CHAPTER – 31
CAPACITOR

1. Given that

Number of electron = 1×10^{12}

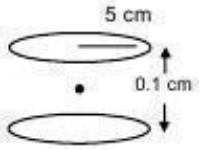
Net charge Q $= 1 \times 10^{12} \times 1.6 \times 10^{-19} = 1.6 \times 10^{-7}$ C

$\therefore$ The net potential difference = 10 L.

$\therefore$ Capacitance – $C = \frac{q}{v} = \frac{1.6 \times 10^{-7}}{10} = 1.6 \times 10^{-8}$ F.

2. $A = \pi r^2 = 25\ \pi cm^2$

d = 0.1 cm



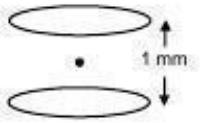
$c = \frac{\varepsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \times 25 \times 3.14}{0.1} = 6.95 \times 10^{-5}\ \mu F.$

3. Let the radius of the disc = R

$\therefore$ Area = πR^2

C = 1f

D = 1 mm = 10^{-3} m



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

$\Rightarrow 1 = \frac{8.85 \times 10^{-12} \times \pi r^2}{10^{-3}} \Rightarrow r^2 = \frac{10^{-3} \times 10^{12}}{8.85 \times \pi} = \frac{10^9}{27.784} = 5998.5\ m = 6\ Km$

4. $A = 25\ cm^2 = 2.5 \times 10^{-3}\ cm^2$

d = 1 mm = 0.01 m

V = 6V Q = ?



$C = \frac{\varepsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \times 2.5 \times 10^{-3}}{0.01}$

$Q = CV = \frac{8.854 \times 10^{-12} \times 2.5 \times 10^{-3}}{0.01} \times 6 = 1.32810 \times 10^{-10}$ C

$W = Q \times V = 1.32810 \times 10^{-10} \times 6 = 8 \times 10^{-10}$ J.

5. Plate area $A = 25\ cm^2 = 2.5 \times 10^{-3}$ m

Separation d = 2 mm = 2×10^{-3} m

Potential v = 12 v



(a) We know $C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 2.5 \times 10^{-3}}{2 \times 10^{-3}} = 11.06 \times 10^{-12}$ F

$C = \frac{q}{v} \Rightarrow 11.06 \times 10^{-12} = \frac{q}{12}$

$\Rightarrow q_1 = 1.32 \times 10^{-10}$ C.

(b) Then d = decreased to 1 mm

$\therefore$ d = 1 mm = 1×10^{-3} m

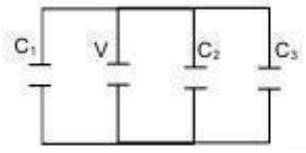
$C = \frac{\varepsilon_0 A}{d} = \frac{q}{v} = \frac{8.85 \times 10^{-12} \times 2.5 \times 10^{-3}}{1 \times 10^{-3}} = \frac{2}{12}$

$\Rightarrow q_2 = 8.85 \times 2.5 \times 12 \times 10^{-12} = 2.65 \times 10^{-10}$ C.

$\therefore$ The extra charge given to plate = $(2.65 - 1.32) \times 10^{-10} = 1.33 \times 10^{-10}$ C.

6. $C_1 = 2\ \mu F$, $C_2 = 4\ \mu F$,

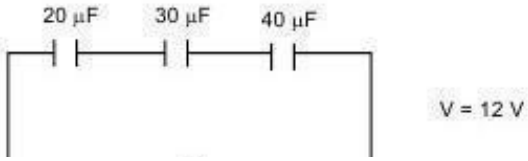
$C_3 = 6\ \mu F$ V = 12 V

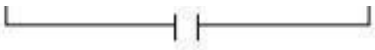


$cq = C_1 + C_2 + C_3 = 2 + 4 + 6 = 12\ \mu F = 12 \times 10^{-6}$ F

$q_1 = 12 \times 2 = 24\ \mu C$, $q_2 = 12 \times 4 = 48\ \mu C$, $q_3 = 12 \times 6 = 72\ \mu C$

7.





∴ The equivalent capacity.

$$C = \frac{C_1C_2C_3}{C_2C_3 + C_1C_3 + C_1C_2} = \frac{20\times30\times40}{30\times40+20\times40+20\times30} = \frac{24000}{2600} = 9.23\ \mu F$$

(a) Let Equivalent charge at the capacitor = q

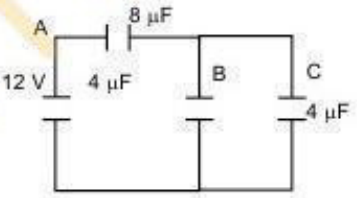
$$C = \frac{q}{V} \Rightarrow q = C \times V = 9.23 \times 12 = 110\ \mu C \text{ on each.}$$

As this is a series combination, the charge on each capacitor is same as the equivalent charge which is 110 μC.

(b) Let the work done by the battery = W

$$\therefore V = \frac{W}{q} \Rightarrow W = Vq = 110 \times 12 \times 10^{-6} = 1.33 \times 10^{-3}\ J.$$

8. $C_1 = 8\ \mu F$, $C_2 = 4\ \mu F$, $C_3 = 4\ \mu F$



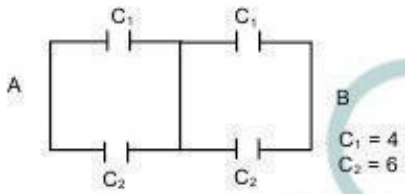
$$Ceq = \frac{(C_2 + C_3)\times C_1}{C_1 + C_2 + C_3}$$

$$= \frac{8\times8}{16} = 4\ \mu F$$

Since B & C are parallel & are in series with A

So, $q_1 = 8 \times 6 = 48\ \mu C$ $q_2 = 4 \times 6 = 24\ \mu C$ $q3 = 4 \times 6 = 24\ \mu C$

9. (a)



∴ C_1, C_1 are series & C_2, C_2 are series as the V is same at p & q. So no current pass through p & q.

$$\frac{1}{C} = \frac{1}{C_1} = \frac{1}{C_2} \Rightarrow \frac{1}{C} = \frac{1+1}{C_1C_2}$$

$$C_p = \frac{C_1}{2} = \frac{4}{2} = 2\ \mu F$$

$$\text{And } C_q = \frac{C_2}{2} = \frac{6}{2} = 3\ \mu F$$

∴ $C = C_p + C_q = 2 + 3 = 5\ \mu F$

(b) $C_1 = 4\ \mu F$, $C_2 = 6\ \mu F$,

In case of p & q, q = 0

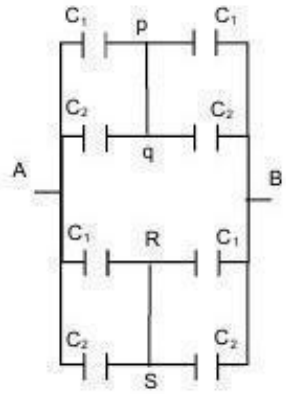
$$\therefore C_p = \frac{C_1}{2} = \frac{4}{2} = 2\ \mu F$$

$$C_q = \frac{C_2}{2} = \frac{6}{2} = 3\ \mu F$$

& $C' = 2 + 3 = 5\ \mu F$

C & $C' = 5\ \mu F$

∴ The equation of capacitor $C = C' + C'' = 5 + 5 = 10\ \mu F$

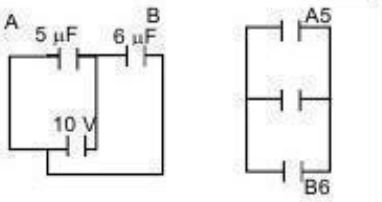


10. V = 10 v

Ceq = $C_1 + C_2$ [∴ They are parallel]

= 5 + 6 = 11 μF

q = CV = 11 × 10 110 μC



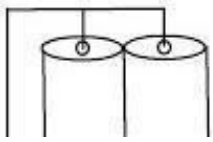
11. The capacitance of the outer sphere = 2.2 μF

C = 2.2 μF

Potential, V = 10 v

Let the charge given to individual cylinder = q.

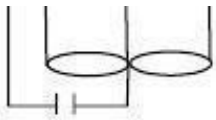
$$C = \frac{q}{}$$



V

$\Rightarrow q = CV = 2.2 \times 10 = 22\ \mu F$

$\therefore$ The total charge given to the inner cylinder = 22 + 22 = 44 μF



12. $C = \frac{q}{V}$, Now $V = \frac{Kq}{R}$

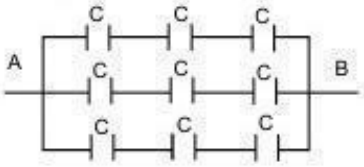
So, $C_1 = \frac{q}{(Kq/R_1)} = \frac{R_1}{K} = 4\ \pi\varepsilon_0 R_1$

Similarly $c_2 = 4\ \pi\varepsilon_0 R_2$

The combination is necessarily parallel.

Hence Ceq = $4\ \pi\varepsilon_0 R_1 + 4\ \pi\varepsilon_0 R_2 = 4\ \pi\varepsilon_0 (R_1 + R_2)$

13.



$\therefore C = 2\ \mu F$

$\therefore$ In this system the capacitance are arranged in series. Then the capacitance is parallel to each other.

(a) $\therefore$ The equation of capacitance in one row

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

(b) and three capacitance of capacity $\frac{C}{3}$ are connected in parallel

$\therefore$ The equation of capacitance

$$C = \frac{C}{3} + \frac{C}{3} + \frac{C}{3} = C = 2\ \mu F$$

As the volt capacitance on each row are same and the individual is

$$= \frac{\text{Total}}{\text{No. of capacitance}} = \frac{60}{3} = 20\ V$$

14. Let there are 'x' no of capacitors in series ie in a row

So, $x \times 50 = 200$

$\Rightarrow x = 4$ capacitors.

