



CURRENT ELECTRICITY

EXERCISE -I

1. $j \rightarrow$ Current density $n \rightarrow$ Charge density

$$j = -nev_d \qquad v_{d1} = \frac{j}{n_1 e}$$

$$v_{d2} = \frac{j}{n_2 e}, \quad \frac{n_1}{n_2} = \frac{1}{4} \Rightarrow n_2 = 4n_1$$

$$\frac{v_{d1}}{v_{d2}} = \frac{n_2}{n_1} = \frac{4n_1}{n_1} = 4 : 1$$

2. $j = \frac{I}{A} = nev_d$

$$\frac{4I}{\pi d^2} = nev \dots (i) \qquad \frac{16I}{\pi d^2} = nev' \dots (ii)$$

From equation (i) & (ii) $\frac{4I}{16I} = \frac{v}{v'} \Rightarrow v' = 4v$

3. $v_d = \frac{i}{Ane}$ As $A \uparrow$ so $v_d \downarrow \Rightarrow v_p > v_o$

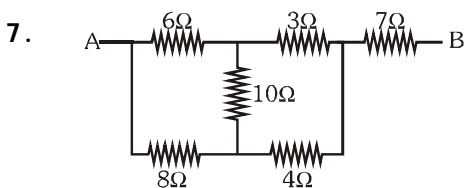
4. $i = nev_d A; I = \frac{2envA}{4} - (-nevA) = \frac{3}{2}nevA$

5. $R = \frac{\rho L}{A} = \frac{\rho L^2}{AL} = \frac{\rho L^2}{V} = \frac{\rho L^2 d}{m}$

$d, \rho \rightarrow$ same for all as the material is same for all.

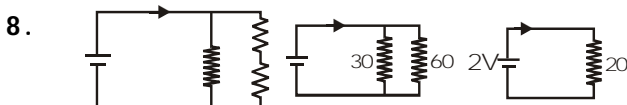
$$\Rightarrow R_1 : R_2 : R_3 = \frac{25}{1} : \frac{9}{3} : \frac{1}{5} = 125 : 15 : 1$$

6. $R = \frac{\rho L}{A} = \frac{\rho L^2}{V} \Rightarrow R \propto L^2$



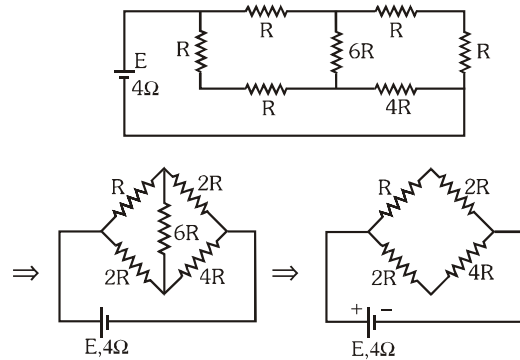
Balanced Wheatstone Bridge

$$\text{As } \frac{1}{9} + \frac{1}{12} = \frac{7}{36} = \frac{36}{7} \quad \text{So } R_{AB} = \frac{36}{7} + 7 = \frac{85\Omega}{7}$$



$$V = IR \Rightarrow 2 = (I)(20) \Rightarrow I = \frac{1}{10} \text{ A}$$

9.



This is balanced wheat stone bridge
From maximum power transfer theorem
Internal resistance = External resistance

$$\Rightarrow 4 = \frac{3R \times 6R}{3R + 6R} \Rightarrow 4 = 2R \Rightarrow R = 2 \Omega$$

10. $P = \frac{V^2}{R}$ Initially, $I = \frac{V}{2R}$

Power across $P_x = P_y = \left(\frac{\epsilon^2}{4R}\right) R$

Finally, $I = \frac{2V}{3R}$, Power $P_x = \frac{4V^2}{9R}$, $P_y = P_z = \frac{2V^2}{9R}$

Hence P_x increases, P_y decreases.

Alternative method :

Brightness $\propto i^2 R$ when S is closed current drawn from battery increases because R_{eq} decreases. i.e. current in X increases. So brightness of X increases and current in Y decreases. So brightness of Y decreases.

