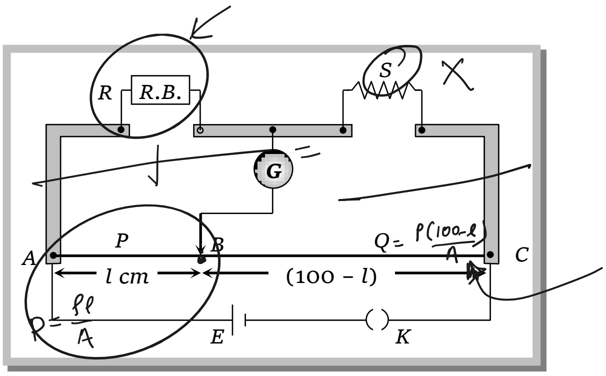
(5) **Meter bridge :** In case of meter bridge, the resistance wire *AC* is 100 *cm* long. Varying the position of tapping point *B*, bridge is balanced. If in balanced position of bridge $AB = l$, BC $(100 - l)$ so that $\frac{Q}{P} = \frac{(100-l)}{l}$. Also $\frac{P}{Q} = \frac{R}{S} \Rightarrow S = \frac{(100-l)}{l}R$



Focus on learning not on writing.

Balancing length is independent from material & thickness of test wire.

$$\frac{R.B.}{\frac{\cancel{\rho} l}{\cancel{A}}} = \frac{S}{\frac{\cancel{\rho}(100-l)}{\cancel{A}}} \quad S \leftarrow X$$

$$\boxed{X = \frac{(100-l)R.B.}{l}}$$

If we interchange galvanometer and battery. then also there will be no affect.

Potentiometer

Potentiometer is a device mainly used to measure emf of a given cell and to compare emf's of cells. It is also used to measure internal resistance of a given cell.

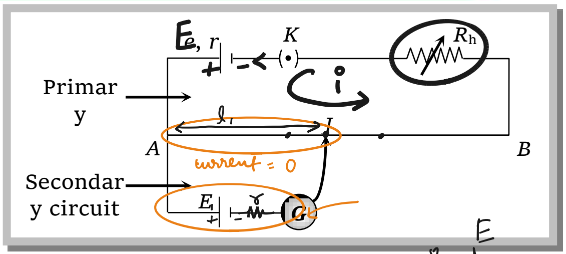
(1) **Superiority of potentiometer over voltmeter** : An ordinary voltmeter cannot measure the emf accurately because it does draw some current to show the deflection.

Potentiometer is based on no deflection method. When the potentiometer gives zero deflection, it does not draw any current from the cell or the circuit

(2) **Circuit diagram :**

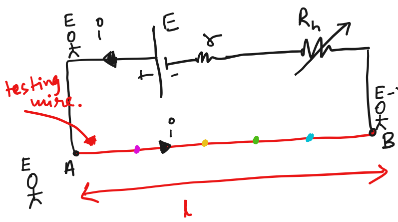
$$V_{AB} = E - ir$$
$$i = 0$$

$\boxed{V_{AB} = E}$



$\boxed{E_1 = l_1 K}$

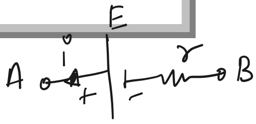
Primary circuit of potentiometer



potential drop on l length of wire is V

potential gradient $K = \frac{V}{l}$

potential drop on wire per unit length of wire.



$V_{AB} = E - i r$

$i = 0$

$\boxed{V_{AB} = E}$

J = Jockey

K = Key

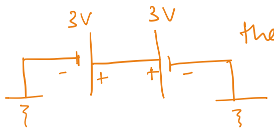
R = Resistance of potentiometer wire,

ρ = Specific resistance of potentiometer wire.

R_h = Variable resistance which controls the current through the wire AB

working concept of potentiometer

current always flows from higher potential to lower potential



there will be No current.

(3) **Points to be remember**

(i) The specific resistance (ρ) of potentiometer wire must be high but its temperature coefficient of resistance (α) must be low.

(ii) All higher potential points (terminals) of primary and secondary circuits must be connected together at point A and all lower potential points must be connected to point B or jockey.

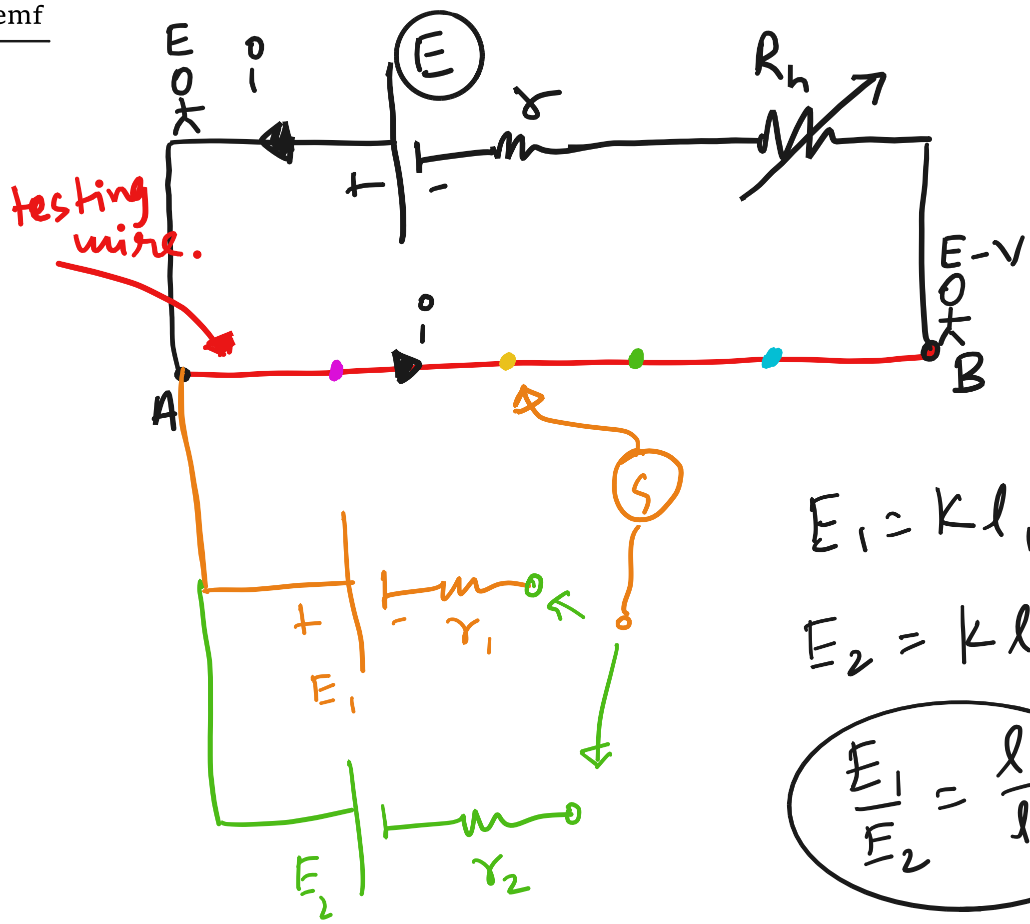
(iii) The value of known potential difference must be greater than the value of unknown potential difference to be measured.

(iv) The potential gradient must remain constant. For this the current in the primary circuit must remain constant and the jockey must not be slided in contact with the wire.

(v) The diameter of potentiometer wire must be uniform everywhere.

Applications of potentiometer

Comparing emf

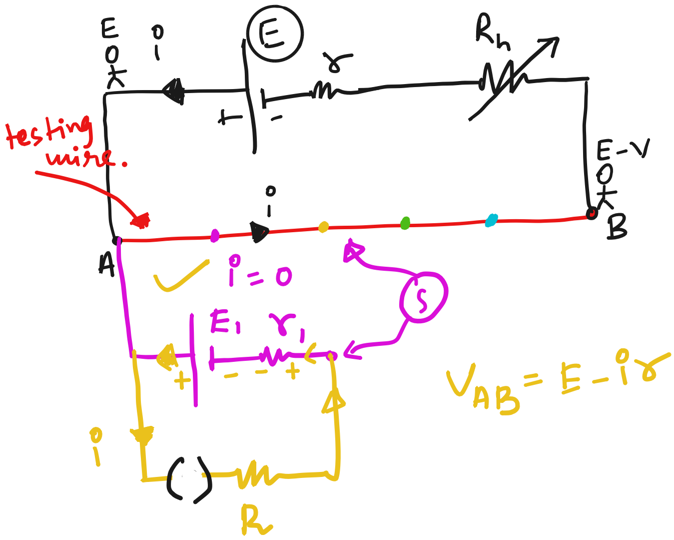


$E_1 = Kl_1$

$E_2 = Kl_2$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Internal resistance of cell-



Switch is on

terminal potential

$V_{AB} = E_1 - ir_1$

$V_{AB} = Kl_2$ — (B)

$r = R\left(\frac{E}{V} - 1\right)$

$r = R\left(\frac{Kl_1}{Kl_2} - 1\right)$

$$\boxed{r = R\left(\frac{l_1}{l_2} - 1\right)}$$

Switch is off. we will get here emf

$E_1 = Kl_1$ — (A)

Capacity.

