
Capacitors

Capacitors

- Two conductors separated by a certain distance form a capacitors. Generally they are given equal and opposite charge.

CHARGE OF A CAPACITOR

The magnitude of charge on one of the conductors forming the capacitor is called the charge of a capacitor.

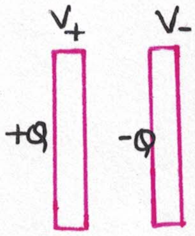
CAPACITANCE

The ratio of charge of the capacitor to the potential difference b/w the two conductors forming the capacitor is called capacitance.

Mathematically,

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

where, $V = V_+ - V_-$



NOTE: Capacitance is purely a geo-metrical factor because the potential difference is directly proportional to field b/w the conductors which in turn is proportional to charge.

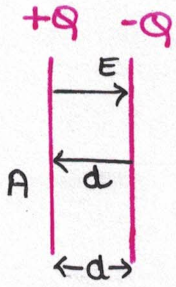
Que.) Find the capacitance of a parallel-plate capacitor with plate area 'A' & a small separation 'd' between the plates.

$$V = \frac{\sigma}{\epsilon_0} d$$

$$Q = \sigma A$$

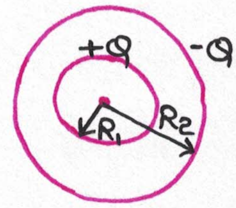
$$C = \frac{Q}{V}$$

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



Que.) Find C of a concentric spherical shell capacitor having inner & outer radii R_1 & R_2.

$$V_+ = \frac{KQ}{R_1} - \frac{KQ}{R_2}$$



$$V_- = \frac{KQ}{R_2} - \frac{KQ}{R_2} = 0$$

$$V = KQ\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$C = \frac{Q}{V} \Rightarrow C = \frac{1}{K} \cdot \frac{R_1 R_2}{(R_2 - R_1)}$$

or

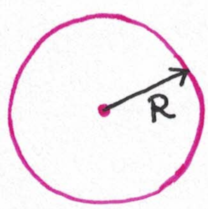
$$C = \frac{4\pi\epsilon_0 R_1 R_2}{R_2 - R_1}$$

(Note: when only one conductor is given, the other is assumed at infinity.)

CAPACITANCE OF ISOLATED SPHERE

$R_1 \to R$

$R_2 \to \infty$

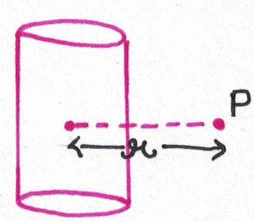


$$C = \frac{4\pi\epsilon_0 R_1 \cancel{R_2}}{\cancel{R_2}\left(1 - \frac{R_1}{R_2}\right)}$$

$$\boxed{C = 4\pi\epsilon_0 R}$$

Que.) Find the capacitance per unit length of a long cylindrical shell capacitor, having inner & outer radii R_1 & R_2.

$$E_p = \frac{\lambda}{2\pi\epsilon_0 r}$$



NOTE: It can be easily shown using Gauss law that the formula for field for a thin cylindrical shell at a point outside the shell at is same as that for thin infinite wire (uniformly charged).

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

$$E = \frac{\lambda}{2\pi\epsilon_0 r} \cdot \hat{r}$$

$$\int_{v_+}^{v_-} dv = \int_{R_1}^{R_2} -\frac{\lambda}{2\pi\epsilon_0 r} \hat{r} \cdot (dr)\hat{r}$$

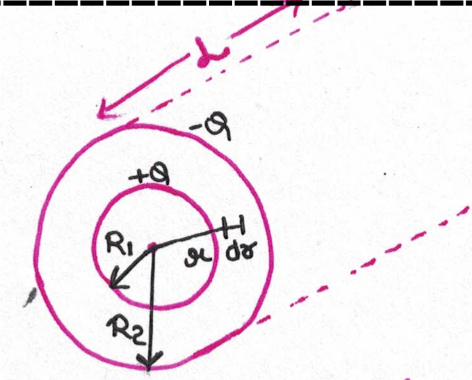
$$(v_- - v_+) = \frac{-\lambda}{2\pi\epsilon_0} \left[\ln(r)\right]_{R_1}^{R_2}$$

$$(v_+ - v_-) = \frac{\lambda}{2\pi\epsilon_0} \left[\ln(R_2) - \ln(R_1)\right]$$

$$v = \frac{\lambda}{2\pi\epsilon_0} \ln\left(\frac{R_2}{R_1}\right)$$

$$C = \frac{Q}{v} \Rightarrow C = \frac{2\pi\epsilon_0 l}{\ln\left(\frac{R_2}{R_1}\right)}$$

$$\frac{C}{l} = \frac{2\pi\epsilon_0}{\ln(R_2/R_1)}$$



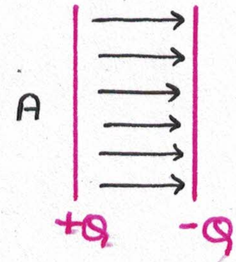
Cross-sectional View

Que.) Find the expression for attractive force b/w the plates of a parallel-plate capacitor having plate area A and charge Q.

$$F = E_1 \times Q$$

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

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

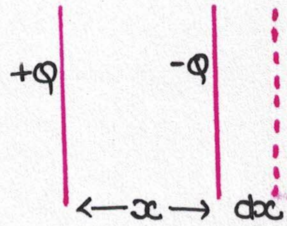


ELECTROSTATIC POTENTIAL ENERGY DENSITY & ENERGY OF A CAPACITOR

Consider two plates of a capacitor separated by a distance 'x'. Let us move the -ve plate by a distance 'dx'. In this process, the change in potential energy is given by

$$du = -\vec{F} \cdot d\vec{x}$$

or $$du = \frac{Q^2}{2A\epsilon_0} \cdot dx$$



We assume that when there was no charge separation, the energy stored was zero. Thus, we can write for final potential energy.

$$\int_0^U dU = \frac{Q^2}{2A\epsilon_0}\int_0^d dx$$

or $$U = \frac{Q^2}{2A\epsilon_0}\cdot d$$

or $$U = \frac{Q^2}{2}\cdot\frac{1}{\left(\frac{A\epsilon_0}{d}\right)} \Rightarrow U = \frac{Q^2}{2C}$$

(The above result is valid for all kinds of capacitors.)

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

$$U = \frac{1}{2}QV$$

volume $\forall = A\,d$

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

$$u = \frac{U}{\forall} \Rightarrow u = \frac{Q^2}{2A^2\epsilon_0}$$

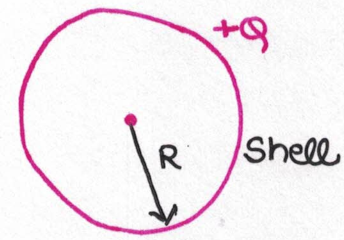
$$E = \frac{Q}{A\epsilon_0} \quad \text{or} \quad Q = EA\epsilon_0$$

$$u = \frac{(EA\epsilon_0)^2}{2A^2\epsilon_0}$$

Energy density in space $\left(u = \frac{1}{2}\epsilon_0 E^2\right)$

NOTE: Even though we have proved this result for a parallel-plate capacitor, the expression for energy density is valid at every point in space.