11. $P = I^2 R = \left(\frac{V}{R}\right)^2 R = \frac{\epsilon^2}{(R+r)^2} R$

ϵ is constant and $(R+r)$ increases rapidly Then $P \downarrow$

12. $P = i^2 R \Rightarrow 10 = i^2 5 \Rightarrow i^2 = \frac{10}{5} = 2 \Rightarrow i = \sqrt{2}$

$$i_4 = \frac{i_5}{2} \Rightarrow P_4 = \left(\frac{i}{2}\right)^2 4, \quad P_5 = (i^2)5$$

$$\frac{P_4}{P_5} = \frac{1}{5} \Rightarrow P_4 = \frac{P_5}{5}, \quad P_4 = \frac{10}{5} = 2 \text{ cal/s}$$

13. $R_1 = \frac{\rho l}{A_1}, \quad R_2 = \frac{\rho l}{A_2}$ As $A_1 < A_2$ so $R_1 > R_2$

In series $H = I^2 R t \quad H \propto R; \quad H_1 > H_2$

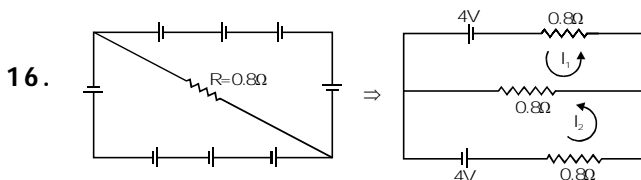


In parallel $H = \frac{V^2}{R}t$ $H \propto \frac{1}{R}$; $H_1 < H_2$

14. $V = \epsilon + i(r) \Rightarrow 12.5 = \epsilon + \frac{1}{2}(1) \Rightarrow \epsilon = 12 \text{ V}$

(As the battery is a storage battery it is getting charged)

15. The correct answer is $R = 0$

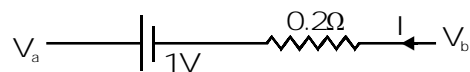


$1.6 I_1 - 0.8 I_2 = 4 \dots(i)$

$1.6 I_2 - 0.8 I_1 = 4 \dots(ii)$

from eq. $I_1 = I_2 = 5$

voltage difference across any of the battery.



$V_a - 1 + 0.2 \times 5 - V_b = 0$

$V_a - V_b = 0 \text{ Volt}$

17. $V = IR \Rightarrow 0.2 = I(20)$

$I_g = 0.01 \text{ A}$ (through the galvanometer)

$I_g G = (i - i_g)S \Rightarrow (0.01)(20) = (10 - 0.01)S$

$\Rightarrow S = 0.020 \Omega$

18. $R_v = \frac{V}{i_g} - G \Rightarrow 910 = \frac{V}{10 \times 10^{-3}} - 90$

$\Rightarrow V = 10 \Rightarrow \text{No. of divisions} = \frac{10}{0.1} = 100$

19. $20 + R = \frac{12}{0.1} \Rightarrow R = 100 \Omega$

20. $I = \frac{12}{4 + 2 + \infty} = 0$. If $i = 0$,

potential difference is equal of EMF of cell. = 12V

21. $\frac{P}{S} = \frac{Q}{625} \Rightarrow \frac{P}{Q} = \frac{S}{625} \dots(i)$

$\frac{Q}{S} = \frac{P}{676} \Rightarrow \frac{P}{Q} = \frac{676}{S} \dots(ii)$

From (i) & (ii) $\frac{676}{S} = \frac{S}{625}$

$(676)(625) = S^2 \Rightarrow S = 650 \Omega$

22. $E = \left(\frac{V}{\ell}\right) \times \frac{\ell}{3}$ & $E = \left(\frac{V}{3\ell/2}\right)(\ell') \Rightarrow \ell' = \frac{\ell}{2}$

23. Potential gradient $x = \left(\frac{E}{10r}\right)\left(\frac{9r}{L}\right)$

According to question

$\frac{E}{2} = \left(\frac{E}{10r}\right)\left(\frac{9r}{L}\right)(\ell) \Rightarrow \ell = \frac{5L}{9}$

24. Potential gradient

$x = \left(\frac{5}{0.5 + 4.5}\right)\left(\frac{4.5}{3}\right) = 1.5 \text{ Vm}^{-1}$

Here $(x)(AC) = 3 \Rightarrow AC = \frac{3}{1.5} = 2 \text{ m}$

25. Potential gradient

$x = \left(\frac{12}{8 + 16}\right) \times 4 = 2 \text{ Vm}^{-1}$

Effective emf of E_1 and E_2

$E = E = \frac{E_2 - E_1}{\frac{r_2}{1/r_1 + 1/r_2}} = \frac{1}{2} \text{ volt}$

Balancing length $AN = \left(\frac{1}{2}\right)\left(\frac{1}{2}\right) = \frac{1}{4} \text{ m} = 25 \text{ cm}$

26. $P = \frac{V^2}{R} = \frac{V^2 A}{\rho \ell} \propto \frac{r^2}{\ell} [V \rightarrow \text{same}]$

27. (25W- 220V)