$Q \propto V$

$Q = CV.$

Capacitance

(1) **Definition :** We know that charge given to a conductor increases it's potential *i.e.*, $Q \propto V \Rightarrow Q = CV$

Where C is a proportionality constant, called capacity or capacitance of conductor. Hence capacitance is the ability of conductor to hold the charge.

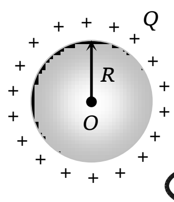
(2) **Unit and dimensional formula** : S.I. unit is $\frac{Coulomb}{Volt} = Farad\ (F)$

Smaller S.I. units are mF, μF, nF and pF ($1mF = 10^{-3}F$, $1\mu F = 10^{-6}F$, $1nF = 10^{-9}F$, $1pF = 1\mu\mu F = 10^{-12}F$)

C.G.S. unit is *Stat Farad* $1F = 9 \times 10^{11}$ *Stat Farad*. Dimension : $[C] = [M^{-1}L^{-2}T^{4}A^{2}]$.

(3) **Capacity of an isolated spherical conductor :** When charge Q is given to a spherical conductor of radius R, then potential at the surface of sphere is

$$V = k.\frac{Q}{R} \qquad \left\{k = \frac{1}{4\pi\varepsilon_0}\right\}$$



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

$4\pi\varepsilon_0 R\, V = Q$

$CV = Q$

$C = 4\pi\varepsilon_0 R$

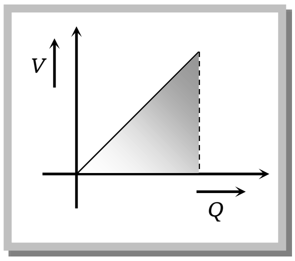
H.W. $C_{earth} = ?$

Hence it's capacity $C = \frac{Q}{V} = 4\pi\varepsilon_0 R \Rightarrow C = 4\pi\varepsilon_0 R = \frac{1}{9 \times 10^9}.R$

in C.G.S. $C = R$

Note : ❑If earth is assumed to be spherical having radius $R = 6400\ km$. It's theortical capacitance $C = \frac{1}{9 \times 10^9} \times 6400 \times 10^3 = 711\ \mu F$. But for all practical purpose capacitance of earth is taken infinity.

(4) **Energy of a charged conductor :** When a conductor is charged it's potential increases from 0 to V as shown in the graph; and work is done against repulsion, between charge stored in the conductor and charge coming from the source (battery). This work is stored as "electrostatic potential energy"

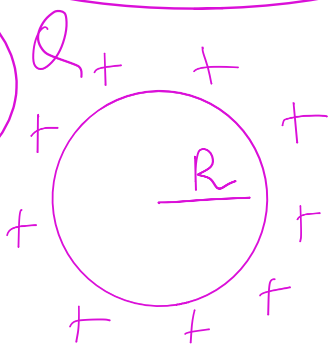


From graph : Work done = Area of graph $= \frac{1}{2}QV$

Hence potential energy $U = \frac{1}{2}QV$; By using $Q = CV$, we can write

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

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



$$U = \frac{1}{2}CV^2 \qquad V = \frac{Q}{4\pi\varepsilon_0 R}$$

$$U = \frac{1}{2}\cancel{4\pi\varepsilon_0 R}\,\frac{Q^2}{(4\pi\varepsilon_0 R)^{\cancel{2}}}$$

(5) **Combination of drops :** Suppose we have n identical drops each having – Radius – r, Capacitance – c, Charge – q, Potential – v and Energy – u.

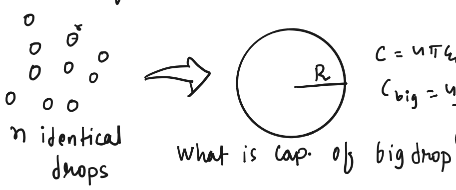
If these drops are combined to form a big drop of – Radius – R, Capacitance – C, Charge – Q, Potential – V and Energy – U then –

(i) **Charge on big drop :** $Q = nq$

(ii) **Radius of big drop :** Volume of big drop = n × volume of a single drop *i.e.*, $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$, $R = n^{1/3} r$

if each small drop has cap c

(iii) **Capacitance of big drop :** $C = n^{1/3} c$



$c = 4\pi\varepsilon_0 R$

$C_{big} = 4\pi\varepsilon_0 r n^{1/3}$

$C_{big} = n^{1/3} C_{small}$

$n \times \frac{4}{3}\cancel{\pi} r^3 = \frac{4}{3}\cancel{\pi} R^3$, $n^{1/3} r = R$

(iv) **Potential of big drop :** $V = \frac{Q}{C} = \frac{nq}{n^{1/3}c}$ $\quad V = n^{2/3}v$

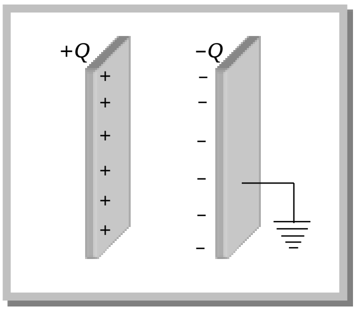
(v) **Energy of big drop :** $U = \frac{1}{2}CV^2 = \frac{1}{2}(n^{1/3}c)(n^{2/3}v)^2$ $\quad U = n^{5/3}u$

Capacitor

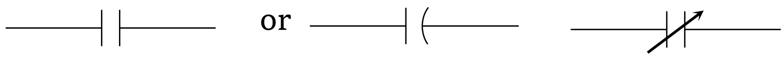
(1) **Definition :** A capacitor is a device that stores electric energy. It is also named condenser.

or

A capacitor is a pair of two conductors of any shape, which are close to each other and have equal and opposite charge.



(2) **Symbol :** The symbol of capacitor are shown below



(6) **Energy stored :** When a capacitor is charged by a voltage source (say battery) it stores the electric energy. If C = Capacitance of capacitor; Q = Charge on capacitor and V = Potential difference across capacitor then energy stored in capacitor $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$

Note : ❑In charging capacitor by battery half the energy supplied is stored in the capacitor and remaining half energy (1/2 QV) is lost in the form of heat.

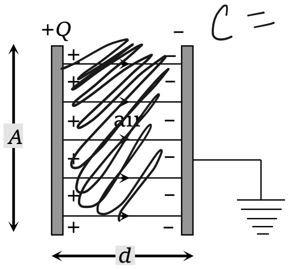
(7) **Types of capacitors :** Capacitors are of mainly three types as described in given table

Parallel Plate Capacitor

It consists of two parallel metallic plates (may be circular, rectangular, square) separated by a small distance

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

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



A = Effective overlaping area of each plate

d = Separation between the plates

Q = Magnitude of charge on the inner side of each plate

σ = Surface density of charge of each plate $\left(=\frac{Q}{A}\right)$

V = Potential difference across the plates

E = Electric field between the plates $\left(=\frac{\sigma}{\varepsilon_0}\right)$

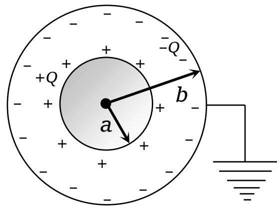
Capacitance : $C = \frac{\varepsilon_0 A}{d}$

in C.G.S. : $C = \frac{A}{4\pi d}$

If a dielectric medium of dielectric constant K is filled completely between the plates then capacitance increases by K times $C' = KC$