Effective capacitance in a row = $\frac{10}{4}$

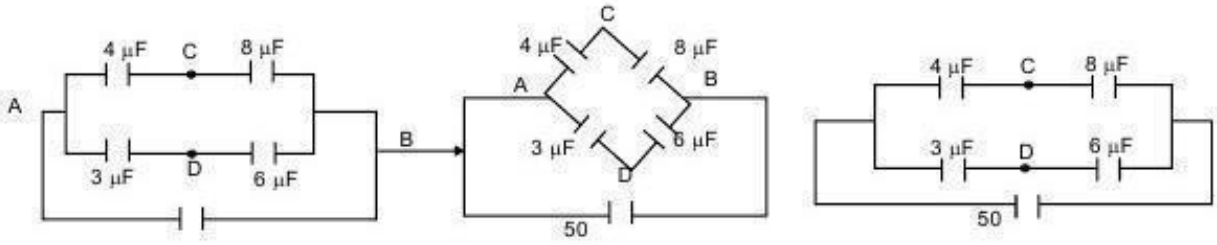
Now, let there are 'y' such rows,

So, $\frac{10}{4} \times y = 10$

$\Rightarrow y = 4$ capacitor.

So, the combinations of four rows each of 4 capacitors.

15.



(a) Capacitor = $\frac{4 \times 8}{4 + 8} = \frac{8}{3}\ \mu$

and $\frac{6 \times 3}{6 + 3} = 2\ \mu F$

(i) The charge on the capacitance $\frac{8}{3}\ \mu F$

$\therefore Q = \frac{8}{3} \times 50 = \frac{400}{3}$

$\therefore$ The potential at 4 $\mu F = \frac{400}{3\times4} = \frac{100}{3}$

at 8 $\mu F = \frac{400}{3\times8} = \frac{100}{6}$

The Potential difference $= \frac{100}{3} - \frac{100}{6} = \frac{50}{3}\ \mu V$

(ii) Hence the effective charge at 2 $\mu F = 50 \times 2 = 100\ \mu F$

$\therefore$ Potential at 3 $\mu F = \frac{100}{3}$; Potential at 6 $\mu F = \frac{100}{6}$

$\therefore$ Difference $= \frac{100}{3} - \frac{100}{6} = \frac{50}{3}\ \mu V$

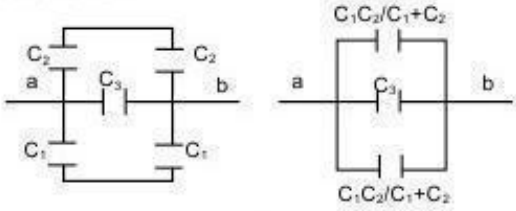
$\therefore$ The potential at C & D is $\frac{50}{3}\ \mu V$

(b) $\therefore \frac{P}{q} = \frac{R}{S} = \frac{1}{2} = \frac{1}{2}$ = It is balanced. So from it is cleared that the wheat star bridge balanced. So the potential at the point C & D are same. So no current flow through the point C & D. So if we connect another capacitor at the point C & D the charge on the capacitor is zero.

16. Ceq between a & b

$= \frac{C_1C_2}{C_1+C_2} + C_3 + \frac{C_1C_2}{C_1+C_2}$

$= C_3 + \frac{2C_1C_2}{C_1+C_2}$ ($\therefore$ The three are parallel)



17. In the figure the three capacitors are arranged in parallel.

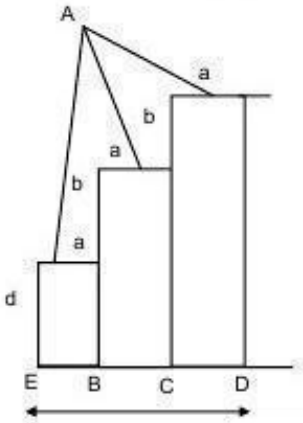
All have same surface area = a = $\frac{A}{3}$

First capacitance $C_1 = \frac{\varepsilon_0 A}{3d}$

2nd capacitance $C_2 = \frac{\varepsilon_0 A}{3(b+d)}$

3rd capacitance $C_3 = \frac{\varepsilon_0 A}{3(2b+d)}$

Ceq = $C_1 + C_2 + C_3$



$= \frac{\varepsilon_0 A}{3d} + \frac{\varepsilon_0 A}{3(b+d)} + \frac{\varepsilon_0 A}{3(2b+d)} = \frac{\varepsilon_0 A}{3}\left(\frac{1}{d} + \frac{1}{b+d} + \frac{1}{2b+d}\right)$

$= \frac{\varepsilon_0 A}{3}\left(\frac{(b+d)(2b+d)+(2b+d)d+(b+d)d}{d(b+d)(2b+d)}\right)$

$= \frac{\varepsilon_0 A\left(3d^2+6bd+2b^2\right)}{3d(b+d)(2b+d)}$

18. (a) $C = \frac{2\varepsilon_0 L}{\ln(R_2/R_1)} = \frac{e\times3.14\times8.85\times10^{-2}\times10^{-1}}{\ln2}$ [ln2 = 0.6932]

$= 80.17 \times 10^{-13} \Rightarrow 8$ PF

(b) Same as R_2/R_1 will be same.

19. Given that

C = 100 PF = 100×10^{-12} F $\quad$ C_{eq} = 20 PF = 20×10^{-12} F

V = 24 V $\quad$ $q = 24 \times 100 \times 10^{-12} = 24 \times 10^{-10}$

q_2 = ?

Let q_1 = The new charge 100 PF $\quad$ V_1 = The Voltage.

Let the new potential is V_1

After the flow of charge, potential is same in the two capacitor

$V_1 = \frac{q_2}{C_2} = \frac{q_1}{C_1}$

$C_2 \quad C_1$

$= \frac{q - q_1}{C_2} = \frac{q_1}{C_1}$

$= \frac{24 \times 10^{-10} - q_1}{24 \times 10^{-12}} = \frac{q_1}{100 \times 10^{-12}}$

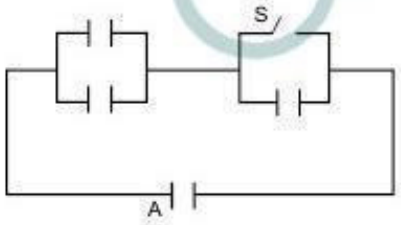
$= 24 \times 10^{-10} - q_1 = \frac{q_1}{5}$

$= 6q_1 = 120 \times 10^{-10}$

$= q_1 = \frac{120}{6} \times 10^{-10} = 20 \times 10^{-10}$

$\therefore V_1 = \frac{q_1}{C_1} = \frac{20 \times 10^{-10}}{100 \times 10^{-12}} = 20\ V$

20.



Initially when 's' is not connected,

$C_{eff} = \frac{2C}{3}q = \frac{2C}{3} \times 50 = \frac{5}{2} \times 10^{-4} = 1.66 \times 10^{-4}\ C$

After the switch is made on,

Then $C_{eff} = 2C = 10^{-5}$

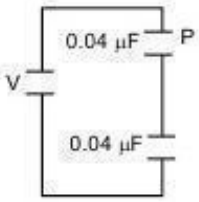
$Q = 10^{-5} \times 50 = 5 \times 10^{-4}$

Now, the initial charge will remain stored in the stored in the short capacitor

Hence net charge flowing

$= 5 \times 10^{-4} - 1.66 \times 10^{-4} = 3.3 \times 10^{-4}\ C.$

21.



Given that mass of particle m = 10 mg

Charge 1 = – 0.01 μC

$A = 100\ cm^2$ Let potential = V

The Equation capacitance $C = \frac{0.04}{2} = 0.02\ \mu F$

The particle may be in equilibrium, so that the wt. of the particle acting down ward, must be balanced by the electric force acting up ward.

$\therefore qE = Mg$

Electric force $= qE = q\frac{V}{d}$ where V – Potential, d – separation of both the plates.

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

$qE = mg$

$= \frac{QVC}{\varepsilon_0 A} = mg$

$= \frac{0.01 \times 0.02 \times V}{8.85 \times 10^{-12} \times 100} = 0.1 \times 980$

$\Rightarrow V = \frac{0.1 \times 980 \times 8.85 \times 10^{-10}}{0.0002} = 0.00043 = 43\ MV$

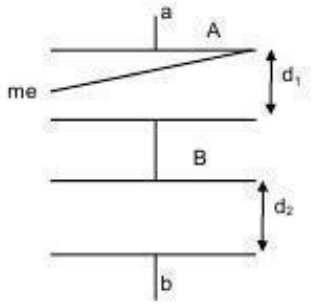
22. Let mass of electron = μ

Charge electron = e

We know, 'q'

For a charged particle to be projected in side to plates of a parallel plate capacitor with electric field E,

$$y = \frac{1qE}{2m}\left(\frac{x}{\mu}\right)^2$$



where y – Vertical distance covered or

x – Horizontal distance covered

μ – Initial velocity

From the given data,

$y = \frac{d_1}{2}$, $E = \frac{V}{R} = \frac{qd_1}{\varepsilon_0 a^2 \times d_1} = \frac{q}{\varepsilon_0 a^2}$, $x = a$, $\mu = ?$

For capacitor A –

$$V_1 = \frac{q}{C_1} = \frac{qd_1}{\varepsilon_0 a^2} \text{ as } C_1 = \frac{\varepsilon_0 a^2}{d_1}$$

Here q = chare on capacitor.

