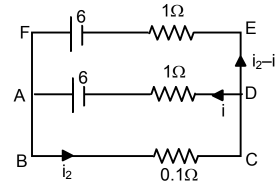
ADEFA,

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

$\Rightarrow$ i – i_2 + i = 0

$\Rightarrow$ 2i – i_2 = 0 $\Rightarrow$ –2i ± 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,

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

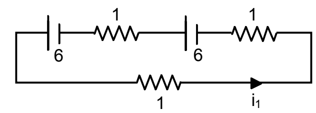
$\Rightarrow i_2 + i_2 - i = 6 \Rightarrow 2i_2 - i = 6$

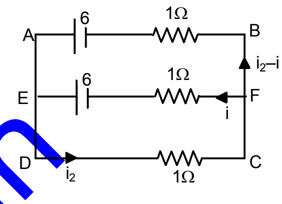
$\Rightarrow -2i_2 \pm 2i = 6 \Rightarrow i = -2$

$i_2 + i = 6$

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

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





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

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

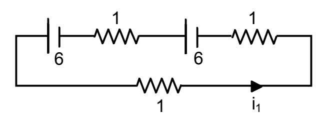
$10i_2 - i_1 - 6 = 0$

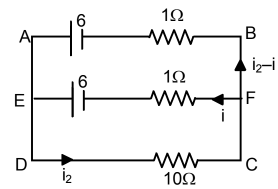
$\Rightarrow 10i_2 - i_1 = 6$

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

$\Rightarrow 11i_2 = 6$

$\Rightarrow -i_2 = 0$





21. a) Total emf = n_1E

in 1 row

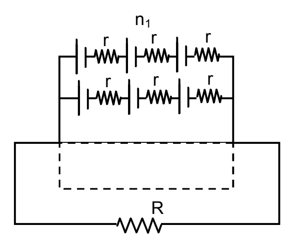
Total emf in all news = n_1E

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

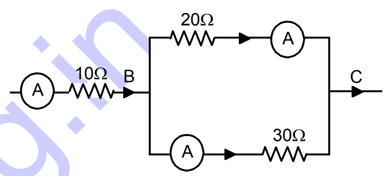
Since A_1 and A_2 are in parallel,

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

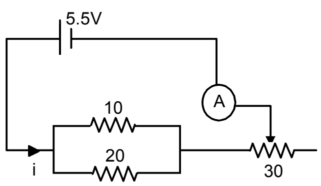
$\Rightarrow X = \frac{20 \times 2.4}{30} = 1.6$ A.

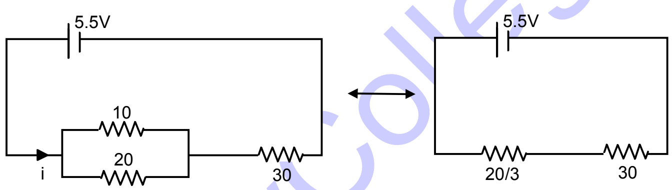
Reading in Ammeter A_2 is 1.6 A.

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

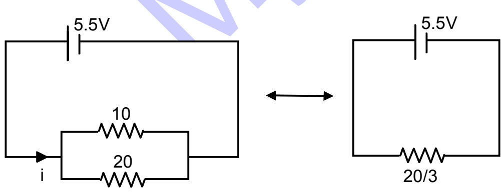


24.





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



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

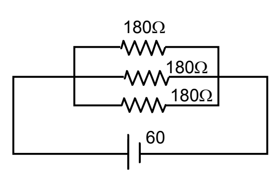
25. a) $R_{eff} = \frac{180}{3} = 60\ \Omega$

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



26. Max. R = (20 + 50 + 100) Ω = 170 Ω

$$\text{Min R} = \frac{1}{\left(\frac{1}{20}+\frac{1}{50}+\frac{1}{100}\right)} = \frac{100}{8} = 12.5\ \Omega.$$

27. The various resistances of the bulbs = $\frac{V^2}{P}$

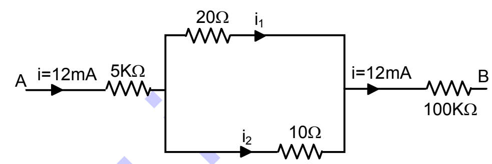
Resistances are $\frac{(15)^2}{10}, \frac{(15)^2}{10}, \frac{(15)^2}{15}$ = 45, 22.5, 15.

Since two resistances when used in parallel have resistances less than both.

The resistances are 45 and 22.5.

28. $i_1 \times 20 = i_2 \times 10$

$\Rightarrow \frac{i_1}{i_2} = \frac{10}{20} = \frac{1}{2}$



$i_1 = 4$ mA, $i_2 = 8$ mA

Current in 20 KΩ resistor = 4 mA

Current in 10 KΩ resistor = 8 mA

Current in 100 KΩ resistor = 12 mA

$V = V_1 + V_2 + V_3$

= 5 KΩ × 12 mA + 10 KΩ × 8 mA + 100 KΩ × 12 mA

= 60 + 80 + 1200 = 1340 volts.

29. $R_1 = R$, $i_1 = 5$ A

$R_2 = \frac{10R}{10+R}$, $i_2 = 6$A

Since potential constant,

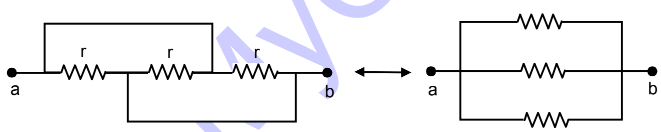
$i_1R_1 = i_2R_2$

$\Rightarrow 5 \times R = \frac{6 \times 10R}{10+R}$

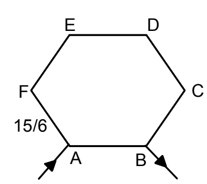
$\Rightarrow$ (10 + R)5 = 60

$\Rightarrow$ 5R = 10 $\Rightarrow$ R = 2 Ω.

30.



Eq. Resistance = r/3.