Spherical Capacitor

It consists of two concentric conducting spheres of radii a and b ($a < b$). Inner sphere is given charge $+Q$, while outer sphere is earthed



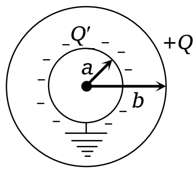
Capacitance $C = 4\pi\varepsilon_0 \cdot \frac{ab}{b-a}$

in C.G.S. $C = \frac{ab}{b-a}$. In the presence of dielectric medium (dielectric constant K) between the spheres $C' = 4\pi\varepsilon_0 K\frac{ab}{b-a}$

IIT

Special Case :

If outer sphere is given a charge $+Q$ while inner sphere is earthed



Induced charge on the inner sphere

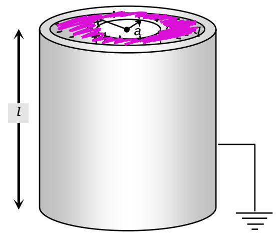
$Q' = -\frac{a}{b}.Q$, $C' = 4\pi\varepsilon_0 \cdot \frac{b^2}{b-a}$

This arrangement is not a capacitor. But it's capacitance is equivalent to the sum of capacitance of spherical capacitor and spherical conductor *i.e.*

$4\pi\varepsilon_0 \cdot \frac{b^2}{b-a} = 4\pi\varepsilon_0\frac{ab}{b-a} + 4\pi\varepsilon_0 b$

Cylindrical Capacitor

It consists of two concentric 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



Capacitance

$C = \frac{2\pi\varepsilon_0 l}{\log_e\left(\frac{b}{a}\right)}$

$C = \frac{2\pi\varepsilon_0 l}{\log(b/a)}$

In the presence of dielectric medium (dielectric constant K) capacitance increases by K times and

$C' = \frac{2\pi\varepsilon_0 Kl}{\log_e\left(\frac{b}{a}\right)}$

Variation of Different Variables (Q, C, V, E and U) of Parallel Plate Capacitor

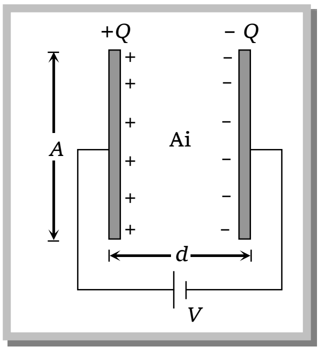
Suppose we have an air filled charged parallel plate capacitor having variables are as follows :

Charge – Q, Surface charge density – $\sigma = \frac{Q}{A}$, Capacitance – $C = \frac{\varepsilon_0 A}{d}$

Potential difference across the plates – $V = E.d$

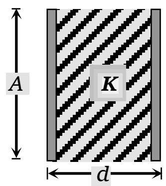
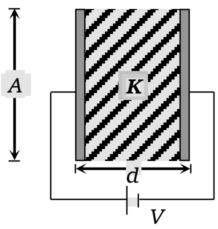
Electric field between the plates – $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

Energy stored – $U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$



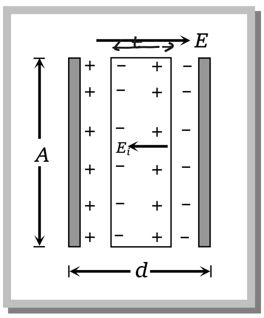
(1) **When dielectric is completely filled between plates :** If a dielectric slab is fills completely the gap between the plates, capacitance increases by K times *i.e.*, $C' = \frac{K\varepsilon_0 A}{d}$ $\Rightarrow$ $C' = KC$

The effect of dielectric on other variables such as charge. Potential difference field and energy associated with a capacitor depends on the fact that whether the charged capacitor is disconnected from the battery or battery is still connected.

Quantity	Battery is Removed	Battery Remains connected
	 $Q = KCV'$ $K\cancel{C}V' = \cancel{C}V$ $V' = V/K$ Charge will remain constant. $Q = CV,$	 $Q = CV$ —(A) $Q' = KCV$ —(B) $Q' = KQ$ potential remains V
Capacity	$C' = KC$	$C' = KC$
Charge	$Q' = Q$ (Charge is conserved)	$Q' = KQ$
Potential	$V' = V/K$	$V' = V$ (Since Battery maintains the potential difference)
Intensity	$E' = E/K$	$E' = E$
Energy	$U' = U/K$ $\downarrow U = \frac{Q^2}{2C\uparrow}$ constant.	[redacted] $U' = KU$ $U' = \frac{CV^2}{2} = \frac{KCV^2}{2} = KU$

Note : ❑ If nothing is said it is to be assumed that battery is disconnected.

(2) **When dielectric is partially filled between the plates :**



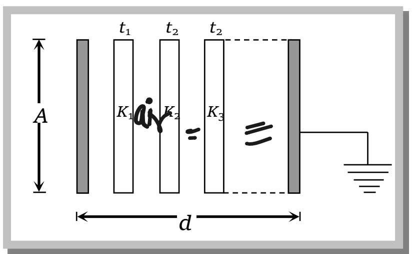
$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$$

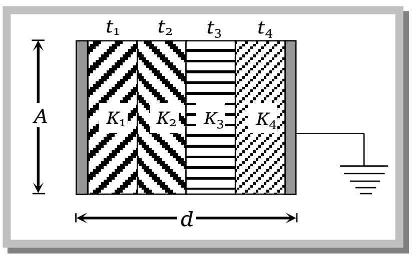
if we place metal $K = \infty$

$$C = \frac{\varepsilon_0 A}{d - t.}$$

Now capacitance of the capacitor

$$C' = \frac{Q}{V'} \Rightarrow C' = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$$

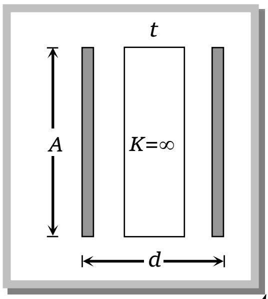


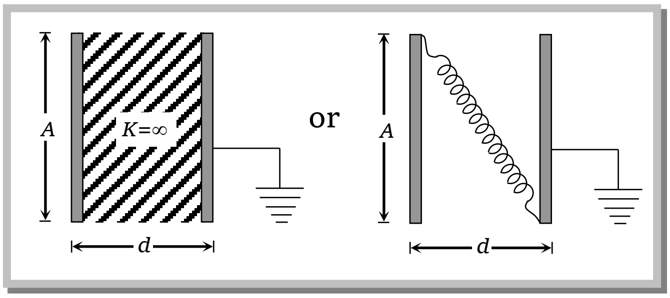


$$C' = \frac{\varepsilon_0 A}{d - (t_1 + t_2 + t_3 + \dots\dots) + \left(\frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3} + \dots\dots\right)}$$

$$C' = \frac{\varepsilon_0 A}{\left(\frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3} + \frac{t_4}{K_4}\right)}$$

(3) **When a metallic slab is inserted between the plates :**



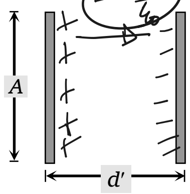
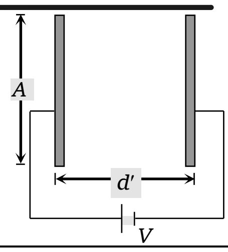


Capacitance $C' = \frac{\varepsilon_0 A}{(d-t)}$

$C' = \infty$ (In this case capacitor is said to be short circuited)

(4) **When separation between the plates is changing :** If separation between the plates changes then it's capacitance also changes according to $C \propto \frac{1}{d}$. The effect on other variables depends on the fact that whether the charged capacitor is disconnected from the battery or battery is still connected.