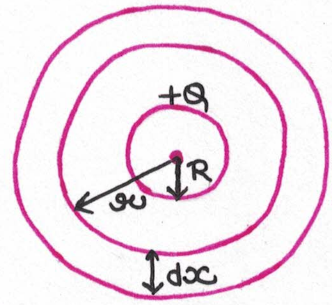
Que.) A spherical shell of radius 'R' carries a charge 'Q'. Find the total energy stored in space by integrating the energy density formula. Also verify your answer using the formula $(Q^2/2C)$.



$$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{x^2}$$

$$dV = 4\pi x^2 . dx$$

$$dU = \frac{1}{2}\epsilon_0 \frac{1}{16\pi^2\epsilon_0^2} \cdot \frac{Q^2}{x^4} \cdot 4\pi x^2 dx$$

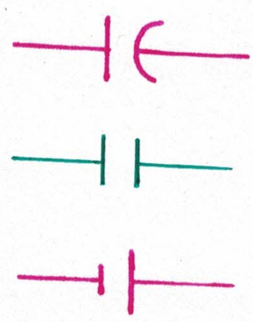


$$\int dU = \frac{Q^2}{2\pi\epsilon_0}\int_R^\infty \frac{1}{x^2} . dx$$

$$U = \frac{Q^2}{8\pi\epsilon_0 R}$$

$$U = \frac{Q^2}{2C} = \frac{Q^2}{2(4\pi\epsilon_0 R)} = \frac{Q^2}{8\pi\epsilon_0 R}$$

CAPACITOR - CIRCUITS



Capacitor

Parallel-plate Capacitor

Cell

Resistor

BATTERY

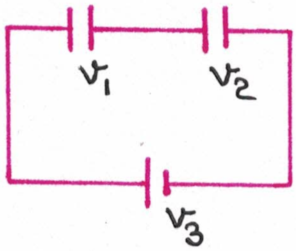
A charged pump which maintains a constant potential difference b/w its terminals.

- If a battery pumps charge from -ve to +ve terminal, the work done by battery $= qV$, where V is potential difference across the battery.
- If the charge goes from +ve to -ve terminal work done by battery $= -qV$.

KIRCHOFF'S LAWS

KIRCHOFF'S LOOP LAW (VOLTAGE LAW)

The sum of potential drops of all the elements along a closed loop in the circuit is zero.



$$V_1 + V_2 + V_3 = 0$$

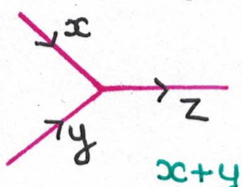
Rise = −ve drop

JUNCTION LAW

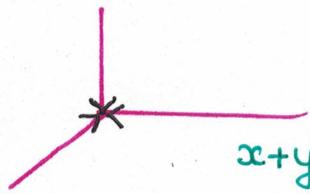
The net charge entering a junction is equal to net charge leaving a junction.

Alternatively, the algebraic sum of all the charges entering a junction (or leaving) is equal to zero.

Eg:



$x + y = z$



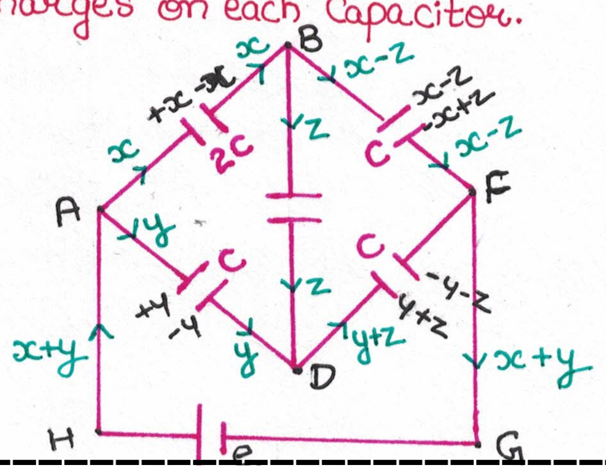
$x + y + z = 0$

NOTE 1: while travelling along a loop if we hit the +ve plate of a capacitor then write $+\frac{Q}{C}$ for the potential drop and if we hit the −ve plate then write $-Q/C$ for potential drop.

NOTE 2: Similarly if we hit +ve terminal of battery, then write $+\varepsilon$ (emf) and if we hit −ve terminal, write $-\varepsilon$.

APPLICATION OF KIRCHOFF'S LAW

Que.) For the shown circuit, develop a system of equations to solve for charges on each capacitor.



ABDA

$$\frac{x}{2C} + \frac{z}{C} + \frac{(-y)}{C} = 0$$

$$\frac{x}{2} + z = y \quad -(1)$$

BFDB

$$\frac{x-z}{C} - \frac{y+z}{C} - \frac{z}{C} = 0$$

$$x - y = 3z \quad -(2)$$

ADFGHA

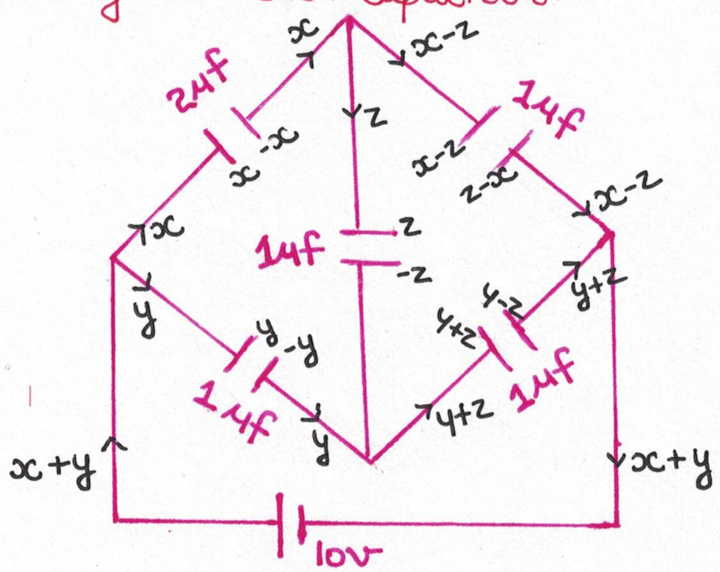
$$\frac{y}{C} + \frac{y+z}{C} - \mathcal{E} = 0$$

$$2y + z = \mathcal{E} \quad -(3)$$

on solving the equations,

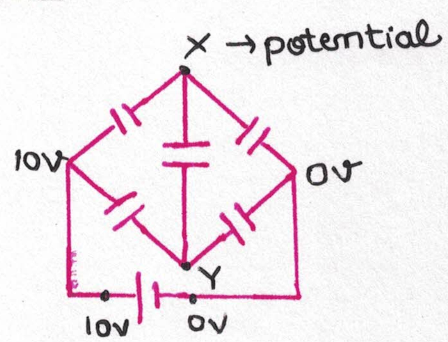
$$z = \frac{\mathcal{E}}{11}, \quad x = \frac{8\mathcal{E}}{11}, \quad y = \frac{5\mathcal{E}}{11}$$

Que.) Find charge on each Capacitor.



$$x = \frac{80}{11}, \quad y = \frac{50}{11}, \quad z = \frac{10}{11}$$

NODE VOLTAGE METHOD (ALTERNATIVE METHOD)



$$2(X-10) + (X-Y) + X = 0$$

$$4X = Y + 20 \quad -(1)$$

$$(Y-10) + (Y-X) + Y = 0$$

$$3Y = X + 10 \quad -(2)$$

$$12X = X + 10 + 60$$

$$X = \frac{70}{11}, \quad Y = \frac{60}{11}$$

NODE VOLTAGE METHOD

Step 1: Arbitrarily choose '0' potential at any one point in the circuit.
(Generally -ve terminal of a battery)

Step 2: Calculate the potentials of the nodes using arithmetic wherever possible.