31. a) $R_{eff} = \dfrac{\frac{15\times5}{6}\times\frac{15}{6}}{\frac{15\times5}{6}+\frac{15}{6}} = \dfrac{\frac{15\times5\times15}{6\times6}}{\frac{75+15}{6}}$

$= \frac{15\times5\times15}{6\times90} = \frac{25}{12}$ = 2.08 Ω.

b) Across AC,

$R_{eff} = \dfrac{\frac{15\times4}{6}\times\frac{15\times2}{6}}{\frac{15\times4}{6}+\frac{15\times2}{6}} = \dfrac{\frac{15\times4\times15\times2}{6\times6}}{\frac{60+30}{6}}$

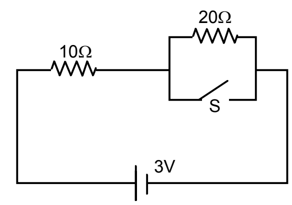
$= \frac{15\times4\times15\times2}{6\times90} = \frac{10}{3}$ = 3.33 Ω.

c) Across AD,

$$R_{eff} = \frac{\frac{15\times3}{6}\times\frac{15\times3}{6}}{\frac{15\times3}{6}+\frac{15\times3}{6}} = \frac{\frac{15\times3\times15\times3}{6\times6}}{\frac{60+30}{6}}$$

$$= \frac{15\times3\times15\times3}{6\times90} = \frac{15}{4} = 3.75\ \Omega.$$

32. a) When S is open



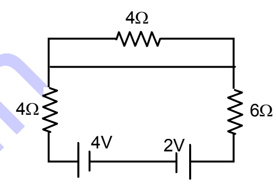
$R_{eq} = (10 + 20)\ \Omega = 30\ \Omega.$

i = When S is closed,

$R_{eq} = 10\ \Omega$

$i = (3/10)\ \Omega = 0.3\ \Omega.$

33. a) Current through (1) 4 Ω resistor = 0



b) Current through (2) and (3)

net E = 4V – 2V = 2V

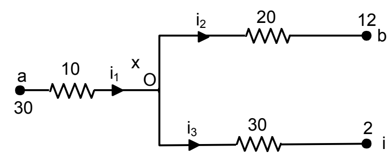
(2) and (3) are in series,

$R_{eff} = 4 + 6 = 10\ \Omega$

$i = 2/10 = 0.2$ A

Current through (2) and (3) are 0.2 A.

34. Let potential at the point be xV.



$(30 – x) = 10\ i_1$

$(x – 12) = 20\ i_2$

$(x – 2) = 30\ i_3$

$i_1 = i_2 + i_3$

$$\Rightarrow \frac{30-x}{10} = \frac{x-12}{20}+\frac{x-2}{30}$$

$$\Rightarrow 30 - x = \frac{x-12}{2}+\frac{x-2}{3}$$

$$\Rightarrow 30 - x = \frac{3x-36+2x-4}{6}$$

$\Rightarrow 180 – 6x = 5x – 40$

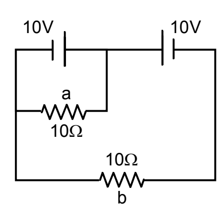
$\Rightarrow 11x = 220 \Rightarrow x = 220 / 11 = 20$ V.

$$i_1 = \frac{30-20}{10} = 1\text{ A}$$

$$i_2 = \frac{20-12}{20} = 0.4\text{ A}$$

$$i_3 = \frac{20-2}{30} = \frac{6}{10} = 0.6\text{ A.}$$

35. a) Potential difference between terminals of ‘a’ is 10 V.

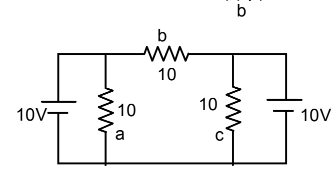


i through a = 10 / 10 = 1A

Potential different between terminals of b is 10 – 10 = 0 V

i through b = 0/10 = 0 A

b) Potential difference across ‘a’ is 10 V



i through a = 10 / 10 = 1A

Potential different between terminals of b is 10 – 10 = 0 V

i through b = 0/10 = 0 A

36. a) In circuit, AB ba A

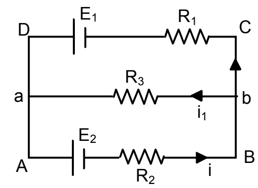
$E_2 + iR_2 + i_1R_3 = 0$

In circuit, $i_1R_3 + E_1 – (i – i_1)R_1 = 0$

$\Rightarrow i_1R_3 + E_1 – iR_1 + i_1R_1 = 0$

$[iR_2 + i_1R_3 \quad = –E_2]R_1$

$[iR_2 – i_1 (R_1 + R_3) = E_1] R_2$



$iR_2R_1 + i_1R_3R_1 \quad = –E_2R_1$

$iR_2R_1 – i_1R_2 (R_1 + R_3) \quad = E_1 R_2$

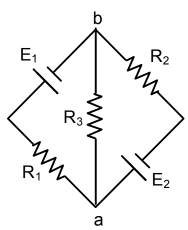
$iR_3R_1 + i_1R_2R_1 + i_1R_2R_3 = E_1R_2 – E_2R_1$

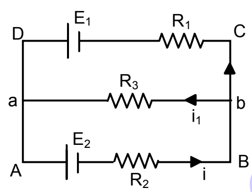
$\Rightarrow i_1(R_3R_1 + R_2R_1 + R_2R_3) = E_1R_2 – E_2R_1$

$$\Rightarrow i_1 = \frac{E_1R_2 - E_2R_1}{R_3R_1 + R_2R_1 + R_2R_3}$$

$$\Rightarrow \frac{E_1R_2R_3 - E_2R_1R_3}{R_3R_1 + R_2R_1 + R_2R_3} = \left(\frac{\frac{E_1}{R_1} - \frac{E_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_3}} \right)$$

b) $\therefore$ Same as a





37. In circuit ABDCA,

$i_1 + 2 – 3 + i = 0$

$\Rightarrow$ $i + i_1 – 1 = 0$ …(1)

In circuit CFEDC,

$(i – i_1) + 1 – 3 + i = 0$

$\Rightarrow$ $2i – i_1 – 2 = 0$ …(2)

From (1) and (2)

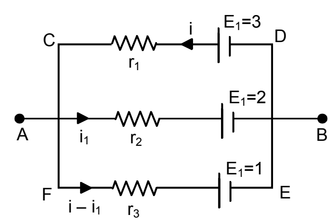
$3i = 3 \Rightarrow i = 1$ A

$i_1 = 1 – i = 0$ A

$i – i_1 = 1- 0 = 1$ A

Potential difference between A and B

$= E – ir = 3 – 1.1 = 2$ V.



38. In the circuit ADCBA,

$3i + 6i_1 – 4.5 = 0$

In the circuit GEFCG,

$3i + 6i_1 = 4.5 \quad = \quad 10i – 10i_1 – 6i_1 = –3$

$\Rightarrow$ $[10i – 16i_1 = –3]3$ …(1)

$[3i + 6i_1 = 4.5]\ 10$ …(2)

From (1) and (2)

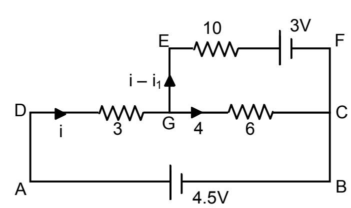
$–108\ i_1 = –54$

$$\Rightarrow i_1 = \frac{54}{108} = \frac{1}{2} = 0.5$$

$3i + 6 \times ½ – 4.5 = 0$

$3i – 1.5 = 0 \Rightarrow i = 0.5.$

Current through 10 Ω resistor = 0 A.