$q = C \times V$ where C = Equivalent capacitance of the total arrangement = $\frac{\varepsilon_0 a^2}{d_1 + d_2}$

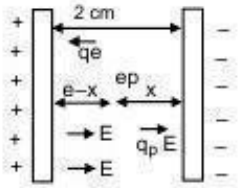
So, $q = \frac{\varepsilon_0 a^2}{d_1 + d_2} \times V$

Hence $E = \frac{q}{\varepsilon_0 a^2} = \frac{\varepsilon_0 a^2 \times V}{(d_1 + d_2)\varepsilon_0 a^2} = \frac{V}{(d_1 + d_2)}$

Substituting the data in the known equation, we get, $\frac{d_1}{2} = \frac{1}{2} \times \frac{e \times V}{(d_1 + d_2)m} \times \frac{a^2}{u^2}$

$$\Rightarrow u^2 = \frac{Vea^2}{d_1 m(d_1 + d_2)} \Rightarrow u = \left(\frac{Vea^2}{d_1 m(d_1 + d_2)}\right)^{1/2}$$

23. The acceleration of electron $a_e = \frac{qeme}{Me}$



The acceleration of proton = $\frac{qpe}{Mp} = ap$

The distance travelled by proton X = $\frac{1}{2}apt^2$ ...(1)

The distance travelled by electron ...(2)

From (1) and (2) $\Rightarrow 2 - X = \frac{1}{2}a_c t^2$ $x = \frac{1}{2}a_c t^2$

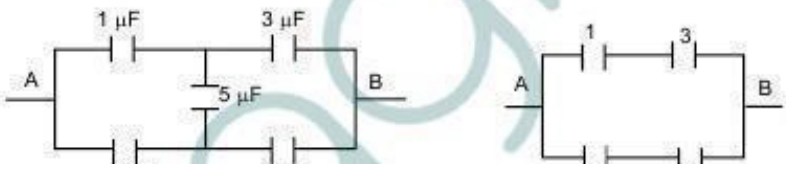
$$\Rightarrow \frac{x}{2-x} = \frac{a_p}{a_c} = \frac{\left(\frac{q_p E}{M_p}\right)}{\left(\frac{q_c F}{M_c}\right)}$$

$$= \frac{x}{2-x} = \frac{M_c}{M_p} = \frac{9.1 \times 10^{-31}}{1.67 \times 10^{-27}} = \frac{9.1}{1.67} \times 10^{-4} = 5.449 \times 10^{-4}$$

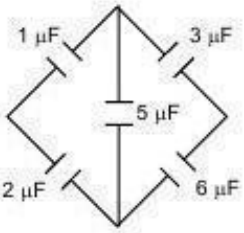
$\Rightarrow x = 10.898 \times 10^{-4} - 5.449 \times 10^{-4} x$

$$\Rightarrow x = \frac{10.898 \times 10^{-4}}{1.0005449} = 0.001089226$$

24. (a)



2 μF 6 μF

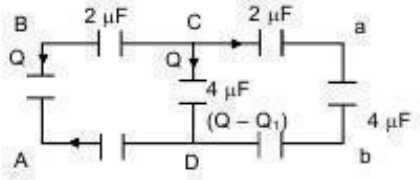


As the bridge in balanced there is no current through the 5 μF capacitor
So, it reduces to
similar in the case of (b) & (c)
as 'b' can also be written as.

$$Ceq = \frac{1\times3}{1+3}+\frac{2\times6}{2+6} = \frac{3}{48}+\frac{12}{8} = \frac{6+12}{8} = 2.25\ \mu F$$

25. (a) By loop method application in the closed circuit ABCabDA

$$-12 + \frac{2Q}{2\mu F}+\frac{Q_1}{2\mu F}+\frac{Q_1}{4\mu F} = 0 \qquad ...(1)$$



In the close circuit ABCDA

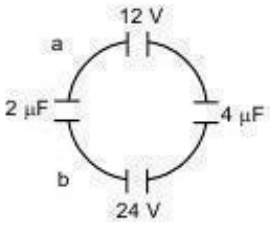
$$-12 + \frac{Q}{2\mu F}+\frac{Q+Q_1}{4\mu F} = 0 \qquad ...(2)$$

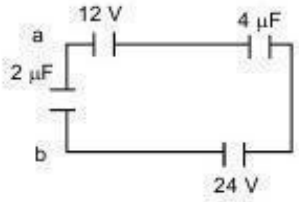
From (1) and (2) $2Q + 3Q_1 = 48$ ...(3)
And $3Q - q_1 = 48$ and subtracting $Q = 4Q_1$, and substitution in equation

$$2Q + 3Q_1 = 48 \Rightarrow 8\ Q_1 + 3Q_1 = 48 \Rightarrow 11Q_1 = 48,\ q_1 = \frac{48}{11}$$

$$Vab = \frac{Q_1}{4\mu F} = \frac{48}{11\times4} = \frac{12}{11}\ V$$

(b)



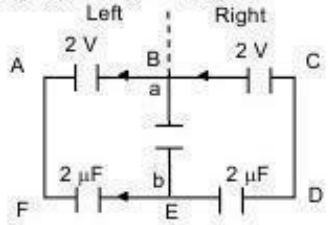


The potential = 24 – 12 = 12

$$\text{Potential difference } V = \frac{(2\times0+12\times4)}{2+4} = \frac{48}{6} = 8\ V$$

∴ The Va – Vb = – 8 V

(c)

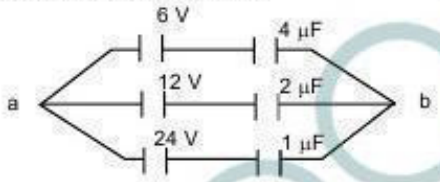


From the figure it is cleared that the left and right branch are symmetry and reversed, so the current go towards BE from BAFEB same as the current from EDCBE.

∴ The net charge Q = 0 $\qquad \therefore V = \frac{Q}{C} = \frac{0}{C} = 0 \qquad \therefore Vab = 0$

∴ The potential at K is zero.

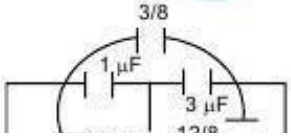
(d)

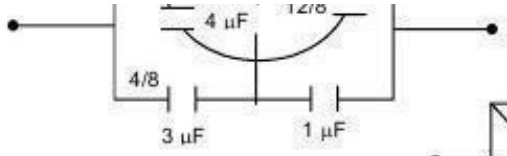


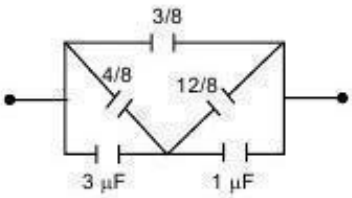
$$\text{The net potential} = \frac{\text{Net charge}}{\text{Net capacitance}} = \frac{24+24+24}{7} = \frac{72}{7}\ 10.3\ V$$

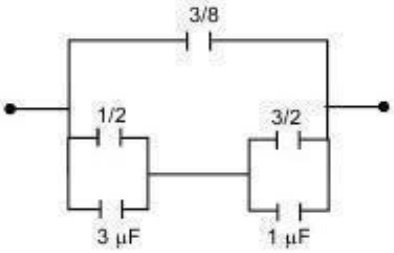
∴ Va – Vb = – 10.3 V

26. (a)





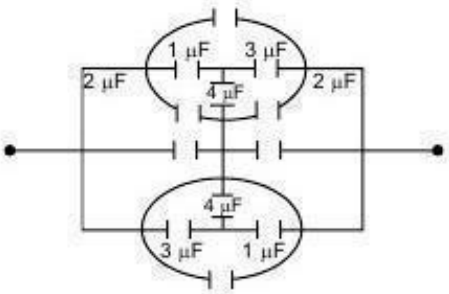




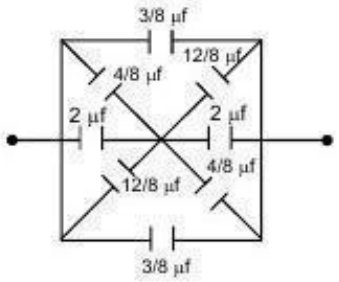
By star Delta conversion

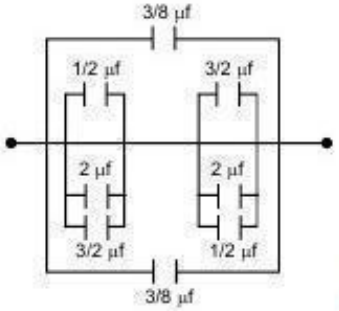
$$C_{eff} = \frac{3}{8} + \left[\frac{\left(3+\frac{1}{2}\right)\times\left(\frac{3}{2}+1\right)}{\left(3+\frac{1}{2}\right)+\left(\frac{3}{2}+1\right)}\right] = \frac{3}{8}+\frac{35}{24} = \frac{9+35}{24} = \frac{11}{6}\ \mu F$$