Step 3: Where not possible, assign the voltage variables to various junctions.
Tip: Try to use minimum possible variables.

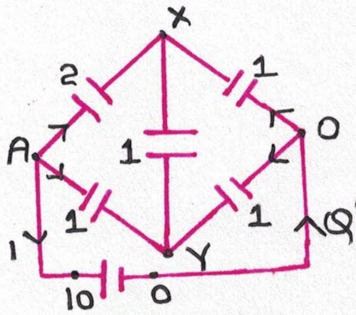
Step 4: Satisfy Kirchoff's Junction rule at various node. Write as many equations as no. of unknowns.
★ P-D is necessary & not absolute potentials.

Step 5: Solve for the unknown potentials.

Step 6: Find charges on the capacitors using $Q = CV$, where V = P-D across the capacitor.

Eq^n: of

$$V_A \equiv (10-X)2 + (10-Y) + (0-Y) + (0-X) = 0$$



EFFECTIVE CAPACITANCE

A given capacitor is said to be equivalent to a system of capacitors if for the same potential difference, it draws the same amount of charge from the battery as the given system.

Similarly, if 'Q_{net}' be the net charge drawn by a system from a battery of potential difference 'V', then effective capacitance is given by

$$C_{eff} = \frac{Q_{net}}{V}$$

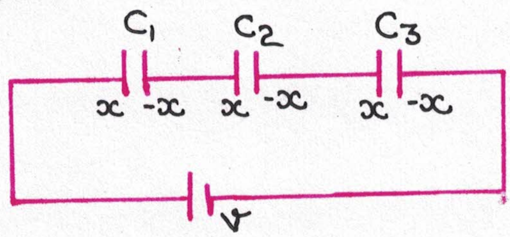
Que.) For the previous circuit, What is the effective capacitance

$$Q_{net} = x + y = \frac{130}{11}, \quad V = 10\,V$$

$$\therefore C_{eff.} = \frac{Q_{net}}{V} = \frac{13}{11}\ \mu F V^{-1}$$

COMBINATION OF CAPACITORS IN "SERIES"

A no. of capacitors are said to be connected in series if by virtue of configuration, they all carry the same charge.
(They lie on the same branch without any branching) in between.



$$\frac{x}{C_1} + \frac{x}{C_2} + \frac{x}{C_3} - v = 0$$

$$x\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) = v$$

$$\frac{x}{v} = \frac{1}{\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)} = C_{eff.}$$

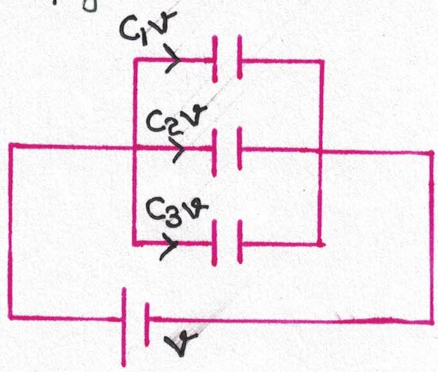
$$\boxed{\frac{1}{C_{eff.}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

NOTE: If v = potential drop across series then potential drop in C_1

$$v_1 = \frac{1/C_1}{1/C_1 + 1/C_2 + 1/C_3} \times v \text{ and so on}$$

PARALLEL COMBINATION

A no. of capacitors are said to be connected in parallel if by virtue of configuration their potential drops are same.



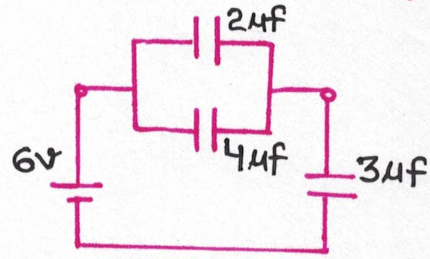
$$q_{net} = (C_1 + C_2 + C_3)\, v$$

$$\boxed{C_{eff} = C_1 + C_2 + C_3}$$

NOTE: If 'Q_{net}' is total charge going into a parallel combination, then charge through C_1

$$Q_1 = \left(\frac{C_1}{C_1+C_2+C_3}\right) Q_{net}$$

Que.) (a) Find effective capacitance.
(b) Find charge on each capacitor & potential drops.

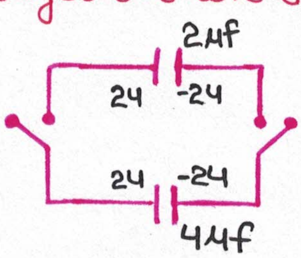


(a) $C_{eff} = \frac{1}{(2+4)} + \frac{1}{3} = 2\mu f$

(b) $Q_3 = 12\mu f$

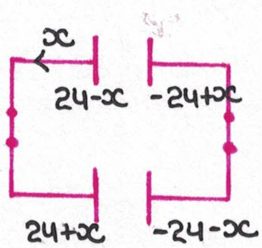
$V_3 = 4v$

Que.) Find final charges on the capacitors when switches are closed.



$$\frac{24+x}{4} + \frac{-24+x}{2} = 0$$

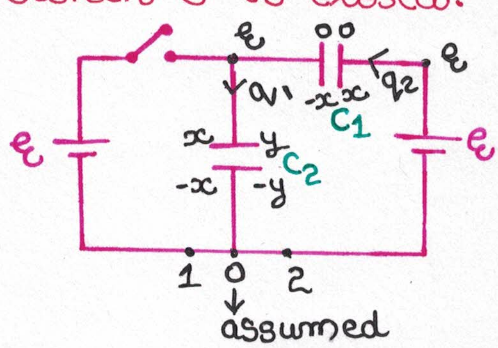
$$x = 8\mu C$$



(**NOTE** - A battery in an open circuit is as good as) not present.

