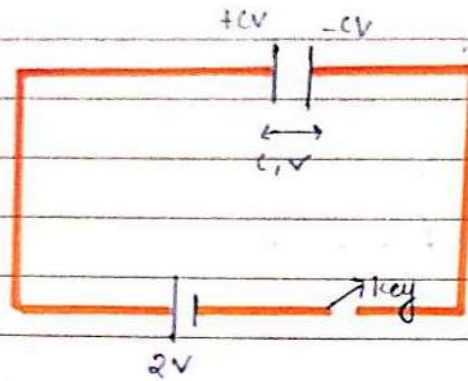
$$W = 2V \times 3CV = 6CV^2$$

$$U_{\text{loss}} = U_i + W - U_f$$

$$= \frac{1}{2}CV^2 + 6CV^2 - \frac{1}{2} \times C \times 4V^2$$

$$\frac{CV^2 + 12CV^2 - 4CV^2}{2} = \frac{9CV^2}{2}$$

Q Initially capacitor of capacitance C is charged with potential V as shown in fig then find loss in energy when key is closed.



$$W = q \Delta V = CV \times 2V = 2CV^2$$

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

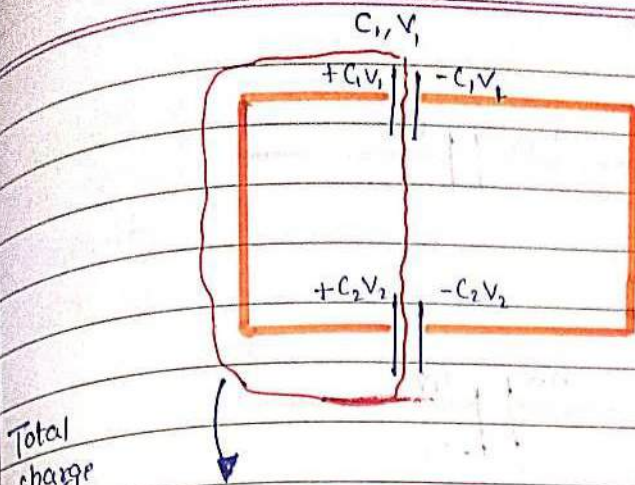
$$U_f = \frac{1}{2} \times C \times 2V^2 = 2CV^2$$

$$U_{\text{loss}} = 0.5CV^2 + 2CV^2 - 2CV^2$$

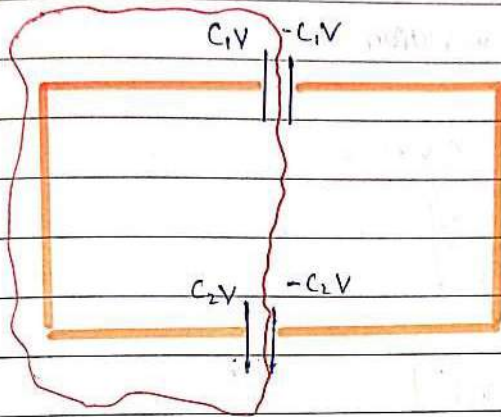
$$= \frac{1}{2} CV^2 \text{ Ans}$$

Q Two capacitors are connected with same polarity.

- (i) Find common potential
- (ii) Charge on each capacitor
- (iii) Loss in energy.



Total charge conserved



$$C_1V_1 + C_2V_2 = C_1V + C_2V$$

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

(ii) Charge on each capacitor = final potential (V) × capacitance

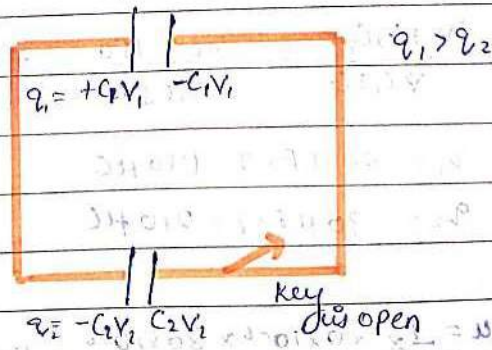
$$(iii) \text{ loss } \Rightarrow \Delta U = \frac{1}{2} \frac{C_1 C_2 (V_1 - V_2)^2}{C_1 + C_2}$$

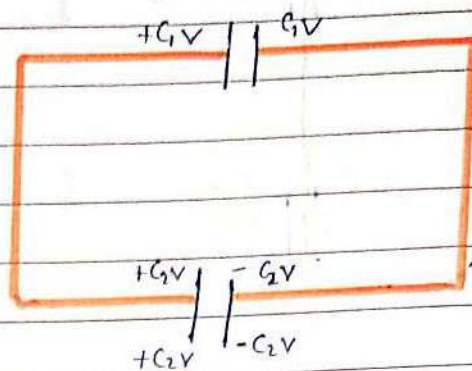
Q When key is closed, capacitors with opposite polarity joined.

(i) Common potential

(ii) Charge on each capacitor

(iii) loss in energy





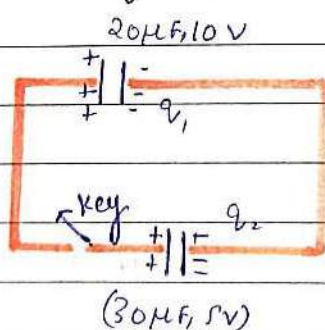
By charge conservation

$$C_1 V_1 - C_2 V_2 = C_1 V + C_2 V$$

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

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

Q When key is closed then find common potential & loss in energy and charge on each capacitor.



$$\text{Soln } V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2} = \frac{200 + 150}{4550} = \frac{350}{4550} = 7 \text{ volt}$$

$$q_1 = 20 \mu\text{F} \times 7 = 140 \mu\text{C}$$

$$q_2 = 30 \mu\text{F} \times 7 = 210 \mu\text{C}$$

$$\Delta U = \frac{1}{2} \times \frac{20 \times 10^{-6} \times 30 \times 10^{-6}}{50 \times 10^{-6}} \times (10-5)^2$$

A capacitor of capacity C_1 is charged upto V volt and then connected in parallel to an uncharged capacitor of capacity C_2 . The final potential difference across each will be.

$$\frac{C_2 V}{C_1 + C_2}$$

$$\text{b) } \frac{C_1 V}{C_1 + C_2}$$

$$\text{c) } 1 + \frac{C_2}{C_1}$$

$$\text{d) } \left(1 - \frac{C_2}{C_1}\right) V$$

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

A capacitor is charged with a battery and energy stored is u . After disconnecting battery another capacitor of same capacity is connected in parallel to the first capacitor. Then energy stored in each capacitor is.

$$\text{a) } u/2 \quad \text{b) } u/4 \quad \text{c) } u \quad \text{d) } 2u$$

$$\text{Ans } u = \frac{1}{2} C V^2$$

After disconnecting battery and connecting another capacitor

$$V_{\text{final}} = \frac{C V + C \times 0}{2C} = \frac{V}{2}$$

$$u_f = \frac{1}{2} \times C \frac{V^2}{4} + \frac{1}{2} C \frac{V^2}{4} = \frac{C V^2}{4}$$

$$u_{\text{total}}$$

$$u_{\text{on each capacitor}} = \frac{1}{2} \frac{C V^2}{4} = \frac{u}{4}$$

Q A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system.

- a) decrease by a factor of 2
- b) Remains the same
- c) increases by a factor of 2
- d) increases by a factor of 4.

Ans

$$U_i = \frac{1}{2} C V^2 \quad V_f = \frac{C V}{2C} = \frac{V}{2}$$

$$U_f = \frac{1}{2} C V^2 \quad \frac{1}{2} C \frac{V^2}{4} + \frac{1}{2} C \frac{V^2}{4}$$

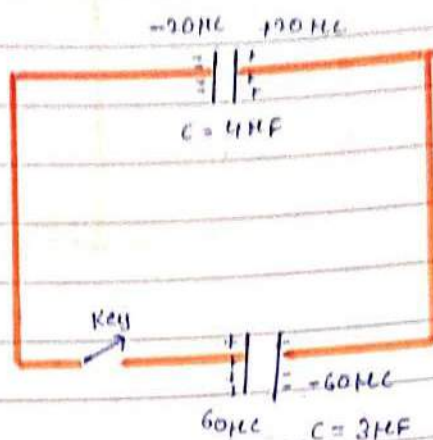
$$= \frac{1}{2} C \frac{V^2}{2}$$

Find loss in energy when key is closed?

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

$$= \frac{1}{2} \times \frac{4 \times 3 \times 10^{-12} (25)^2}{7 \times 10^{-6}}$$

$$\Delta U = \left(\frac{6 \times 625 \times 10^{-6}}{7} \right) \text{ J}$$



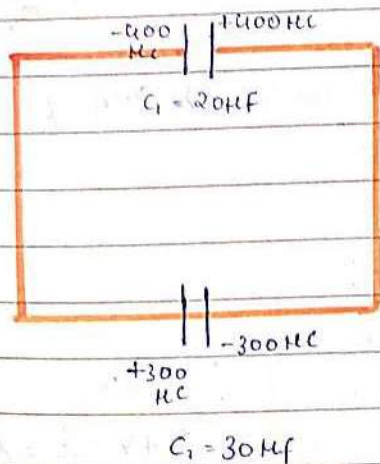
$$V_{\text{common}} = \frac{C_1 V_1 - C_2 V_2}{C_1 + C_2}$$

$$V_{\text{common}} = \frac{q_1 - q_2}{C_1 + C_2} = \frac{20 - 60}{4 + 3} = \frac{-40}{7} \text{ volt}$$

Common
Magnitude of
charge.

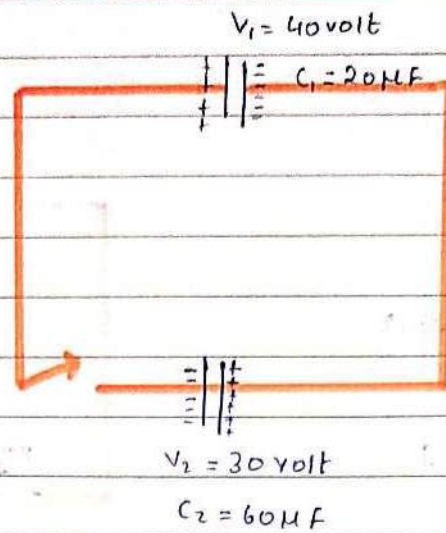
$$\frac{60 - 20}{4 + 3} = \frac{40}{7} \text{ volt}$$

Find common potential when key is closed.



$$V_{\text{common}} = \frac{400 - 300}{50} = \frac{100}{50} = 2 \text{ V}$$

Q



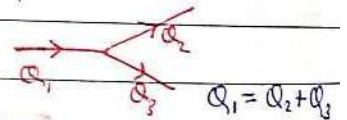
$$\text{Common potential} = \frac{1800 - 800}{80} = \frac{1000}{80} = 12.5 \text{ V Ans}$$

KIRCHOFF'S LAW

Conservation of charge

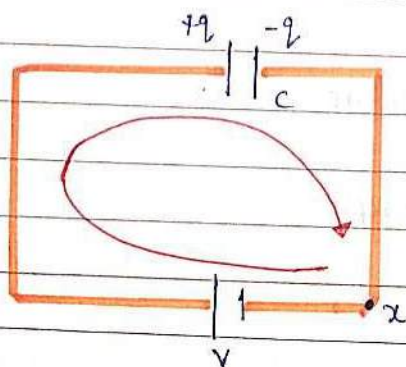
- Point Rule → at any point total sum of charges is zero

$$\sum Q_{in} = \sum Q_{out} \quad \text{or} \quad \sum Q_{net} = 0$$



- Loop Rule → Conservation of energy → sum of potential in close loop is always zero.

$$\sum \text{Potential} = 0$$



$$V_x = x$$

$$x + V - \frac{q}{C} = x$$

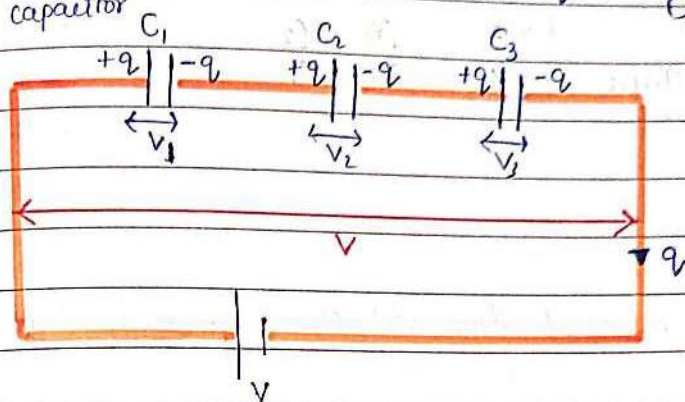
$$V = \frac{q}{C}$$

ye aana bhi chahiye tha

COMBINATION OF CAPACITOR

Charge same on each capacitor ✓

Sum of potential in capacitor is equal to the potential of Battery

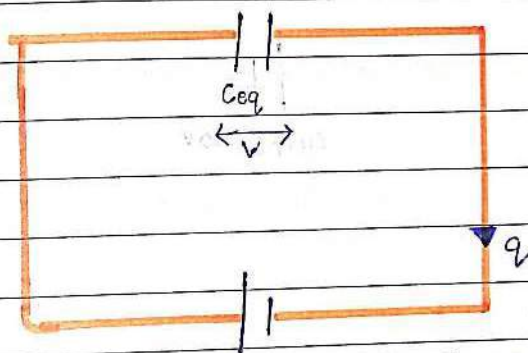


$$\sum \text{potential} = 0$$

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

$$\text{Given OR } V - V_1 - V_2 - V_3 = 0$$

$$V = V_1 + V_2 + V_3 \quad \dots \dots (i)$$



$$q = C_{eq} V$$

$$V = \frac{q}{C_{eq}} \quad \dots \dots (ii)$$

From (i) and (ii)

$$\frac{q}{C_{eq}} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

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

LAW OF POTENTIAL CONSTANT DROP

In series combination

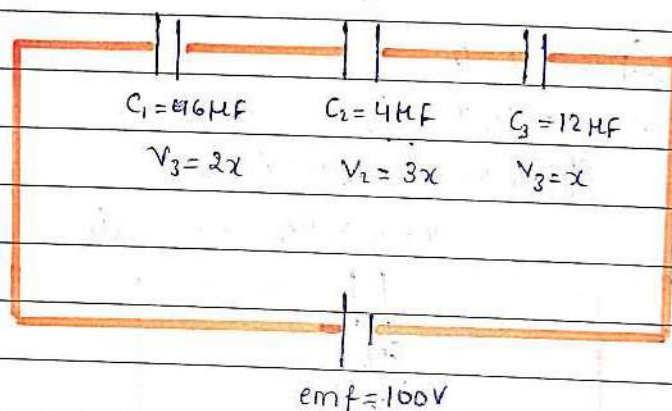
$$\rightarrow Q = CV$$

constant

$$C \propto \frac{1}{V}$$

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

Q Find potential drop and charge on each capacitor.



Ans

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{6} + \frac{1}{4} + \frac{1}{12} = \frac{2+3+1}{12}$$

$$C_{eq} = 2$$

$$Q = C_{eq} V = 200 \text{ HC}$$

$$V_1 = \frac{200}{6} = \frac{100}{3} \text{ V}$$

$$V_2 = \frac{200}{4} = 50 \text{ V}$$

$$V_3 = \frac{200}{12} \text{ V}$$

$$q = CV = \text{const} \cdot n$$

$$V \propto \frac{1}{C}$$

$$\text{If } V_3 = x \quad V_3 = 6 \cdot 2x$$

$$V_3 = 3x$$

$$V = V_1 + V_2 + V_3$$

$$\Rightarrow 100 = 6x$$

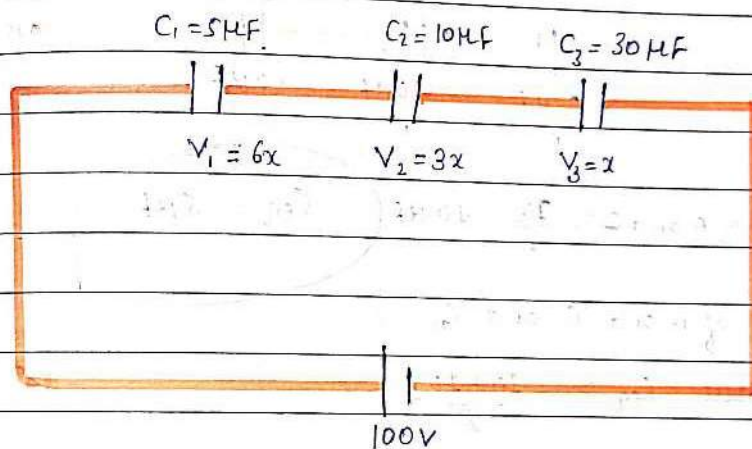
$$x = \frac{100}{6} \text{ Volt}$$

$$V_3 = \frac{100}{6} \text{ Volt}$$

$$V_2 = \frac{300}{6} \text{ Volt}$$

$$V_1 = \frac{600}{6} \text{ Volt}$$

Find charge and potential drop across each capacitor.



$$Q = C_{eq} V$$

$$Q = 3 \times 100 = 300 \mu C$$

$$\frac{1}{C_{eq}} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30}$$

$$\frac{1}{C_{eq}} = \frac{6 + 3 + 1}{30} = \frac{10}{30} \quad C_{eq} = 3 \mu F$$

potential from C_{eq} each capacitor.

$$6x + 3x + x = 100$$

$$10x = 100$$

$$x = 10$$

$$V_3 = 10V$$

$$V_2 = 30V$$

$$V_1 = 60V$$

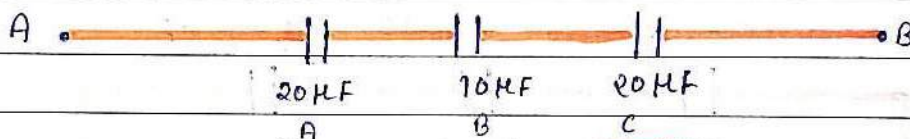
Q n capacitor of equal capacitance 'C' connected in series then find equivalent capacitance.

Ans $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} \dots \dots \frac{n^{th}}{C}$

$$\frac{1}{C_{eq}} = \frac{n}{C}$$

$$C_{eq} = \frac{C}{n}$$

Q Find equivalent capacitance b/w A and B.