(i) **Separation is increasing**

Quantity	Battery is removed	Battery remains connected
	$C = \frac{\varepsilon_0 A}{d}$ $E = \frac{\sigma}{\varepsilon_0}$  Charge remains constant $Q = CV$	 Self.
Capacity	Decreases because $C \propto \frac{1}{d}$ *i.e.,* $C' < C$	Decreases *i.e.,* $C' < C$
Charge	Remains constant because a battery is not present *i.e.,* $Q' = Q$	Decreases because battery is present i.e., $Q' < Q$ Remaining charge $(Q - Q')$ goes back to the battery.
Potential difference	Increases because $V = \frac{Q}{C} \Rightarrow V \propto \frac{1}{C}$ *i.e.,* $V' > V$	$V' = V$ (Since Battery maintains the potential difference)
Electric field	Remains constant because $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$ *i.e.,* $E' = E$	Decrease because $E = \frac{Q}{A\varepsilon_0} \Rightarrow E \propto Q$ *i.e.,* $E' < E$
Energy	Increases because $U = \frac{Q^2}{2C} \Rightarrow U \propto \frac{1}{C}$ *i.e.,* $U' > U$	Decreases because $U = \frac{1}{2}CV^2 \Rightarrow U \propto C$ *i.e.,* $U' < U$

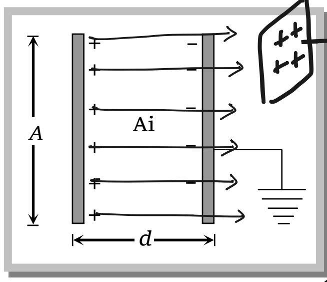
$U = \frac{Q^2}{2C}$

Force Between the Plates of a Parallel Plate Capacitor

Field due to charge on one plate on the other is $E = \frac{\sigma}{2\varepsilon_0}$, hence the force $F = QE$

$$F = -\sigma A \times \left(\frac{\sigma}{2\varepsilon_0}\right) = -\frac{\sigma^2}{2\varepsilon_0} A$$

$$\Rightarrow \qquad |F| = \frac{\sigma^2 A}{2\varepsilon_0} = \frac{Q^2}{2\varepsilon_0 A}$$



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

$F = qE$

$F = qE$

$F = q\frac{\sigma}{2\varepsilon_0}$

$F = q \times \frac{q}{2A\varepsilon_0}$

$F = \frac{q^2}{2A\varepsilon_0}$

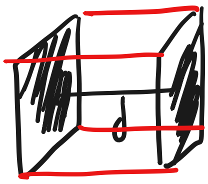
mug up.

Energy Density Between the Plates of a Parallel Plate Capacitor

The energy stored in a capacitor is not localised on the charges or the plates but is distributed in the field. And as in case of a parallel plate capacitor field is only between the plates *i.e.* in a volume ($A\times d$), the so called **energy density**.

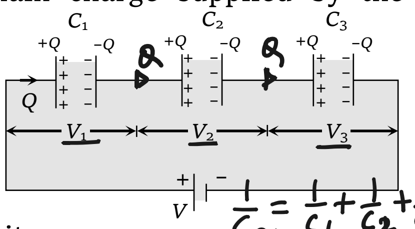
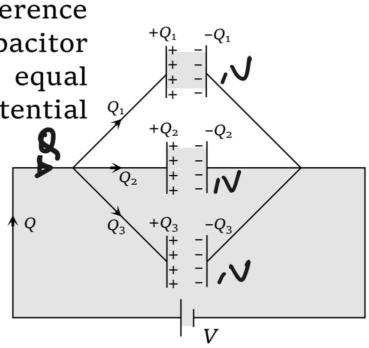
For cap. use $E = \frac{V}{l} = \frac{V}{d}$

Hence Energy density $= \frac{\text{Energy}}{\text{Volume}} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{1}{2}\left[\frac{\varepsilon_0 A}{d}\right]\frac{V^2}{Ad} = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2 = \frac{1}{2}\varepsilon_0 E^2$. directly.



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

Grouping of Capacitors

Series grouping	Parallel grouping
(1) Charge on each capacitor remains same and equals to the main charge supplied by the battery  $V = V_1 + V_2 + V_3$ $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	(1) Potential difference across each capacitor remains same and equal to the applied potential difference  $Q = Q_1 + Q_2 + Q_3$
(2) Equivalent capacitance $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ or $C_{eq} = (C_1^{-1} + C_2^{-1} + C_3^{-1})^{-1}$	(2) $C_{eq} = C_1 + C_2 + C_3$
(3) In series combination potential difference and energy distribution in the reverse ratio of capacitance i.e., $V \propto \frac{1}{C}$ and $U \propto \frac{1}{C}$.	(3) In parallel combination charge and energy distributes in the ratio of capacitance *i.e.* $Q \propto C$ and $U \propto C$
(4) If two capacitors having capacitances C_1 and C_2 are connected in series then $C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{\text{Multiplication}}{\text{Addition}}$	(4) If two capacitors having capacitance C_1 and C_2 respectively are connected in parallel then

$C_1 \quad C_2$

$V_1 = \left(\frac{C_1}{C_1 + C_2}\right).V$ and $V_2 = \left(\frac{C_2}{C_1 + C_2}\right).V$

(5) If n identical capacitors each having capacitances C are connected in series with supply voltage V then Equivalent capacitance $C_{eq} = \frac{C}{n}$ and Potential difference across each capacitor $V' = \frac{V}{n}$.

$C_{eq} = C_1 + C_2$

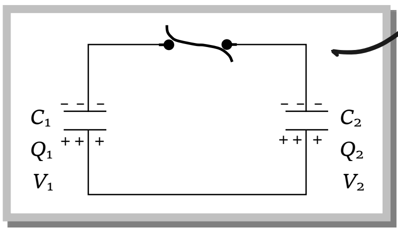
$Q_1 = \left(\frac{C_1}{C_1 + C_2}\right).Q$ and $Q_2 = \left(\frac{C_2}{C_1 + C_2}\right).Q$

(5) If n identical capacitors are connected in parallel

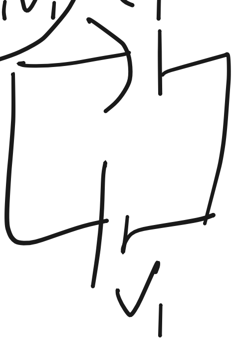
Equivalent capacitance $C_{eq} = nC$ and Charge on each capacitor $Q' = \frac{Q}{n}$

Redistribution of Charge Between Two Capacitors

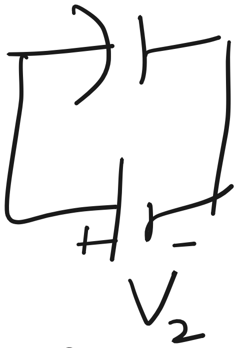
common potential

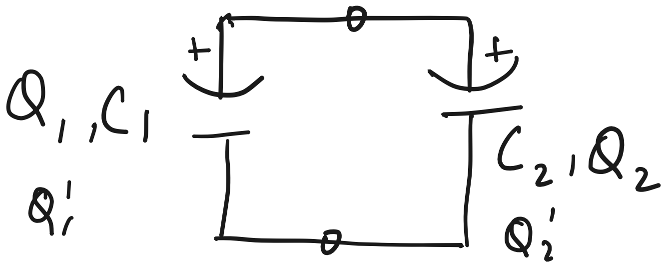


$Q_1 = C_1V_1$



C_2 $Q_2 = C_2V_2$





$V_{common} = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

Charge on capacitors redistributed and new charge on them will be $Q_1' = Q\left(\frac{C_1}{C_1 + C_2}\right)$, $Q_2' = Q\left(\frac{C_2}{C_1 + C_2}\right)$

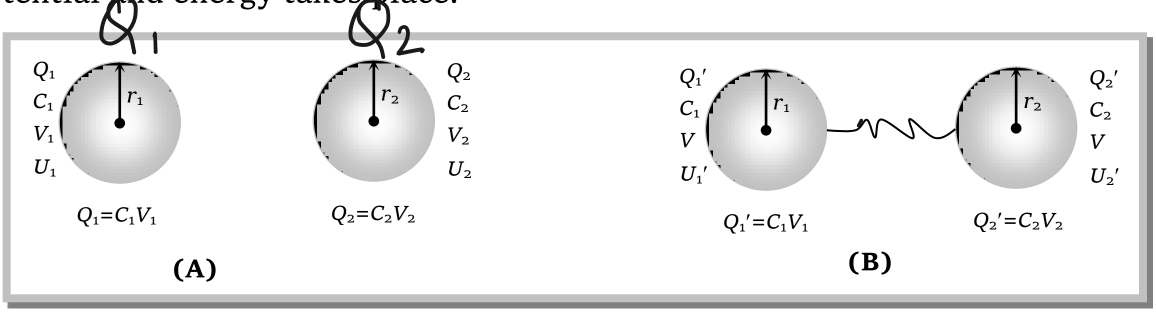
The common potential $V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ and loss of energy $\Delta U = \frac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$

$\Delta U = \frac{m_1 m_2}{2(m_1 + m_2)}(v_1 - v_2)^2(1 - e^2)$

Note: ❑ Two capacitors of capacitances C_1 and C_2 are charged to potential of V_1 and V_2 respectively. After disconnecting from batteries they are again connected to each other with reverse polarity *i.e.*, positive plate of a capacitor connected to negative plate of other. So common potential $V = \frac{Q_1 - Q_2}{C_1 + C_2} = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$.