39. In AHGBA,

$2 + (i - i_1) - 2 = 0$

$\Rightarrow i - i_1 = 0$

In circuit CFEDC,

$-(i_1 - i_2) + 2 + i_2 - 2 = 0$

$\Rightarrow i_2 - i_1 + i_2 = 0 \Rightarrow 2i_2 - i_1 = 0.$

In circuit BGFCB,

$-(i_1 - i_2) + 2 + (i_1 - i_2) - 2 = 0$

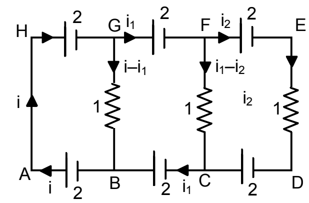
$\Rightarrow i_1 - i + i_1 - i_2 = 0 \quad \Rightarrow 2i_1 - i - i_2 = 0 \quad \ldots(1)$

$\Rightarrow i_1 - (i - i_1) - i_2 = 0 \quad \Rightarrow i_1 - i_2 = 0 \quad \ldots(2)$

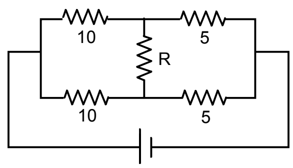
$\therefore i_1 - i_2 = 0$

From (1) and (2)

Current in the three resistors is 0.



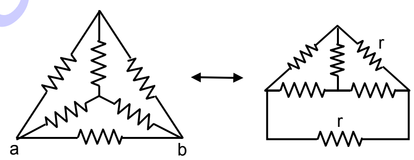
40.



For an value of R, the current in the branch is 0.

41. a) $R_{eff} = \dfrac{(2r/2)\times r}{(2r/2)+r}$

$= \dfrac{r^2}{2r} = \dfrac{r}{2}$

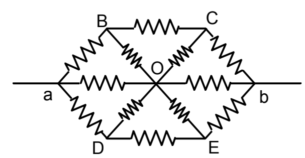


b) At 0 current coming to the junction is current going from BO = Current going along OE.

Current on CO = Current on OD

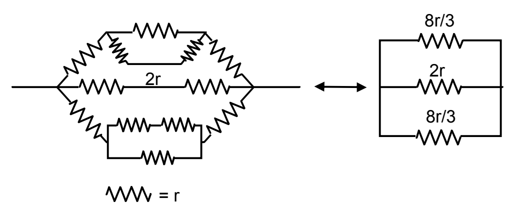
Thus it can be assumed that current coming in OC goes in OB.

Thus the figure becomes

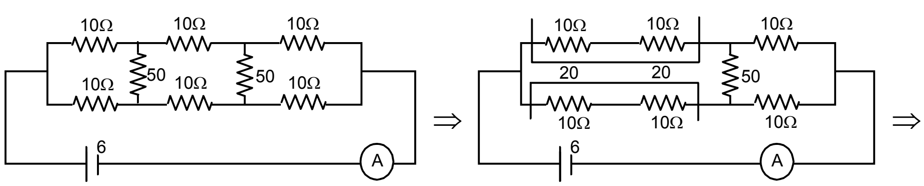


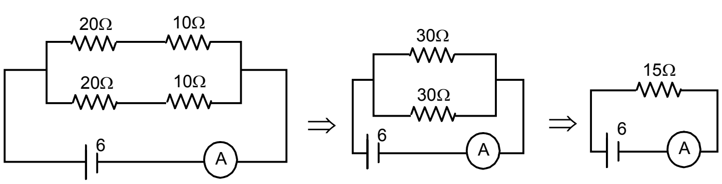
$\left[r + \left(\dfrac{2r.r}{3r}\right) + r\right] = 2r + \dfrac{2r}{3} = \dfrac{8r}{3}$

$R_{eff} = \dfrac{(8r/6)\times 2r}{(8r/6)+2r} = \dfrac{8r^2/3}{20r/6} = \dfrac{8r^2}{3}\times\dfrac{6}{20} = \dfrac{8r}{10} = 4r.$



42.





$I = \dfrac{6}{15} = \dfrac{2}{5} = 0.4 \text{ A}.$

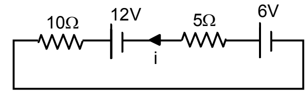
43. a) Applying Kirchoff's law,

$10i - 6 + 5i - 12 = 0$

$\Rightarrow 10i + 5i = 18$

$\Rightarrow 15i = 18$

$\Rightarrow i = \frac{18}{15} = \frac{6}{5} = 1.2$ A.



b) Potential drop across 5 Ω resistor,

$i\,5 = 1.2 \times 5$ V = 6 V

c) Potential drop across 10 Ω resistor

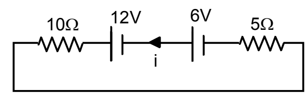
$i\,10 = 1.2 \times 10$ V = 12 V

d) $10i - 6 + 5i - 12 = 0$

$\Rightarrow 10i + 5i = 18$

$\Rightarrow 15i = 18$

$\Rightarrow i = \frac{18}{15} = \frac{6}{5} = 1.2$ A.



Potential drop across 5 Ω resistor = 6 V

Potential drop across 10 Ω resistor = 12 V

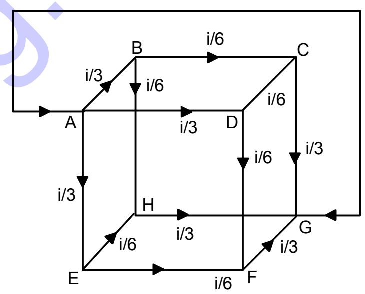
44. Taking circuit ABHGA,

$$\frac{i}{3r} + \frac{i}{6r} + \frac{i}{3r} = V$$

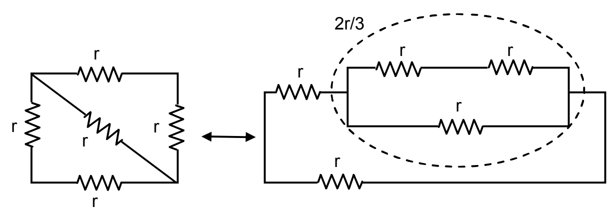
$$\Rightarrow \left(\frac{2i}{3} + \frac{i}{6}\right) r = V$$

$$\Rightarrow V = \frac{5i}{6} r$$

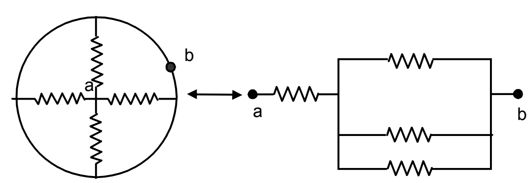
$$\Rightarrow R_{eff} = \frac{V}{i} = \frac{5}{6r}$$