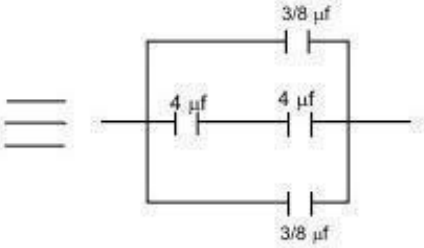
(b)



by star Delta convensor

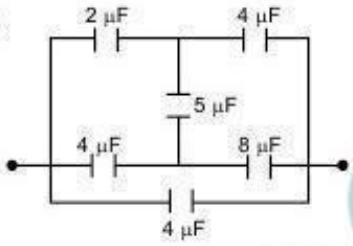






$$= \frac{3}{8}+\frac{16}{8}+\frac{3}{8} = \frac{11}{4}\ \mu f$$

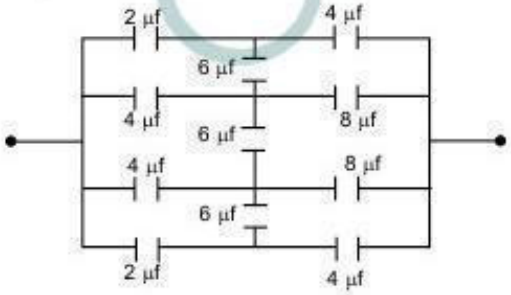
(c)

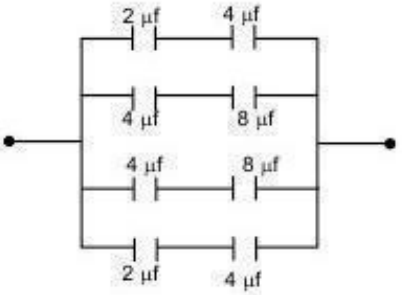


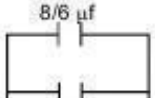


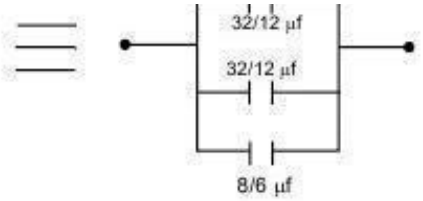
$$Cef = \frac{4}{3}+\frac{8}{3}+4 = 8\ \mu F$$

(d)



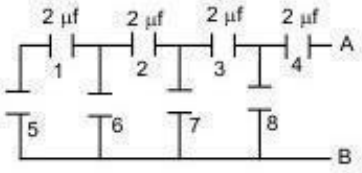






$$Cef = \frac{3}{8}+\frac{32}{12}+\frac{32}{12}+\frac{8}{6} = \frac{16+32}{6} = 8\ \mu f$$

27.



= C_5 and C_1 are in series

$$C_{eq} = \frac{2\times2}{2+2} = 1$$

This is parallel to $C_6 = 1 + 1 = 2$

Which is series to $C_2 = \frac{2\times2}{2+2} = 1$

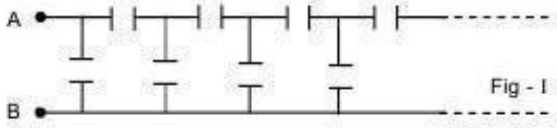
Which is parallel to $C_7 = 1 + 1 = 2$

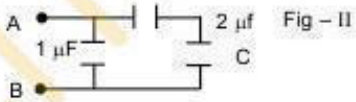
Which is series to $C_3 = \frac{2\times2}{2+2} = 1$

Which is parallel to $C_8 = 1 + 1 = 2$

This is series to $C_4 = \frac{2\times2}{2+2} = 1$

28.





Let the equivalent capacitance be C. Since it is an infinite series. So, there will be negligible change if the arrangement is done an in Fig – II

$$C_{eq} = \frac{2\times C}{2+C} + 1 \Rightarrow C = \frac{2C+2+C}{2+C}$$

$\Rightarrow (2 + C) \times C = 3C + 2$

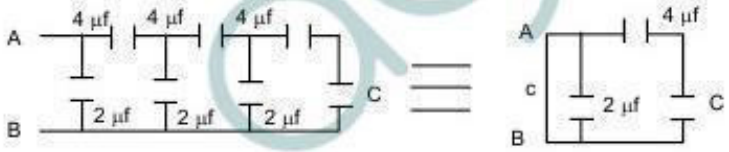
$\Rightarrow C^2 - C - 2 = 0$

$\Rightarrow (C - 2)(C + 1) = 0$

$C = -1$ (Impossible)

So, $C = 2\ \mu F$

29.



= C and 4 μf are in series

So, $C_1 = \frac{4\times C}{4+C}$

Then C_1 and 2 μf are parallel

$C = C_1 + 2\ \mu f$

$$\Rightarrow \frac{4\times C}{4+C}+2 \Rightarrow \frac{4C+8+2C}{4+C} = C$$

$\Rightarrow 4C + 8 + 2C = 4C + C^2 = C^2 - 2C - 8 = 0$

$$C = \frac{2\pm\sqrt{4+4\times1\times8}}{2} = \frac{2\pm\sqrt{36}}{2} = \frac{2\pm6}{2}$$

$$C = \frac{2+6}{2} = 4\ \mu f$$

∴ The value of C is 4 μf

30. $q_1 = +2.0 \times 10^{-8}$ c $\quad q_2 = -1.0 \times 10^{-8}$ c

$C = 1.2 \times 10^{-3}\ \mu F = 1.2 \times 10^{-9}$ F

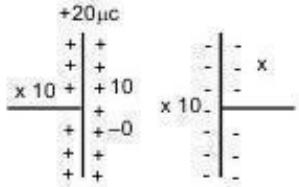
$$\text{net } q = \frac{q_1 - q_2}{2} = \frac{3.0 \times 10^{-8}}{2}$$

$$V = \frac{q}{c} = \frac{3 \times 10^{-8}}{2} \times \frac{1}{1.2 \times 10^{-9}} = 12.5 \text{ V}$$

31. ∴ Given that

Capacitance = 10 μF

Charge = 20 μc



$$\therefore \text{The effective charge} = \frac{20 - 0}{2} = 10\ \mu F$$

$$\therefore C = \frac{q}{V} \Rightarrow V = \frac{q}{C} = \frac{10}{10} = 1 \text{ V}$$

32. $q_1 = 1\ \mu C = 1 \times 10^{-6}$ C $\quad C = 0.1\ \mu F = 1 \times 10^{-7} F$

$q_2 = 2\ \mu C = 2 \times 10^{-6}$ C

$$\text{net } q = \frac{q_1 - q_2}{2} = \frac{(1-2) \times 10^{-6}}{2} = -0.5 \times 10^{-6} \text{ C}$$

$$\text{Potential 'V'} = \frac{q}{c} = \frac{1 \times 10^{-7}}{-5 \times 10^{-7}} = -5 \text{ V}$$

But potential can never be (–)ve. So, V = 5 V

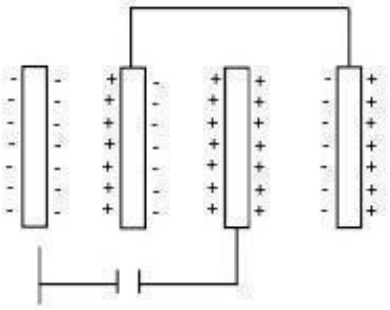
33. Here three capacitors are formed

And each of

$$A = \frac{96}{\varepsilon_0} \times 10^{-12} \text{ f.m.}$$

$d = 4$ mm $= 4 \times 10^{-3}$ m

∴ Capacitance of a capacitor



$$C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 \dfrac{96 \times 10^{-12}}{\varepsilon_0}}{4 \times 10^{-3}} = 24 \times 10^{-9} \text{ F.}$$

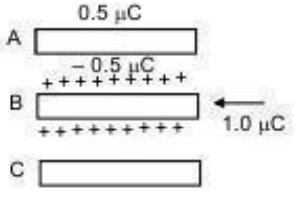
∴ As three capacitor are arranged is series

$$\text{So, Ceq} = \frac{C}{q} = \frac{24 \times 10^{-9}}{3} = 8 \times 10^{-9}$$

∴ The total charge to a capacitor = $8 \times 10^{-9} \times 10 = 8 \times 10^{-8}$ c

∴ The charge of a single Plate = $2 \times 8 \times 10^{-8} = 16 \times 10^{-8} = 0.16 \times 10^{-6} = 0.16$ μc.

34. (a) When charge of 1 μc is introduced to the B plate, we also get 0.5 μc charge on the upper surface of Plate 'A'.



(b) Given C = 50 μF = 50×10^{-9} F = 5×10^{-8} F

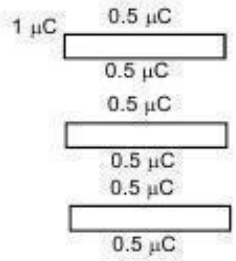
Now charge = 0.5×10^{-6} C

$$V = \frac{q}{C} = \frac{5 \times 10^{-7} C}{5 \times 10^{-8} F} = 10 \text{ V}$$

35. Here given,

Capacitance of each capacitor, C = 50 μf = 0.05 μf

Charge Q = 1 μF which is given to upper plate = 0.5 μc charge appear on outer and inner side of upper plate and 0.5 μc of charge also see on the middle.