(6) **Sharing of charge :** When two conductors joined together through a conducting wire, charge begins to flow from one conductor to another till both have the same potential, due to flow of charge, loss of energy also takes place in the form of heat.

Suppose there are two spherical conductors of radii r_1 and r_2, having charge Q_1 and Q_2, potential V_1 and V_2, energies U_1 and U_2 and capacitance C_1 and C_2 respectively, as shown in figure. If these two spheres are connected through a conducting wire, then alteration of charge, potential and energy takes place.



(i) **New charge :** According to the conservation of charge $Q_1 + Q_2 = Q_1' + Q_2' = Q$ (say), also

$$\frac{Q_1'}{Q_2'} = \frac{C_1 V}{C_2 V} = \frac{4\pi\varepsilon_0 r_1}{4\pi\varepsilon_0 r_2},\ \frac{Q_1'}{Q_2'} = \frac{r_1}{r_2} \quad \Rightarrow \quad 1 + \frac{Q_1'}{Q_2'} = 1 + \frac{r_1}{r_2} \Rightarrow \quad \frac{Q_1' + Q_2'}{Q_2'} = \frac{r_1 + r_2}{r_2}$$

$$\Rightarrow \quad Q_2' = Q\left[\frac{r_2}{r_1 + r_2}\right] \quad \text{and similarly } Q_1' = Q\left[\frac{r_1}{r_1 + r_2}\right]$$

(ii) **Common potential :** Common potential $(V) = \dfrac{\text{Total charge}}{\text{Total capacity}} = \dfrac{Q_1 + Q_2}{C_1 + C_2} = \dfrac{Q_1' + Q_2'}{C_1 + C_2} \Rightarrow$

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

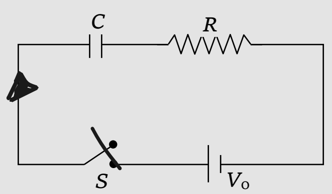
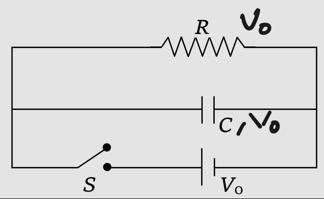
(iii) **Energy loss :** As electrical energy stored in the system before and after connecting the spheres is

$$U_i = \frac{1}{2}C_1 V_1^2 + \frac{1}{2}C_2 V_2^2 \quad \text{and} \quad U_f = \frac{1}{2}(C_1 + C_2).V^2 = \frac{1}{2}(C_1 + C_2)\left(\frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}\right)^2$$

so energy loss $\Delta U = U_i - U_f = \dfrac{C_1 C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$

Circuit With Resistors and Capacitors

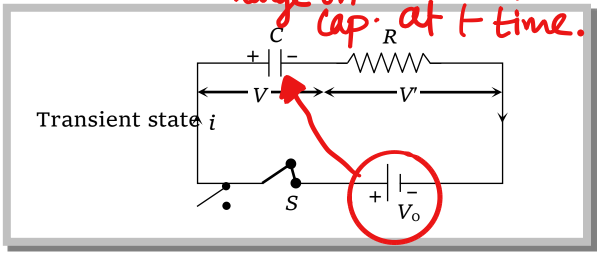
(1) A resistor may be connected either in series or in parallel with the capacitor as shown below

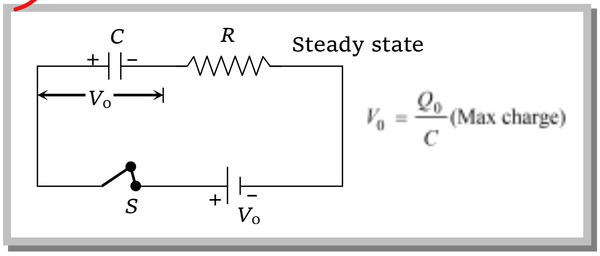
Series RC Circuit	Parallel RC Circuit
	
In this combination capacitor takes longer time to charge.	Resistor has no effect on the charging of capacitor.
The charging current is maximum in the beginning; it decreases with time and becomes zero after a long time.	Resistor provides an alternative path for the electric current.

$Q_0 = CV_0$ maximum charge

$t=0,\ Q=0$

Charge on cap. at t time. $Q = Q_0\left(1-e^{-t/RC}\right)$



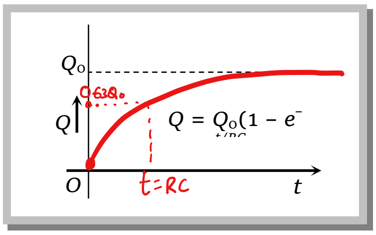


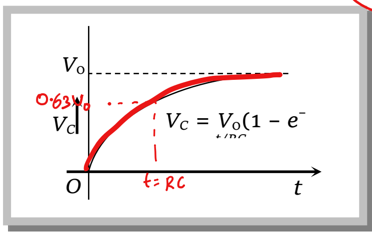
(i) **Charging :**

$$V = V_0\left(1 - e^{\frac{-t}{RC}}\right)$$

$V = V_0\left(1-e^{-t/RC}\right)$, $V = V_0\left(1-e^{-1}\right) = V_0\left(1-\frac{1}{e}\right)$

$V = 0.63V_0$



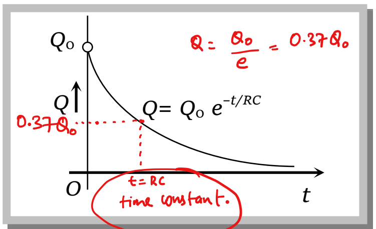


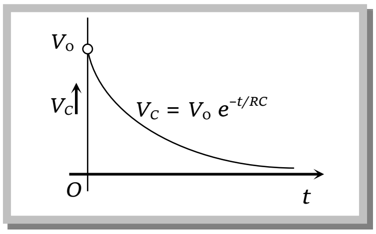
(ii) **Discharging :** $V = V_0 e^{-t/CR}$. $V = \frac{V_0}{e^{+t/RC}}$

$Q = Q_0 e^{-t/RC}$

$Q = \frac{Q_0}{e^{t/RC}}$

$t=0,\ Q=Q_0$

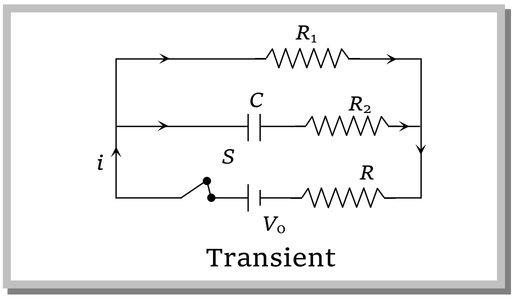


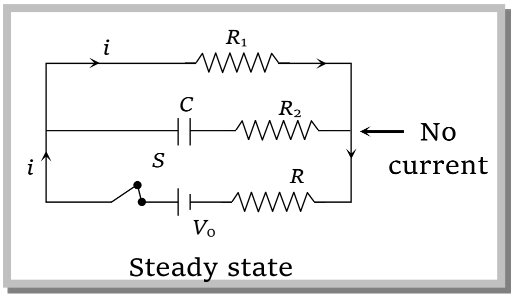


in this time 63% charge gone
37% left.