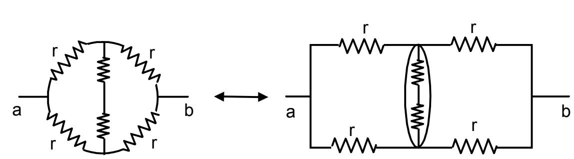
45. $R_{eff} = \frac{\left(\frac{2r}{3} + r\right) r}{\left(\frac{2r}{3} + r + r\right)} = \frac{5r}{8}$



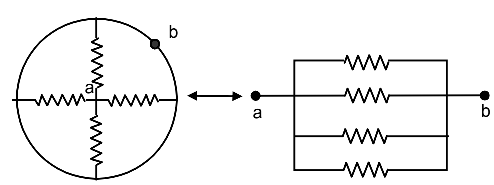
$$R_{eff} = \frac{r}{3} + r = \frac{4r}{3}$$



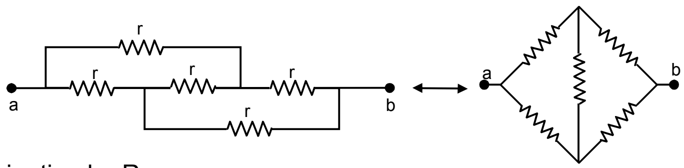
$$R_{eff} = \frac{2r}{2} = r$$



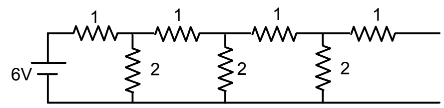
$$R_{eff} = \frac{r}{4}$$



$R_{eff} = r$



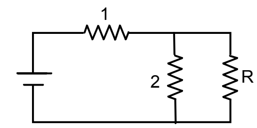
46. a) Let the equation resistance of the combination be R.



$$\left(\frac{2R}{R+2}\right) + 1 = R$$

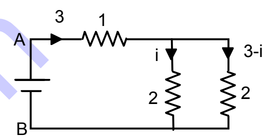
$$\Rightarrow \frac{2R + R + 2}{R+2} = R \Rightarrow 3R + 2 = R^2 + 2R$$

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



$$\Rightarrow R = \frac{+1 \pm \sqrt{1 + 4.1.2}}{2.1} = \frac{1 \pm \sqrt{9}}{2} = \frac{1 \pm 3}{2} = 2\ \Omega.$$

b) Total current sent by battery = $\frac{6}{R_{eff}} = \frac{6}{2} = 3$



Potential between A and B

$3.1 + 2.i = 6$

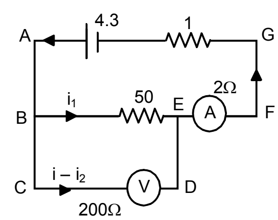
$\Rightarrow 3 + 2i = 6 \Rightarrow 2i = 3$

$\Rightarrow i = 1.5$ a

47. a) In circuit ABFGA,

$i_1\ 50 + 2i + i - 4.3 = 0$

$\Rightarrow 50i_1 + 3i = 4.3$ …(1)



In circuit BEDCB,

$50i_1 - (i - i_1)200 = 0$

$\Rightarrow 50i_1 - 200i + 200i_1 = 0$

$\Rightarrow 250\ i_1 - 200i = 0$

$\Rightarrow 50i_1 - 40i = 0$ …(2)

From (1) and (2)

$43i = 4.3$ $\Rightarrow i = 0.1$

$5i_1 = 4 \times i = 4 \times 0.1$ $\Rightarrow i_1 = \frac{4 \times 0.1}{5} = 0.08$ A.

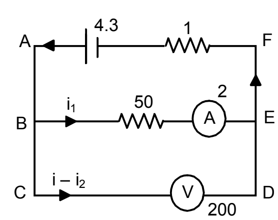
Ammeter reads a current = i = 0.1 A.

Voltmeter reads a potential difference equal to $i_1 \times 50 = 0.08 \times 50 = 4$ V.

b) In circuit ABEFA,

$50i_1 + 2i_1 + 1i - 4.3 = 0$

$\Rightarrow 52i_1 + i = 4.3$



$\Rightarrow 200 \times 52i_1 + 200\ i = 4.3 \times 200$ …(1)

In circuit BCDEB,

$(i - i_1)200 - i_1 2 - i_1 50 = 0$

$\Rightarrow 200i - 200i_1 - 2i_1 - 50i_1 = 0$

$\Rightarrow 200i - 252i_1 = 0$ …(2)

From (1) and (2)

$i_1(10652) = 4.3 \times 2 \times 100$

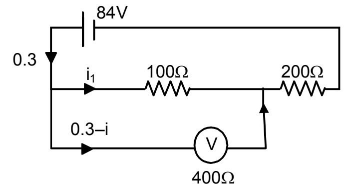
$$\Rightarrow i_1 = \frac{4.3 \times 2 \times 100}{10652} = 0.08$$

$i = 4.3 - 52 \times 0.08 = 0.14$

Reading of the ammeter = 0.08 a

Reading of the voltmeter = $(i - i_1)200 = (0.14 - 0.08) \times 200 = 12$ V.

48. a) $R_{eff} = \frac{100 \times 400}{500} + 200 = 280$



$i = \frac{84}{280} = 0.3$

$100i = (0.3 - i)\ 400$

$\Rightarrow$ $i = 1.2 - 4i$

$\Rightarrow$ $5i = 1.2 \Rightarrow i = 0.24.$

Voltage measured by the voltmeter = $\frac{0.24 \times 100}{24V}$

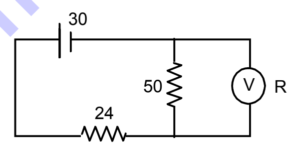
b) If voltmeter is not connected

$R_{eff} = (200 + 100) = 300\ \Omega$

$i = \frac{84}{300} = 0.28$ A

Voltage across 100 Ω = (0.28 × 100) = 28 V.

49. Let resistance of the voltmeter be R Ω.



$R_1 = \frac{50R}{50+R}$, $R_2 = 24$

Both are in series.

$30 = V_1 + V_2$

$\Rightarrow 30 = iR_1 + iR_2$

$\Rightarrow 30 - iR_2 = iR_1$

$\Rightarrow iR_1 = 30 - \frac{30}{R_1 + R_2} R_2$

$\Rightarrow V_1 = 30\left(1 - \frac{R_2}{R_1 + R_2}\right)$

$\Rightarrow V_1 = 30\left(\frac{R_1}{R_1 + R_2}\right)$

$$\Rightarrow 18 = 30\left(\frac{50R}{50 + R\left(\frac{50R}{50+R} + 24\right)}\right)$$

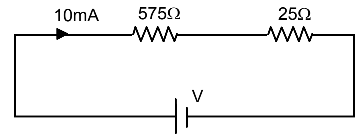
$$\Rightarrow 18 = 30\left(\frac{50R \times (50+R)}{(50+R) + (50R+24)(50+R)}\right) = \frac{30(50R)}{50R + 1200 + 24R}$$

$\Rightarrow 18 = \frac{30 \times 50 \times R}{74R + 1200}$ = 18(74R + 1200) = 1500 R

$\Rightarrow$ 1332R + 21600 = 1500 R $\Rightarrow$ 21600 = 1.68 R

$\Rightarrow$ R = 21600 / 168 = 128.57.