Ans $C_{eq} \text{ of A and C} = \frac{20}{2} = 10 \mu F$ $C_{eq} = 5 \mu F$

$$C_{eq} \text{ of A and C and } C_B =$$

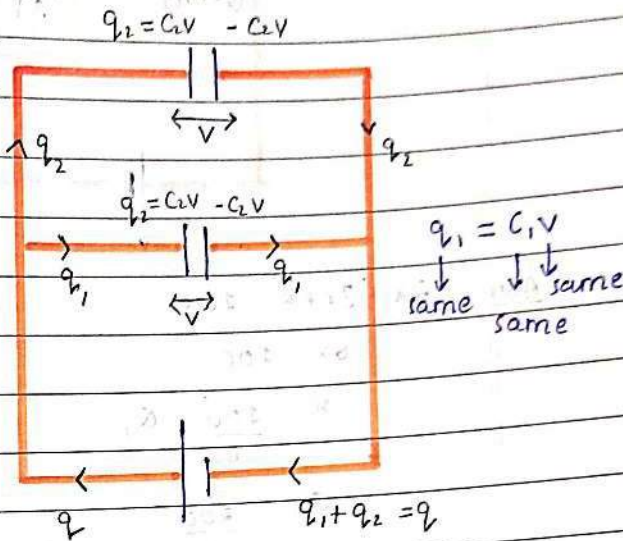
$$\text{Total } C_{eq} = \frac{10 + 10}{2} =$$

PARALLEL CAPACITOR.

drop is

- Potential same across each capacitor.
- (charge)_{net} = Sum of all the charge

- Sum of charge on each capacitor will be equal to the charge flowing through the battery



$$q = q_1 + q_2$$

$$q_{Ceq} = C_1V + C_2V$$

$$C_{eq} = C_1 + C_2$$

doosre capacitor ke aane se
koi fark nahi padega pehle
capacitor ko

In parallel combination potential drop is same but charge is diff.

law of charge distribution

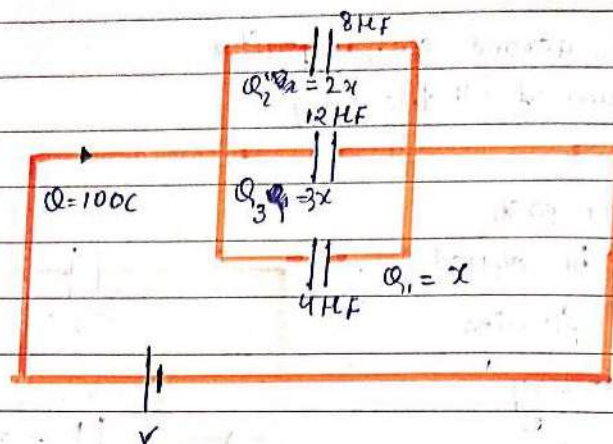
$$\Rightarrow q = C \cdot V$$

↓
constant

$$q \propto C$$

$$\frac{q_1}{q_2} = \frac{C_1}{C_2}$$

Q Find charge on each capacitor?



Ans $2x + 3x + x = 100$

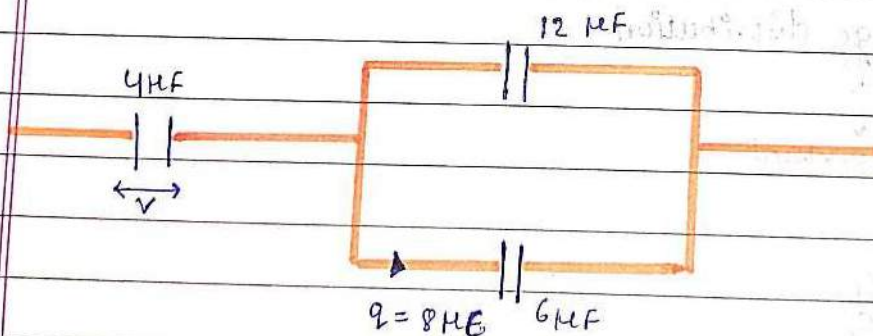
$6x = 100$

$x = \frac{100}{6} = Q_1$

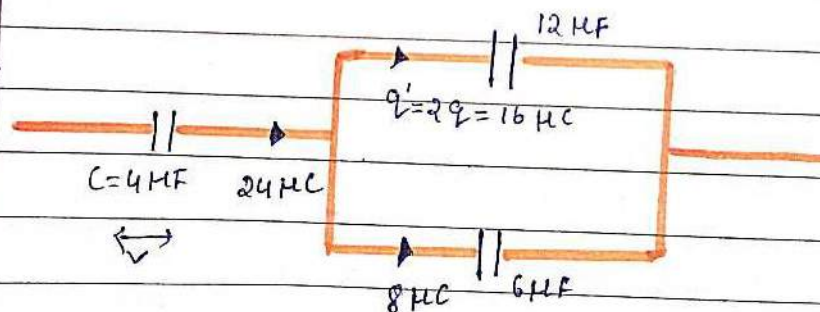
$Q_2 = \frac{200}{6}$

$Q_3 = \frac{300}{6}$

Q Charge on 6 μF is 8 μC then find potential drop across 4 μF.

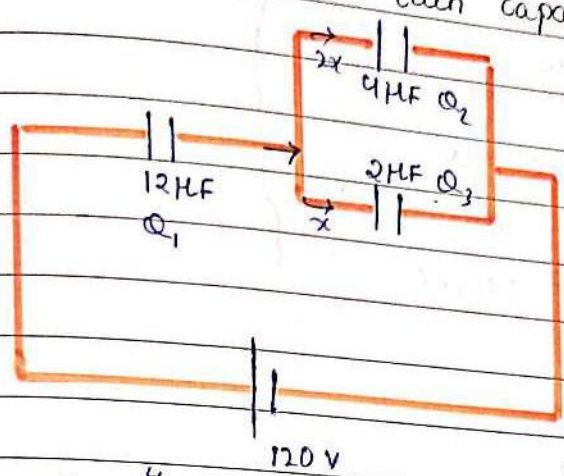


Ans



$$Q = CV \Rightarrow V = \frac{Q}{C} = \frac{24 \times 6}{4} = 6V \text{ Any}$$

Find charge and potential across each capacitor.



$$Q = CeqV$$

$$Q = 4 \times 120$$

$$= 480 \mu C$$

$$Q_1 = 480 \mu C$$

$$Q_{total} = x + 2x = 480$$

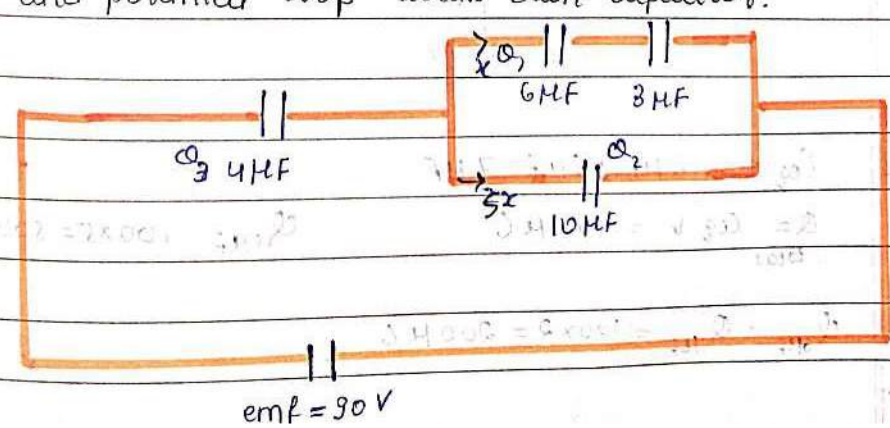
$$3x = 480$$

$$x = 160 = Q_3$$

$$2x = 320 = Q_2$$

$$V_{on 12 \mu F} = \frac{480}{12} = 40V$$

Q Find charge and potential drop across each capacitor.



Ans

$$Q = C_{eq} V$$

$$Q = 3 \times 90 = 270 \mu C$$

$$x + 5x = 270$$

$$6x = 270$$

$$x = 45 \mu C = Q_1$$

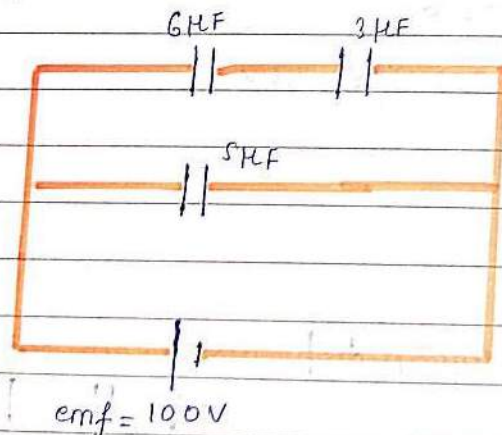
$$Q_2 = 5x = 225 \mu C$$

$$Q_3 = 270 \mu C$$

$$V_3 = \frac{Q}{C} = \frac{270}{4} = 67.5$$

$$V_2 = V_1 = 90 - 67.5 = 22.5 V$$

Q Find charge and potential across each capacitor



Ans

$$C_{eq} = 2 \mu F + 5 \mu F = 7 \mu F$$

$$Q_{total} = C_{eq} V = 700 \mu C$$

$$Q_{5\mu F} = 100 \times 5 = 500 \mu C$$

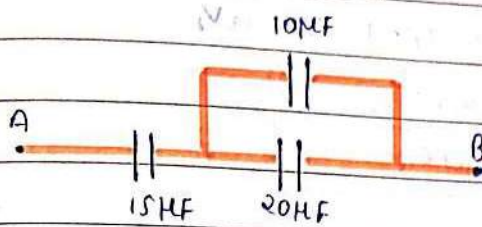
$$Q_{6\mu F} = Q_{3\mu F} = 100 \times 2 = 200 \mu C$$

$$V_{5\mu F} = 100V$$

$$V_{6\mu F} = 100 \times \frac{200}{6} = \frac{100}{3} \text{ V}$$

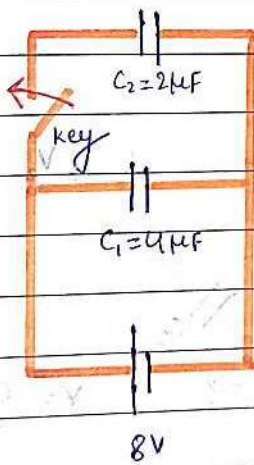
$$V_{3\mu F} = \frac{200}{3} \text{ V}$$

In the arrangement shown, find the equivalent capacitance between A and B



$$C_{eq} = \frac{10 \times 35}{45} = 7.78 \mu F$$

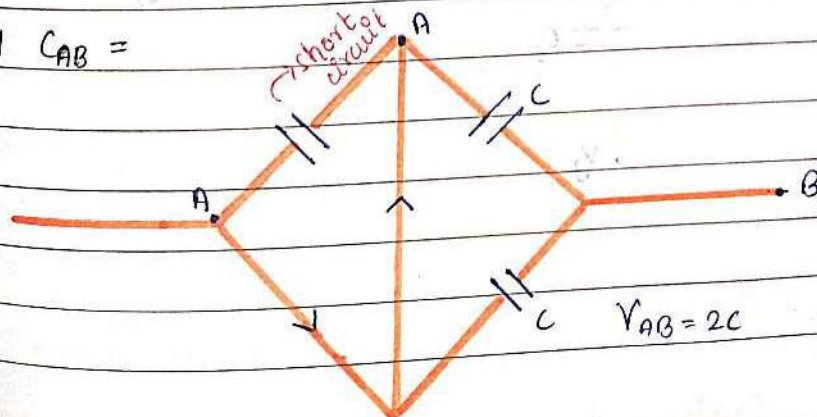
Find total change in charge on 4μF when key is closed.



$$\Delta Q = 0$$

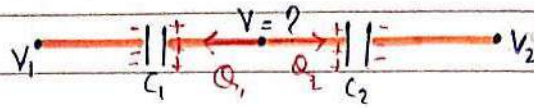
$$Q_1 = 4 \times 8 = 32 \mu C$$

Find $C_{AB} =$



$$V_{AB} = 2C$$

Q Find $V = ?$



Solⁿ $\sum Q_{in} = \sum Q_{out}$

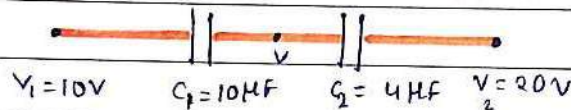
$$0 = Q_1 + Q_2$$

$$0 = C_1(V - V_1) + C_2(V - V_2)$$

$$0 = C_1V - C_1V_1 + C_2V - C_2V_2$$

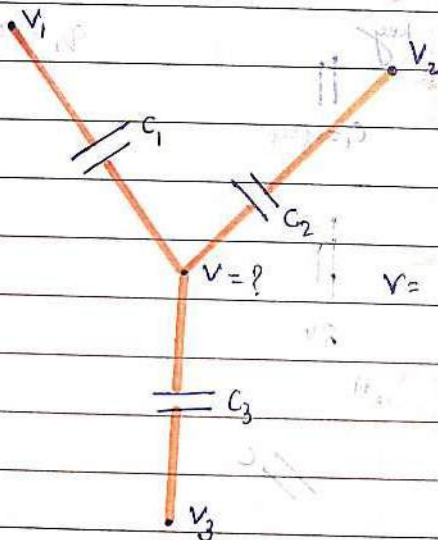
$$\boxed{\frac{C_1V_1 + C_2V_2}{C_1 + C_2} = V}$$

Q



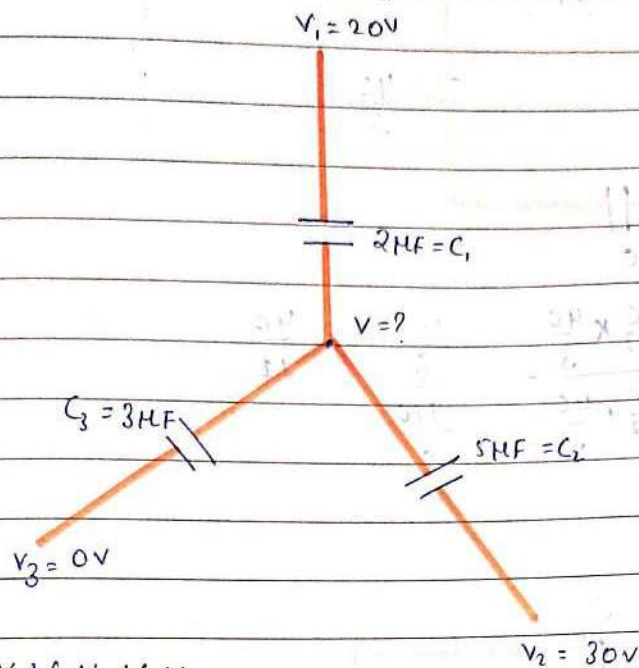
$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{100 + 80}{14} = \frac{180}{14} \text{ Volt.}$$

Q



$$V = \frac{C_1V_1 + C_2V_2 + C_3V_3}{C_1 + C_2 + C_3}$$

Q Find common potential and charge on each plate.



Ans
$$V = \frac{C_1 V_1 + C_2 V_2 + C_3 V_3}{C_1 + C_2 + C_3}$$

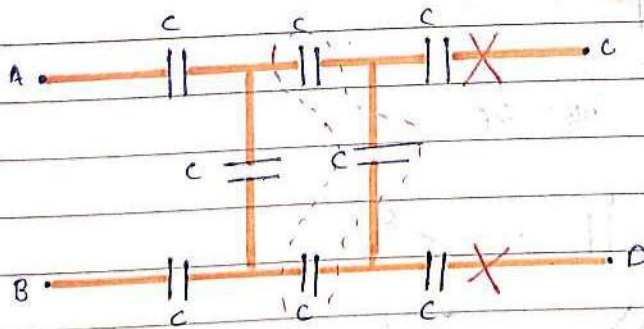
$$= \frac{40 + 150}{10} = 19 \text{ volt}$$

$$Q_1 = C_1 \Delta V_1 = 2\mu\text{F} \times 10 \text{ volt} = 2\mu\text{C}$$

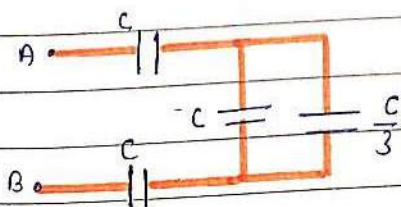
$$Q_2 = C_2 \Delta V_2 = 5\mu\text{F} \times 11 = 55\mu\text{C}$$

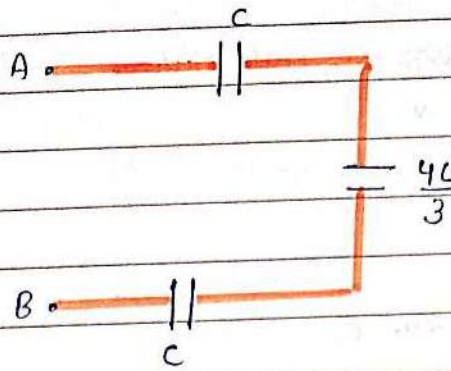
$$Q_3 = C_3 \Delta V_3 = 3\mu\text{F} \times 19 = 57\mu\text{C}$$

Q Find



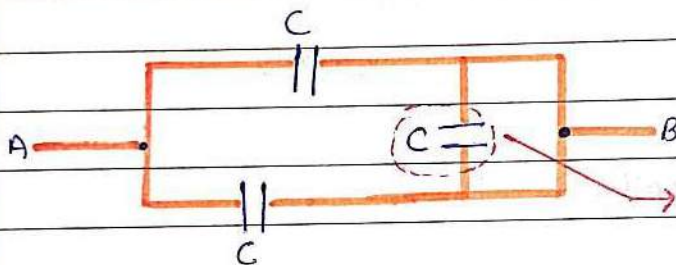
Ans



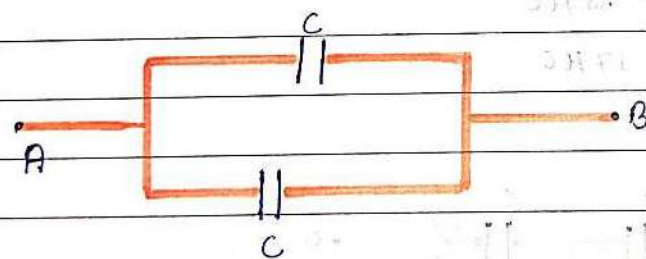


$$C_{AB} = \frac{\frac{C}{2} \times \frac{4C}{3}}{\frac{C}{2} + \frac{4C}{3}} = \frac{\frac{4C^2}{6}}{\frac{7C}{6}} = \frac{4C}{11}$$