(a) Charge of each plate = 0.5 μc

Capacitance = 0.5 μf

$$\therefore C = \frac{q}{V} \therefore V = \frac{q}{C} = \frac{0.5}{0.05} = 10 \text{ v}$$

(b) The charge on lower plate also = 0.5 μc

Capacitance = 0.5 μF

$$\therefore C = \frac{q}{V} \Rightarrow V = \frac{q}{C} = \frac{0.5}{\quad} = 10 \text{ V}$$

$\therefore C = \frac{q}{V} \Rightarrow V = \frac{q}{C} = \frac{}{0.05} = 10$ V

$\therefore$ The potential in 10 V

36. $C_1 = 20$ PF $= 20 \times 10^{-12}$ F, $C_2 = 50$ PF $= 50 \times 10^{-12}$ F

Effective $C = \frac{C_1C_2}{C_1 + C_2} = \frac{2\times10^{-11}\times5\times10^{-11}}{2\times10^{-11}+5\times10^{-11}} = 1.428 \times 10^{-11}$ F

Charge 'q' $= 1.428 \times 10^{-11} \times 6 = 8.568 \times 10^{-11}$ C

$V_1 = \frac{q}{C_1} = \frac{8.568\times10^{-11}}{2\times10^{-11}} = 4.284$ V

$V_2 = \frac{q}{C_2} = \frac{8.568\times10^{-11}}{5\times10^{-11}} = 1.71$ V

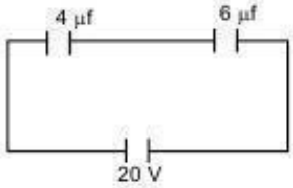
Energy stored in each capacitor

$E_1 = (1/2)\, C_1V_1^2 = (1/2) \times 2 \times 10^{-11} \times (4.284)^2 = 18.35 \times 10^{-11} \approx 184$ PJ

$E_2 = (1/2)\, C_2V_2^2 = (1/2) \times 5 \times 10^{-11} \times (1.71)^2 = 7.35 \times 10^{-11} \approx 73.5$ PJ

37. $\therefore C_1 = 4\ \mu$F, $C_2 = 6\ \mu$F, $V = 20$ V

Eq. capacitor $C_{eq} = \frac{C_1C_2}{C_1 + C_2} = \frac{4\times6}{4+6} = 2.4$



$\therefore$ The Eq Capacitance $C_{eq} = 2.5\ \mu$F

$\therefore$ The energy supplied by the battery to each plate

$E = (1/2)\, CV^2 = (1/2) \times 2.4 \times 20^2 = 480\ \mu$J

$\therefore$ The energy supplies by the battery to capacitor $= 2 \times 480 = 960\ \mu$J

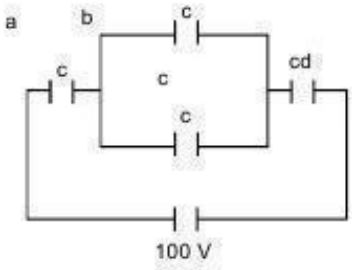
38. $C = 10\ \mu$F $= 10 \times 10^{-6}$ F

For a & d

$q = 4 \times 10^{-4}$ C

$c = 10^{-5}$ F

$E = \frac{1}{2}\frac{q^2}{c} = \frac{1}{2}\frac{\left(4\times10^{-4}\right)^2}{10^{-5}} = 8 \times 10^{-3}$ J $= 8$ mJ



For b & c

$q = 4 \times 10^{-4}$ c

$C_{eq} = 2c = 2 \times 10^{-5}$ F

$V = \frac{4\times10^{-4}}{2\times10^{-5}} = 20$ V

$E = (1/2)\, cv^2 = (1/2) \times 10^{-5} \times (20)^2 = 2 \times 10^{-3}$ J $= 2$ mJ

39. Stored energy of capacitor $C_1 = 4.0$ J

$= \frac{1}{2}\frac{q^2}{c^2} = 4.0$ J

When then connected, the charge shared

$\frac{1}{2}\frac{q_1^2}{c^2} = \frac{1}{2}\frac{q_2^2}{c^2} \Rightarrow q_1 = q_2$

So that the energy should divided.

$\therefore$ The total energy stored in the two capacitors each is 2 J.

40. Initial charge stored $= C \times V = 12 \times 2 \times 10^{-6} = 24 \times 10^{-6}$ c

Let the charges on 2 & 4 capacitors be q_1 & q_2 respectively

There, $V = \frac{q_1}{C_1} = \frac{q_2}{C_2} \Rightarrow \frac{q_1}{2} = \frac{q_2}{4} \Rightarrow q_2 = 2q_1$.

or $q_1 + q_2 = 24 \times 10^{-6}$ C

$\Rightarrow q_1 = 8 \times 10^{-6}\ \mu$c

$q_2 = 2q_1 = 2 \times 8 \times 10^{-6} = 16 \times 10^{-6}\ \mu$c

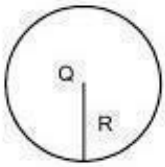
$E_1 = (1/2) \times C_1 \times V_1^2 = (1/2) \times 2 \times \left(\frac{8}{2}\right)^2 = 16\ \mu$J

$E_2 = (1/2) \times C_2 \times V_2^2 = (1/2) \times 4 \times \left(\frac{8}{}\right)^2 = 8\ \mu$J

$E_2 = (1/2) \times C_2 \times V_2^2 = (1/2) \times 4 \times \left(\frac{}{4}\right)$ = 8 μJ

41. Charge = Q

Radius of sphere = R



∴ Capacitance of the sphere = $C = 4\pi\varepsilon_0 R$

$$\text{Energy} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q^2}{4\pi\varepsilon_0 R} = \frac{Q^2}{8\pi\varepsilon_0 R}$$

42. $Q = CV = 4\pi\varepsilon_0 R \times V$

$$E = \frac{1}{2}\frac{q^2}{C} \qquad [\because \text{'C' in a spherical shell} = 4\pi\varepsilon_0 R]$$

$$E = \frac{1}{2}\frac{16\pi^2\varepsilon_0^{\,2} \times R^2 \times V^2}{4\pi\varepsilon_0 \times 2R} = 2\pi\varepsilon_0 R V^2 \qquad [\text{'C' of bigger shell} = 4\pi\varepsilon_0 R]$$

43. $\sigma = 1 \times 10^{-4}\ c/m^2$

$a = 1\ cm = 1 \times 10^{-2}\ m$ $\qquad a^3 = 10^{-6}\ m$

$$\text{The energy stored in the plane} = \frac{1}{2}\frac{\sigma^2}{\varepsilon_0} = \frac{1}{2}\frac{(1\times10^{-4})^2}{8.85\times10^{-12}} = \frac{10^4}{17.7} = 564.97$$

The necessary electro static energy stored in a cubical volume of edge 1 cm infront of the plane

$$= \frac{1}{2}\frac{\sigma^2}{\varepsilon_0}a^3 = 265 \times 10^{-6} = 5.65 \times 10^{-4}\ J$$

44. area $= a = 20\ cm^2 = 2 \times 10^{-2}\ m^2$

d = separation $= 1\ mm = 10^{-3}\ m$

$$C_i = \frac{\varepsilon_0 \times 2\times10^{-3}}{10^{-3}} = 2\varepsilon_0 \qquad C_f = \frac{\varepsilon_0 \times 2\times10^{-3}}{2\times10^{-3}} = \varepsilon_0$$

$q_i = 24\ \varepsilon_0$ $\qquad q_f = 12\ \varepsilon_0$ $\qquad$ So, q flown out $12\ \varepsilon_0$. ie, $q_i - q_f$.

(a) So, $q = 12 \times 8.85 \times 10^{-12} = 106.2 \times 10^{-12}\ C = 1.06 \times 10^{-10}\ C$

(b) Energy absorbed by battery during the process

$= q \times v = 1.06 \times 10^{-10}\ C \times 12 = 12.7 \times 10^{-10}\ J$

(c) Before the process

$E_i = (1/2) \times Ci \times v^2 = (1/2) \times 2 \times 8.85 \times 10^{-12} \times 144 = 12.7 \times 10^{-10}\ J$

After the force

$E_i = (1/2) \times Cf \times v^2 = (1/2) \times 8.85 \times 10^{-12} \times 144 = 6.35 \times 10^{-10}\ J$

(d) Workdone = Force × Distance

$$= \frac{1}{2}\frac{q^2}{\varepsilon_0 A} = 1 \times 10^3 \qquad = \frac{1}{2} \times \frac{12\times12\times\varepsilon_0\times\varepsilon_0\times10^{-3}}{\varepsilon_0\times2\times10^{-3}}$$

(e) From (c) and (d) we have calculated, the energy loss by the separation of plates is equal to the work done by the man on plate. Hence no heat is produced in transformer.

---

45. (a) Before reconnection

$C = 100\ \mu f$ $\qquad V = 24\ V$

$q = CV = 2400\ \mu c$ (Before reconnection)

After connection

When $C = 100\ \mu f$ $\qquad V = 12\ V$

$q = CV = 1200\ \mu c$ (After connection)

(b) $C = 100$, $\qquad V = 12\ V$

$\therefore q = CV = 1200\ v$

(c) We know $V = \frac{W}{q}$

$W = vq = 12 \times 1200 = 14400\ J = 14.4\ mJ$

The work done on the battery.

(d) Initial electrostatic field energy $Ui = (1/2)\ CV_1^2$

Final Electrostatic field energy $Uf = (1/2)\ CV_2^2$

∴ Decrease in Electrostatic

Field energy $= (1/2)\ CV_1^2 - (1/2)\ CV_2^2$

$= (1/2)\, C(V_1^2 - V_2^2) = (1/2) \times 100(576 - 144) = 21600 J$

$\therefore$ Energy = 21600 j = 21.6 mJ

(e)After reconnection

C = 100 μc, V = 12 v

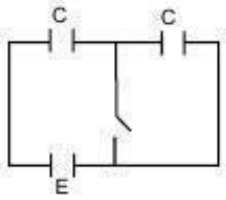
$\therefore$ The energy appeared = $(1/2)\, CV^2 = (1/2) \times 100 \times 144 = 7200$ J = 7.2 mJ

This amount of energy is developed as heat when the charge flow through the capacitor.

46. (a) Since the switch was open for a long time, hence the charge flown must be due to the both, when the switch is closed.