$P_1 = \frac{V_1^2}{R_1}$, $R_1 = \frac{(220)^2}{25} = 1936 \Omega$

(100W-220V)

$P_2 = \frac{V_2^2}{R_2}$, $R_2 = \frac{(220)^2}{100} = 484 \Omega$

In Series (I same)

$H = I^2 R t$, $H \propto R$ so if $R_1 > R_2$ then $H_1 > H_2$

R_1 is likely to fuse

28. $P \Rightarrow \frac{V^2}{R} \Rightarrow \frac{V^2 A}{L \rho} \dots(i)$

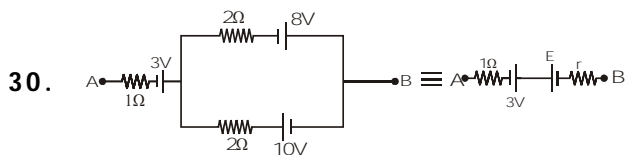


$$P' = \frac{V^2 A}{\left(L - \frac{L}{10}\right) \rho} \Rightarrow \frac{10V^2 A}{9L\rho} \dots(ii)$$

from eq. (i) & (ii) $P' = \frac{10}{9}P$

$$\frac{\Delta P}{P} \times 100 \Rightarrow \frac{\left(\frac{10}{9}P - P\right)}{P} \times 100 \Rightarrow \frac{1}{9} \times 100 \Rightarrow 11.11\%$$

29. In parallel combination the equivalent resistance is less than the two individual resistance connected and in series combination equivalent resistance is more than the two individual components.

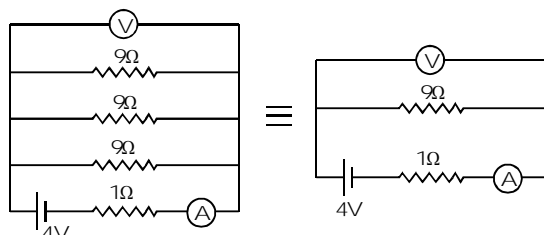


$$E = \frac{E_1 + E_2}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{10 + (-8)}{\frac{1}{2} + \frac{1}{2}} = 1 \text{ volt and}$$

$$r = \frac{r_1 r_2}{r_1 + r_2} = 1\Omega . \text{ Therefore } \text{A} \text{---} \text{---} \text{---} \text{B}$$

31. **Ans. (A)**

32. Given circuit can be reduced to



Reading of ammeter

$$= \frac{4}{3+1} = 1A$$

Reading of voltmeter

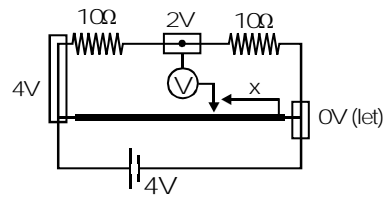
$$= 3 \times 1 = 3V$$

33. $I_{\text{wire}} = \frac{4V}{0.4 \times 50\Omega} = 0.2 A$

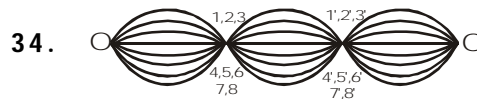
Potential difference across voltmeter,

$$V = Ir - 2$$

$$\Rightarrow 2 \sin\pi t = 0.2 \times 50 \times -2 \Rightarrow 2 \pi \cos\pi t = 10 V$$



$$\Rightarrow V = 20 \pi (\cos\pi t) \text{ cm/s}$$



Points 1, 2, 3.....8 are of same potential and 1', 2', 3'.....8' are of same potential.

$$R_{\text{eq}} = \frac{3R}{8}$$

35. Total length of wire

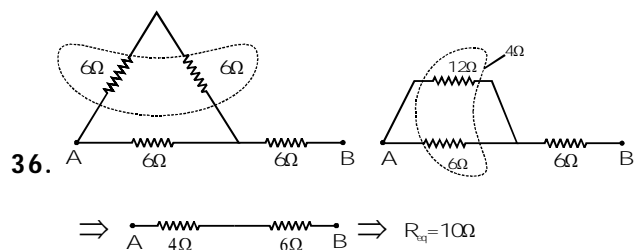
$$= 90 + 90 = 180 \text{ m ;}$$

Total resistance of wire

$$= 180/5 = 12 \Omega .$$

$$\text{As } I = \frac{nE}{R + nr} \Rightarrow 0.25 = \frac{n \times 1.4}{12 + 5 + n \times 2} \Rightarrow n = 4.7$$