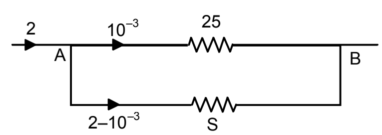
50. Full deflection current = 10 mA = (10×10^{-3})A



$R_{eff} = (575 + 25)\Omega = 600\ \Omega$

$V = R_{eff} \times i = 600 \times 10 \times 10^{-3} = 6$ V.

51. G = 25 Ω, Ig = 1 ma, I = 2A, S = ?



Potential across A B is same

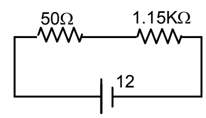
$25 \times 10^{-3} = (2 - 10^{-3})S$

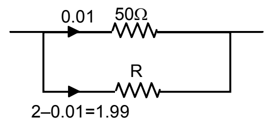
$\Rightarrow S = \frac{25 \times 10^{-3}}{2 - 10^{-3}} = \frac{25 \times 10^{-3}}{1.999}$

$= 12.5 \times 10^{-3} = 1.25 \times 10^{-2}$.

52. $R_{eff} = (1150 + 50)\Omega = 1200\ \Omega$
$i = (12 / 1200)A = 0.01$ A.
(The resistor of 50 Ω can tolerate)
Let R be the resistance of sheet used.
The potential across both the resistors is same.
$0.01 \times 50 = 1.99 \times R$

$\Rightarrow R = \dfrac{0.01 \times 50}{1.99} = \dfrac{50}{199} = 0.251\ \Omega.$

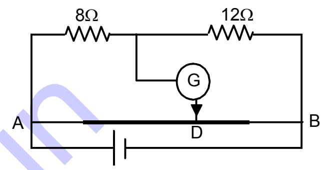




53. If the wire is connected to the potentiometer wire so that $\dfrac{R_{AD}}{R_{DB}} = \dfrac{8}{12}$, then according to wheat stone's bridge no current will flow through galvanometer.

$\dfrac{R_{AB}}{R_{DB}} = \dfrac{L_{AB}}{L_B} = \dfrac{8}{12} = \dfrac{2}{3}$ (Acc. To principle of potentiometer).

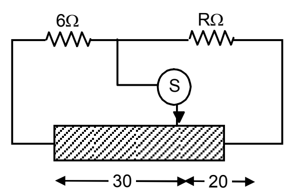
$l_{AB} + l_{DB} = 40$ cm
$\Rightarrow l_{DB}\ 2/3 + l_{DB} = 40$ cm
$\Rightarrow (2/3 + 1)l_{DB} = 40$ cm
$\Rightarrow 5/3\ l_{DB} = 40 \Rightarrow L_{DB} = \dfrac{40 \times 3}{5} = 24$ cm.
$l_{AB} = (40 - 24)$ cm $= 16$ cm.



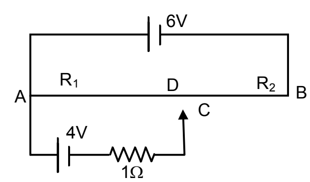
54. The deflections does not occur in galvanometer if the condition is a balanced wheatstone bridge.
Let Resistance / unit length = r.
Resistance of 30 m length = 30 r.
Resistance of 20 m length = 20 r.

For balanced wheatstones bridge = $\dfrac{6}{R} = \dfrac{30r}{20r}$

$\Rightarrow 30\ R = 20 \times 6 \Rightarrow R = \dfrac{20 \times 6}{30} = 4\ \Omega.$



55. a) Potential difference between A and B is 6 V.
B is at 0 potential.
Thus potential of A point is 6 V.
The potential difference between Ac is 4 V.
$V_A - V_C = 0.4$
$V_C = V_A - 4 = 6 - 4 = 2$ V.



b) The potential at D = 2V, $V_{AD} = 4$ V ; $V_{BD} =$ OV
Current through the resisters R_1 and R_2 are equal.

Thus, $\dfrac{4}{R_1} = \dfrac{2}{R_2}$

$\Rightarrow \dfrac{R_1}{R_2} = 2$

$\Rightarrow \dfrac{l_1}{l_2} = 2$ (Acc. to the law of potentiometer)

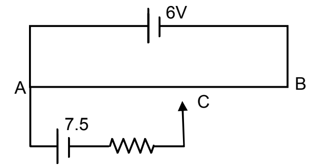
$l_1 + l_2 = 100$ cm

$\Rightarrow l_1 + \dfrac{l_1}{2} = 100 \text{ cm} \Rightarrow \dfrac{3l_1}{2} = 100$ cm

$\Rightarrow l_1 = \dfrac{200}{3}$ cm = 66.67 cm.

AD = 66.67 cm

c) When the points C and D are connected by a wire current flowing through it is 0 since the points are equipotential.



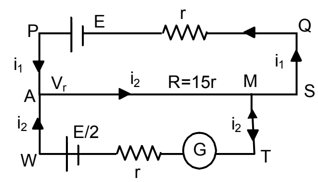
d) Potential at A = 6 v

Potential at C = 6 – 7.5 = –1.5 V

The potential at B = 0 and towards A potential increases.

Thus –ve potential point does not come within the wire.

56. Resistance per unit length = $\frac{15r}{6}$



For length x, Rx = $\frac{15r}{6} \times x$

a) For the loop PASQ $(i_1 + i_2)\frac{15}{6}rx + \frac{15}{6}(6 - x)i_1 + i_1R = E$ …(1)

For the loop AWTM, $-i_2.R - \frac{15}{6}rx\,(i_1 + i_2) = E/2$

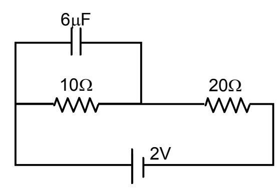
$\Rightarrow i_2R + \frac{15}{6}r \times (i_1 + i_2) = E/2$ …(2)

For zero deflection galvanometer $i_2 = 0 \Rightarrow \frac{15}{6}rx\,.\,i_1 = E/2 = i_1 = \frac{E}{5x \cdot r}$

Putting $i_1 = \frac{E}{5x \cdot r}$ and $i_2 = 0$ in equation (1), we get x = 320 cm.

b) Putting x = 5.6 and solving equation (1) and (2) we get $i_2 = \frac{3E}{22r}$.