(iii) **Time constant (τ)**

(iv) **Mixed *RC* circuit :**

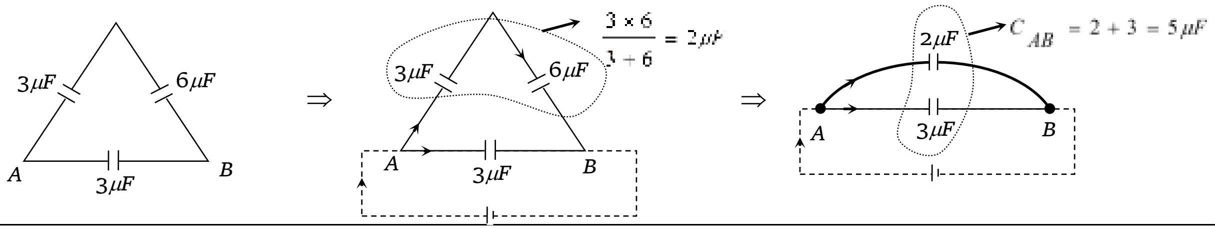




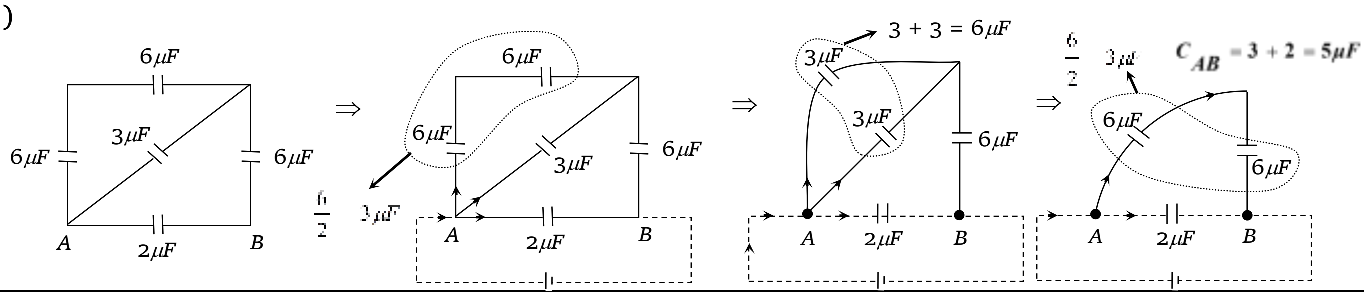
Network Solving

Suppose equivalent capacitance is to be determined in the following networks between points *A* and *B*

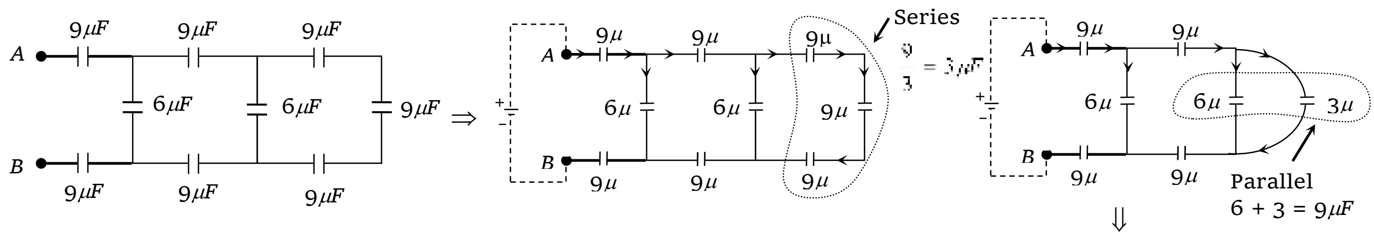
(i)



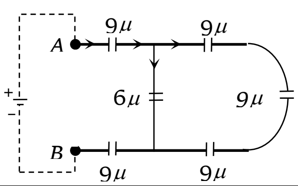
(ii)



(iii)

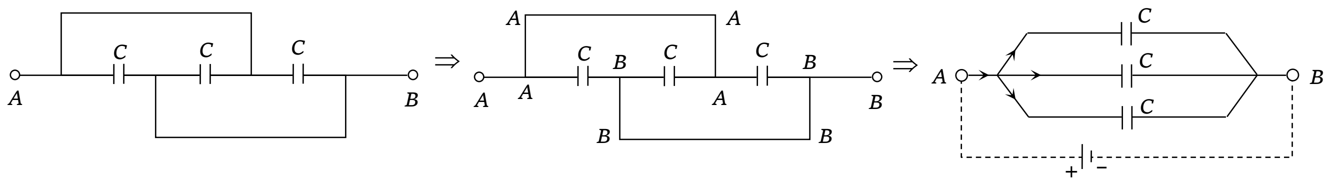


By similar process $C_{AB} = 3\mu F$ ⇐



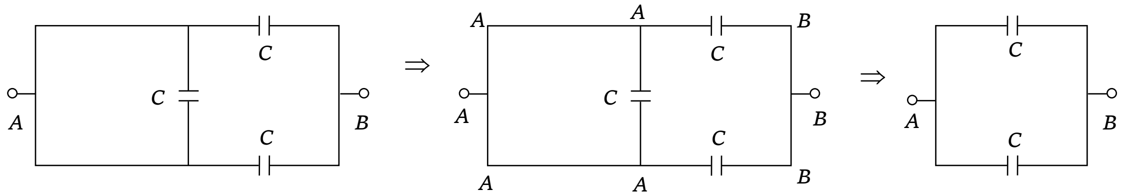
(2) **Circuits with extra wire :** If there is no capacitor in any branch of a network then every point of this branch will be at same potential. Suppose equivalent capacitance is to be determine in following cases

(i)



$C_{AB} = 3C$

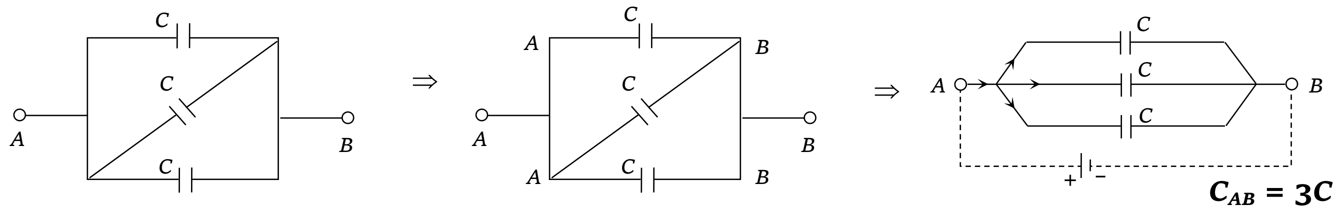
(ii)



No p.d. across vertical

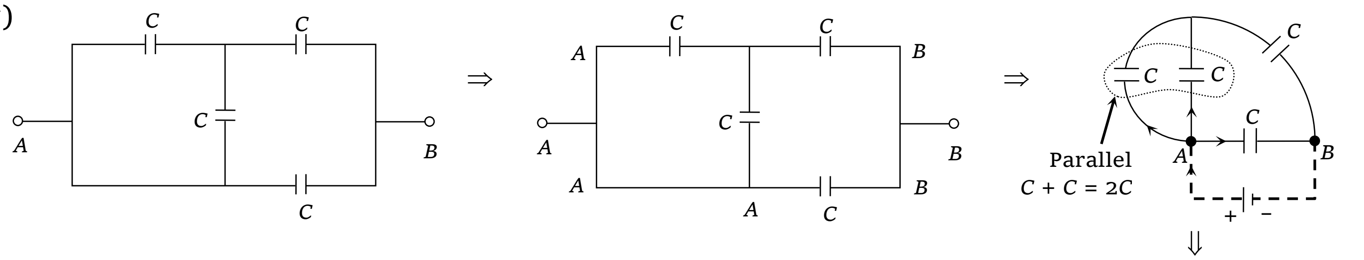
$C_{AB} = 2C$

(iii)

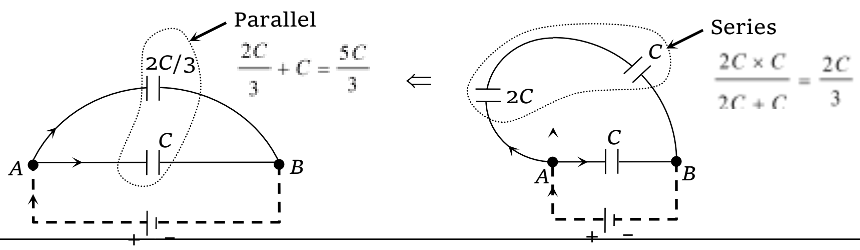


$C_{AB} = 3C$

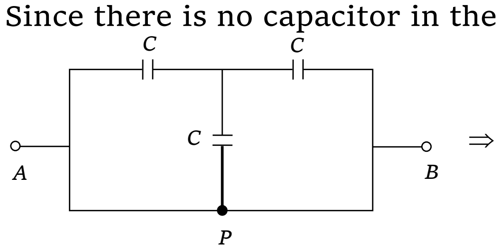
(iv)



Hence equivalent capacitance between A and B is $\frac{5C}{3}$



(v) Since there is no capacitor in the path APB, the points A, P and B are electrically same i.e.,

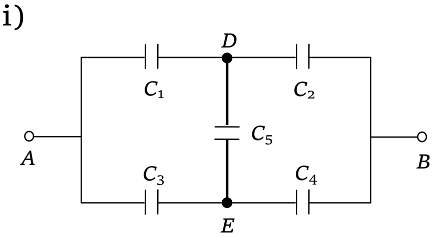


the input and output points are directly connected (short circuited).