\Rightarrow Total number of cells required = 5

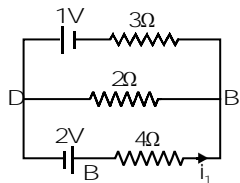


$$\Rightarrow \text{A} \text{---} \text{---} \text{---} \text{B} \Rightarrow R_{\text{eq}} = 10\Omega$$

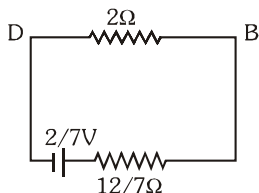
EXERCISE -II

1. Free-electron density and the total current passing through wire does not depend on 'n'.

2. $E_{\text{eq}} = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2} = \frac{2 \times 3 - 1 \times 4}{3 + 4} = \frac{2}{7}$



$$r_{eq} = \frac{3 \times 4}{3+4} = \frac{12}{7}; i = \frac{2/7}{2 + \frac{12}{7}} = \frac{1}{13} \text{ A}$$



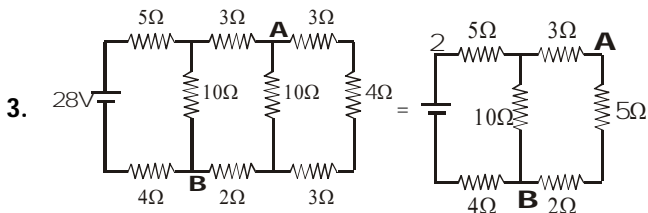
$$V_B > V_D = 2 \left(\frac{1}{13} \right); V_D - V_B = - \frac{2}{13} \text{ V}$$

From Figure 1 :

$$V_B + 4i_1 - 2 - V_D = 0; \frac{2}{13} - 2 + 4i = 0$$

$$i = \frac{6}{13} \text{ A}; V_G = 3 - 3 \times \frac{6}{13}$$

$$V_G = \frac{21}{13} \text{ V}, V_H = 1 + 1 \times \frac{6}{13} = V_H = \frac{19}{13} \text{ V}$$



$$R_{eq} = 14\Omega \Rightarrow I = 2\text{A}; V_{AB} = iR = 7 \text{ volt}$$

4. Both '4Ω' and '6Ω' resistors are short circuited therefore R_{eq} of the circuit in 2Ω is 10 A.

$$\text{Power (5)} = VI = 200 \text{ watt}$$

$$\text{Potential difference across both 'A' and 'B' = 0}$$

5. $I = \frac{dq}{dt} = 2 - 16t$

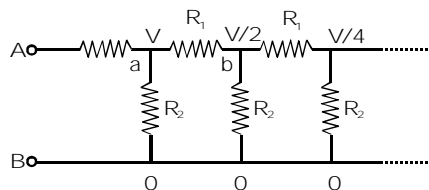
$$\text{Power : } P = I^2 R = (2 - 16t)^2 R$$

$$\text{Heat produced} = \int P dt = \int_0^{\frac{1}{8}} (4 - 256t^2 - 64t) R dt$$

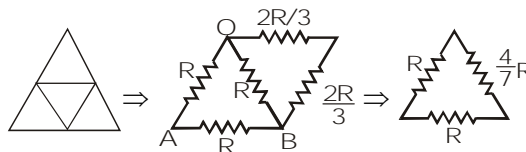
$$= \left[\left(4t - \frac{256t^3}{3} - \frac{64t^2}{2} \right) R \right]_0^{\frac{1}{8}} = \frac{R}{6} \text{ joules}$$

6. It is the concept of potentiometer.

7. By applying node analysis at point b



$$\frac{\frac{V}{2} - V}{R_1} + \frac{\frac{V}{2} - \frac{V}{4}}{R_1} + \frac{\frac{V}{2}}{R_2} = 0 \Rightarrow \frac{R_1}{R_2} = \frac{1}{2}$$



- 8.

$$R_{AB} = \frac{11R}{18}$$

9. For wheat stone Bridge condition is $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Therefore null point is independent of the battery voltage.

10. $V = E - ir \Rightarrow V = -ri + E$
Slope of graph 'V' and 'i' gives 'r' intercept of graph 'V' and 'i' gives E $\Rightarrow \tan \theta = \frac{y}{x} = r$.

11. $\Delta V = E + ir$ and in charging current flows from positive terminal to negative terminal.