Q

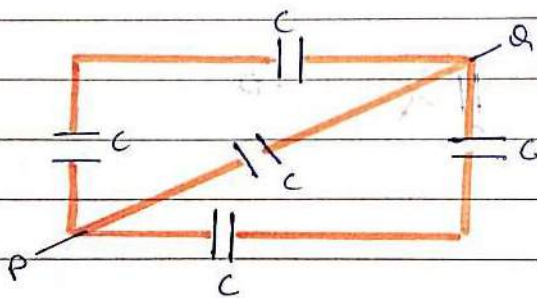


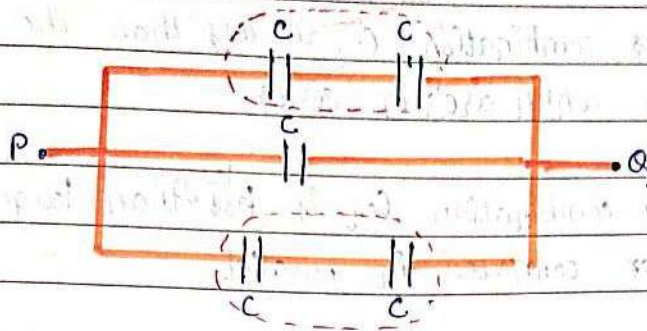
Short circuit = when both plate of capacitor connected to same point or having same potential



$$C_{AB} = 2C$$

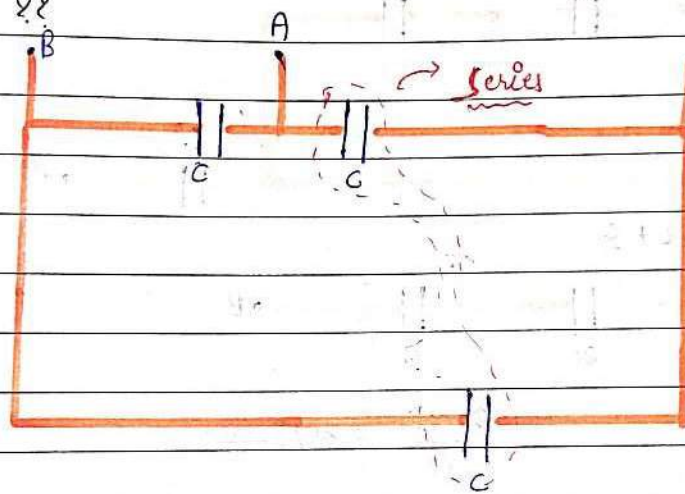
Q





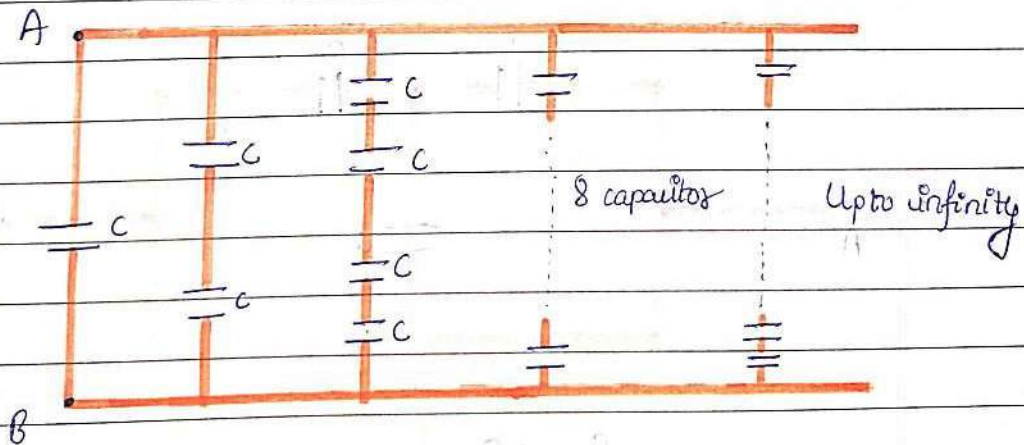
$$C_{eq} = \frac{C}{2} + \frac{C}{2} + C = 2C$$

Q Find $C_{AB} = ?$



Ans $\frac{C}{2} + C = \frac{3C}{2}$

Q



Ans $C_{eq} = C + \frac{C}{2} + \frac{C}{4} + \frac{C}{8} \dots$

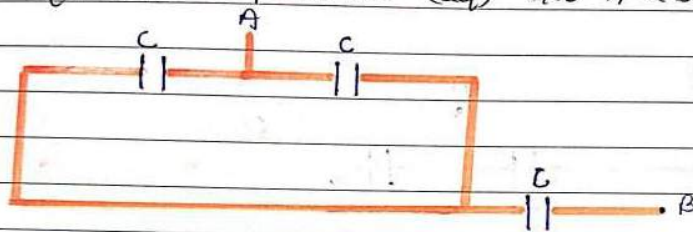
$$C \left[1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} \dots \right]$$

$$C \left[\frac{1}{1-1/2} \right] = 2C \text{ Ans}$$

Statement-1 In series combination, C_{eq} is less than the smallest capacitance which are in series.

Statement-2 In parallel combination C_{eq} is ^{larger} less than largest capacitance of capacitor connected in parallel.

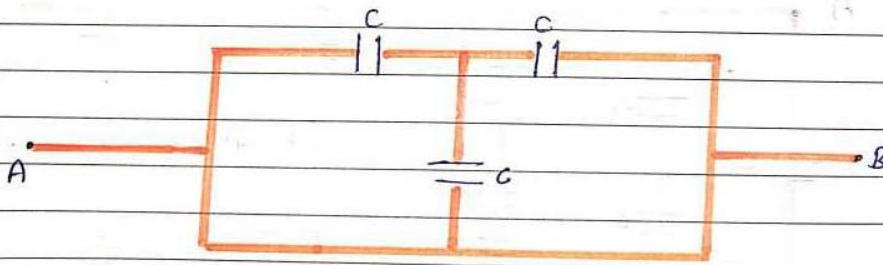
Q Find equivalent capacitance (C_{eq}) b/w A & B:



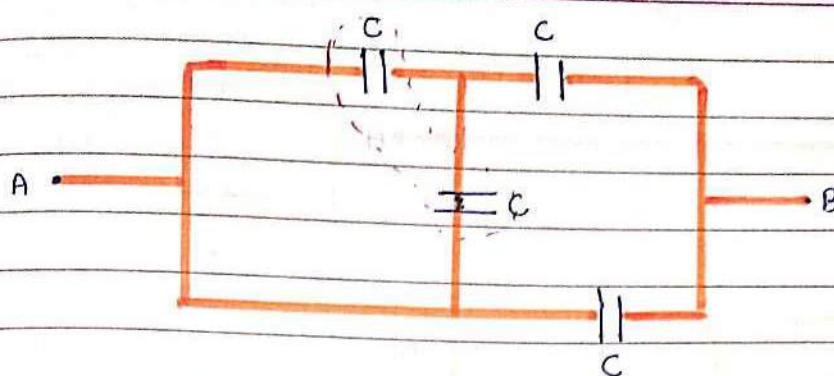
Ans

$$\begin{aligned}
 & \text{Let } \underline{\quad} \\
 & A \text{ --- } 2C \text{ --- } C \text{ --- } B \\
 & = \frac{2C \times C}{2C + C} = 2C/3 \text{ Ans}
 \end{aligned}$$

Q Find capacitance (C_{eq}) b/w A & B

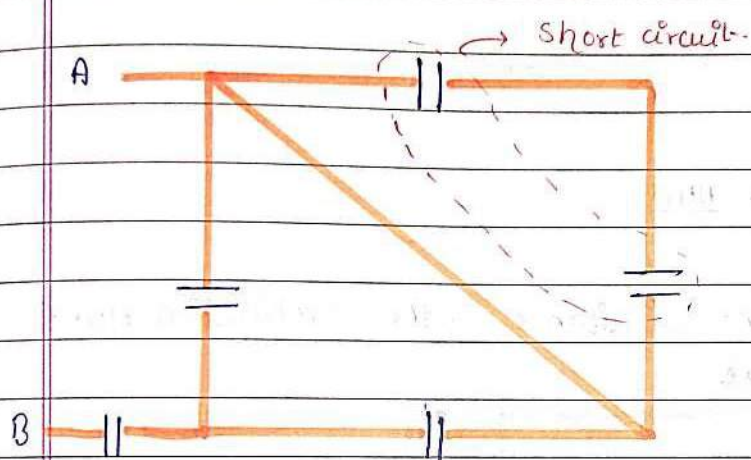


$$C_{AB} = 0$$



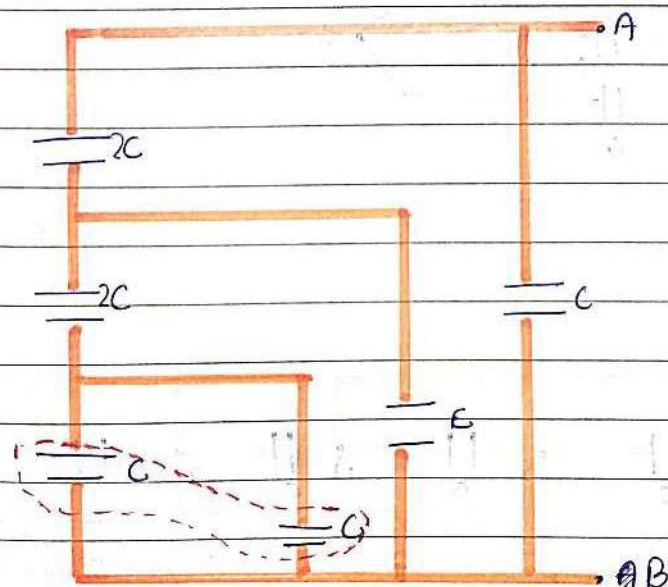
$$C_{eq} = \frac{2C \times C}{2C + C} + C = \frac{2C}{3} + C = \frac{5C}{3}$$

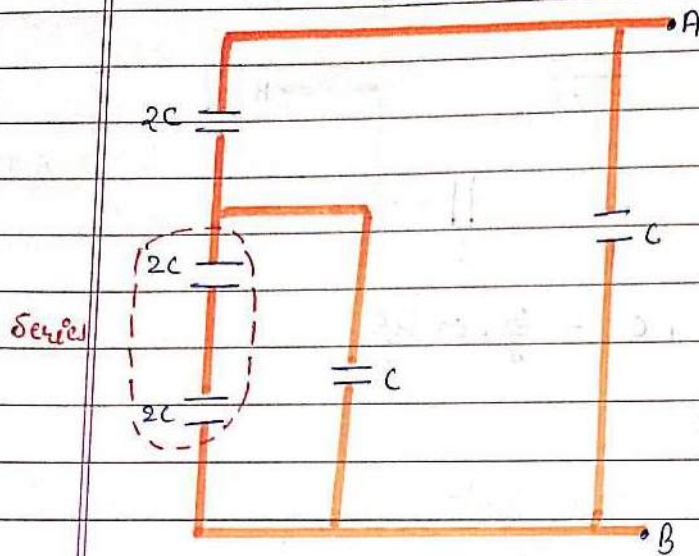
Q Find C_{eq} b/w A & B



$$C_{eq} = \frac{2C \times C}{3C} = \frac{2C}{3}$$

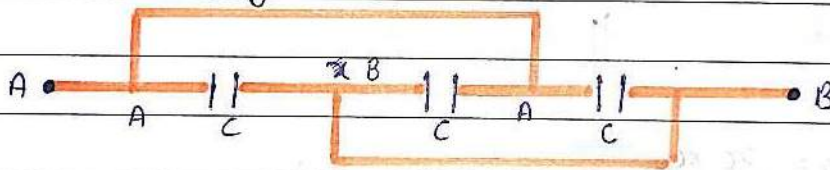
Q



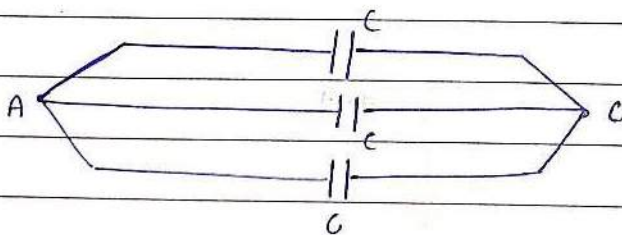


$$C_{eq} = 2C \text{ Ans}$$

Q Find the equivalent capacitance of the combination b/w A and B in the figure

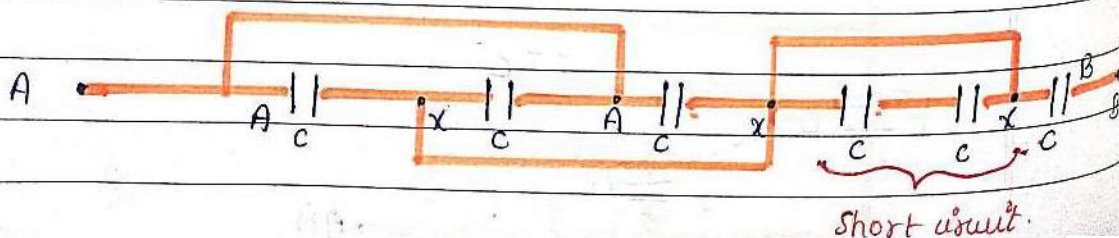


Ans



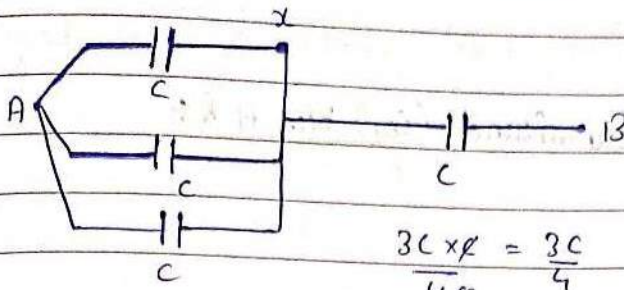
$$C_{eq} = 3C$$

Q Find $C_{eq} = ??$



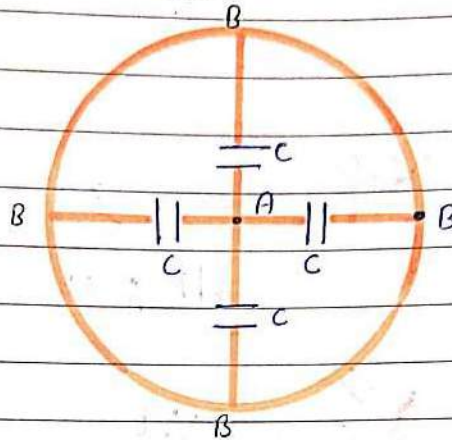
Short circuit.

Ans



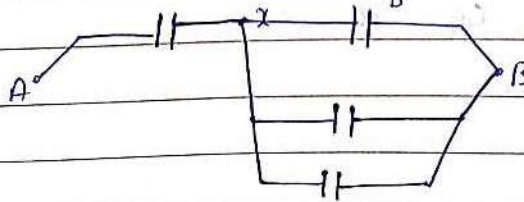
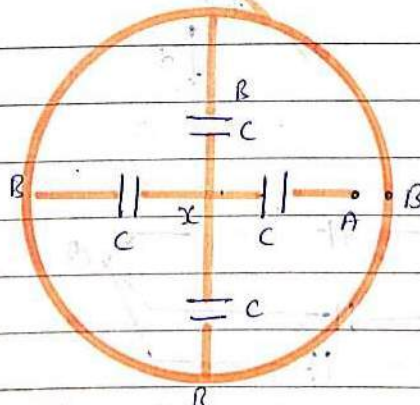
$$\frac{3C \times C}{4C} = \frac{3C}{4}$$

Q



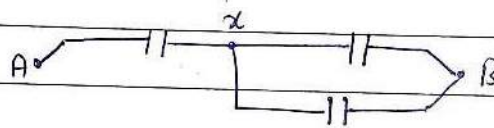
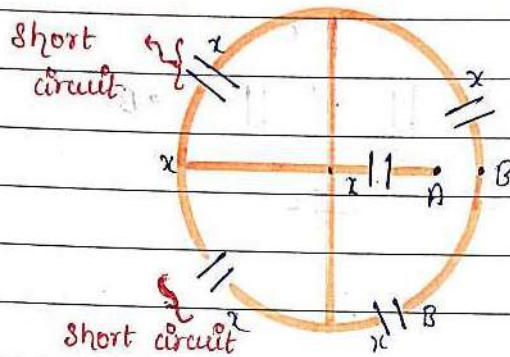
Soln

$$C_{AB} = 4C$$



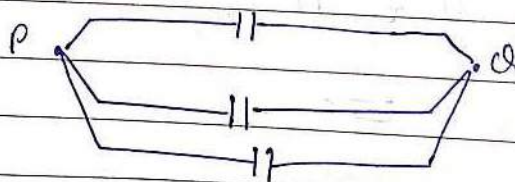
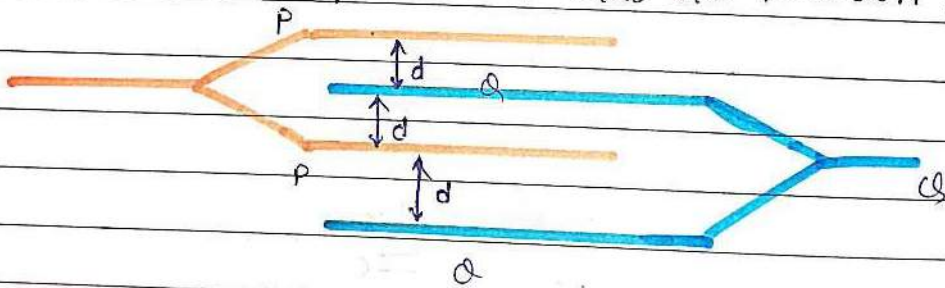
$$C_{AB} = \frac{3C}{4}$$

Q Find equivalent capacitance (C_{eq}) b/w A & B



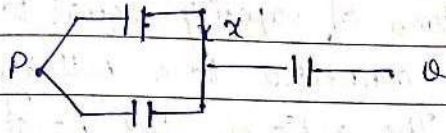
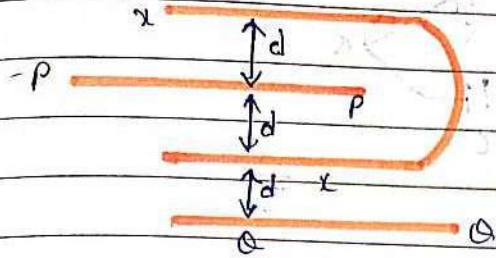
$$C_{AB} = \frac{2C}{3}$$

Q Find equivalent capacitance if area b/w plate is A & distance is 'd'



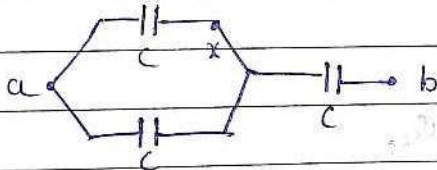
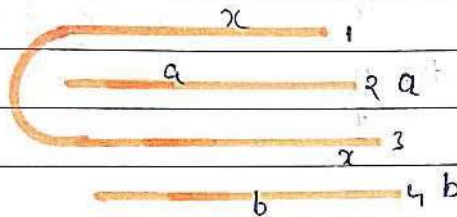
$$C_{eq} = 3C$$

Q Find equivalent capacitance (C_{eq}) b/w P & Q if Area is A & distance is d .