Cef = C/2

So $q = \frac{E \times C}{2}$



(b) Workdone = $q \times v = \frac{EC}{2} \times E = \frac{E^2C}{2}$

(c) $E_i = \frac{1}{2} \times \frac{C}{2} \times E^2 = \frac{E^2C}{4}$

$E_f = (1/2) \times C \times E^2 = \frac{E^2C}{2}$

$E_i - E_f = \frac{E^2C}{4}$

(d) The net charge in the energy is wasted as heat.

47. $C_1 = 5$ μf $V_1 = 24$ V

$q_1 = C_1V_1 = 5 \times 24 = 120$ μc

and $C_2 = 6$ μf $V_2 = R$

$q_2 = C_2V_2 = 6 \times 12 = 72$

$\therefore$ Energy stored on first capacitor

$E_1 = \frac{1}{2}\frac{q_1^2}{C_1} = \frac{1}{2} \times \frac{(120)^2}{2} = 1440$ J = 1.44 mJ

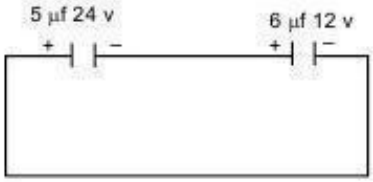
Energy stored on 2nd capacitor

$E_2 = \frac{1}{2}\frac{q_2^2}{C_2} = \frac{1}{2} \times \frac{(72)^2}{6} = 432$ J = 4.32 mJ

(b) C_1V_1 C_2V_2

Let the effective potential = V

$V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2} = \frac{120 - 72}{5 + 6} = 4.36$



The new charge $C_1V = 5 \times 4.36 = 21.8$ μc

and $C_2V = 6 \times 4.36 = 26.2$ μc

(c) $U_1 = (1/2)\, C_1V^2$

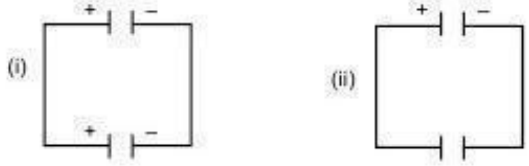
$U_2 = (1/2)\, C_2V^2$

$U_f = (1/2)\, V^2 (C_1 + C_2) = (1/2)\, (4.36)^2\, (5 + 6) = 104.5 \times 10^{-6}$ J = 0.1045 mJ

But $U_i = 1.44 + 0.433 = 1.873$

$\therefore$ The loss in KE = 1.873 – 0.1045 = 1.7687 = 1.77 mJ

48.



When the capacitor is connected to the battery, a charge Q = CE appears on one plate and –Q on the other. When the polarity is reversed, a charge –Q appears on the first plate and +Q on the second. A charge 2Q, therefore passes through the battery from the negative to the positive terminal.

The battery does a work.

$W = Q \times E = 2QE = 2CE^2$

In this process. The energy stored in the capacitor is the same in the two cases. Thus the workdone

by battery appears as heat in the connecting wires. The heat produced is therefore,

$2CE^2 = 2 \times 5 \times 10^{-6} \times 144 = 144 \times 10^{-5}$ J = 1.44 mJ [have C = 5 μf V = E = 12V]

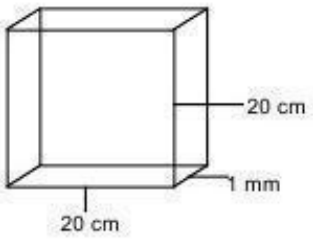
49. A = 20 cm × 20 cm = 4×10^{-2} m

d = 1 m = 1×10^{-3} m

k = 4 t = d

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

$$= \frac{8.85 \times 10^{-12} \times 4 \times 10^{-2} \times 4}{1 \times 10^{-3}} = 141.6 \times 10^{-9} \text{ F} = 1.42 \text{ nf}$$



50. Dielectric const. = 4

F = 1.42 nf, V = 6 V

Charge supplied = q = CV = $1.42 \times 10^{-9} \times 6 = 8.52 \times 10^{-9}$ C

Charge Induced = q(1 – 1/k) = $8.52 \times 10^{-9} \times (1 - 0.25) = 6.39 \times 10^{-9} = 6.4$ nc

Net charge appearing on one coated surface = $\frac{8.52\mu c}{4} = 2.13$ nc



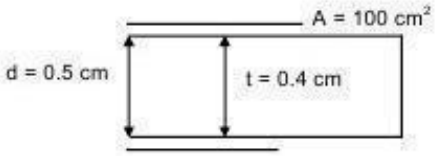
51. Here

Plate area = 100 cm^2 = 10^{-2} m^2

Separation d = .5 cm = 5×10^{-3} m

Thickness of metal t = .4 cm = 4×10^{-3} m

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}} = \frac{\varepsilon_0 A}{d - t} = \frac{8.585 \times 10^{-12} \times 10^{-2}}{(5-4) \times 10^{-3}} = 88 \text{ pF}$$



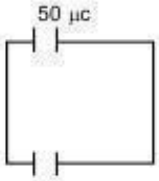
Here the capacitance is independent of the position of metal. At any position the net separation is d – t. As d is the separation and t is the thickness.

52. Initial charge stored = 50 μc

Let the dielectric constant of the material induced be 'k'.

Now, when the extra charge flown through battery is 100.

So, net charge stored in capacitor = 150 μc



Now $C_1 = \frac{\varepsilon_0 A}{d}$ or $\frac{q_1}{V} = \frac{\varepsilon_0 A}{d}$ ...(1)

$C_2 = \frac{\varepsilon_0 Ak}{d}$ or, $\frac{q_2}{V} = \frac{\varepsilon_0 Ak}{d}$ ...(2)

Deviding (1) and (2) we get $\frac{q_1}{q_2} = \frac{1}{k}$

$\Rightarrow \frac{50}{150} = \frac{1}{k} \Rightarrow k = 3$

53. C = 5 μf V = 6 V d = 2 mm = 2×10^{-3} m.

(a) the charge on the +ve plate

q = CV = 5 μf × 6 V = 30 μc

(b) $E = \frac{V}{d} = \frac{6V}{2 \times 10^{-3} m} = 3 \times 10^3$ V/M

(c) d = 2×10^{-3} m

t = 1×10^{-3} m

k = 5 or $C = \frac{\varepsilon_0 A}{d}$ $\Rightarrow 5 \times 10^{-6} = \frac{8.85 \times A \times 10^{-12}}{2 \times 10^{-3}} \times 10^{-9} \Rightarrow A = \frac{10^4}{8.85}$

When the dielectric placed on it

$$C_1 = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}} = \frac{8.85 \times 10^{-12} \times \frac{10^4}{8.85}}{10^{-3} + \frac{10^{-3}}{5}} = \frac{10^{-12} \times 10^4 \times 5}{6 \times 10^{-3}} = \frac{5}{6} \times 10^{-5} = 0.00000833 = 8.33 \ \mu\text{F}.$$

(d) C = 5×10^{-6} f. V = 6 V

$\therefore$ Q = CV = 3×10^{-5} f = 30 μf

$\therefore Q = CV = 3 \times 10^{-6} \times 10 = 30\ \mu f$

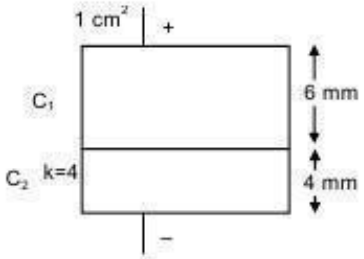
$C' = 8.3 \times 10^{-6}$ f

$V = 6$ V

$\therefore Q' = C'V = 8.3 \times 10^{-6} \times 6 \approx 50\ \mu F$

$\therefore$ charge flown $= Q' - Q = 20\ \mu F$

54. Let the capacitances be C_1 & C_2 net capacitance 'C' $= \dfrac{C_1C_2}{C_1 + C_2}$



Now $C_1 = \dfrac{\varepsilon_0 A k_1}{d_1}$ $\qquad C_2 = \dfrac{\varepsilon_0 A k_2}{d_2}$

$$C = \frac{\frac{\varepsilon_0 A k_1}{d_1} \times \frac{\varepsilon_0 A k_2}{d_2}}{\frac{\varepsilon_0 A k_1}{d_1} + \frac{\varepsilon_0 A k_2}{d_2}} = \frac{\varepsilon_0 A\left(\frac{k_1 k_2}{d_1 d_2}\right)}{\varepsilon_0 A\left(\frac{k_1 d_2 + k_2 d_1}{d_1 d_2}\right)} = \frac{8.85 \times 10^{-12} \times 10^{-2} \times 24}{6 \times 4 \times 10^{-3} + 4 \times 6 \times 10^{-3}}$$

$= 4.425 \times 10^{-11}$ C $= 44.25$ pc.