Que.) In the shown circuit, find the charges flown through sections 1 and 2 after the switch S is closed.

$$x = \frac{\mathcal{E} C_1 C_2}{C_1+C_2}$$



$v_1 = 0 \Rightarrow Q_1 = 0$

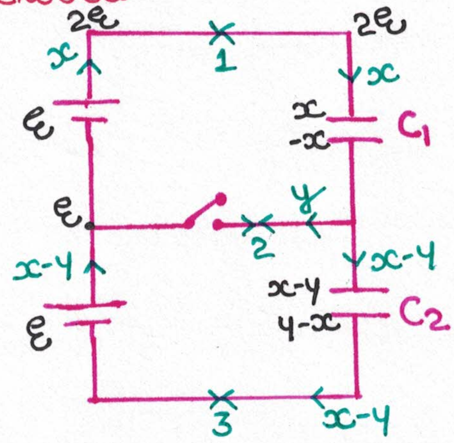
$V_2 = \mathcal{E} C_2 = y$

$q_1 = 0-(-x)+y-x = y$

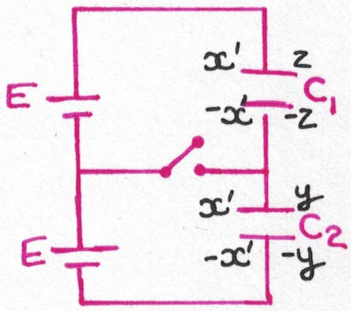
$q_1 = \mathcal{E} C_2$

$$q_2 = 0 - x = -\frac{\varepsilon C_1 C_2}{C_1 + C_2}$$

Que.) Find charges flowing through sections 1, 2 & 3 when switch S is closed.



initial charge on C_1 $\Rightarrow x' = \dfrac{2\varepsilon C_1 C_2}{C_1 + C_2}$



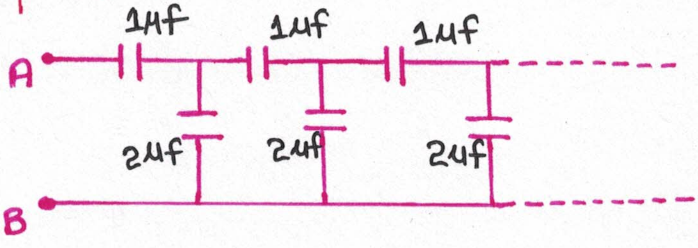
$$z = \varepsilon C_1$$
$$y = \varepsilon C_2$$

$$q_2 = (y - x) + (-z - (-x))$$
$$q_2 = y - z$$
$$q_2 = \varepsilon (C_2 - C_1)$$

$$q_1 = z - x$$
$$= \varepsilon \left(C_1 - \frac{2C_1 C_2}{C_1 + C_2} \right) = \frac{\varepsilon C_1 (C_1 - C_2)}{C_1 + C_2}$$

$$q_3 = -y + x$$
$$= -\varepsilon C_2 + \frac{2\varepsilon C_1 C_2}{C_1 + C_2} = \frac{\varepsilon C_2 (C_1 - C_2)}{C_1 + C_2}$$

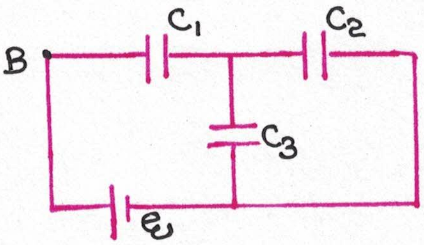
Que.) Find effective capacitance b/w points A & B for the infinite ladder of capacitors.



$$\frac{(C+2) \times 1}{(C+2) + 1} = C$$

$$C+2 = C^2 + 3C$$
$$C^2 = -2C + 2$$
$$C^2 + 2C - 2 = 0$$
$$C = (\sqrt{3} - 1)\,\mu F$$

Que.)



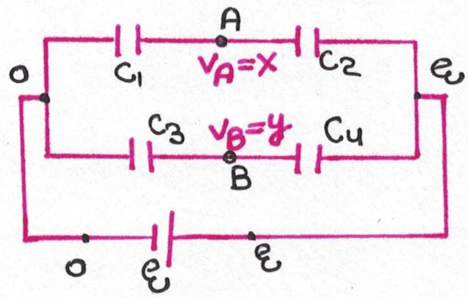
$$V_B - V_A = V_{C_1} + V_{C_2}$$

i.e. To find potential drop b/w two point in a circuit, travel from first point to the second point along any path & keep on mind adding all the potential drops.

If potential drop across a capacitor is zero, no charge will flow.

Que.) Find potential drop b/w points, A & B

(i)



(ii) Under what conditions is $V_A = V_B$?

(i) $(x - \varepsilon) C_2 + x C_1 = 0$

$$x = \frac{\varepsilon C_2}{C_1 + C_2}$$

$$y = \frac{\varepsilon C_4}{C_3 + C_4}$$

$$(x - y) = \varepsilon \left(\frac{C_2}{C_1 + C_2} - \frac{C_4}{C_3 + C_4} \right)$$

$$(x - y) = \frac{\varepsilon (C_2 C_3 - C_1 C_4)}{(C_1 + C_2)(C_3 + C_4)} = V_A - V_B$$

(ii) $V_B = V_A$

if $C_2 C_3 = C_1 C_4$

i.e. $V_A = V_B$ if $\dfrac{C_1}{C_3} = \dfrac{C_2}{C_4}$

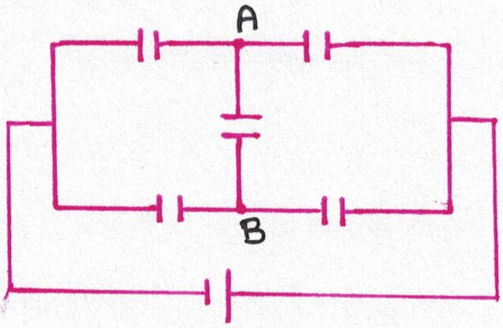
If we place any capacitor b/w A and B, it is meaningless as $V_A = V_B$

WHEATSTONE BRIDGE

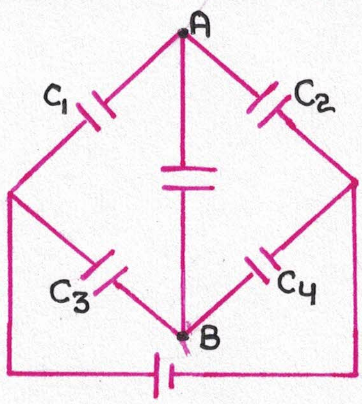
In the shown circuit, whenever

$$\left(\frac{C_1}{C_3} = \frac{C_2}{C_4} \quad \text{or} \quad \frac{C_1}{C_2} = \frac{C_3}{4}\right)$$

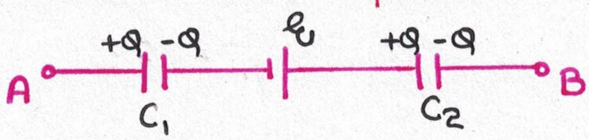
then any passive branch (ie not containing a battery) b/w points A and B becomes meaningless and can be safely removed from the circuit.



Alternately, for above we can draw



Que.) In the shown circuit, $V_A - V_B = 5v$ & $\mathcal{E}$ (emf) = 10v
$C_1 = 1\mu f$, $C_2 = 2\mu f$
Find voltage across each capacitor.



$$\frac{q}{C_1} - 10 + \frac{q}{C_2} = 5$$

$$q = \frac{15}{\frac{1}{C_1} + \frac{1}{C_2}} = \frac{15}{3/2} = 10$$

$V_{C_1} = 10$, $V_{C_2} = 5$

HEAT GENERATION IN CAPACITOR CIRCUITS

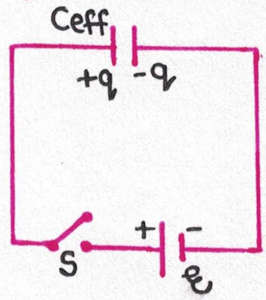
Work done by the battery (S) either gets stored by increasing the energy of the capacitor OR gets dissipated in the form of heat (Electromagnetic radiation).