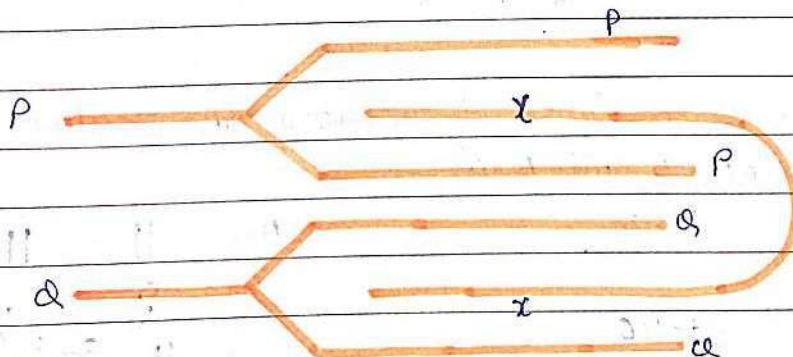
$$C_{AB} = \frac{2C}{3}$$

Q Capacitance b/w A & B

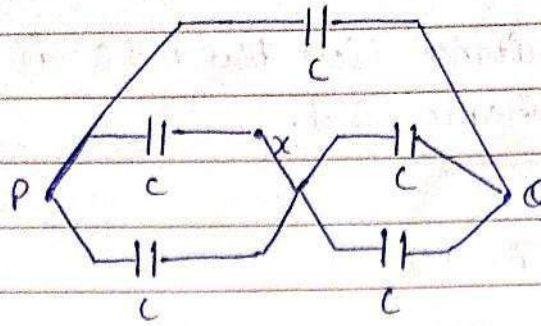


$$C_{AB} = \frac{2C}{3} = \frac{2\epsilon_0 A}{d}$$

Q



Q



$$C_{PQ} = 2C$$

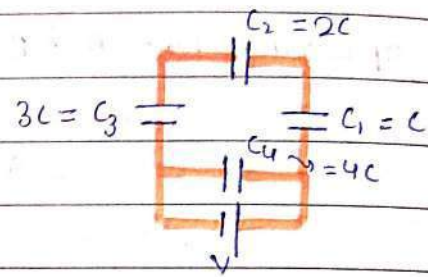
Q A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are connected to a battery as shown in the figure. The ratio of the charge on C_2 and C_4 is.

a) $\frac{22}{3}$

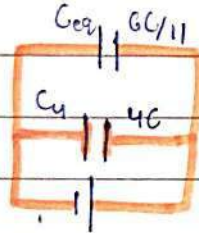
~~(25)~~ $\frac{3}{22}$

c) $\frac{7}{4}$

d) $\frac{4}{7}$



Ans



$$Q_{Ceq} = Q_{C2}$$

$$\therefore \frac{Q_{Ceq}}{Q_{C4}} = \frac{C_{eq}}{C_4} = \frac{6}{11 \times 4} = \frac{3}{22}$$

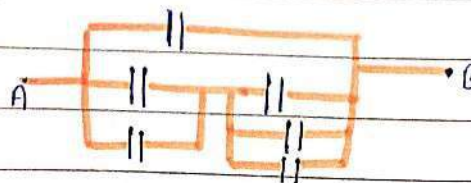
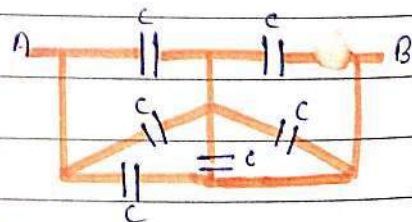
Q In the given figure of capacitor, the equivalent capacitance b/w point A and B is

a) $\frac{6}{5}C$

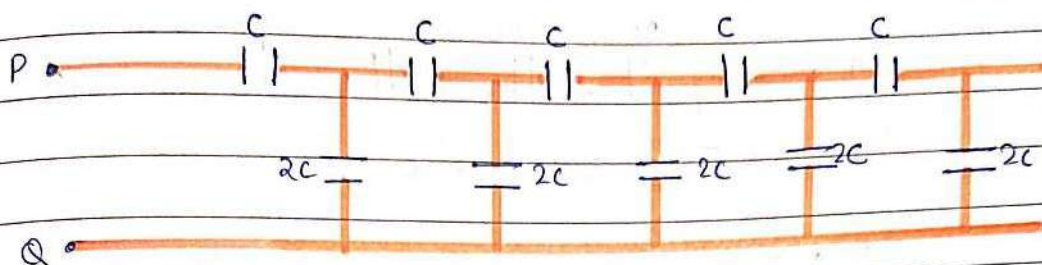
b) $2C$

c) $\frac{9}{7}C$

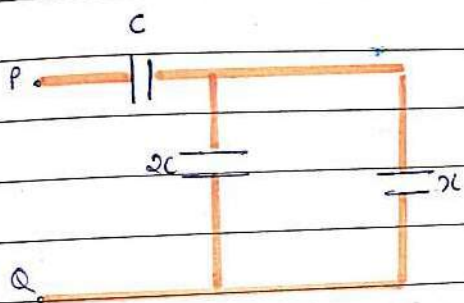
~~(110)~~ $\frac{11C}{5}$



LADDER NETWORK



Let equivalent resistance be x



$$\frac{(x+2C)C}{x+2C+C} = x$$

$$\frac{Cx + 2C^2}{3C + x} = x$$

$$Cx + 2C^2 = 3Cx + x^2$$

$$2Cx + x^2 - 2C^2 = 0$$

$$x^2 + 2Cx - 2C^2 = 0$$

$$a = 1$$

$$b = 2C$$

$$c = -2C^2$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

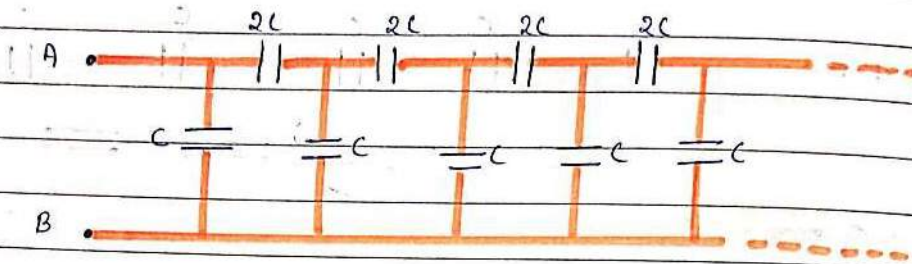
$$x = \frac{-2C \pm \sqrt{4C^2 + 8C^2}}{2}$$

$$x = \frac{-2C + 2C\sqrt{3}}{2}$$

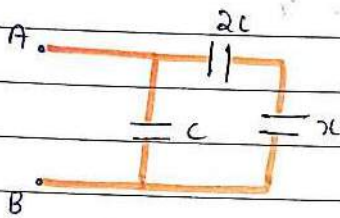
$$x = \frac{2C(\sqrt{3}-1)}{2}$$

$$x = (\sqrt{3}-1)C$$

Q Find the equivalent capacitance of the infinite ladder as shown in the figure b/w the points A and B



Ans



$$\frac{X \times 2C}{2C + X} + C = X$$

$$2CX + 2C^2 + CX = 2CX + X^2$$

$$X^2 - CX - 2C^2 = 0$$

$$a = 1$$

$$b = -C$$

$$c = -2C^2$$

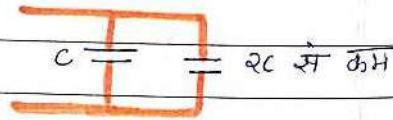
$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

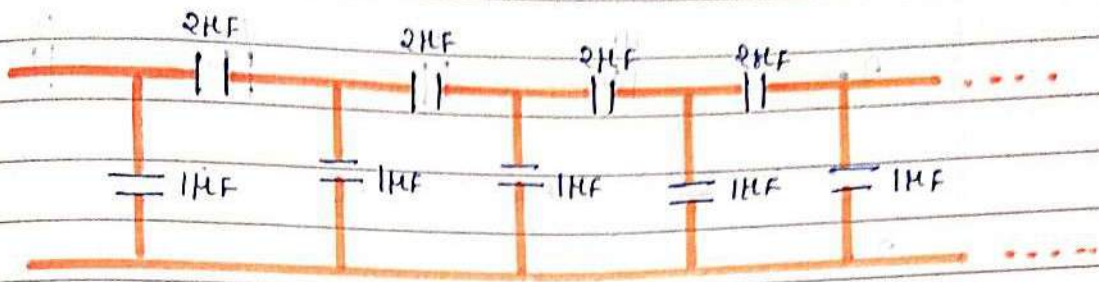
Two capacitors

cannot be
subtracted.

$$= \frac{C \pm \sqrt{C^2 + 8C^2}}{2} = \frac{C + 3C}{2} = 2C \text{ Ans}$$

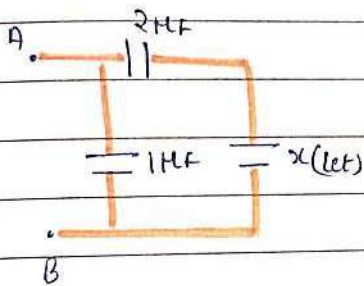
$$C < C_{eq} < 3C$$





- a) $(\sqrt{5}+1)$ Hf
 b) 4 Hf
 c) 2 Hf
 d) 8 Hf

Ans



$$\frac{2x}{2+x} + 1 = x$$

$$\frac{2}{x} + 2 + x = \frac{2}{x} + x^2$$

$$x^2 - 2 - x = 0$$

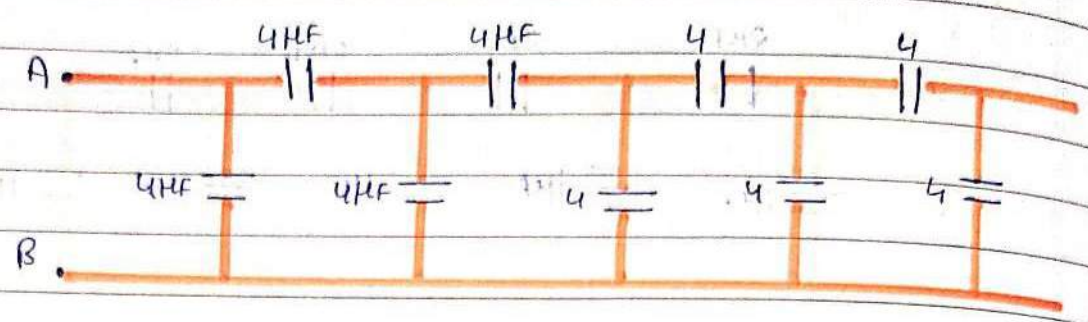
$$x^2 - 2x + x - 2 = 0$$

$$x(x-2) + 1(x-2) = 0$$

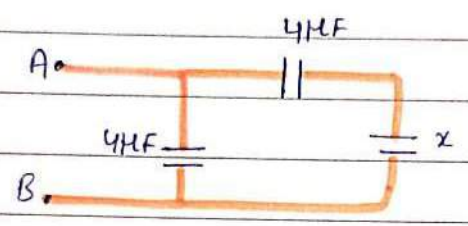
$$(x+1)(x-2) = 0$$

$$x = 2 \text{ Hf Ans}$$

Q



Ans



⇒

$$\frac{4x}{4+x} + 4 = x$$

$$4x + 16 + 4x = 4x + x^2$$

$$x^2 - 4x - 16 = 0$$

$$x^2 - 4x - 16 = 0$$

$$a = 1$$

$$b = -4$$

$$c = -16$$

$$x = \frac{4 \pm \sqrt{16 + 64}}{2}$$

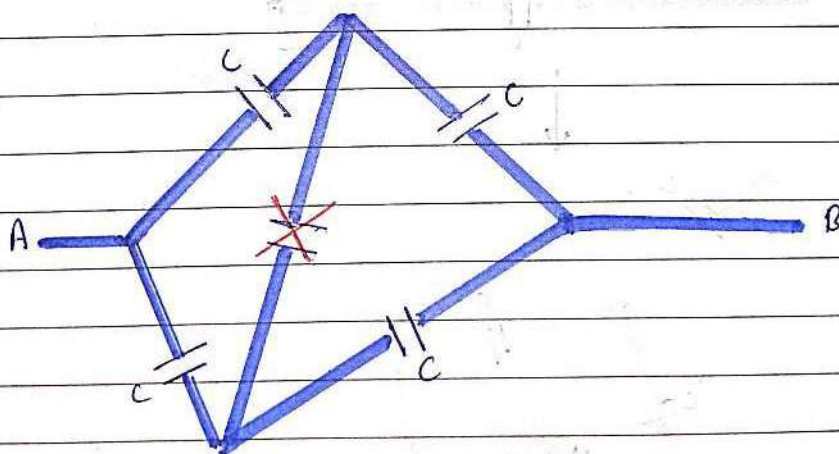
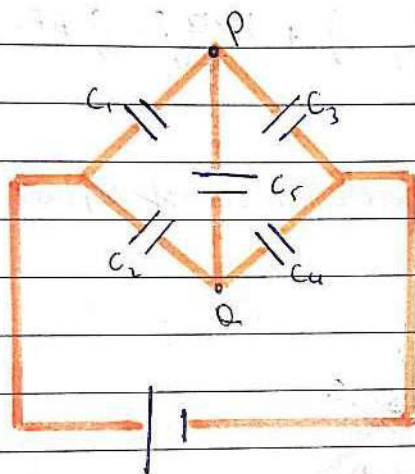
$$x = \frac{4 + \sqrt{80}}{2} = \frac{4 + 2\sqrt{20}}{2} = (2 + \sqrt{20}) \text{ MF}$$

$$4 \text{ MF} < C_{eq} < 8 \text{ MF}$$

WHEATSTONE BRIDGE

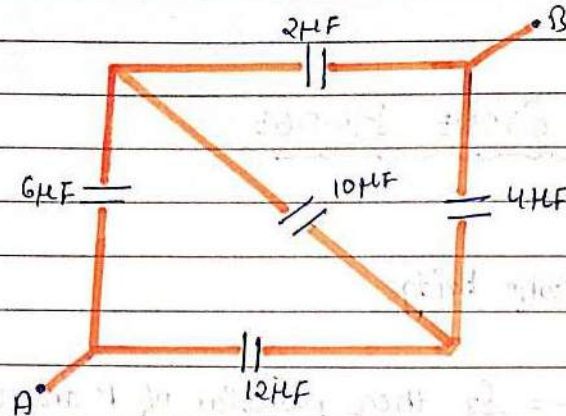
Balanced Wheat stone bridge

If $\frac{C_1}{C_2} = \frac{C_3}{C_4}$ then potential of P and Q will be same then no charge on C_5 .



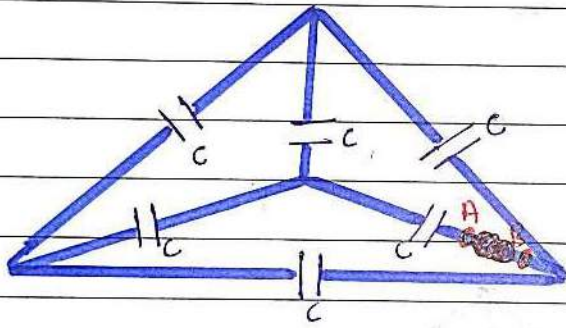
$$C_{AB} = C$$

Q

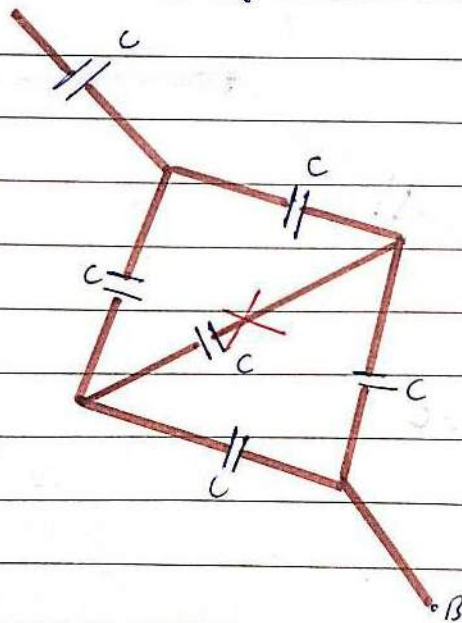
Find $C_{A,B}$??

$$\Rightarrow C_{eq} = \frac{3 \times 2}{8 \times 2} = \frac{3}{2} + \frac{4 \times 12}{164} = \frac{9}{2} \mu F$$

Q Equivalent capacitance of combination of capacitor.

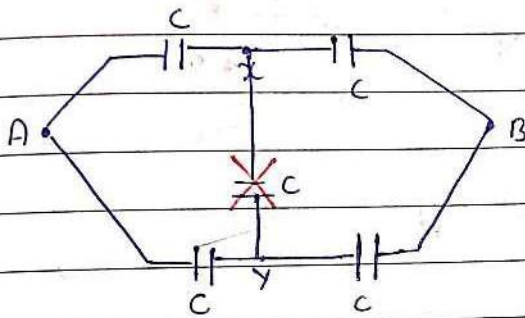
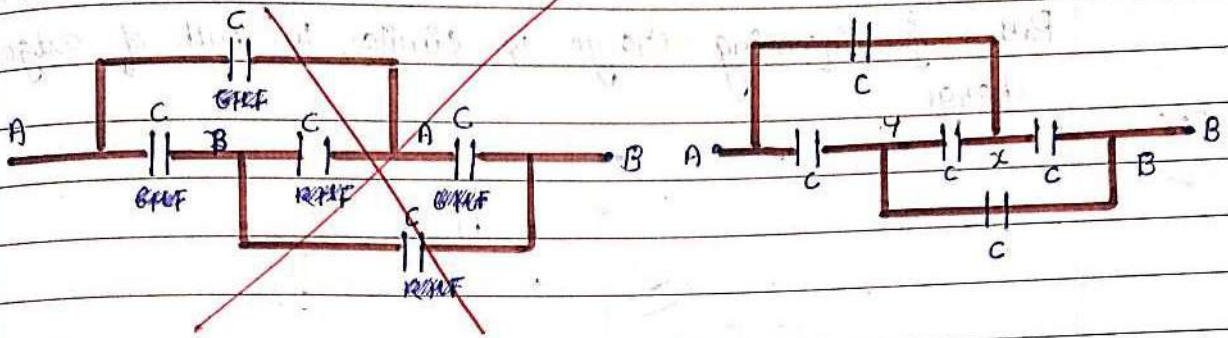