55. $A = 400\ cm^2 = 4 \times 10^{-2}\ m^2$

$d = 1$ cm $= 1 \times 10^{-3}$ m

$V = 160$ V

$t = 0.5 = 5 \times 10^{-4}$ m

$k = 5$

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}} = \frac{8.85 \times 10^{-12} \times 4 \times 10^{-2}}{10^{-3} - 5 \times 10^{-4} + \frac{5 \times 10^{-4}}{5}} = \frac{35.4 \times 10^{-4}}{10^{-3} - 0.5}$$

56. (a) Area = A

Separation = d



$$C_1 = \frac{\varepsilon_0 A k_1}{d/2} \qquad C_2 = \frac{\varepsilon_0 A k_2}{d/2}$$

$$C = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{2\varepsilon_0 A k_1}{d} \times \frac{2\varepsilon_0 A k_2}{d}}{\frac{2\varepsilon_0 A k_1}{d} + \frac{2\varepsilon_0 A k_2}{d}} = \frac{\frac{(2\varepsilon_0 A)^2 k_1 k_2}{d^2}}{(2\varepsilon_0 A)\frac{k_1 d + k_2 d}{d^2}} = \frac{2k_1 k_2 \varepsilon_0 A}{d(k_1 + k_2)}$$

(b) similarly

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{\frac{3\varepsilon_0 A k_1}{d}} + \frac{1}{\frac{3\varepsilon_0 A k_2}{d}} + \frac{1}{\frac{3\varepsilon_0 A k_3}{d}}$$

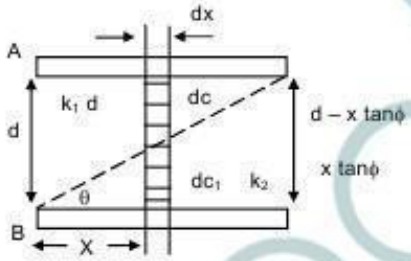
$$= \frac{d}{3\varepsilon_0 A}\left[\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}\right] = \frac{d}{3\varepsilon_0 A}\left[\frac{k_2 k_3 + k_1 k_3 + k_1 k_2}{k_1 k_2 k_3}\right]$$

$$\therefore C = \frac{3\varepsilon_0 A k_1 k_2 k_3}{d(k_1 k_2 + k_2 k_3 + k_1 k_3)}$$

(c) $C = C_1 + C_2$

$$= \frac{\varepsilon_0 \frac{A}{2} k_1}{d} + \frac{\varepsilon_0 \frac{A}{2} k_2}{d} = \frac{\varepsilon_0 A}{2d}(k_1 + k_2)$$

57.



Consider an elemental capacitor of with dx our at a distance 'x' from one end. It is constituted of two capacitor elements of dielectric constants k_1 and k_2 with plate separation xtanϕ and d –xtanϕ respectively in series

respectively in series

$$\frac{1}{dcR} = \frac{1}{dc_1} + \frac{1}{dc_2} = \frac{x\tan\phi}{\varepsilon_0 k_2(bdx)} + \frac{d - x\tan\phi}{\varepsilon_0 k_1(bdx)}$$

$$dcR = \frac{\varepsilon_0 bdx}{\frac{x\tan\phi}{k_2} + \frac{(d - x\tan\phi)}{k_1}}$$

$$\text{or } C_R = \varepsilon_0 bk_1k_2 \int \frac{dx}{k_2 d + (k_1 - k_2)x\tan\phi}$$

$$= \frac{\varepsilon_0 bk_1k_2}{\tan\phi(k_1 - k_2)} [\log_e k_2 d + (k_1 - k_2) \times \tan\phi]a$$

$$= \frac{\varepsilon_0 bk_1k_2}{\tan\phi(k_1 - k_2)} [\log_e k_2 d + (k_1 - k_2)\, a\tan\phi - \log_e k_2 d]$$

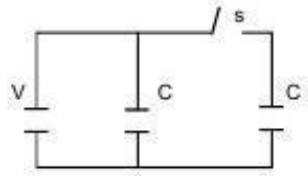
$$\therefore \tan\phi = \frac{d}{a} \text{ and } A = a \times a$$

$$C_R = \frac{\varepsilon_0 ak_1k_2}{\frac{d}{a}(k_1 - k_2)} \qquad \left[\log_e\left(\frac{k_1}{k_2}\right)\right]$$

$$C_R = \frac{\varepsilon_0 a^2k_1k_2}{d(k_1 - k_2)} \qquad \left[\log_e\left(\frac{k_1}{k_2}\right)\right]$$

$$C_R = \frac{\varepsilon_0 a^2k_1k_2}{d(k_1 - k_2)} \quad \ln\frac{k_1}{k_2}$$

58.



I. Initially when switch 's' is closed

Total Initial Energy = (1/2) CV^2 + (1/2) CV^2 = CV^2 ...(1)

II. When switch is open the capacitance in each of capacitors varies, hence the energy also varies.

i.e. in case of 'B', the charge remains

Same i.e. cv

$C_{eff} = 3C$

$$E = \frac{1}{2} \times \frac{q^2}{c} = \frac{1}{2} \times \frac{c^2v^2}{3c} = \frac{cv^2}{6}$$

In case of 'A'

$C_{eff} = 3c$

$$E = \frac{1}{2} \times C_{eff}v^2 = \frac{1}{2} \times 3c \times v^2 = \frac{3}{2}cv^2$$

$$\text{Total final energy} = \frac{cv^2}{6} + \frac{3cv^2}{2} = \frac{10cv^2}{6}$$

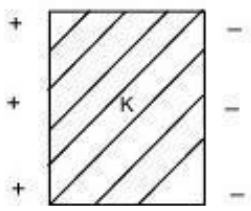
$$\text{Now, } \frac{\text{Initial Energy}}{\text{Final Energy}} = \frac{cv^2}{\frac{10cv^2}{6}} = 3$$

59. Before inserting

$$C = \frac{\varepsilon_0 A}{d}C \qquad Q = \frac{\varepsilon_0 AV}{d}C$$

After inserting

$$C = \frac{\varepsilon_0 A}{\frac{d}{k}} = \frac{\varepsilon_0 Ak}{d} \qquad Q_1 = \frac{\varepsilon_0 Ak}{d}V$$



The charge flown through the power supply

$Q = Q_1 - Q$

$= \frac{\varepsilon_0 AkV}{d} - \frac{\varepsilon_0 AV}{d} = \frac{\varepsilon_0 AV}{d}(k-1)$

Workdone = Charge in emf

$= \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}\frac{\frac{\varepsilon_0{}^2 A^2 V^2}{d^2}(k-1)^2}{\frac{\varepsilon_0 A}{d}(k-1)} = \frac{\varepsilon_0 AV^2}{2d}(k-1)$

60. Capacitance = 100 μF = 10^{-4} F

P.d = 30 V

(a) $q = CV = 10^{-4} \times 50 = 5 \times 10^{-3}$ c = 5 mc

Dielectric constant = 2.5

(b) New C = C′ = 2.5 × C = 2.5 × 10^{-4} F

New p.d = $\frac{q}{c^1}$ [∴ 'q' remains same after disconnection of battery]

$= \frac{5\times10^{-3}}{2.5\times10^{-4}} = 20$ V.

(c) In the absence of the dielectric slab, the charge that must have produced

C × V = $10^{-4} \times 20 = 2 \times 10^{-3}$ c = 2 mc

(d) Charge induced at a surface of the dielectric slab

= q (1 –1/k) (where k = dielectric constant, q = charge of plate)

$= 5 \times 10^{-3}\left(1-\frac{1}{2.5}\right) = 5 \times 10^{-3} \times \frac{3}{5} = 3 \times 10^{-3} = 3$ mc.

61. Here we should consider a capacitor cac and cabc in series

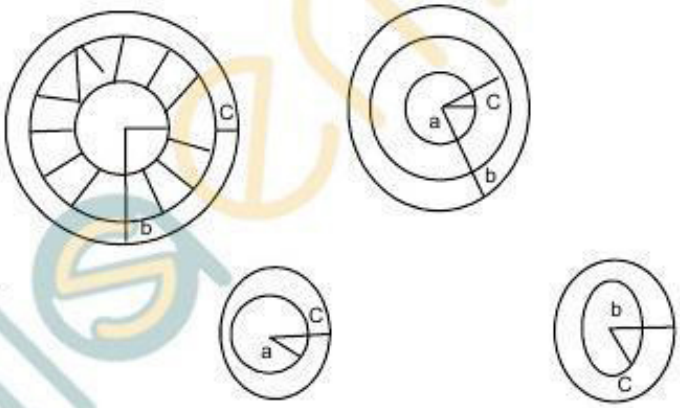
$Cac = \frac{4\pi\varepsilon_0 ack}{k(c-a)}$

$Cbc = \frac{4\pi\varepsilon_0 bc}{(b-c)}$

$\frac{1}{C} = \frac{1}{Cac} + \frac{1}{Cbc}$

$= \frac{(c-a)}{4\pi\varepsilon_0 ack} + \frac{(b-c)}{4\pi\varepsilon_0 bc} = \frac{b(c-a)+ka(b-c)}{k4\pi\varepsilon_0 abc}$

$C = \frac{4\pi\varepsilon_0 kabc}{ka(b-c)+b(c-a)}$



62. These three metallic hollow spheres form two spherical capacitors, which are connected in series.

Solving them individually, for (1) and (2)

$C_1 = \frac{4\pi\varepsilon_0 ab}{b-a}$ (∴ for a spherical capacitor formed by two spheres of radii $R_2 > R_1$)

$C = \frac{4\pi\varepsilon_0 R_2 R_1}{R_2 - R_2}$

Similarly for (2) and (3)

$C_2 = \frac{4\pi\varepsilon_0 bc}{c-b}$

$C_{eff} = \frac{C_1 C_2}{C_1 + C_2}$ $\frac{(4\pi\varepsilon_0)^2 ab^2 c}{4\pi\varepsilon_0\left[\frac{ab(c-b)+bc(b-a)}{(b-a)(c-b)}\right]}$

$= \frac{4\pi\varepsilon_0 ab^2 c}{abc - ab^2 + b^2 c - abc} = \frac{4\pi\varepsilon_0 ab^2 c}{b^2(c-a)} = \frac{4\pi\varepsilon_0 ac}{c-a}$