Mathematically,

$$\boxed{W_{battery} = \Delta U_{capacitor} + \Delta H}$$

work done by battery — Change in PE of capacitor — Heat liberated

Que.) Show that in charging any system of capacitors, begining from zero charge, using a battery, only 50% of the energy gets stored in the capacitors?



$q = C_{eff} \cdot \varepsilon$

$W_{batt} = q\varepsilon$

$= C_{eff} \cdot \varepsilon^2$

$\Delta U = \frac{1}{2} C_{eff} \cdot \varepsilon^2$

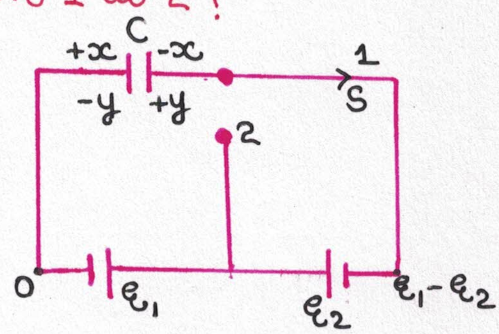
$\therefore \Delta H = W_{batt} - \Delta U_{capac.}$

$= C_{eff} \cdot \varepsilon^2 - \frac{1}{2} C_{eff} \cdot \varepsilon^2$

Heat liberated $= \frac{1}{2} C_{eff} \cdot \varepsilon^2$

also true in resistance circuits.

Que.) What will be the heat generated in the circuit after the switch is shifted from position 1 to 2?



$x = (\varepsilon_2 - \varepsilon_1)C$

$y = \varepsilon_1 C$

$U_i = \frac{1}{2} C (\varepsilon_2 - \varepsilon_1)^2$

$U_f = \frac{1}{2} C \varepsilon_1^2$

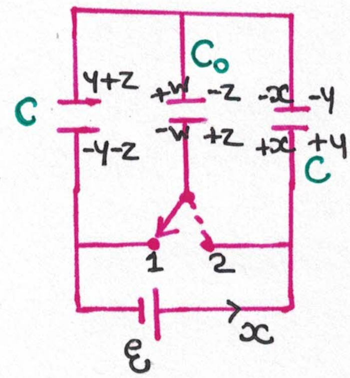
$\Delta U = \frac{1}{2} C \left[\varepsilon_1^2 - \varepsilon_2^2 - \varepsilon_1^2 + 2\varepsilon_1\varepsilon_2\right]$

$= \frac{1}{2} C \left[2\varepsilon_1\varepsilon_2 - \varepsilon_2^2\right]$

$$W_{Batt} = (+x+y)\,\mathcal{E}_1 = \Delta q \cdot \mathcal{E}_1$$
$$= (+\mathcal{E}_2 C + \mathcal{E}_1 C - \mathcal{E}_1 C)\,\mathcal{E}_1$$
$$= +\mathcal{E}_1 \mathcal{E}_2 C$$

$$\Delta H = +\mathcal{E}_1\mathcal{E}_2 C - \mathcal{E}_1\mathcal{E}_2 C + \frac{\mathcal{E}_2^2 C}{2}$$
$$= \frac{1}{2} C \mathcal{E}_2^2$$
$$\Delta H = \frac{1}{2} C \mathcal{E}_2^2$$

Que.) Find the heat generated after switch is shifted from position 1 to position 2? x & u are initial charges.



$$\Delta U = 0$$
$$\because U_i = \frac{1}{2} C_{eff}\, \mathcal{E}^2$$
$$\& \; U_f = \frac{1}{2} C_{eff}\, \mathcal{E}^2$$

$$C_{eff} = \frac{C(C+C_0)}{2C+C_0}$$

$$q = \mathcal{E} \times C_{eff}$$

$$W = \mathcal{E}^2 \times C_{eff}.$$

$$\Delta H = \frac{\mathcal{E}^2 \cdot C \cdot (C+C_0)}{(2C+C_0)}$$

$$x = \frac{C(C+C_0) \cdot \mathcal{E}}{2C+C_0}$$

$$y+z = x$$

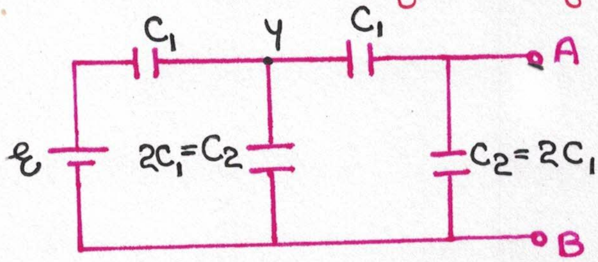
$$w = \frac{x\,C_0}{C+C_0}$$

$$W_{batt.} = (y-x+z+w)\,\mathcal{E}$$
$$= (y+z+w-x)\,\mathcal{E}$$
$$= +w\mathcal{E}$$
$$= \frac{C\,C_0\,\mathcal{E}^2}{2C+C_0}$$

Que.) Find potential difference b/w A & B in terms of $\mathcal{E}$ & η.