Ans

 C_{eq}

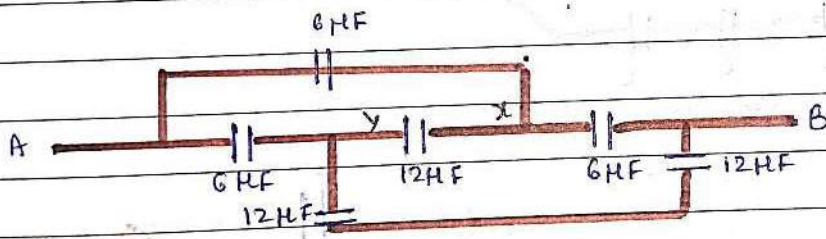
→ $C_{eq} = \frac{C}{2}$

Q Find C_{AB}

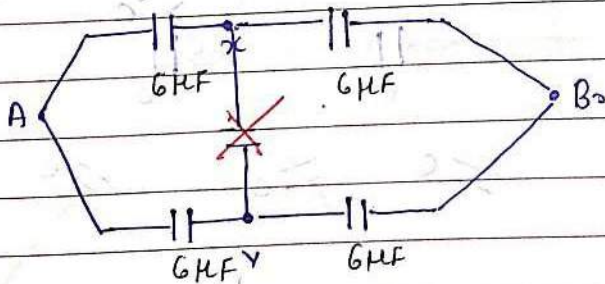


$C_{eq} = C$

Q



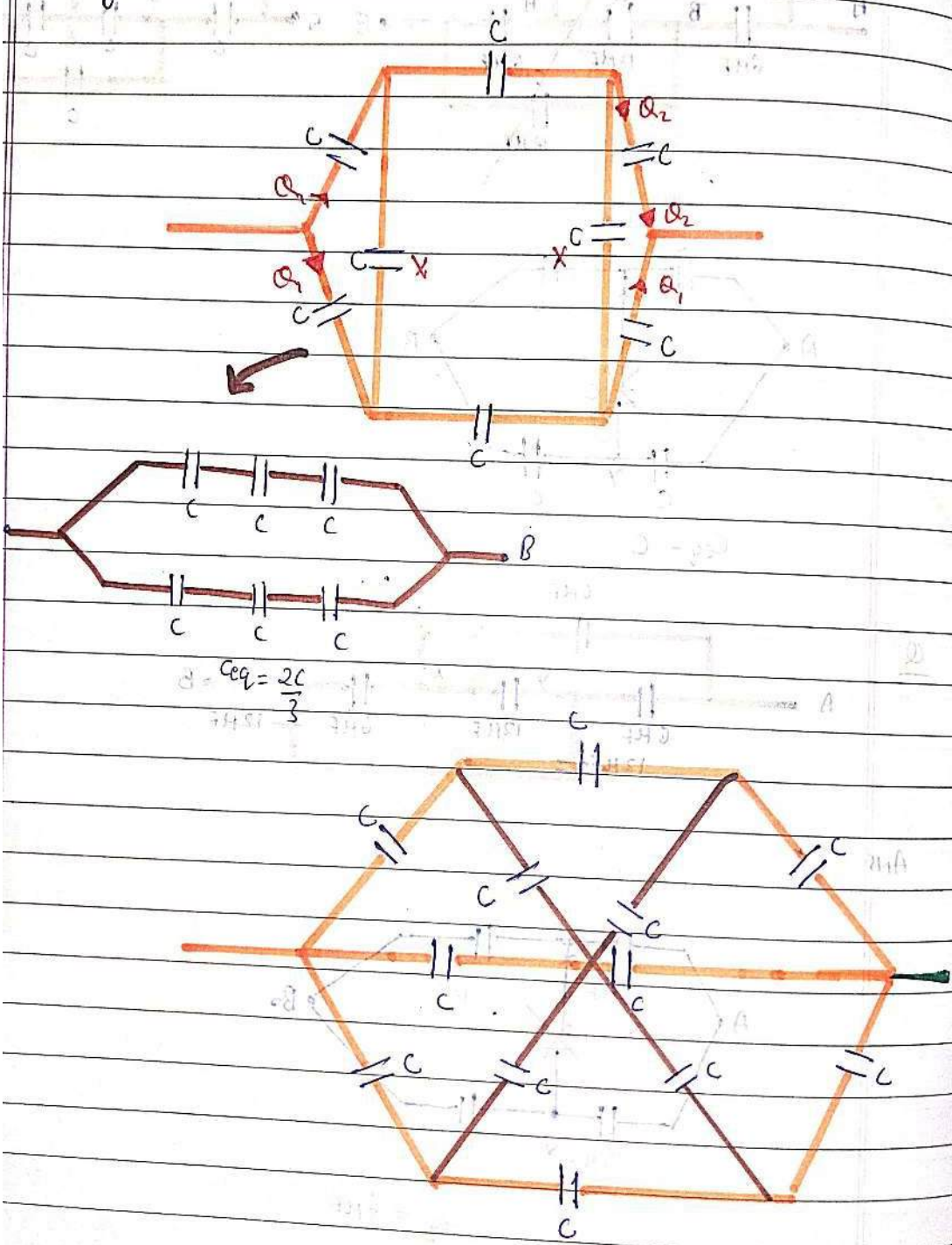
Ans

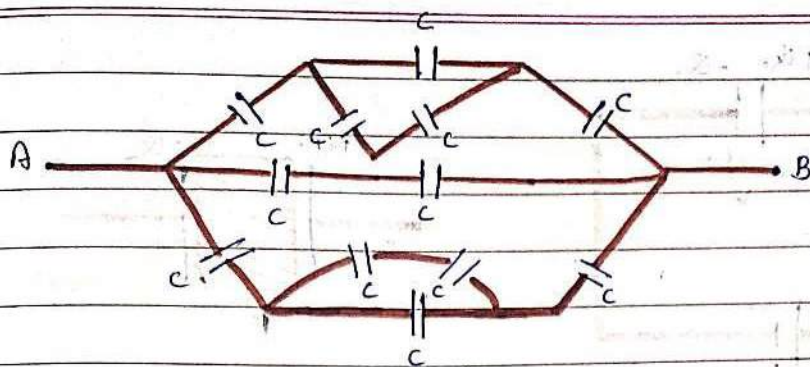


$C_{eq} = 6\mu F$

SYMMETRIC CIRCUIT

Path for incoming charge is similar to path of outgoing charge.

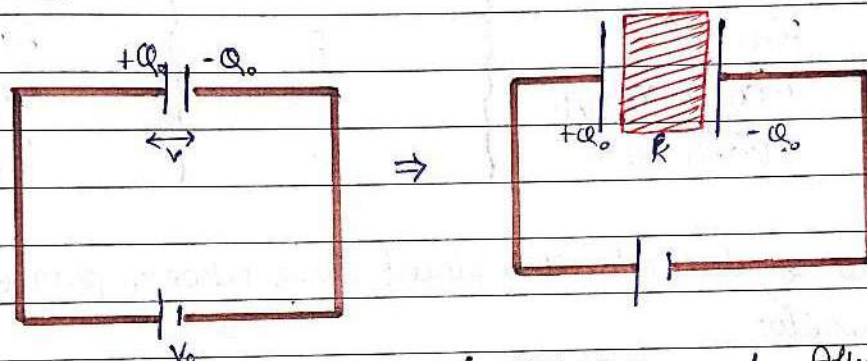




$$C_{eq} = \frac{C}{3}$$

$$C_{eq} = \frac{\epsilon_0 \epsilon_r A}{d}$$

* Capacitor is charged and then battery remains connected, dielectric is placed.



Capacitance

Potential

Charge

Electric field

U_0 (Energy)

F_0 (Force on plate)

Initially

C_0

V_0

Q_0

E_0

U_0

F_0

After dielectric placed

$C = kC_0$

V_0 (because battery is attached)

$Q' = kQ_0$

E_0 ($E' = \frac{Q'}{A\epsilon_0} = \frac{kQ_0}{A\epsilon_0} = kE_0$)

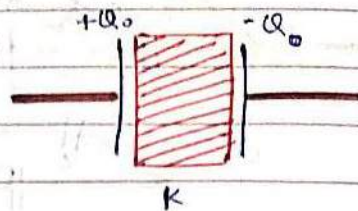
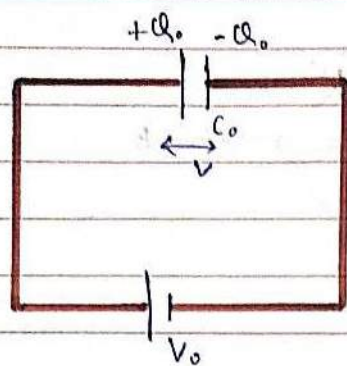
$U' = kU_0$

$F = kF_0$

$$E' = \frac{Qk}{A\epsilon_0} = \frac{Q}{A\epsilon_0} = E_0$$

* Capacitor is charged then di-electric is placed inside capacitor.

$$\left(\frac{Qk}{A\epsilon_0} \right) = \left(\frac{Q}{A\epsilon_0} \right)$$



	Initially	After dielectric is placed
Charge	Q_0	Q_0
Capacitance	C_0	$C_0 = K C_0$
Potential	V_0	V_0 / K
Force	F_0	F_0 / K
Potential energy	U_0	U_0 / K
Electric field	E_0	E_0 / K

Q Effect of dielectric slab placed along between parallel plate capacitor.

Ans $\Delta V =$ Potential diff b/w the plate

$$\Delta V = \frac{Q}{A\epsilon_0} (d-t) + \frac{Q}{A\epsilon_0 K} t$$

$$\Delta V = \frac{Q}{A\epsilon_0} \left[d-t + \frac{t}{K} \right]$$

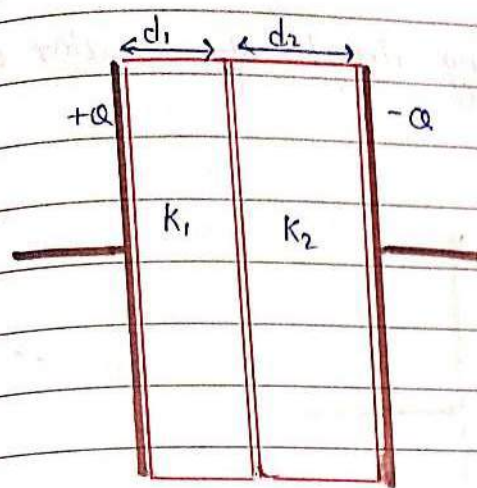
$$C = \frac{Q}{\Delta V}$$

$$C = \frac{Q}{\frac{Q}{A\epsilon_0} \left[d-t + \frac{t}{K} \right]}$$

$$C = \frac{A\epsilon_0}{\left(\frac{t}{K} + \frac{d-t}{1} \right)}$$

$$C = \frac{A\epsilon_0}{\left(\frac{t}{K} + d-t \right)} = \left(\frac{A\epsilon_0}{\frac{t}{K} + d-t} \right)$$



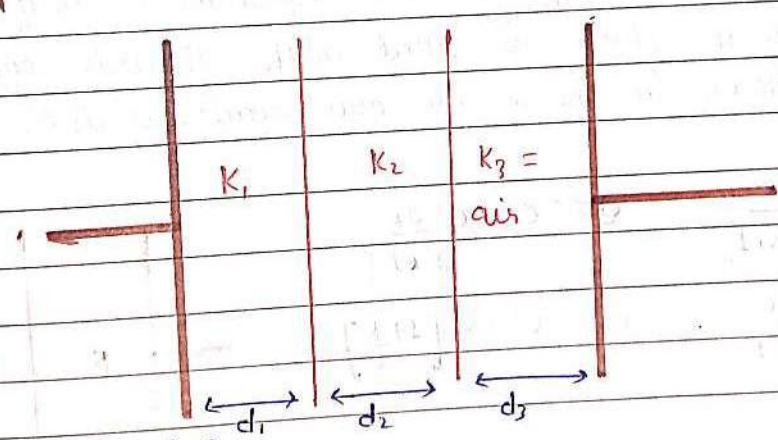


$$\Delta V = \frac{Qd_1}{A\epsilon_0 K_1} + \frac{Qd_2}{A\epsilon_0 K_2}$$

$$\Delta V = \frac{Q}{A\epsilon_0} \left[\frac{d_1}{K_1} + \frac{d_2}{K_2} \right]$$

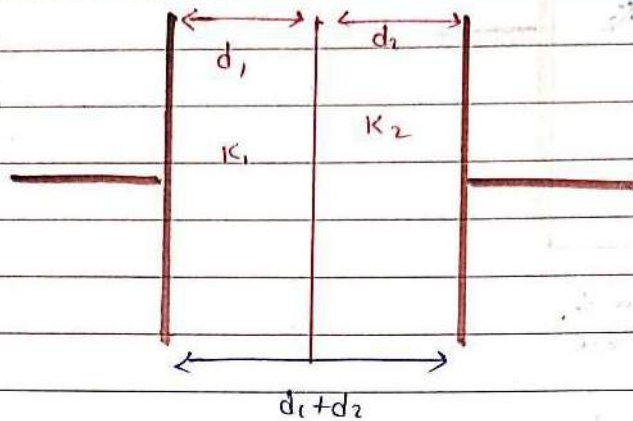
$$C = \frac{Q}{\Delta V} = \frac{A\epsilon_0}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$$

Q Series combination of dielectric



$$C = \frac{\epsilon_0 A}{\frac{d_1}{K_1} + \frac{d_2}{K_2} + \frac{d_3}{K_3}} \quad K_3 = 1$$

Q Dielectric slabs placed along length of capacitor in series combination then find K_{eq} .



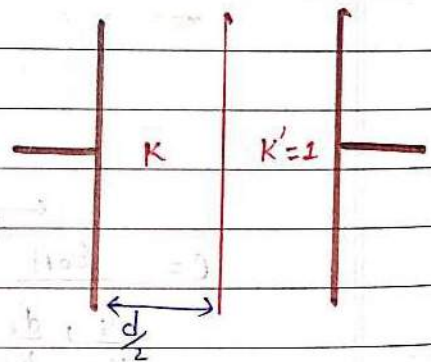
$$C = \frac{\epsilon_0 A}{\frac{d_1}{K_1} + \frac{d_2}{K_2}} = \frac{\epsilon_0 K_{eq} A}{d_1 + d_2}$$

$$K_{eq} = \frac{d_1 + d_2}{\frac{d_1}{K_1} + \frac{d_2}{K_2}} \rightarrow \text{For series combination.}$$

Q A parallel plate ^{air} capacitor has capacitance C . Half of space between the plates is filled with dielectric constant K as shown in figure. The new capacitance is C' , then.

a) $C' = C \left(\frac{K}{K+1} \right)$ ~~b) $C' = C \left(\frac{2K}{K+1} \right)$~~

c) $C' = \left(\frac{2C}{K+1} \right)$ d) $C' = C \left[\frac{1+K}{2} \right]$



Ans $C' = \frac{\epsilon_0 K A}{\frac{d}{2K} + \frac{d}{2}} = \frac{\epsilon_0 A}{d \left[\frac{2+2K}{4K} \right]} = \frac{C_0^2 4K}{2(1+K)}$

$$C' = \frac{2C_0 K}{1+K}$$

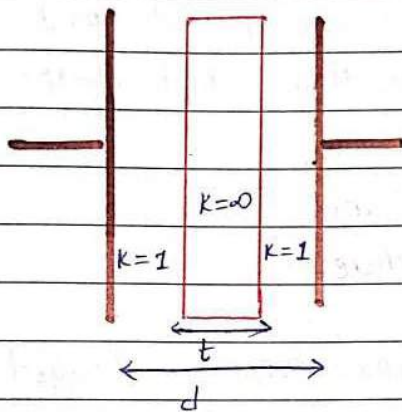
If $k=1$

then $C'=C$

If $k=\infty$

then $C' \neq 0$

In parallel plate capacitor thick conductor is placed.



$$C = \frac{A\epsilon_0}{\frac{t}{k} + \frac{d-t}{1}} = \frac{A\epsilon_0}{d-t} = \frac{A\epsilon_0}{d-t} \text{ Ans}$$

If conductor is very thin then $d \gg t$
then $C = \frac{A\epsilon_0}{d}$

Q A parallel plate air capacitor has a capacity of 2 pF. The separation of the plates is doubled and the interspace b/w the plates is filled with wax. If the capacity is increased to 6 pF, the dielectric constant of wax is.

- a) 2 (b) 3
c) 4 (d) 6

$$C = 2 = \frac{\epsilon_0 A}{d} \quad C' = 6 = \frac{k\epsilon_0 A}{2d}$$

$$2) C = \frac{\epsilon_0 A}{d}$$

$$3) C' = \frac{k \epsilon_0 A}{2d}$$

$$\frac{1}{3} = \frac{2}{k}$$

$$k = 6 \text{ mu}$$

Q A parallel plate capacitor after charging is kept connected to a battery and the plates are pulled apart with the help of insulating handles. Now which of the following quantities will decrease.

- a) Charge (b) capacitance
c) Energy stored ~~Ans~~ All of these

Q A capacitor with plate separation d is charged to V volts. The battery is disconnected and a dielectric slab of thickness $\frac{d}{2}$ and dielectric constant '2' is inserted b/w the plates. The potential difference across its terminals become

- a) V (b) $2V$
3) $\frac{4V}{3}$ ~~(d)~~ $\frac{3V}{4}$

Ans $C' = \frac{\epsilon_0 A}{\frac{d}{2 \times 2} + \frac{d}{2}} = \frac{4\epsilon_0 A}{3d} = \frac{4}{3} C$

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

as charge remains same

$$\Delta V = \frac{Q}{\frac{4}{3} C} = \frac{3}{4} \frac{Q}{C} = \frac{3}{4} V$$

Q There are two identical capacitors, the first one is uncharged and filled with a dielectric of constant k while the other one is charged to potential V having air b/w its plates. If two capacitors are joined end to end, the common potential will be.