63. Here we should consider two spherical capacitor of capacitance

cab and cbc in series

$$Cab = \frac{4\pi\varepsilon_0 abk}{(b-a)} \qquad Cbc = \frac{4\pi\varepsilon_0 bc}{(c-b)}$$

$$\frac{1}{C} = \frac{1}{Cab} + \frac{1}{Cbc} = \frac{(b-a)}{4\pi\varepsilon_0 abk} + \frac{(c-b)}{4\pi\varepsilon_0 bc} = \frac{c(b-a)+ka(c-b)}{k4\pi\varepsilon_0 abc}$$

$$C = \frac{4\pi\varepsilon_0 kabc}{c(b-a)+ka(c-b)}$$

64. $Q = 12\ \mu c$

$V = 1200\ V$

$$\frac{v}{d} = 3 \times {}^{10-6}\ \frac{v}{m}$$

$$d = \frac{V}{(v/d)} = \frac{1200}{3\times10^{-6}} = 4 \times 10^{-4}\ m$$

$$c = \frac{Q}{v} = \frac{12\times10^{-6}}{1200} = 10^{-8}\ f$$

$$\therefore C = \frac{\varepsilon_0 A}{d} = 10^{-8}\ f$$

$$\Rightarrow A = \frac{10^{-8}\times d}{\varepsilon_0} = \frac{10^{-8}\times 4\times10^{-4}}{8.854\times10^{-4}}\ 0.45\ m^2$$

65. $A = 100\ cm^2 = 10^{-2}\ m^2$

$d = 1\ cm = 10^{-2}\ m$

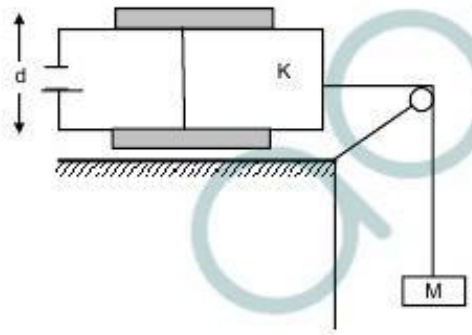
$V = 24\ V_0$

$$\therefore \text{The capacitance } C = \frac{\varepsilon_0 A}{d} = \frac{8.85\times10^{-12}\times10^{-2}}{10^{-2}} = 8.85 \times 10^{-12}$$

$$\therefore \text{The energy stored } C_1 = (1/2)\ CV^2 = (1/2) \times 10^{-12} \times (24)^2 = 2548.8 \times 10^{-12}$$

$$\therefore \text{The forced attraction between the plates} = \frac{C_1}{d} = \frac{2548.8\times10^{-12}}{10^{-2}} = 2.54 \times 10^{-7}\ N.$$

66.



We knows

In this particular case the electricfield attracts the dielectric into the capacitor with a force $\frac{\varepsilon_0 bV^2(k-1)}{2d}$

Where b – Width of plates
k – Dielectric constant
d – Separation between plates
V = E = Potential difference.

Hence in this case the surfaces are frictionless, this force is counteracted by the weight.

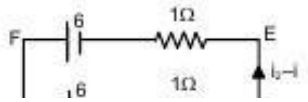
$$\text{So, } \frac{\varepsilon_0 bE^2(k-1)}{2d} = Mg$$

$$\Rightarrow M = \frac{\varepsilon_0 bE^2(k-1)}{2dg}$$

ADEFA,

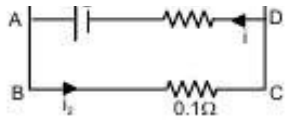
$\Rightarrow i - 6 + 6 - (i_2 - i)1 = 0$

$\Rightarrow i - i_2 + i = 0$



$\Rightarrow 2i - i_2 = 0 \Rightarrow -2i \pm 0.2i = 0$

$\Rightarrow i_2 = 0.$

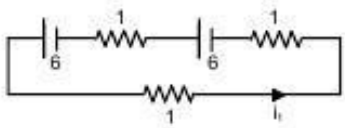


b) $1i_1 + 1\,i_1 - 6 + 1i_1 = 0$

$\Rightarrow 3i_1 = 12 \Rightarrow i_1 = 4$

DCFED

$\Rightarrow i_2 + i - 6 = 0 \Rightarrow i_2 + i = 6$



ABCDA,

$i_2 + (i_2 - i) - 6 = 0$

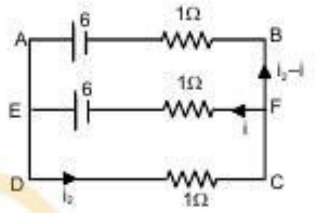
$\Rightarrow i_2 + i_2 - i = 6 \Rightarrow 2i_2 - i = 6$

$\Rightarrow -2i_2 \pm 2i = 6 \Rightarrow i = -2$

$i_2 + i = 6$

$\Rightarrow i_2 - 2 = 6 \Rightarrow i_2 = 8$

$\frac{i_1}{i_2} = \frac{4}{8} = \frac{1}{2}.$



c) $10i_1 + 1i_1 - 6 + 1i_1 - 6 = 0$

$\Rightarrow 12i_1 = 12 \Rightarrow i_1 = 1$

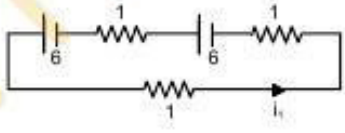
$10i_2 - i_1 - 6 = 0$

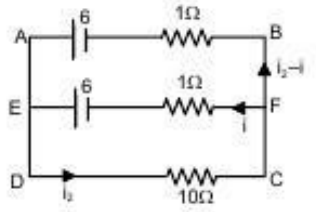
$\Rightarrow 10i_2 - i_1 = 6$

$\Rightarrow 10i_2 + (i_2 - i)1 - 6 = 0$

$\Rightarrow 11i_2 = 6$

$\Rightarrow -i_2 = 0$





1. a) Total emf = n_1E

in 1 row

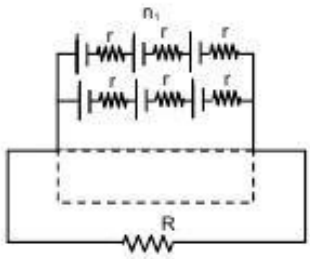
Total emf in all news = n_1E

Total resistance in one row = n_1r

Total resistance in all rows = $\frac{n_1r}{n_2}$

Net resistance = $\frac{n_1r}{n_2} + R$

Current = $\frac{n_1E}{n_1/n_2r + R} = \frac{n_1n_2E}{n_1r + n_2R}$



b) $I = \frac{n_1n_2E}{n_1r + n_2R}$

for I = max,

$n_1r + n_2R = \min$

$\Rightarrow \left(\sqrt{n_1r} - \sqrt{n_2R}\right)^2 + 2\sqrt{n_1rn_2R} = \min$

it is min, when

$\sqrt{n_1r} = \sqrt{n_2R}$

$\Rightarrow n_1r = n_2R$

I is max when $n_1r = n_2R$.

22. E = 100 V, R′ = 100 kΩ = 100000 Ω

R = 1 – 100

When no other resister is added or R = 0.

$i = \frac{E}{R'} = \frac{100}{100000} = 0.001\text{Amp}$

When R = 1

$$i = \frac{100}{100000+1} = \frac{100}{100001} = 0.0009A$$

When R = 100

$$i = \frac{100}{100000+100} = \frac{100}{100100} = 0.000999\ A\ .$$

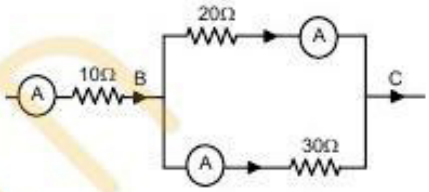
Upto R = 100 the current does not upto 2 significant digits. Thus it proved.

23. $A_1 = 2.4$ A

Since A_1 and A_2 are in parallel,

$\Rightarrow 20 \times 2.4 = 30 \times X$

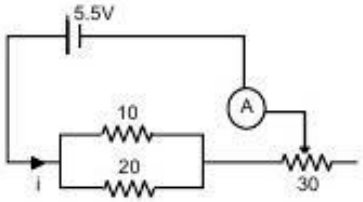
$$\Rightarrow X = \frac{20\times 2.4}{30} = 1.6\ A.$$

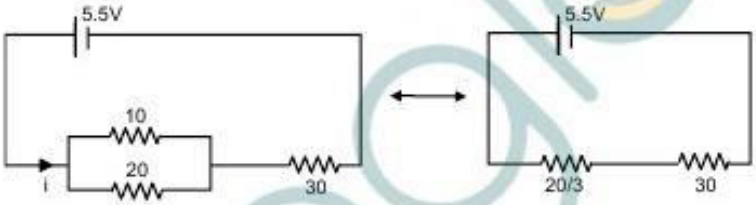


Reading in Ammeter A_2 is 1.6 A.

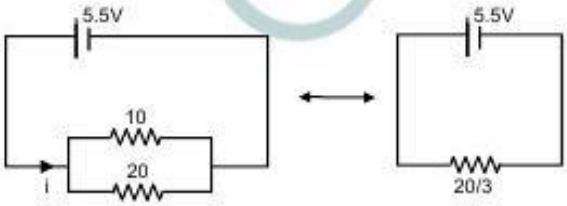
$A_3 = A_1 + A_2 = 2.4 + 1.6 = 4.0$ A.

24.





$$i_{min} = \frac{5.5\times 3}{110} = 0.15$$



$$i_{max} = \frac{5.5\times 3}{20} = \frac{16.5}{20} = 0.825.$$

25. a) $R_{eff} = \frac{180}{3} = 60\ \Omega$

i = 60 / 60 = 1 A

b) $R_{eff} = \frac{180}{2} = 90\ \Omega$

i = 60 / 90 = 0.67 A

c) $R_{eff} = 180\ \Omega \Rightarrow$ i = 60 / 180 = 0.33 A