$$\frac{C_2}{C_1} = \eta = 2$$

$$\mathcal{E} = 110 v$$



$$\Rightarrow xC_2 + (-y+x)C_1 = 0 \quad -①$$

$$xC_2 + xC_1 = yC_1$$

$$x = \frac{yC_1}{C_1+C_2}$$

$$\Rightarrow (y-x)C_1 + yC_2 + (y-\mathcal{E})C_1 = 0$$

$$yC_1 - xC_1 + yC_2 + yC_1 - \mathcal{E}C_1 = 0$$

$$y = \frac{xC_1 + \mathcal{E}C_1}{2C_1+C_2}$$

$$\frac{xC_1 + \mathcal{E}C_1}{2C_1+C_2} = \frac{xC_1 + xC_2}{C_1}$$

$$xC_1^2 + \mathcal{E}C_1^2 = 2xC_1^2 + 2xC_1C_2 + xC_1C_2 + xC_2^2$$

$$x(C_1^2 - 2C_1^2 - C_1C_2 - 2C_1C_2 - C_2^2) = -\mathcal{E}C_1^2$$

$$x = \frac{-\mathcal{E}C_1^2}{-C_1^2 - C_2^2 - 3C_1C_2}$$

$$= \frac{\mathcal{E}C_1^2}{C_1^2 + C_2^2 + 3C_1C_2}$$

$$= \frac{\mathcal{E}}{1+\eta^2+3\eta}$$

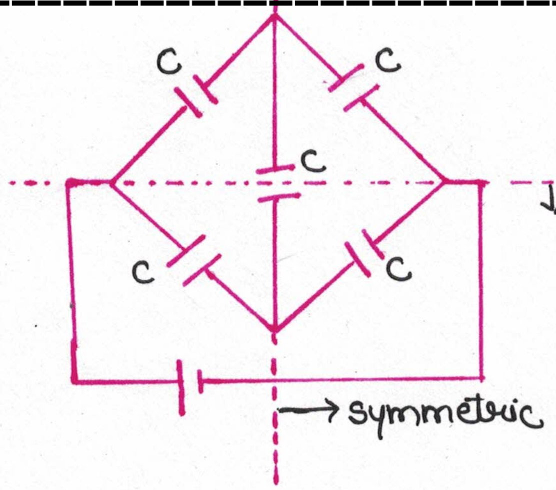
$$= \frac{110}{1+4+6} = 10 v$$

SYMMETRY IN ELECTRICAL CIRCUITS

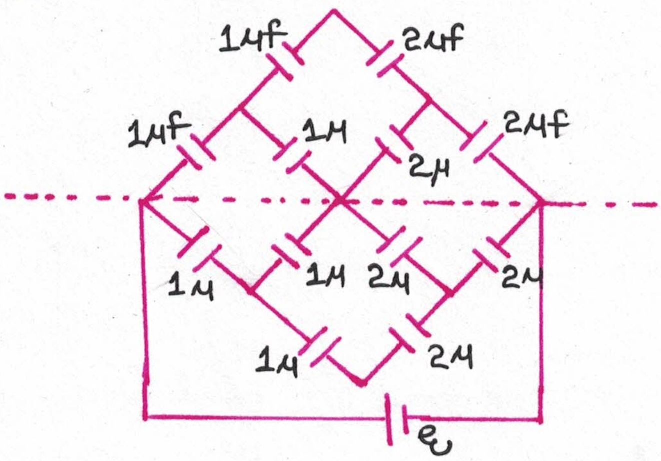
SYMMETRY ABOUT AXIS

If there exists mirror image elements about the general direction of charge flow in a circuit, then we say the circuit has axial symmetry.

In such cases the mirror image points have exactly the same potential & thus the circuit can be safely folded by joining the equipotential points for the purpose of simplification.



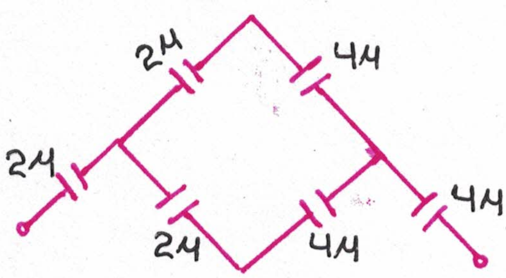
Que.) Find effective capacitance



$\frac{8}{3}$ series with $\frac{8}{6}$

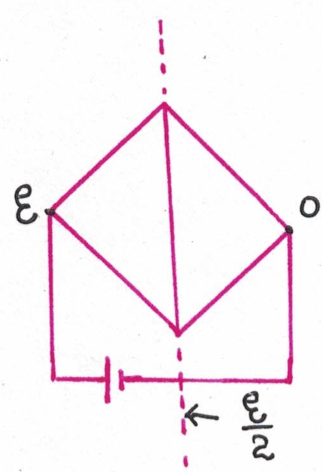
$$= \frac{\frac{8}{3} \times \frac{4}{3}}{\frac{8}{3} + \frac{4}{3}}$$

$$= \frac{32}{36} \Rightarrow \frac{8}{9}\mu = C_{eff}.$$

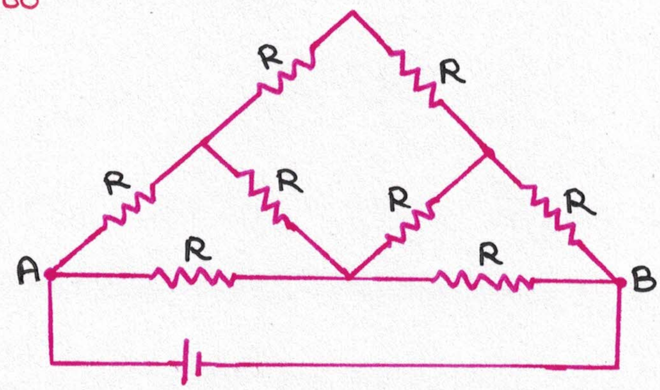


SYMMETRY ABOUT EQUATOR

Whenever there exists an equator in the circuit, all the points on the equator will have same potential. Therefore they can all be collapsed together or disjointed from each other if they are already joined.



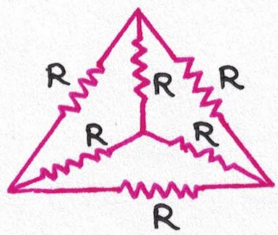
Que.) Find effective resistance.

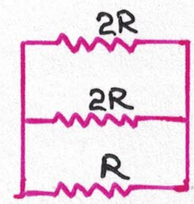


$3R \parallel 2R$

$$\frac{3R \times 2R}{3R + 2R} = \frac{6}{5}R = R_{eff.}$$

Que.) Find effective resistance b/w points A & B.



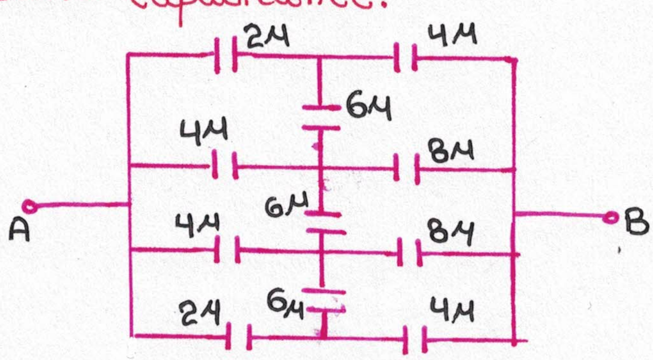


$$\Rightarrow \frac{2R \times 2R}{2R + 2R} = R$$

$$\Rightarrow \frac{R \times R}{R + R} = \frac{R^2}{2R}$$

$$\Rightarrow R_{eff.} = \frac{R}{2}$$

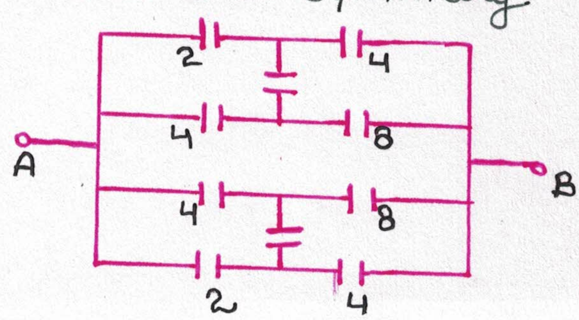
Que.) Find effective capacitance.



$$\frac{4}{3} + \frac{4}{3} + \frac{8}{3} + \frac{8}{3}$$

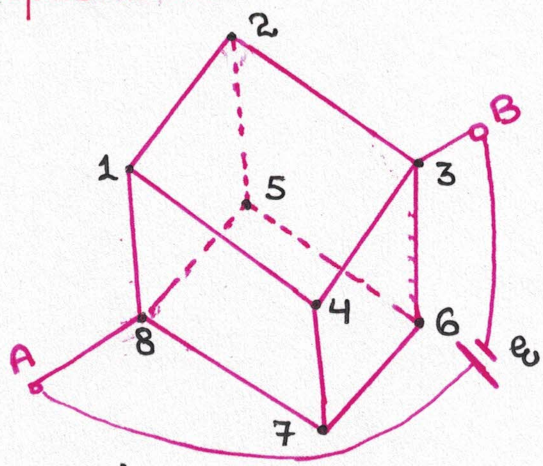
$$\therefore \; C_{eff} = 8 \mu f$$

Due to axial symmetry



whenever any two points in a circuit are equipotential, even while being disconnected then they can be safely brough together (joined).