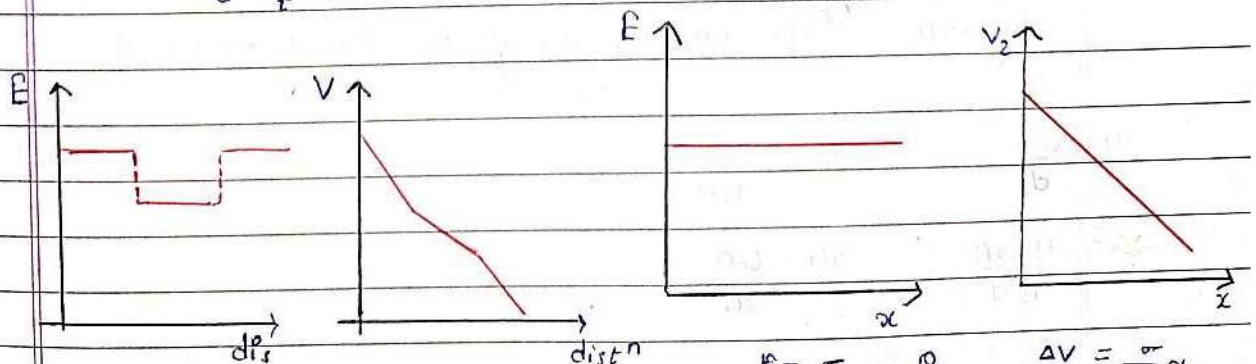
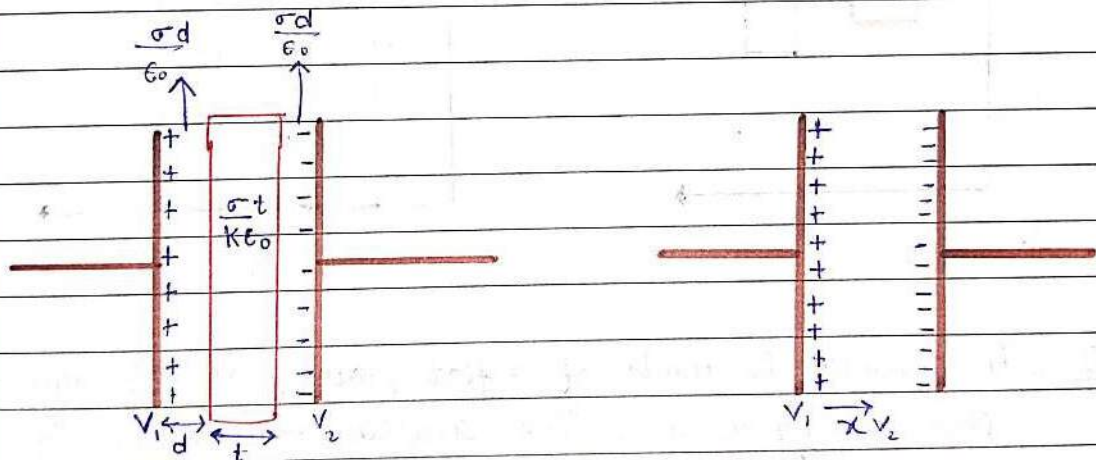
a) $\frac{V}{k-1}$ b) $\frac{kV}{k+1}$

c) $\frac{kV}{k-1}$ d) $\frac{V}{k+1}$

Ans

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

$$V' = \frac{CV + 0}{C + Ck} = \frac{V}{k+1} \text{ Ans}$$



$$V_2 = V_1 - \frac{\sigma x}{\epsilon_0}$$

then
initially

$$V_2 + V_1 = \frac{\sigma x}{\epsilon_0}$$

where dielectric is placed

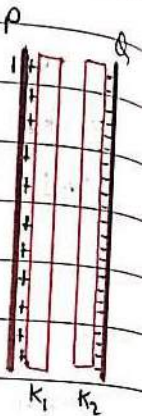
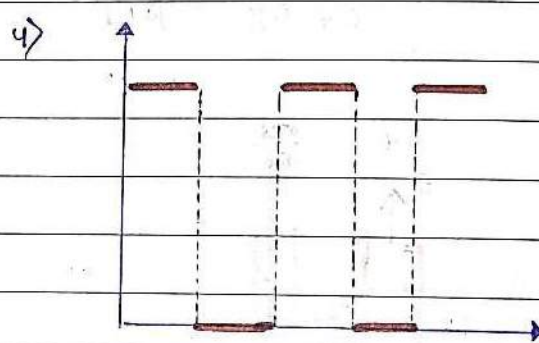
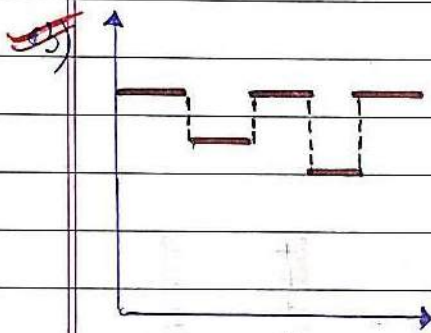
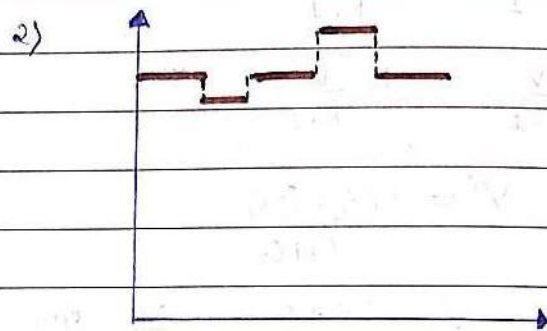
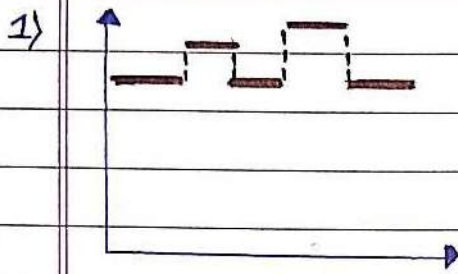
$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$$

$$\Delta V = \frac{\sigma}{\epsilon_0} x$$

$$V_1 - V_2 = \frac{\sigma x}{\epsilon_0}$$

$$V_2 = V_1 - \frac{\sigma x}{\epsilon_0}$$

Q Two thin dielectric slabs of dielectric constants k_1 and k_2 ($k_1 < k_2$) are inserted b/w the plates of a parallel capacitor as shown in the figure. The variation of electric field E between the plates with distance d as measured from plate P is correctly shown by.



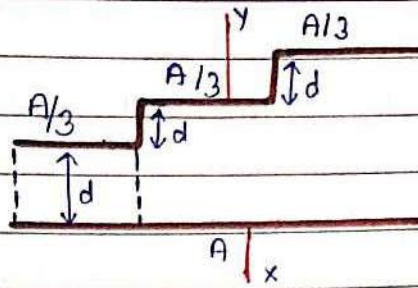
Q A capacitor is made of a flat plate of area A and a second plate having a stair like structure as shown in diagram. The capacitance of the arrangement is.

a) $\frac{\epsilon_0 A}{d}$

(b) $\frac{18\epsilon_0 A}{11d}$

~~c) $\frac{11\epsilon_0 A}{18d}$~~

(d) $\frac{\epsilon_0 A}{3d}$



$$\text{Ans } C_{eq} = \frac{\epsilon_0 A}{3d} + \frac{\epsilon_0 A}{3 \times 2d} + \frac{\epsilon_0 A}{3 \times 3d}$$

$$= \frac{\epsilon_0 A}{3d} + \frac{\epsilon_0 A}{6d} + \frac{\epsilon_0 A}{9d}$$

$$= \frac{6\epsilon_0 A + 3\epsilon_0 A + 2\epsilon_0 A}{18d} = \frac{11\epsilon_0 A}{18d} \quad \text{Ans}$$

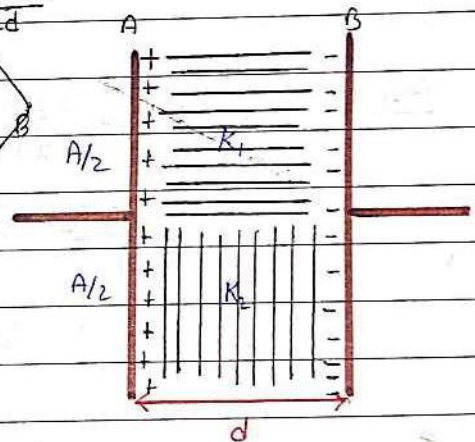
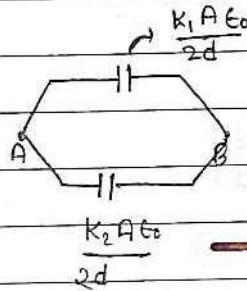
DIELECTRIC SLAB PLACED BETWEEN CAPACITOR IN PARALLEL

COMBINATION

$$C_{eq} = \frac{k_1 \epsilon_0 d A}{2d} + \frac{k_2 \epsilon_0 A}{2d}$$

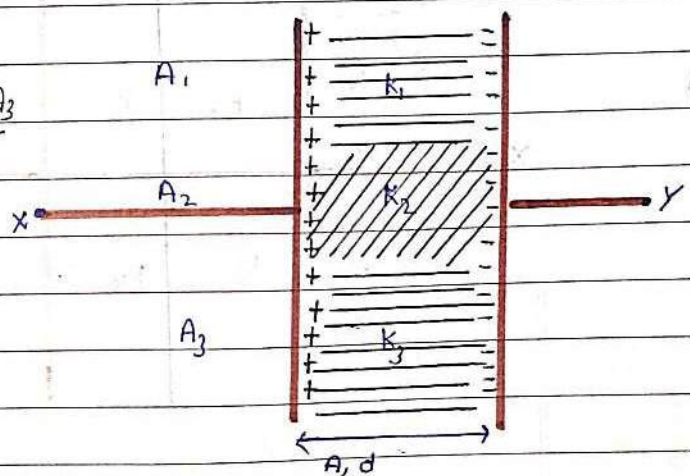
$$\frac{\epsilon_0 A}{2d} (k_1 + k_2) = C_{eq}$$

$$K_{eq} = \frac{k_1 + k_2}{2}$$



Q) Find C_{xy}

$$C_{eq} = \frac{k_1 \epsilon_0 A_1}{d} + \frac{k_2 \epsilon_0 A_2}{d} + \frac{k_3 \epsilon_0 A_3}{d}$$



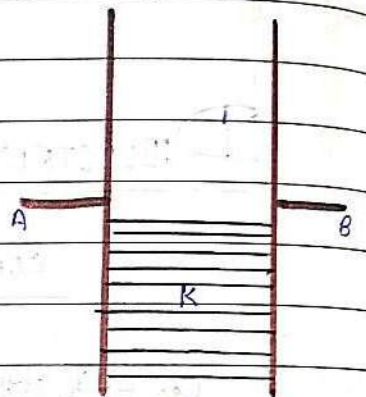
Q A parallel plate ^{air} capacitor has a capacitance C . Now half of the space is filled with a dielectric material with dielectric constant K as shown in figure. The new capacitance is C' . Then

a) $C' = \frac{C}{2} [1+K]$

b) $C' = C [1+K]$

c) $C' = C [1 + \frac{K}{2}]$

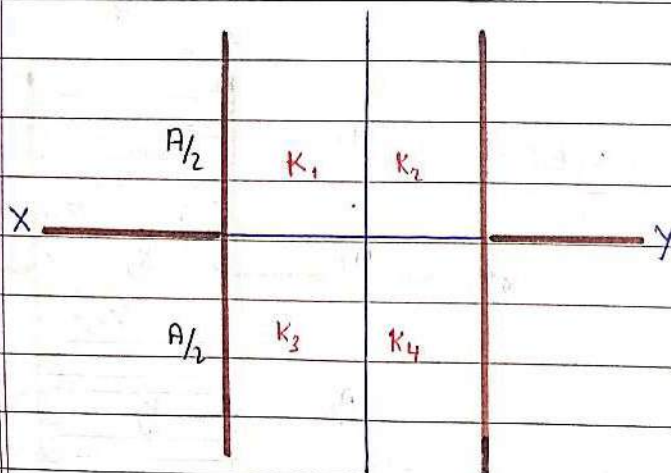
d) $C' = C [1 + \frac{K}{3}]$



Ans $C_{eq} = \frac{\epsilon_0 A}{2d} + \frac{K\epsilon_0 A}{2d}$
 $= \frac{\epsilon_0 A}{2d} [1+K]$

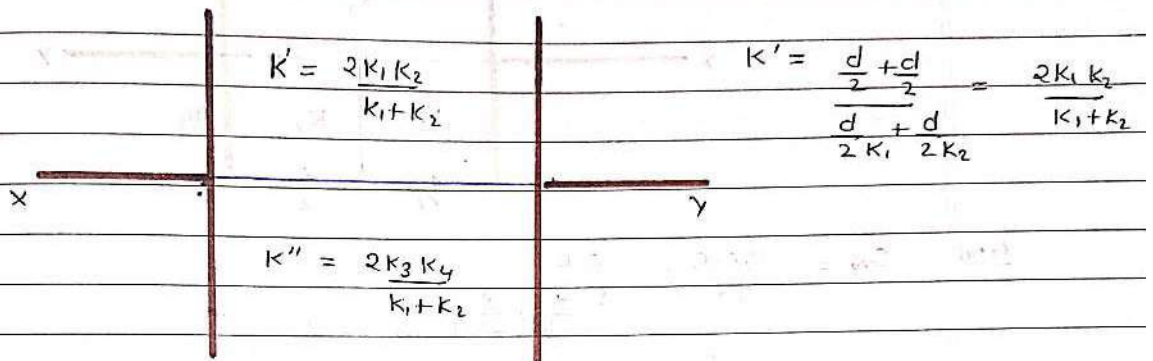
As $C = \frac{\epsilon_0 A}{d}$ $\therefore C_{eq} = \frac{C}{2} [1+K]$

Q



Ans Can we take K_1 & K_2 in parallel, it correct?
 ↳ No because potential is not same

Therefore we solve this question by taking K_1 and K_2 in series.



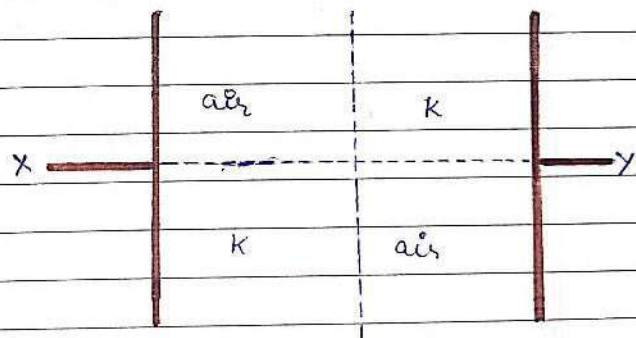
$$C_{eq} = \frac{\frac{2K_1K_2}{K_1+K_2} \epsilon_0 A}{\cancel{2d}} + \frac{\frac{2K_3K_4}{K_1+K_2} \epsilon_0 A}{\cancel{2d}}$$

$$= \frac{\epsilon_0 A}{d} \left[\frac{K_1K_2}{K_1+K_2} + \frac{K_3K_4}{K_1+K_2} \right]$$

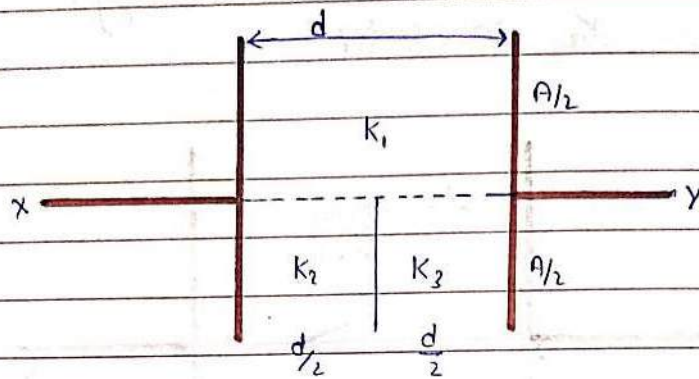
Q Find C_{xy}

$$C_{xy} = \frac{\epsilon_0 A}{\cancel{2} \left[\frac{d}{2K} + \frac{d}{2} \right]}$$

$$C_{xy} = \frac{2\epsilon_0 A}{d \left[\frac{K+1}{K} \right]} \quad \text{Ans}$$



Q Calculate capacitance b/w x and y



Ans $C_{xy} = \frac{K_1 \epsilon_0 A}{2d} + \frac{\epsilon_0 A}{2 \left[\frac{d}{2K_2} + \frac{d}{2K_3} \right]}$

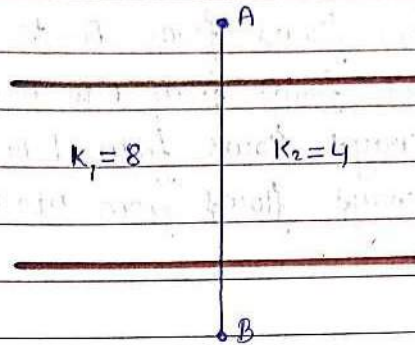
$$C_{xy} = \frac{\epsilon_0 A}{2d} \left[K_1 + \frac{1}{\left[\frac{1}{2K_2} + \frac{1}{2K_3} \right]} \right]$$

Q A capacitor having capacitance $1\mu F$ with air, is filled half-half with two dielectrics as shown. How many times capacitance will become?

a) 12

~~b) 6~~c) $8/3$

d) 3



Ans

$$1\mu F = \frac{\epsilon_0 A}{d}$$

$$C' = \frac{K_1 \epsilon_0 A}{d} + \frac{K_2 \epsilon_0 A}{d}$$

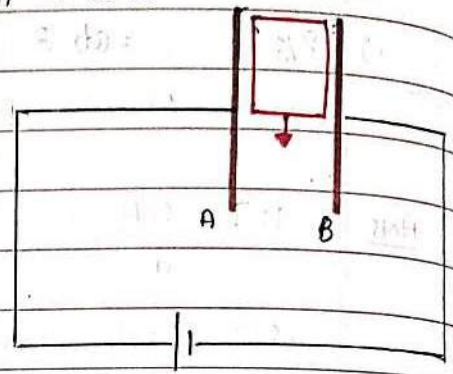
$$C' = \frac{8\epsilon_0 A}{2d} + \frac{4\epsilon_0 A}{2d}$$

$$= \frac{6 \times 8 \epsilon_0 A}{2d} = \frac{6 \epsilon_0 A}{d} = 6C$$

244

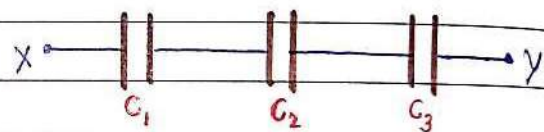
*** Q An insulator plate is passed through the plates of a capacitor. Then current outside the capacitor

- a) First flows from A to B and then from B to A
 b) First flows from B to A and then from A to B
 c) Always flows from B to A
 d) Always flows from A to B



Q In the circuit below $C_1 = 20 \mu F$, $C_2 = 40 \mu F$ and $C_3 = 50 \mu F$. If no capacitor can sustain more than 50V, then maximum potential between X and Y is.

- a) 95V (b) 75V
 c) 150V (d) 50V



Ans $q_{\max}$ on $C_1 = 1000 \mu C$
 $q_{\max}$ on $C_2 = 2000 \mu C$
 $q_{\max}$ on $C_3 = 2500 \mu C$

So in order to save each capacitor from burning

$$q_{\min} = 1000 \mu C$$

$$q = C_{eq} V$$

$$5 \times 1000 = \frac{200}{19} V$$

$$V = 95V$$

$$C_{eq} = \frac{40 \times 20}{30} = \frac{40}{3} \times 50 = \frac{200}{3}$$

$$\frac{190}{3}$$

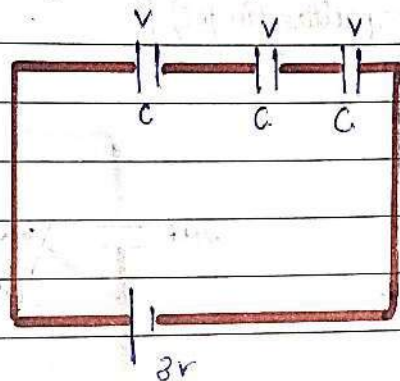
Q Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be.

a) $3C, \frac{V}{3}$

~~b) $\frac{C}{3}, 3V$~~

3) $3C, 3V$

4) $\frac{C}{3}, \frac{V}{3}$



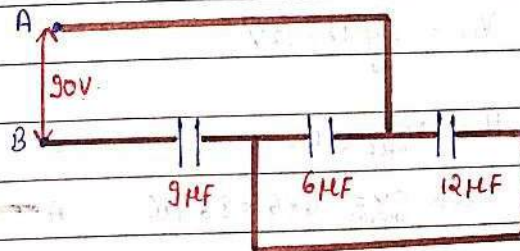
Q The charge on the $6\mu F$ capacitor in the circuit shown is.

a) $540\mu C$

b) $270\mu C$

~~c) $180\mu C$~~

d) $90\mu C$

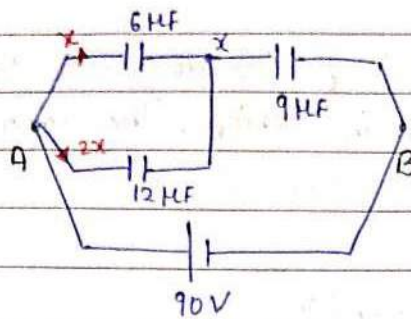


Ans

$C_{eq} = ?$

$6 + 12 = 18\mu F$

$\frac{18 \times 9}{18 + 9} = \frac{18 \times 9}{27} = 6\mu F$



$$3x = 540 \mu C$$

$$x = 180 \mu C \text{ Ans}$$

Q Few capacitors are connected to a battery of 12 V. What will be charge on each capacitor (in μC)?