57. In steady stage condition no current flows through the capacitor.



$R_{eff} = 10 + 20 = 30\ \Omega$

$i = \frac{2}{30} = \frac{1}{15}A$

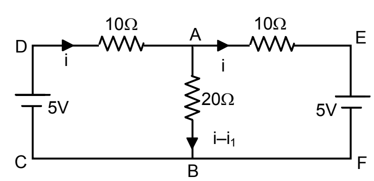
Voltage drop across 10 Ω resistor = i × R

$= \frac{1}{15} \times 10 = \frac{10}{15} = \frac{2}{3}V$

Charge stored on the capacitor (Q) = CV

$= 6 \times 10^{-6} \times 2/3 = 4 \times 10^{-6}$ C = 4 μC.

58. Taking circuit, ABCDA,



$10i + 20(i - i_1) - 5 = 0$

$\Rightarrow 10i + 20i - 20i_1 - 5 = 0$

$\Rightarrow 30i - 20i_1 - 5 = 0$ …(1)

Taking circuit ABFEA,

$20(i - i_1) - 5 - 10i_1 = 0$

$\Rightarrow 10i - 20i_1 - 10i_1 - 5 = 0$

$\Rightarrow 20i - 30i_1 - 5 = 0$ …(2)

From (1) and (2)

$(90 - 40)i_1 = 0$

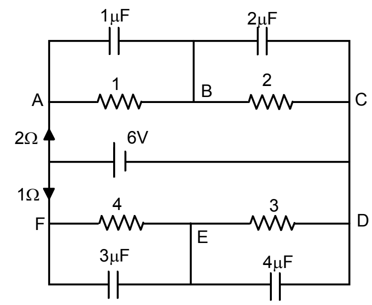
$\Rightarrow i_1 = 0$

$30i - 5 = 0$

$\Rightarrow i = 5/30 = 0.16$ A

Current through 20 Ω is 0.16 A.

59. At steady state no current flows through the capacitor.



$R_{eq} = \frac{3 \times 6}{3+6} = 2\ \Omega.$

$i = \frac{6}{2} = 3.$

Since current is divided in the inverse ratio of the resistance in each branch, thus 2Ω will pass through 1, 2 Ω branch and 1 through 3, 3Ω branch

$V_{AB} = 2 \times 1 = 2V.$

Q on 1 μF capacitor = 2 × 1 μc = 2 μC

$V_{BC} = 2 \times 2 = 4V.$

Q on 2 μF capacitor = 4 × 2 μc = 8 μC

$V_{DE} = 1 \times 3 = 2V.$

Q on 4 μF capacitor = 3 × 4 μc = 12 μC

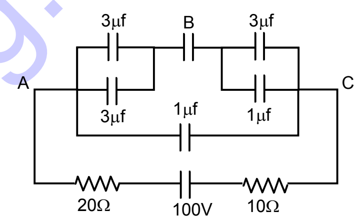
$V_{FE} = 3 \times 1 = V.$

Q across 3 μF capacitor = 3 × 3 μc = 9 μC.

60. C_{eq} = [(3 μf p 3 μf) s (1 μf p 1 μf)] p (1 μf)

= [(3 + 3)μf s (2μf)] p 1 μf

= 3/2 + 1 = 5/2 μf



V = 100 V

Q = CV = 5/2 × 100 = 250 μc

Charge stored across 1 μf capacitor = 100 μc

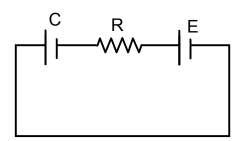
C_{eq} between A and B is 6 μf = C

Potential drop across AB = V = Q/C = 25 V

Potential drop across BC = 75 V.

61. a) Potential difference = E across resistor

b) Current in the circuit = E/R



c) Pd. Across capacitor = E/R

d) Energy stored in capacitor = $\frac{1}{2}CE^2$

e) Power delivered by battery = E × I = $E \times \frac{E}{R} = \frac{E^2}{R}$

f) Power converted to heat = $\frac{E^2}{R}$

62. A = 20 cm^2 = 20 × 10^{-4} m^2

d = 1 mm = 1 × 10^{-3} m ; R = 10 KΩ

$C = \frac{E_0 A}{d} = \frac{8.85 \times 10^{-12} \times 20 \times 10^{-4}}{1 \times 10^{-3}}$

$= \frac{8.85 \times 10^{-12} \times 2 \times 10^{-3}}{10^{-3}}$ = 17.7 × 10^{-2} Farad.

Time constant = CR = 17.7 × 10^{-2} × 10 × 10^{3}

= 17.7 × 10^{-8} = 0.177 × 10^{-6} s = 0.18 μs.

63. C = 10 μF = 10^{-5} F, emf = 2 V

t = 50 ms = 5 × 10^{-2} s, $q = Q(1 - e^{-t/RC})$

Q = CV = 10^{-5} × 2

q = 12.6 × 10^{-6} F

$\Rightarrow 12.6 \times 10^{-6} = 2 \times 10^{-5}\ (1 - e^{-5\times10^{-2}/R\times10^{-5}})$

$\Rightarrow \dfrac{12.6\times10^{-6}}{2\times10^{-5}} = 1 - e^{-5\times10^{-2}/R\times10^{-5}}$

$\Rightarrow$ $1 - 0.63 = e^{-5\times10^{3}/R}$

$\Rightarrow \dfrac{-5000}{R} = \ln 0.37$

$\Rightarrow$ $R = \dfrac{5000}{0.9942} = 5028\ \Omega = 5.028 \times 10^{3}\Omega = 5\ K\Omega.$

64. $C = 20 \times 10^{-6}$ F, E = 6 V, R = 100 Ω

$t = 2 \times 10^{-3}$ sec

$q = EC\ (1 - e^{-t/RC})$

$= 6\times20\times10^{-6}\left(1-e^{\frac{-2\times10^{-3}}{100\times20\times10^{-6}}}\right)$

$= 12 \text{ x } 10^{-5}\ (1 - e^{-1}) = 7.12 \times 0.63 \times 10^{-5} = 7.56 \times 10^{-5}$

$= 75.6 \times 10^{-6} = 76\ \mu c.$

65. $C = 10\ \mu F$, $Q = 60\ \mu C$, $R = 10\ \Omega$

a) at t = 0, q = 60 μc

b) at t = 30 μs, $q = Qe^{-t/RC}$

$= 60 \times 10^{-6} \times e^{-0.3} = 44\ \mu c$

c) at t = 120 μs, $q = 60 \times 10^{-6} \times e^{-1.2} = 18\ \mu c$

d) at t = 1.0 ms, $q = 60 \times 10^{-6} \times e^{-10} = 0.00272 = 0.003\ \mu c.$