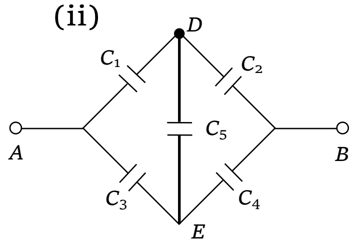
Thus, entire charge will prefer to flow along path APB. It means that the capacitors connected in the circuit will not receive any charge for storing. Thus equivalent capacitance of this circuit is zero.

(3) **Wheatstone bride based circuit :** If in a network five capacitors are arranged as shown in following figure, the network is called wheatstone bridge type circuit. If it is balanced then $\frac{C_1}{C_2} = \frac{C_3}{C_4}$ hence C_5 is removed and equivalent capacitance between A and B

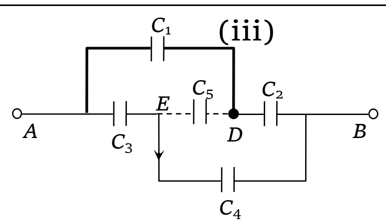
(i)



(ii)

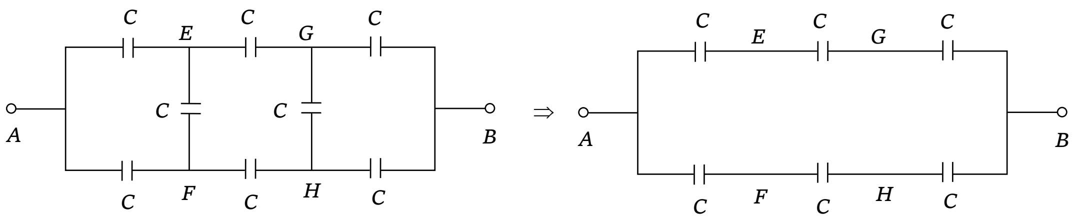


(iii)



$$C_{AB} = \frac{C_1 C_2}{C_1 + C_2} + \frac{C_3 C_4}{C_3 + C_4}$$

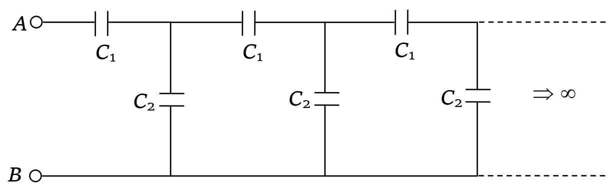
(4) **Extended wheatstone bridge :**



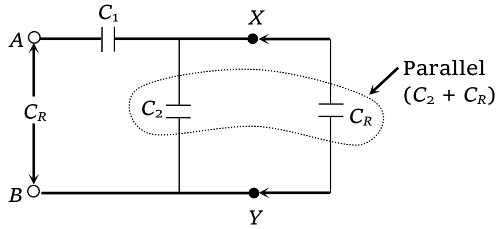
$$C_{AB} = \frac{2C}{3}$$

(5) **Infinite chain of capacitors :** In the following figure equivalent capacitance between A and B

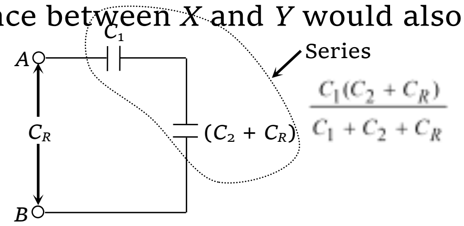
(i)



Suppose the effective capacitance between A and B is C_R. Since the network is infinite, even if we remove one pair of capacitors from the chain, remaining network would still have infinite pair of capacitors, i.e., effective capacitance between X and Y would also be C_R



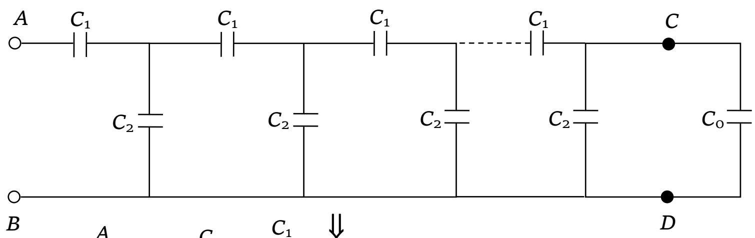
$\Rightarrow$



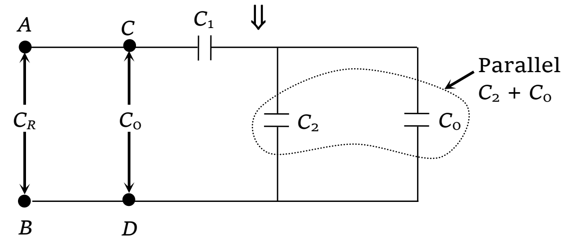
Hence equivalent capacitance between A and B

$$C_{AB} = \frac{C_1(C_2 + C_R)}{C_1 + C_2 + C_R} = C_R \quad \Rightarrow \quad C_{AB} = \frac{C_2}{2}\left[\sqrt{\left(1 + 4\frac{C_1}{C_2}\right)} - 1\right]$$

(ii) For what value of C_0 in the circuit shown below will the net effective capacitance between A and B be independent of the number of sections in the chain



$\Downarrow$



Suppose there are n sections between A and B and the network is terminated by C_0 with equivalent capacitance C_R. Now if we add one more sections to the network between D and C (as shown in the following figure), the equivalent capacitance of the network C_R will be independent of number of sections if the capacitance between D and C still remains C_0 i.e.,

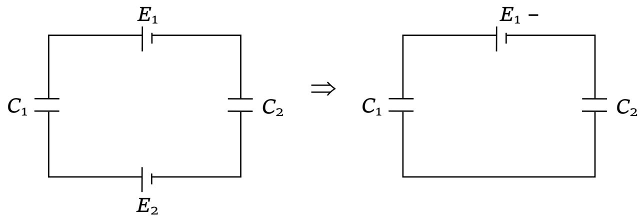
Hence $\quad C_0 = \dfrac{C_1 \times (C_2 + C_0)}{C_1 + C_2 + C_0} \quad \Rightarrow$

$$C_0^2 + C_2C_0 - C_1C_2 = 0$$

On simplification $C_0 = \frac{C_2}{2}\left[\sqrt{\left(1+4\frac{C_1}{C_2}\right)}-1\right]$

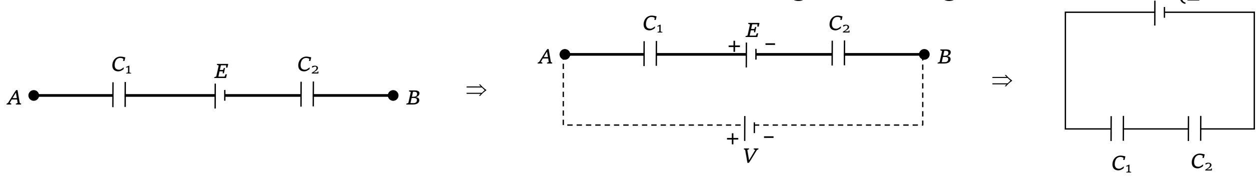
(6) **Network with more than one cell :**

(i)



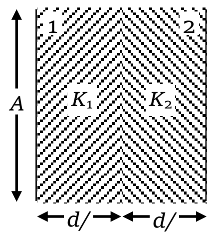
Potential difference across C_1 is $\left(\frac{C_2}{C_1+C_2}\right)(E_1-E_2)$ and potential difference across C_2 is $\left(\frac{C_1}{C_1+C_2}\right)(E_1-E_2)$

(ii) Potential difference between the ends of this arrangement is given V.