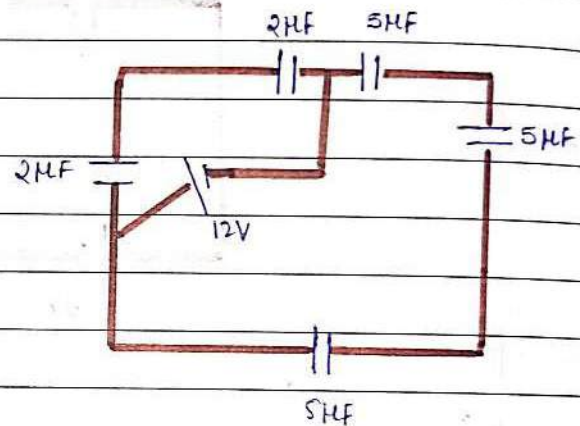
Ans $C_{eq} = \frac{5}{3} + 1 = \frac{8}{3} \mu F$

$$Q = C_{eq} V$$

$$Q = \frac{8}{3} \times 12 = 32 \mu C$$

$$Q_{2\mu C} = 1 \times 12 = 12 \mu C$$

$$Q_{5\mu C} = 20 \mu C \text{ Ans}$$



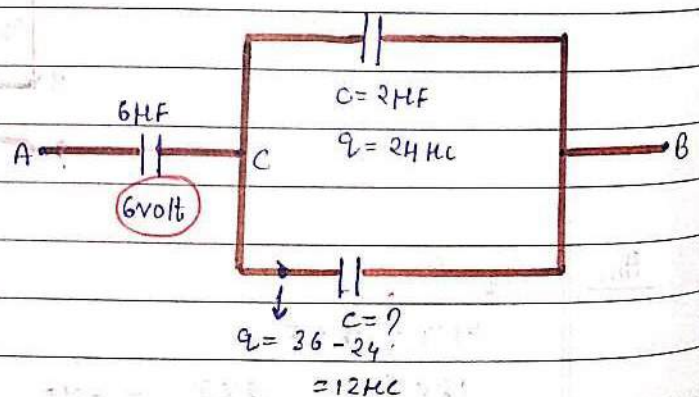
Q In the given circuit, the potential difference b/w A & B is 18V and charge on $2\mu F$ capacitor is $24\mu C$. The value of C_{10} .

Ans $V_{CB} = \frac{24}{2} = 12V$

the $V_{6\mu F} = 6V$

$$Q = \frac{CV}{C_{10} + C_{10}} = 6 \times 6 = 36 \mu C$$

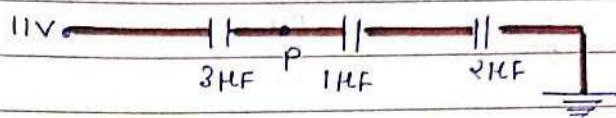
$$C = \frac{Q}{V} = \frac{12}{12} = 1 \text{ Volt Ans}$$



$$Q = 36 - 24 = 12 \mu C$$

Q In the given circuit the electric potential of P will be.

- 1) 5V 2) 6V
3) 8V ~~4) 9V~~

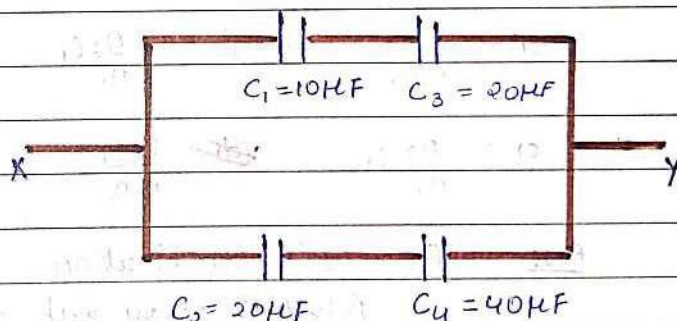


Ans $V_{\text{function}} = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2} = \frac{3 \times 11 + \frac{2}{3} \times 0}{3 + \frac{2}{3}}$
 $= \frac{\frac{11}{3}}{\frac{11}{3}} = 9V$

मूलदर्श
 $11V - \frac{Q}{3} - \frac{2Q}{2} = 0$
 $11V = \frac{2Q + 9Q}{6}$
 $66 = 11Q$
 $Q = 6$
 $V_P = 11 - \frac{Q}{3} = 11 - \frac{6}{3} = 9V$

Q In the circuit shown below $C_1 = 10\mu F$, $C_2 = C_3 = 20\mu F$ and $C_4 = 40\mu F$. If the charge on C_1 is $20\mu C$ then potential difference b/w x and y is

- a) 2V ~~b) 3V~~
c) 6V 4) 3.5V



Ans $Q = CV$
 $20 = \frac{20 \times 10}{3} V$
 $V = 3V$ Ans

Q A parallel plate capacitor has a uniform electric field E in the space b/w the plates. If the distance b/w the plates is d and area of each plate is A , the energy stored in the capacitor is.

a) $\frac{1}{2} \epsilon_0 E^2$ 2) $\frac{E^2 A d}{\epsilon_0}$

~~c) $\frac{1}{2} \epsilon_0 E^2 A d$~~ d) $\epsilon_0 E A d$

Q A series combination of n_1 capacitors each of value C_1 , is charged by a source of potential difference $4V$. When another parallel combination of n_2 capacitors, each of value C_2 , is charged by a source of potential difference V , it has the same (total) energy stored in it, as the first combination of this. The value of C_2 in terms of C_1 is then.

a) $\frac{2C_1}{n_1 n_2}$ b) $16 \frac{n_2 C_1}{n_1}$

c) $\frac{2n_2 C_1}{n_1}$ ~~d) $\frac{16 C_1}{n_1 n_2}$~~

Ans For series combination

Potential across each capacitor = $\frac{4}{n_1} \left[\frac{1}{2} \frac{C_1}{n_1} 16V^2 + \frac{1}{2} C_2 n_2 V^2 \right]$

$\frac{1}{2} C_1 \frac{16V^2}{n_1^2} \dots$

P. Total energy of n_1 capacitors = $n_1 \times \frac{1}{2} C_1 \frac{16}{n_1^2} \dots$

$\Rightarrow \frac{1}{2} C_1 \frac{16}{n_1} \dots \dots \dots (i)$

For parallel combination

Potential across each capacitor is V

then $\frac{1}{2} C_2 V^2$

$$\text{Total energy} = n_2 \frac{1}{2} C_2 V^2 \dots (ii)$$

$$\text{as } (i) = (ii)$$

$$n_1 \frac{1}{2} C_1 \frac{16 V^2}{n_1} = n_2 \frac{1}{2} C_2 V^2$$

$$C_2 = \frac{16 C_1}{n_1 n_2} \text{ ANS}$$

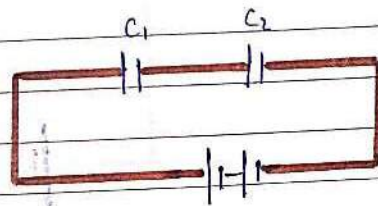
Q A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K , which can just fill the gap of the capacitor is now inserted in it. Which of the following is incorrect?

- a) The change in energy stored is $\frac{1}{2} CV^2 \left(\frac{1}{K} - 1 \right)$
- ☒ b) The charge on the capacitor is not conserved
- c) The potential difference between the plates decreases K times
- d) The energy stored in the capacitor decreases K times

Q In the circuit below, if a dielectric is inserted into C_2 , then the charge on C_1 will,

- ☒ a) Increase
- b) Decrease
- c) Remain same
- d) Be halved.

ANS C_{eq} will increase
but potential across
the two capacitors
must be constant $\therefore$
 q will increase



Q Find common potential at junction and charge on each plate

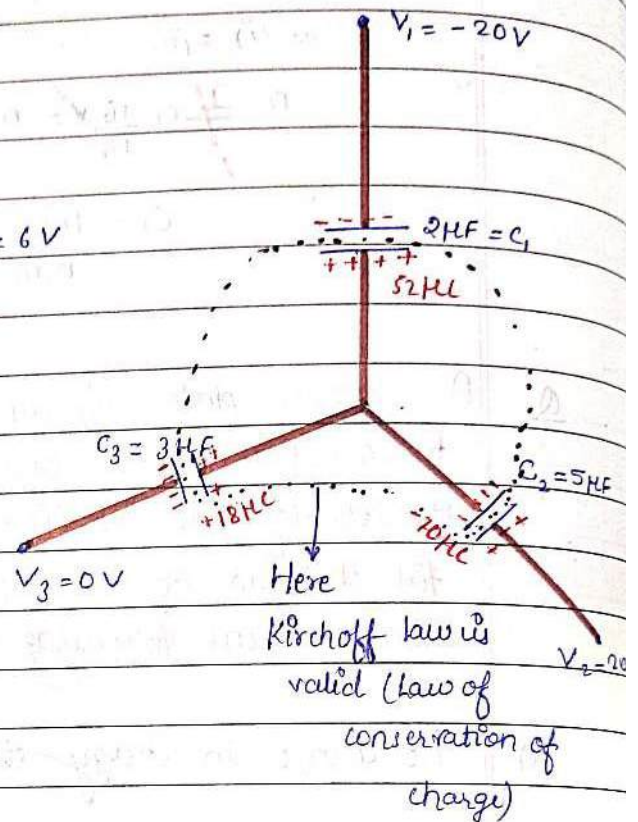
Ans
$$V_{\text{junction}} = \frac{V_1 C_1 + V_2 C_2 + V_3 C_3}{C_1 + C_2 + C_3}$$

$$= \frac{-40 + 100 + 0}{10} = \frac{60}{10} = 6V$$

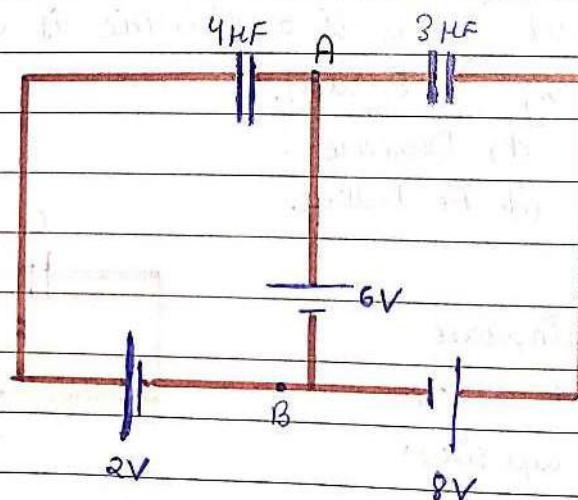
$$Q_{3HF} = Q_{\Delta V} = 3 \times 6 = 18HC$$

$$Q_{5HF} = 5 \times 14 = 70HC$$

$$Q_{2HF} = 2 \times 26 = 52HC$$

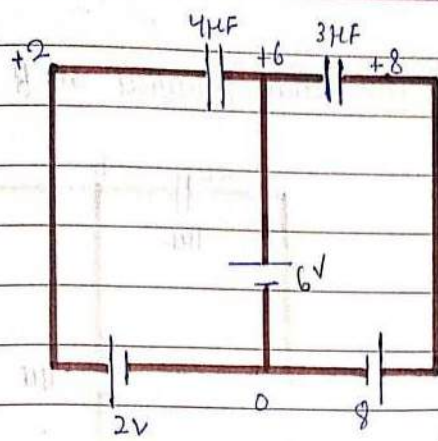


Q Find potential at A, charge on each capacitor and potential difference across each capacitor.
 No we cannot calculate exact potential of point A

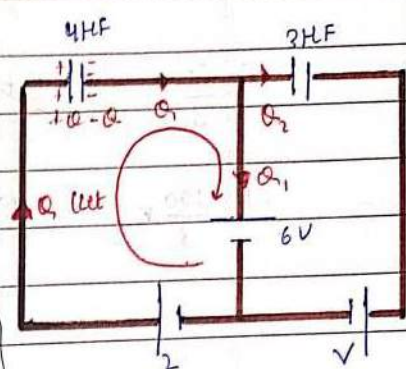


Ans Lets assume potential at pt B be zero.

then



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Here potential of A comes to be 6 but it is not correct, if we chose different point as reference point then potential at A will be different but potential diff across A $4\mu F$ and $3\mu F$ will be same
 $\therefore Q_{4\mu F} = C\Delta V = 4 \times 4 = 16\mu C$
 $Q_{3\mu F} = C\Delta V = 3 \times 2 = 6\mu C$

By kirchoff rule

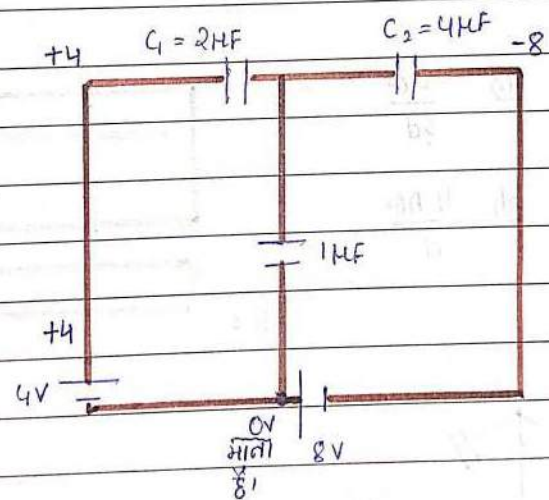
$$2 - \frac{Q}{4} - 6 = 0$$

$$-4 = \frac{Q}{4}$$

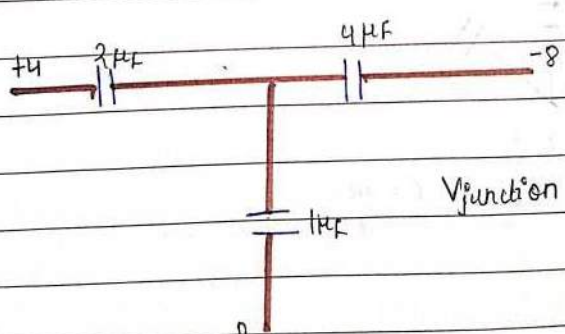
$$Q = -16$$

indicates jo humne direction main charge ko movement ki uske opposite hoga charge ka movement.

Q Find potential at junction.



Ans

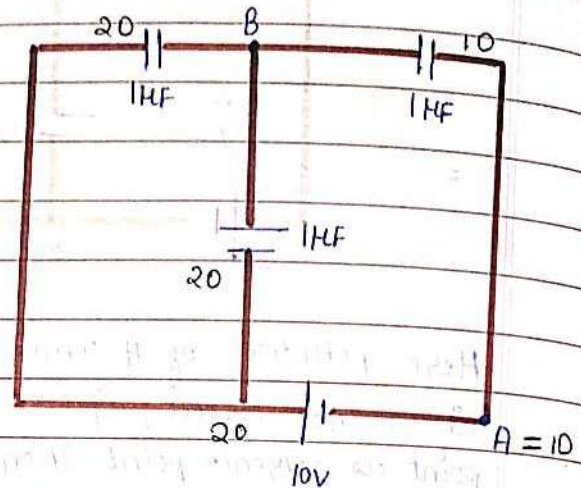


$$V_{\text{junction}} = \frac{8 + (-32)}{7}$$

$$= \frac{-24}{7}$$

Q If potential at A is 10V then potential at B is ?

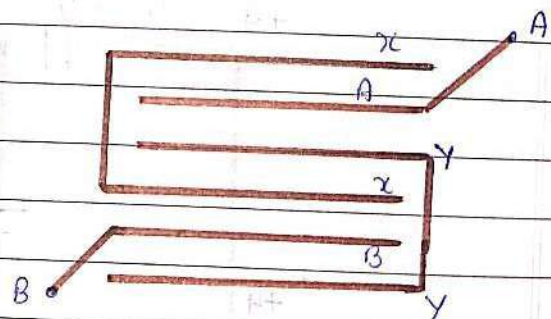
- a) $\frac{25}{3} V$ ~~b) $\frac{50}{3}$~~
c) $\frac{100}{3} V$ (d) 50V



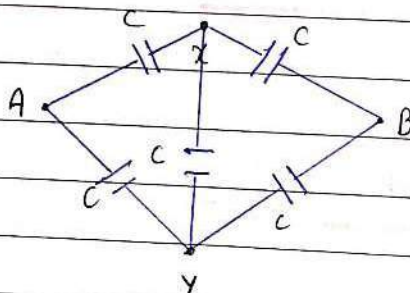
Ans
$$V_{\text{junction}} = \frac{20 \times 1 + 10 \times 1 + 1 \times 20}{1+1+1} = \frac{50}{3} V \text{ Ans}$$

Q If each plate has area A and separation b/w successive plates is d from equivalent capacitance between A and B is.