66. $C = 8\ \mu F$, E = 6V, R = 24 Ω

a) $I = \dfrac{V}{R} = \dfrac{6}{24} = 0.25A$

b) $q = Q(1 - e^{-t/RC})$

$= (8 \times 10^{-6} \times 6)\ [1 - c^{-1}] = 48 \times 10^{-6} \times 0.63 = 3.024 \times 10^{-5}$

$V = \dfrac{Q}{C} = \dfrac{3.024\times10^{-5}}{8\times10^{-6}} = 3.78$

$E = V + iR$

$\Rightarrow 6 = 3.78 + i24$

$\Rightarrow i = 0.09$ Å

67. $A = 40\ m^2 = 40 \times 10^{-4}$

$d = 0.1\ mm = 1 \times 10^{-4}\ m$

R = 16 Ω ; emf = 2 V

$C = \dfrac{E_0 A}{d} = \dfrac{8.85\times10^{-12}\times40\times10^{-4}}{1\times10^{-4}} = 35.4 \times 10^{-11}$ F

Now, $E = \dfrac{Q}{AE_0}(1-e^{-t/RC}) = \dfrac{CV}{AE_0}(1-e^{-t/RC})$

$= \dfrac{35.4\times10^{-11}\times2}{40\times10^{-4}\times8.85\times10^{-12}}(1-e^{-1.76})$

$= 1.655 \times 10^{-4} = 1.7 \times 10^{-4}$ V/m.

68. $A = 20\ cm^2$, d = 1 mm, K = 5, e = 6 V

$R = 100 \times 10^{3}\ \Omega$, $t = 8.9 \times 10^{-5}$ s

$C = \dfrac{KE_0 A}{d} = \dfrac{5\times8.85\times10^{-12}\times20\times10^{-4}}{1\times10^{-3}}$

$= \dfrac{10\times8.85\times10^{-3}\times10^{-12}}{10^{-3}} = 88.5 \times 10^{-12}$

$q = EC(1 - e^{-t/RC})$

$= 6 \times 88.5 \times 10^{-12} \left(1 - e^{\frac{-89\times10^{-6}}{88.5\times10^{-12}\times10^{4}}}\right) = 530.97$

Energy = $\frac{1}{2} \times \frac{500.97 \times 530}{88.5 \times 10^{-12}}$

$= \frac{530.97 \times 530.97}{88.5 \times 2} \times 10^{12}$

69. Time constant $RC = 1 \times 10^6 \times 100 \times 10^6 = 100$ sec

a) $q = VC(1 - e^{-t/CR})$

I = Current = $dq/dt = VC.(-)\, e^{-t/RC}, (-1)/RC$

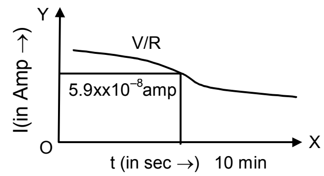
$= \frac{V}{R} e^{-t/RC} = \frac{V}{R \cdot e^{t/RC}} = \frac{24}{10^6} \cdot \frac{1}{e^{t/100}}$

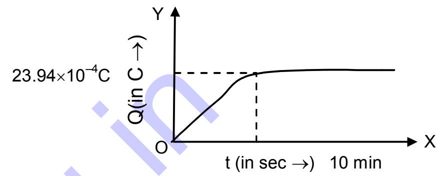
$= 24 \times 10^{-6}\ 1/e^{t/100}$

t = 10 min, 600 sec.

$Q = 24 \times 10+-4 \times (1 - e^{-6}) = 23.99 \times 10^{-4}$

$I = \frac{24}{10^6} \cdot \frac{1}{e^6} = 5.9 \times 10^{-8}$ Amp. .





b) $q = VC(1 - e^{-t/CR})$

70. $Q/2 = Q(1 - e^{-t/CR})$

$\Rightarrow \frac{1}{2} = (1 - e^{-t/CR})$

$\Rightarrow e^{-t/CR} = ½$

$\Rightarrow \frac{t}{RC} = \log 2 \Rightarrow n = 0.69.$

71. $q = Qe^{-t/RC}$

$q = 0.1\ \%\ Q$ RC $\Rightarrow$ Time constant

$= 1 \times 10^{-3}\,Q$

So, $1 \times 10^{-3}\ Q = Q \times e^{-t/RC}$

$\Rightarrow e^{-t/RC} = \ln 10^{-3}$

$\Rightarrow t/RC = -(-6.9) = 6.9$

72. $q = Q(1 - e^{-n})$

$\frac{1}{2}\frac{Q^2}{C} =$ Initial value ; $\frac{1}{2}\frac{q^2}{c} =$ Final value

$\frac{1}{2}\frac{q^2}{c} \times 2 = \frac{1}{2}\frac{Q^2}{C}$

$\Rightarrow q^2 = \frac{Q^2}{2} \Rightarrow q = \frac{Q}{\sqrt{2}}$

$\frac{Q}{\sqrt{2}} = Q(1 - e^{-n})$

$\Rightarrow \frac{1}{\sqrt{2}} = 1 - e^{-n} \Rightarrow e^{-n} = 1 - \frac{1}{\sqrt{2}}$

$\Rightarrow n = \log\left(\frac{\sqrt{2}}{\sqrt{2} - 1}\right) = 1.22$

73. Power $= CV^2 = Q \times V$

Now, $\frac{QV}{2} = QV \times e^{-t/RC}$

$\Rightarrow \frac{1}{2} = e^{-t/RC}$

$\Rightarrow \dfrac{t}{RC} = -\ln 0.5$

$\Rightarrow -(-0.69) = 0.69$

74. Let at any time t, $q = EC\,(1 - e^{-t/CR})$

E = Energy stored = $\dfrac{q^2}{2c} = \dfrac{E^2C^2}{2c}(1 - e^{-t/CR})^2 = \dfrac{E^2C}{2}(1 - e^{-t/CR})^2$

R = rate of energy stored = $\dfrac{dE}{dt} = \dfrac{-E^2C}{2}\left(\dfrac{-1}{RC}\right)^2(1 - e^{-t/RC})e^{-t/RC} = \dfrac{E^2}{CR}\cdot e^{-t/RC}\left(1 - e^{-t/CR}\right)$

$$\frac{dR}{dt} = \frac{E^2}{2R}\left[\frac{-1}{RC}e^{-t/CR}\cdot(1 - e^{-t/CR}) + (-)\cdot e^{-t/CR(1-/RC)}\cdot e^{-t/CR}\right]$$

$$\frac{E^2}{2R} = \left(\frac{-e^{-t/CR}}{RC} + \frac{e^{-2t/CR}}{RC} + \frac{1}{RC}\cdot e^{-2t/CR}\right) = \frac{E^2}{2R}\left(\frac{2}{RC}\cdot e^{-2t/CR} - \frac{e^{-t/CR}}{RC}\right) \qquad \ldots(1)$$

For R_{max} $dR/dt = 0 \Rightarrow 2.e^{-t/RC} - 1 = 0 \Rightarrow e^{-t/CR} = 1/2$

$\Rightarrow -t/RC = -\ln^2 \Rightarrow t = RC \ln 2$

$\therefore$ Putting $t = RC \ln 2$ in equation (1) We get $\dfrac{dR}{dt} = \dfrac{E^2}{4R}$.