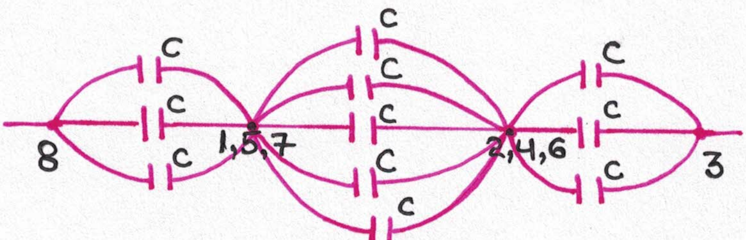
Que.) Find effective capacitance b/w points A & B given that each corner has capacitance.



5, 7, 1 → equi potential

2, 4, 6 → equi potential

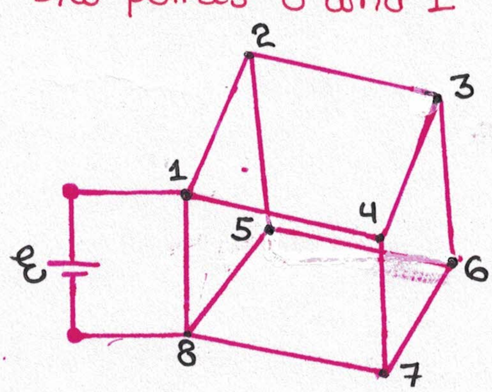
∴ above is equivalent to



$$\frac{1.5 \times 6}{1.5+6} = \frac{9}{7.5}$$

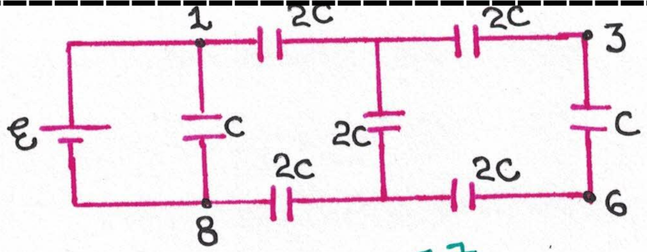
$$C_{eff} = \frac{6}{5}C$$

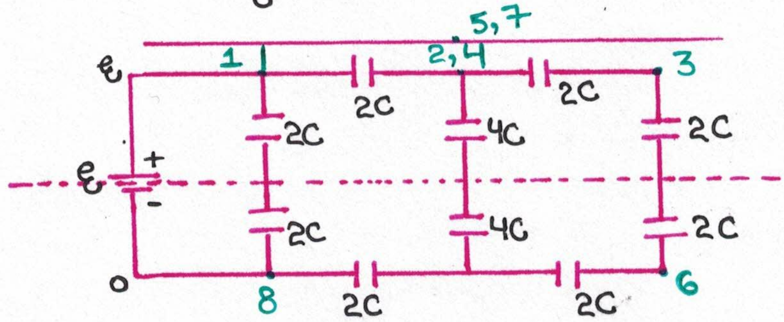
Que.) Find C_{eff} b/w points 8 and 1

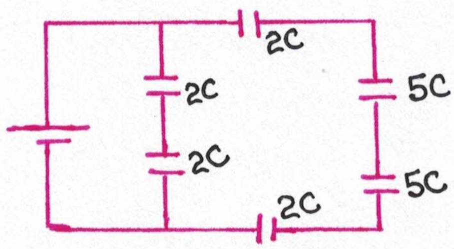


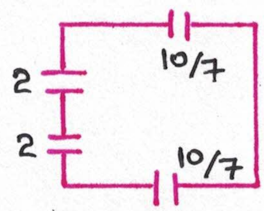
2, 4 - equipotential

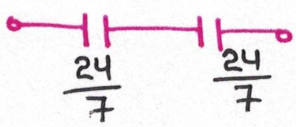
5, 7 - equi potential





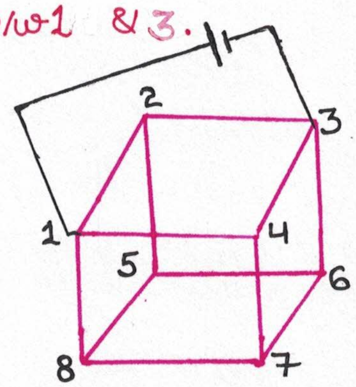






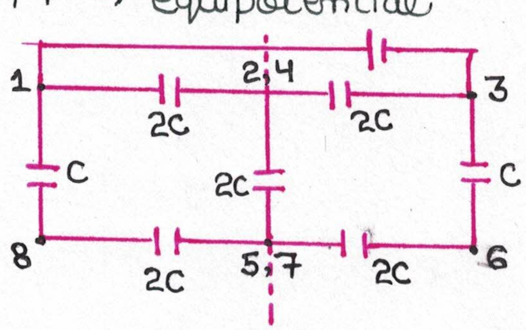
$$\therefore C_{eff} = \frac{12}{7} C$$

Que.) Find C_{eff} b/w 1 & 3.



2, 4 → equipotential

5, 7 → equipotential



Symmetry about equator

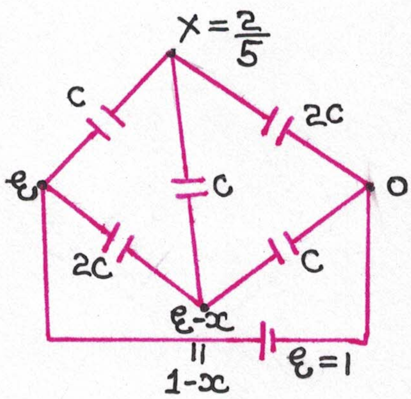
$C \parallel \frac{C}{3}$

$\therefore C_{eff.} = \frac{4}{3}C$

SYMMETRY ABOUT A POINT (ANTI SYMMETRY)

Whenever there exists symmetry about a point in a circuit, then the analogous elements have the same charge, flows in the same direction.
They also have the same potential drops in the same direction.