- ~~a) $\frac{A\epsilon_0}{d}$~~ (b) $\frac{4\epsilon_0}{2d}$
c) $\frac{4A\epsilon_0}{d}$ (d) $\frac{4A\epsilon_0}{d}$

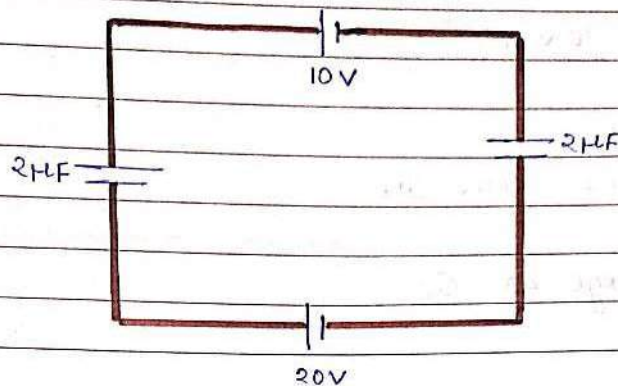


Ans



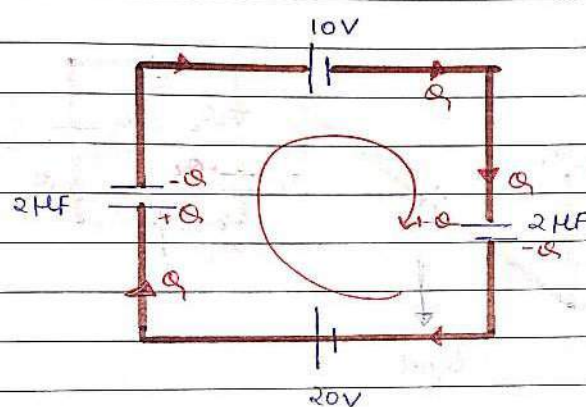
$$C_{eq} = C = \frac{A\epsilon_0}{d}$$

Q



Ans

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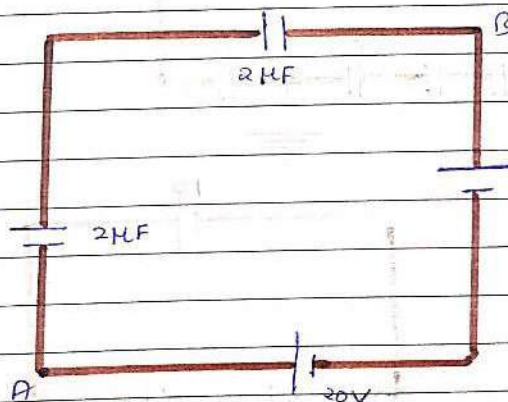


$$20 - \frac{Q}{2} - 10 - \frac{Q}{2} = 0$$

$$10 = Q$$

$$Q = 10 \mu C$$

TRICK



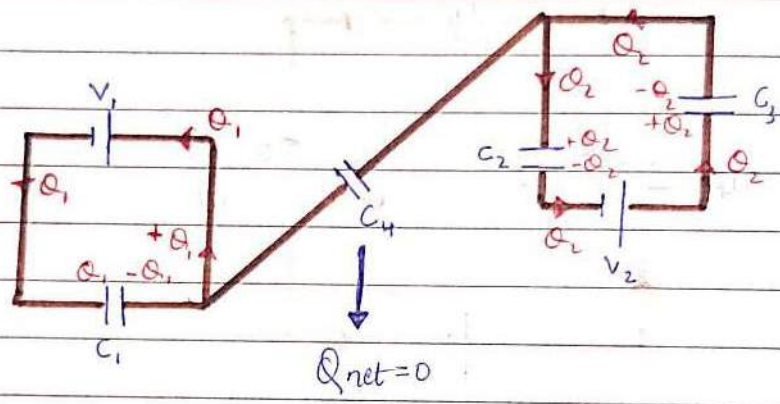
We can do like this if u b/w two batteries there is a capacitor.

$V_{AB} = 10 \text{ volt}$

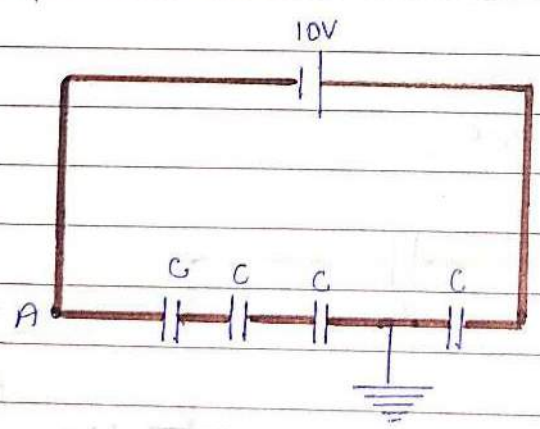
$Q = CV$

$Q = 10 \times 1 = 10 \mu\text{C}$ Ans

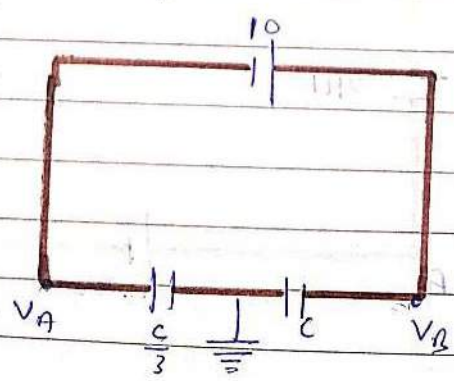
*** Find charge on C_4



* Q Find potential at A



Ans Method-1

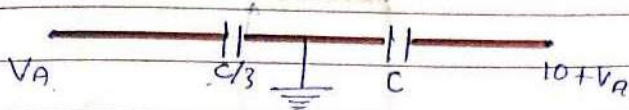


$$V_A - V_B = -10$$

OR

$$V_B - V_A = 10V$$

then.



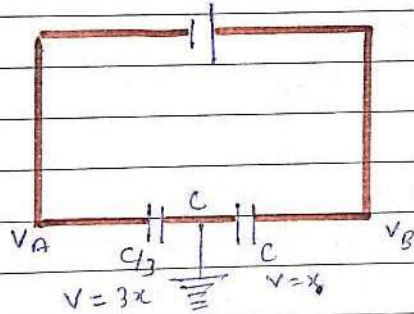
$$V_{\text{junction}} = \frac{\frac{C}{3} V_A + C(10 + V_A)}{\frac{C}{3} + C} = 0$$

$$\frac{4}{3} V_A = -10 \quad - V_A$$

$$4V_A = -30$$

$$V_A = -\frac{15}{2} V$$

Method-2



$$3x + x = 10V$$

$$4x = 10V$$

$$x = \frac{10V}{4} = \frac{5}{2} V$$

$$x = \text{Potential across } \frac{C}{3}$$

$$\text{then } V_C - V_A = \frac{15}{2}$$

$$0 - V_A = \frac{15}{2}$$

$$V_A = -\frac{15}{2} V \quad \underline{\text{Ans}}$$

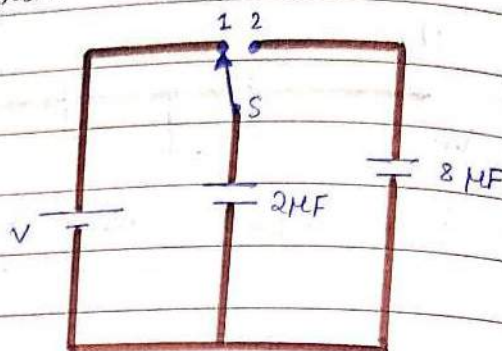
Q A capacitor of $2\mu\text{F}$ is charged as shown in the diagram when the switch S is turned to position 2, the %age of its stored energy dissipated is.

~~a) 80%~~

b) 0%

c) 20%

(d) 75%



Ans

Initially energy stored

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

Loss in energy after connect it to point 2

$$\text{is } \frac{1}{2} \times \frac{C_1 C_2 (AV)^2}{C_1 + C_2} = \frac{1}{2} \times \frac{2 \times 8}{10} V^2$$

$$\% \text{ loss} = \frac{\frac{1}{2} \times \frac{2 \times 8}{10} V^2}{\frac{1}{2} \times 2 V^2} \times 100$$

$$\Rightarrow 80\%$$

Q

Two identical capacitors C_1 and C_2 of equal capacitance are connected as shown in the circuit. Terminals a and b of the key K are connected to charge capacitor C_1 using battery of emf V volt. Now disconnecting a and b , the terminal b and c are connected. Due to this what will be the percentage loss of energy.

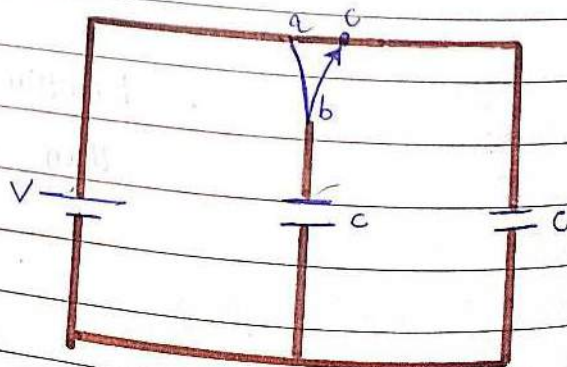
Ans

a) 75%

b) 0%

~~c) 50%~~

d) 25%



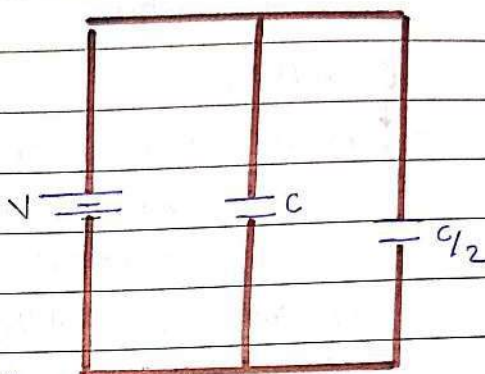
Ans

$$\frac{\frac{1}{2} \times \frac{C_1 C_2}{2C} V^2}{\frac{1}{2} CV^2} \times 100 = 50\%$$

Q Two condensers one of capacity c and other of capacity $\frac{c}{2}$ are connected to a V -volt battery as shown in figure. The work done in charging fully both the condensers is.

a) $\frac{1}{4}cv^2$ ~~b) $\frac{3}{4}cv^2$~~

c) $\frac{1}{2}cv^2$ (d) $2cv^2$

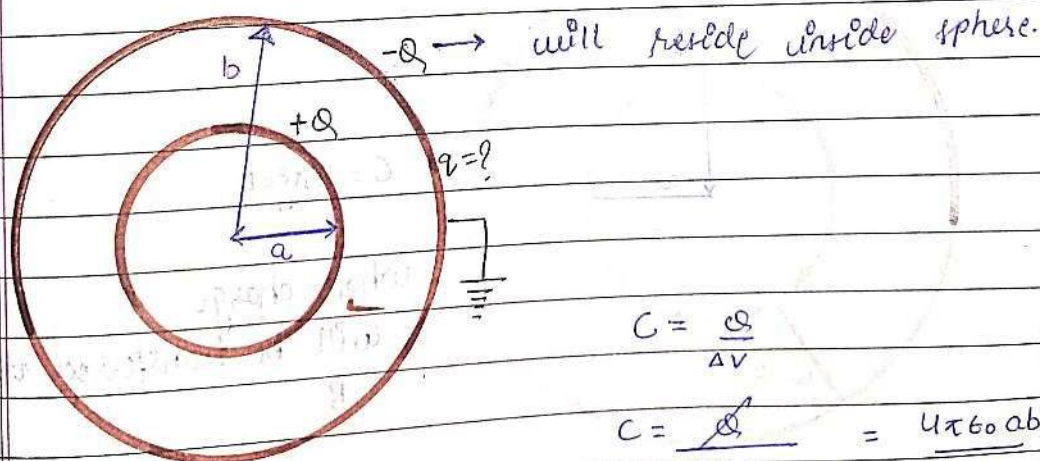


Ans $C_{eq} = \frac{c}{2} + c = \frac{3c}{2}$

Work done by the battery
= 2 work done in charging

$\Rightarrow \frac{1}{2} \frac{3c}{2} v^2 = \frac{3}{4} cv^2$

Q COMBINATION OF TWO CONCENTRIC SPHERE ; OUTER IS EARTHED AND INNER IS GIVEN CHARGE Q



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

$C = \frac{Q}{kQ[\frac{1}{a} - \frac{1}{b}]} = \frac{4\pi\epsilon_0 ab}{b-a}$

Potential in outer sphere
should be zero

$\therefore \frac{kQ}{b} + \frac{kq}{b} = 0$
 $q = -Q$

$C = \frac{4\pi\epsilon_0 ab}{b-a}$

MR* Formula feel

1) If $a=b$

then it will behave as
single sphere.

$C = \infty$

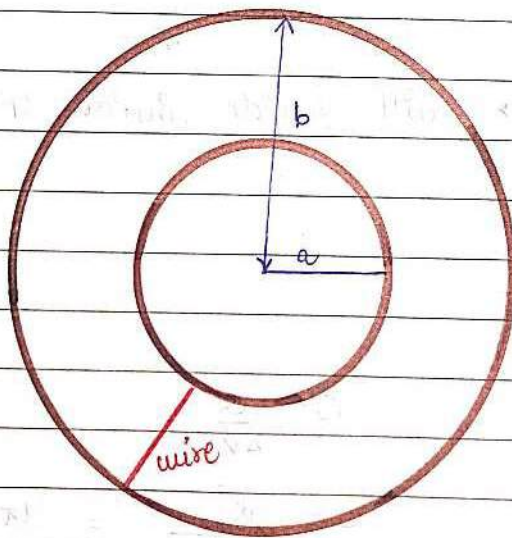
how much charge it can
store for unit change
in voltage

and since after adding such a large
amount of charge potential is not
increasing therefore its
capacitance is infinite.

2) $b = \infty$

then $C = 4\pi\epsilon_0 a$

Important
ques



$$C = 4\pi\epsilon_0 b$$

whole charge
will be transferred to
B

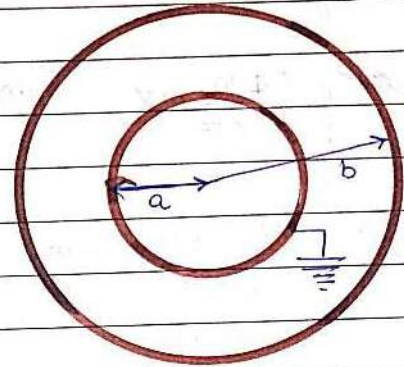
* Q Two spherical conductors A and B of radii a and b ($b > a$) are placed concentrically in air. B is given a charge $(+Q)$ and A is earthed. The equivalent capacitance of the system is.

a) $4\pi\epsilon_0 \left(\frac{ab}{b-a} \right)$

b) $4\pi\epsilon_0 [a+b]$

c) $4\pi\epsilon_0 b$

~~a)~~ $4\pi\epsilon_0 \frac{b^2}{b-a}$



Ans $Q_{\text{inner}} = ?$ let q
 $\frac{kq}{a} + \frac{kQ}{b} = 0$
 $q = -\frac{Qa}{b}$

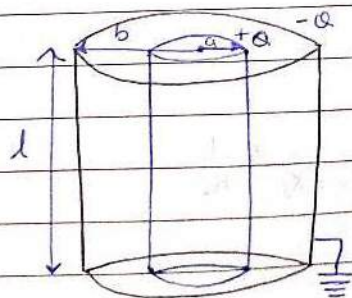
$\Delta V = V_{\text{outer sphere}} - V_{\text{inner sphere}}$
 $= \frac{kQ}{b} - \frac{kQa}{b^2} = 0$

$C = \frac{Q}{\Delta V}$ (given charge) $= \frac{Q}{kQ \left[\frac{1}{b} - \frac{a}{b^2} \right]} = \frac{4\pi\epsilon_0 b^3}{b^2 - ba} = \frac{4\pi\epsilon_0 b^2}{b-a}$

CYLINDRICAL CAPACITOR.

It consists of two co-axial cylinders of radii a and b ($a < b$), inner cylinder is given charge $+Q$ while outer cylinder is earthed. Common length of the cylinders is l then.

$C = \frac{2\pi\epsilon_0 l}{\log_e \frac{b}{a}}$



Q A cylinder capacitor has two coaxial cylinders of length 20cm and radii $2r$ and r . Inner cylinder is given a charge $10\mu C$ and outer cylinder ^{a charge} of $-10\mu C$. The potential difference b/w the two cylinders will be

- (a) $\frac{0.1 \ln 2}{4\pi\epsilon_0} mV$ (b) $\frac{\ln 2}{4\pi\epsilon_0} mV$ (c) $\frac{10 \ln 2}{4\pi\epsilon_0} mV$ (d) $\frac{0.01 \ln 2}{4\pi\epsilon_0} mV$

Ans

$$l = 20cm = 0.2m$$

$$b = 2r$$

$$a = r$$

$$Q = 10\mu C$$

$$C = \frac{2\pi\epsilon_0 l}{\log_e \frac{2r}{r}} (20 \times 10^{-2})$$

$$\log_e \frac{2r}{r}$$

$$= \frac{2\pi\epsilon_0 \cdot 0.2}{\ln 2} = \frac{0.4\pi\epsilon_0}{\ln 2}$$

$$\Delta V = \frac{Q}{C} = \frac{10\mu C \ln 2}{0.4\pi\epsilon_0}$$

$$= \frac{100 \ln 2 \times 10^{-6}}{4\pi\epsilon_0}$$

$$= 0.3 + \frac{0.1 \ln 2}{4\pi\epsilon_0} 10^{-3} V$$

$$= \frac{0.1 \ln 2}{4\pi\epsilon_0} mV \text{ Ans}$$

Q A parallel plate capacitor of area A , plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure below. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by

a) $\frac{2}{K} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$

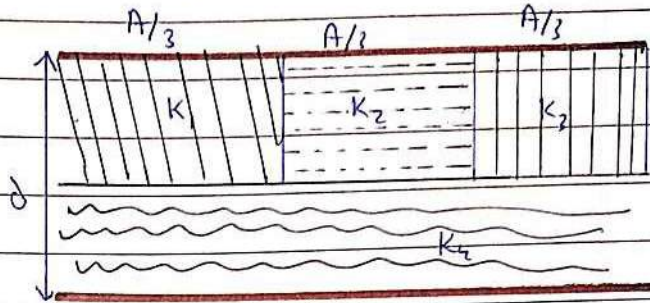
b) $\frac{1}{K} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{3}{2k_4}$

c) $K = K_1 + K_2 + K_3 + 3K_4$

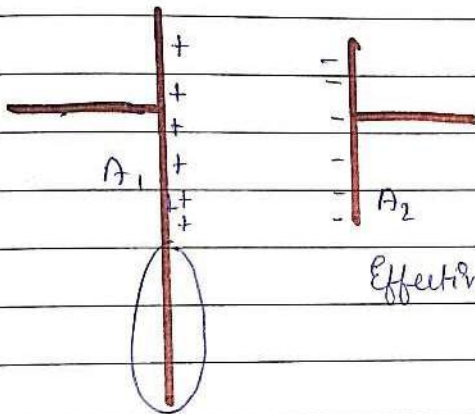
(d) $K = \frac{2}{3}(K_1 + K_2 + K_3) + 2K_4$

Ans

MR* If $K_1 = K_2 = K_3 = 1$
 $K = 1$



Imp

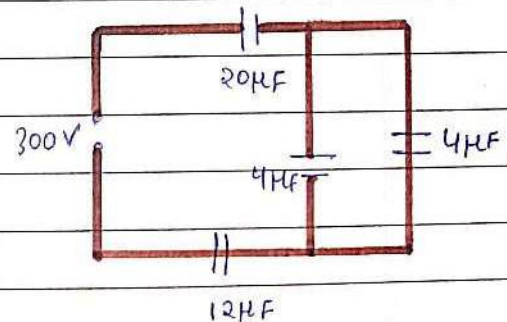


Effective area = A_2

Q In the adjoining figure, four capacitors are shown with their respective capacitances and the PD, applied. The charge and the PD, across the $4\mu F$ capacitor will be

Ans a) $600\mu C$, 150 volt b) $300\mu C$, 75 V

c) $800\mu C$, 200 V ~~(d)~~ $580\mu C$, 145 V



Ans

$$C_{eq} = \frac{120}{31}$$

$$Q = CV = \frac{120}{31} \times \frac{300}{2} = 580\mu C$$

$$V_{4\mu F} = \frac{580}{4} = 145\text{ V}$$