75. $C = 12.0\ \mu F = 12 \times 10^{-6}$

emf = 6.00 V, $R = 1\ \Omega$

$t = 12\ \mu c$, $i = i_0\, e^{-t/RC}$

$= \dfrac{CV}{T} \times e^{-t/RC} = \dfrac{12 \times 10^{-6} \times 6}{12 \times 10^{-6}} \times e^{-1}$

= 2.207 = 2.1 A

b) Power delivered by battery

We known, $V = V_0\, e^{-t/RC}$ (where V and V_0 are potential VI)

$VI = V_0 I\, e^{-t/RC}$

$\Rightarrow VI = V_0 I \times e^{-1} = 6 \times 6 \times e^{-1} = 13.24$ W

c) $U = \dfrac{CV^2}{T}(e^{-t/RC})^2$ $\left[\dfrac{CV^2}{T}\right.$ = energy drawing per unit time]

$= \dfrac{12 \times 10^{-6} \times 36}{12 \times 10^{-6}} \times (e^{-1})^2 = 4.872$.

76. Energy stored at a part time in discharging = $\dfrac{1}{2}CV^2(e^{-t/RC})^2$

Heat dissipated at any time

= (Energy stored at t = 0) – (Energy stored at time t)

$= \dfrac{1}{2}CV^2 - \dfrac{1}{2}CV^2(-e^{-1})^2 = \dfrac{1}{2}CV^2(1 - e^{-2})$

77. $\int i^2 R\,dt = \int i_0^2 R e^{-2t/RC}\,dt = i_0^2 R \int e^{-2t/RC}dt$

$= i_0^2 R(-RC/2)e^{-2t/RC} = \dfrac{1}{2}Ci_0^2R^2e^{-2t/RC} = \dfrac{1}{2}CV^2$ (Proved).

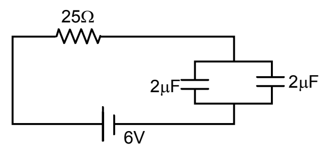
78. Equation of discharging capacitor

$= q_0 e^{-t/RC} = \dfrac{K \in_0 AV}{d} e^{\frac{-1}{(\rho d K \in_0 A)/Ad}} = \dfrac{K \in_0 AV}{d} e^{-t/\rho K \in_0}$

$\therefore \tau = \rho K \in_0$

$\therefore$ Time constant is $\rho K \in_0$ is independent of plate area or separation between the plate.

79. $q = q_0(1 - e^{-t/RC})$

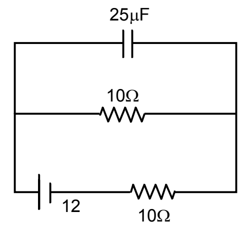


$= 25(2 + 2) \times 10^{-6}\left(1 - e^{\frac{-0.2\times10^{-3}}{25\times4\times10^{-6}}}\right)$

$= 24 \times 10^{-6}(1 - e^{-2}) = 20.75$

Charge on each capacitor = 20.75/2 = 10.3

80. In steady state condition, no current passes through the 25 μF capacitor,



$\therefore$ Net resistance = $\dfrac{10\Omega}{2} = 5\Omega$.

Net current = $\dfrac{12}{5}$

Potential difference across the capacitor = 5

Potential difference across the 10 Ω resistor

$= 12/5 \times 10 = 24$ V

$q = Q(e^{-t/RC}) = V \times C(e^{-t/RC}) = 24 \times 25 \times 10^{-6}\left[e^{-1\times10^{-3}/10\times25\times10^{-4}}\right]$

$= 24 \times 25 \times 10^{-6}\, e^{-4} = 24 \times 25 \times 10^{-6} \times 0.0183 = 10.9 \times 10^{-6}$ C

Charge given by the capacitor after time t.

Current in the 10 Ω resistor = $\dfrac{10.9\times10^{-6}\,C}{1\times10^{-3}\,sec} = 11mA$.

81. C = 100 μF, emf = 6 V, R = 20 KΩ, t = 4 S.

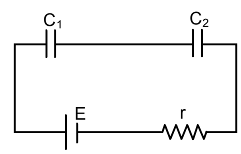
Charging : $Q = CV(1 - e^{-t/RC})$ $\quad \left[\dfrac{-t}{RC} = \dfrac{4}{2\times10^{4}\times10^{-4}}\right]$

$= 6 \times 10^{-4}(1 - e^{-2}) = 5.187 \times 10^{-4}$ C = Q

Discharging : $q = Q(e^{-t/RC}) = 5.184 \times 10^{-4} \times e^{-2}$

$= 0.7 \times 10^{-4}$ C = 70 μc.

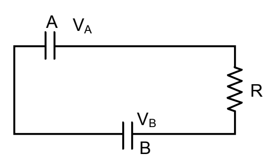
82. $C_{eff} = \dfrac{C_1C_2}{C_1 + C_2}$



$Q = C_{eff}\,E(1 - e^{-t/RC}) = \dfrac{C_1C_2}{C_1 + C_2}\,E(1 - e^{-t/RC})$

83. Let after time t charge on plate B is +Q.

Hence charge on plate A is Q – q.



$V_A = \dfrac{Q - q}{C}$, $V_B = \dfrac{q}{C}$

$V_A - V_B = \dfrac{Q - q}{C} - \dfrac{q}{C} = \dfrac{Q - 2q}{C}$

Current = $\dfrac{V_A - V_B}{R} = \dfrac{Q - 2q}{CR}$

Current = $\dfrac{dq}{dt} = \dfrac{Q - 2q}{CR}$

$\Rightarrow \dfrac{dq}{Q - 2q} = \dfrac{1}{RC}\cdot dt \quad \Rightarrow \int_0^q \dfrac{dq}{Q - 2q} = \dfrac{1}{RC}\cdot\int_0^t dt$

$\Rightarrow -\dfrac{1}{2}[\ln(Q - 2q) - \ln Q] = \dfrac{1}{RC}\cdot t \Rightarrow \ln\dfrac{Q - 2q}{Q} = \dfrac{-2}{RC}\cdot t$

$\Rightarrow Q - 2q = Q\,e^{-2t/RC} \Rightarrow 2q = Q(1 - e^{-2t/RC})$

$\Rightarrow q = \dfrac{Q}{2}(1 - e^{-2t/RC})$

84. The capacitor is given a charge Q. It will discharge and the capacitor will be charged up when connected with battery.

Net charge at time t = $Qe^{-t/RC} + Q(1 - e^{-t/RC})$.