(7) **Advance case of compound dielectrics :** If several dielectric medium filled between the plates of a parallel plate capacitor in different ways as shown.

(i)

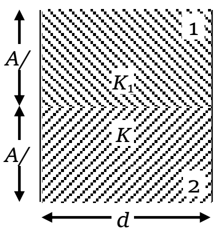


The system can be assumed to be made up of two capacitors C_1 and C_2 which may be said to connected in series

$$C_1 = \frac{K_1\varepsilon_0 A}{\frac{d}{2}}, \quad C_2 = \frac{K_2\varepsilon_0 A}{\frac{d}{2}} \text{ and } \frac{1}{C_{eq}} = \frac{1}{C_1}+\frac{1}{C_2} \Rightarrow C_{eq} = \left(\frac{2K_1K_2}{K_1+K_2}\right).\frac{\varepsilon_0 A}{d}$$

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

(ii)



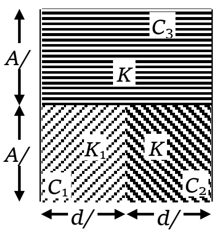
In this case these two capacitors are in parallel and

$$C_1 = \frac{K_1\varepsilon_0 A}{2d}, \quad C_2 = \frac{K_2\varepsilon_0 A}{2d}$$

Hence, $C_{eq} = C_1 + C_2 \Rightarrow C_{eq} = \left(\frac{K_1+K_2}{2}\right).\frac{\varepsilon_0 A}{d}$

Also $K_{eq} = \frac{K_1+K_2}{2}$

(iii)



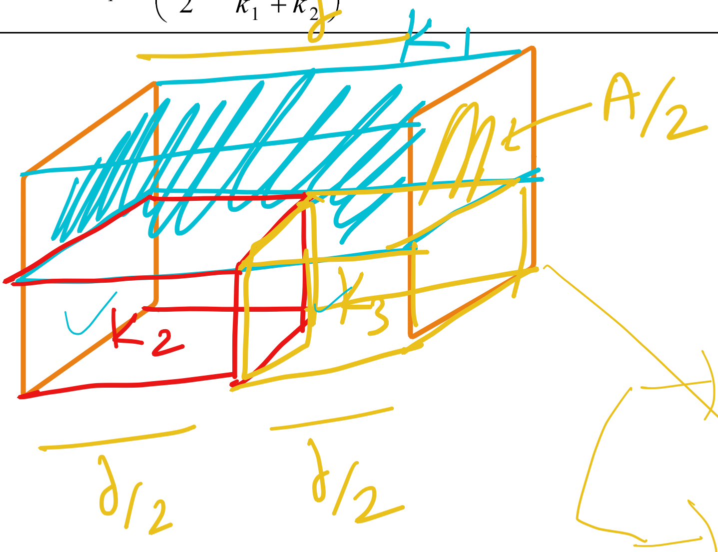
In this case C_1 and C_2 are in series while this combination is in parallel with C_3

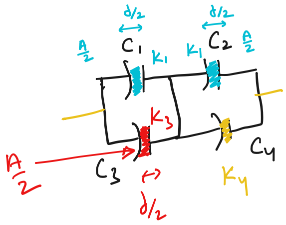
$$C_1 = \frac{K_1\varepsilon_0\frac{A}{2}}{\frac{d}{2}} = \frac{K_1\varepsilon_0 A}{d}, \quad C_2 = \frac{K_1\varepsilon_0\frac{A}{2}}{\frac{d}{2}} = \frac{K_2\varepsilon_0 A}{d} \text{ and } C_3 = \frac{K_3\varepsilon_0\frac{A}{2}}{\frac{d}{2}} = \frac{K_3\varepsilon_0 A}{2d}$$

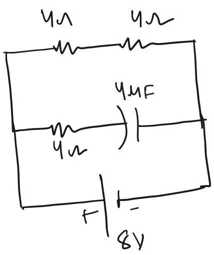
$$\text{Hence, } C_{eq} = \frac{C_1C_2}{C_1+C_2} + C_3 = \frac{\frac{k_1\varepsilon_0 A}{d}\times\frac{k_2\varepsilon_0 A}{d}}{\frac{k_1\varepsilon_0 A}{d}+\frac{k_2\varepsilon_0 A}{d}} + \frac{k_3\varepsilon_0 A}{2d} \Rightarrow$$

$$C_{eq} = \left(\frac{k_1 k_2}{k_1 + k_2} + \frac{k_3}{2}\right) \cdot \frac{\varepsilon_0 A}{d}$$

$$\text{Also } k_{eq} = \left(\frac{k_3}{2} + \frac{k_1 k_2}{k_1 + k_2}\right)$$





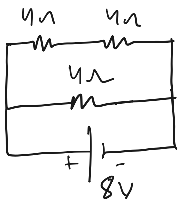


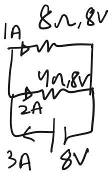
Find current in the ckt at $t=0$

Cap. is uncharged so it will flow current.

replace cap. by a wire at $t=0$

$\frac{8\times4}{12} = \frac{8}{3}\Omega$





$V = IR$

$I = \frac{V}{R} = \frac{8}{8/3} = 3A$

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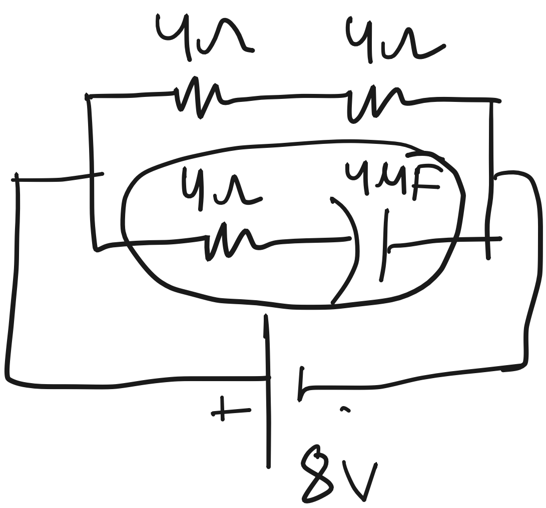
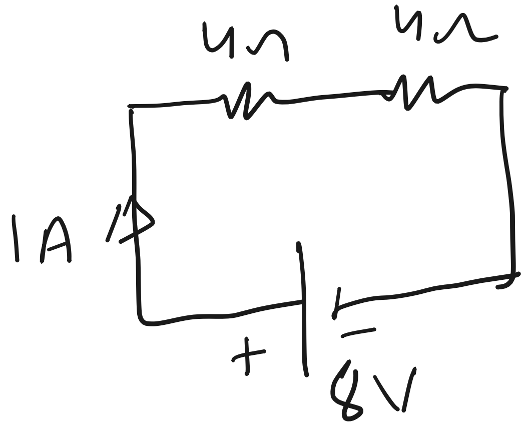
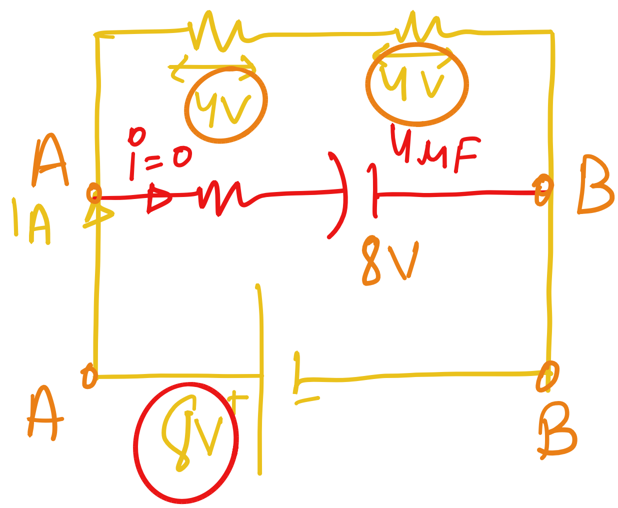
when cap. is fully charged it will not allow charge (current) to flow at $t=\infty$ sec also known as stady state. remove branch containg capacitor.



at $t=\infty$ sec.



at $t=\infty$ what is Charge store in capacitor.



$Q = CV = 4 \times 8 = 32 \mu C.$