Que.) Find $C_{eff.}$



$(1-x)C + (1-2x)C + (0-x)2C = 0$

$C - Cx + C - 2xC - 2xC = 0$

$2\cancel{C} = 5\cancel{C}x$

$x = \frac{2}{5}$

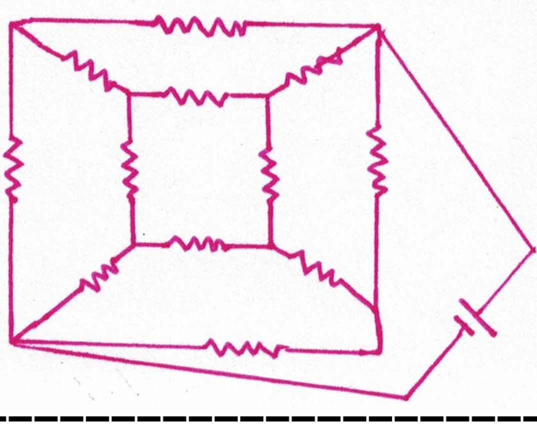
$Q_{net} = \frac{3}{5}C + \frac{4}{5}C$

$C_{eff.} = \frac{7}{5}C$

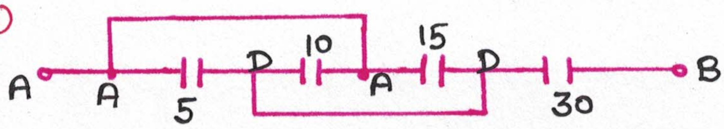
→ When various points in a circuit are connected by a resistance less wire (hence equipotential), all such points can represented by a single point for the purpose of simplifying the circuit.

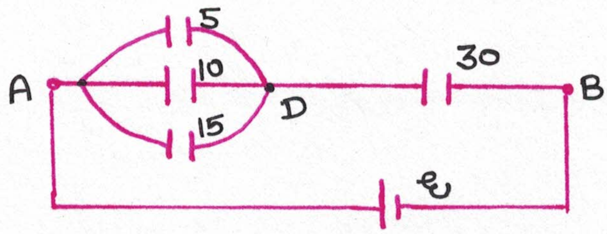
→ If the junctions are maintained then geometrical re-arrangement of wires does not affect the circuit.

Eg:- Can be considered as a cube showing its top view.



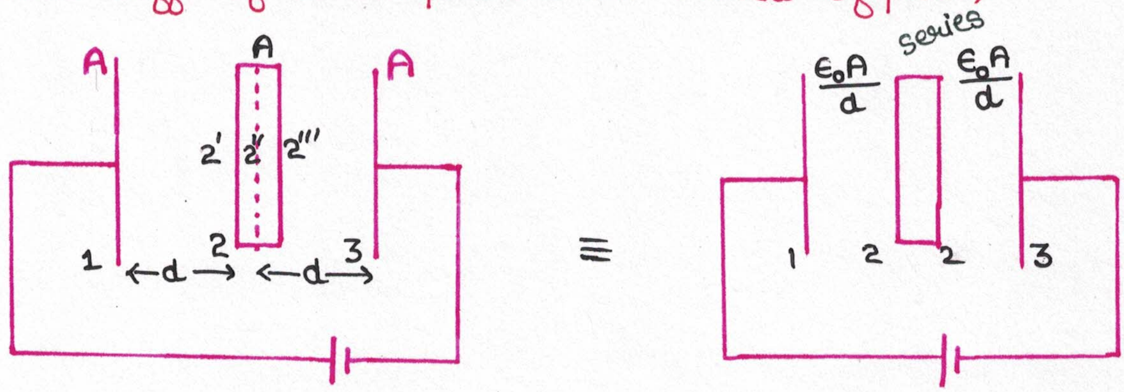
Que.)





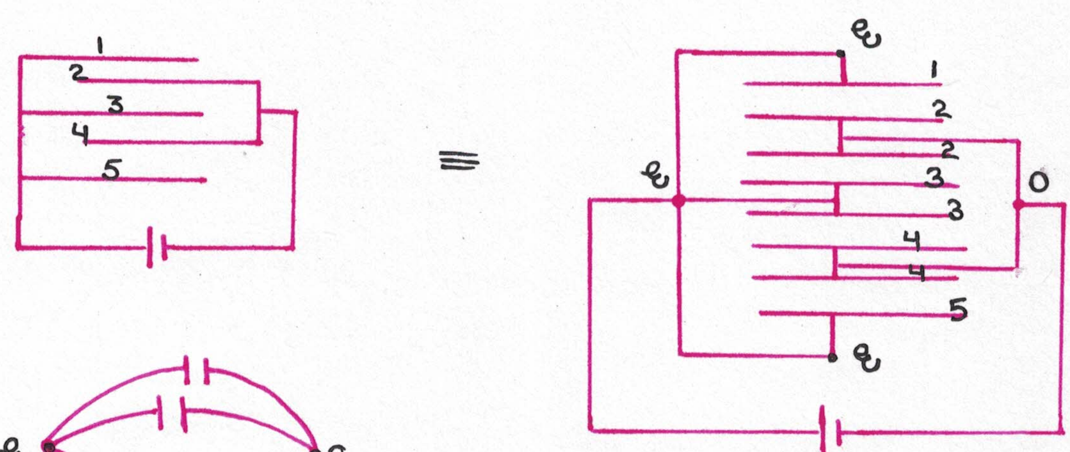
$C_{eff} = 15 \mu F$

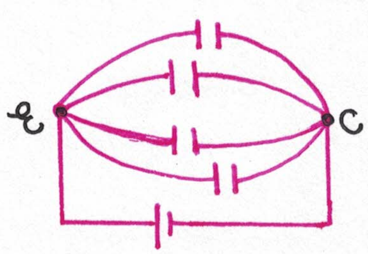
Que.) Find C_{eff} of the system. ($A \rightarrow$ area of plate)



$$C_{eff} = \frac{\epsilon_0 A}{2d}$$

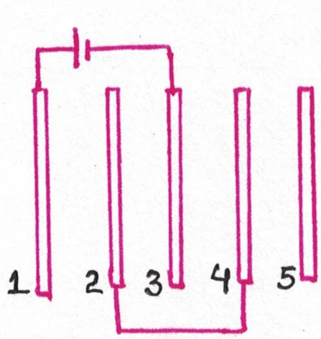
Que.)

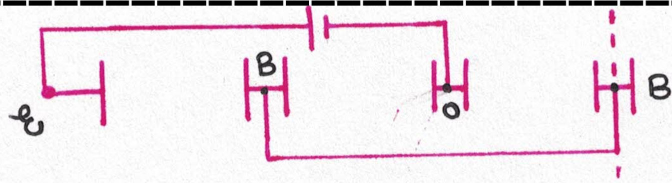


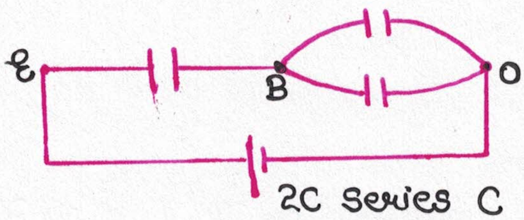


$$C_{eff} = \frac{4\epsilon_0 A}{2}$$

Que.)





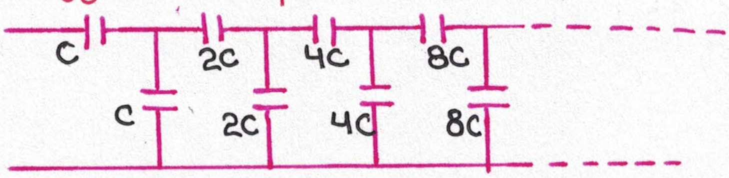


2C series C

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

$$q = \frac{\varepsilon 2C}{3} = \frac{\varepsilon 2\epsilon_0 A}{3d}$$

Que.) Find effective capacitance.



Que.) Find Reff. b/w A and B