12. Slope of 'V' vs 'i' graph give internal resistance $\therefore r = 5\Omega$

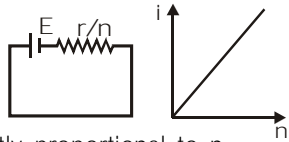
Intercept gives the value of e.m.f. E = 10 volt

$$\text{Maximum current is } i_{max} = \frac{E}{r} \Rightarrow 2\text{A}$$

13. If n batteries are in series than the circuit can be made as

$$i = \frac{nE}{nr} \Rightarrow \frac{E}{r} \left[\text{Circuit diagram with } nE \text{ and } nr \right] \text{ i.e. independent of n.}$$

14. If n batteries are in parallel than the circuit can be made as $i = \frac{nE}{r}$



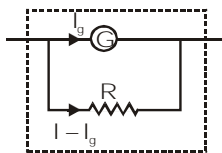
i is directly proportional to n .

15. In parallel combination current gets divided therefore parallel combination supports $i = i_1 + i_2$ is 20A in series current remain same therefore the series combination supports $i = 10A$.

16. As power in 2Ω is maximum when the current in it is maximum. Current in it will maximum when the value of R_{eq} is minimum. $\therefore R = 0$

Heat $\Rightarrow i^2 R T \Rightarrow (36)(2) = 72 \text{ W}$

17. For Ammeter $I_g G = (I - I_g) R$



$50 \times 10^{-6} \times 100 = 5 \times 10^{-3} \times (R) \Rightarrow R \cong 1\Omega$

For voltmeter $I_g (R + G) = V$

$\Rightarrow 50 \mu A (R + G) = 10V$

$\Rightarrow R + G = 200 \text{ k}\Omega$

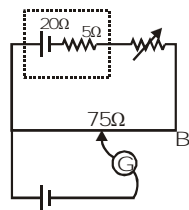
$\Rightarrow R \cong 200\text{k}\Omega$

18. $i_{\min} = \frac{20}{R_{\min}} = \frac{20}{200} = \frac{1}{10} \text{ A}$

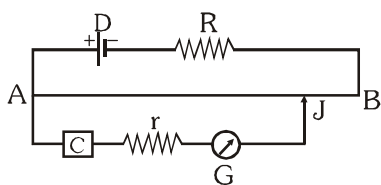
$i_{\max} = \frac{20}{R_{\max}} = \frac{20}{250} = \frac{2}{25} \text{ Amp}$

Potential $= i_{\min} R_{PM} = \frac{1}{10} \times 75 = 7.5 \text{ V}$

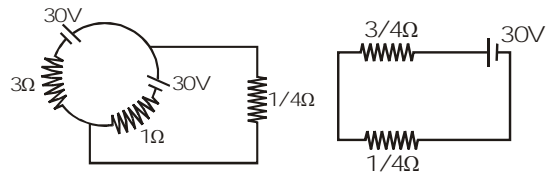
Across potentiometer $V = i_{\max} R_{PM} = \frac{2}{25} \times 75 = 6 \text{ V}$



19. If e.m.f of c is greater than the e.m.f. of the 'D'
 $I_r = 0$
 So r does not play any role of zero deflection in galvanometer.



20.



Both 30V are in parallel

$30 - \frac{1}{4}i - \frac{3}{4}i = 0 \Rightarrow i = 30 \text{ A}$

21.

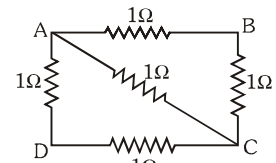
Assume $DE \Rightarrow R_1 \Omega$

$EC \Rightarrow R_2 \Omega$

$R_1 + R_2 = 1\Omega$

$V_B = V_E$

Means balance wheat stone bridge



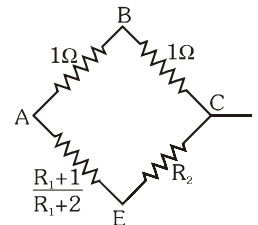
$\frac{P}{Q} = \frac{R}{S}; \frac{1}{1} = \frac{R_1 + 1}{R_1 + 2}$

$R_2 = \frac{R_1 + 1}{R_1 + 2} = 1 - R_1$

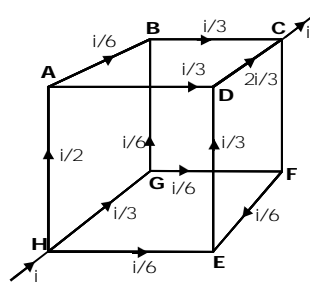
$R_1 + 1 = R_1 + 2 - R_1^2 - 2R_1$

$R_1^2 + 2R_1 - 1 = 0 \Rightarrow R_1 = -1 + \sqrt{2} \Rightarrow R_2 = 2 - \sqrt{2}$

$\frac{CE}{ED} = \frac{R_2}{R_1} = \frac{2 - \sqrt{2}}{\sqrt{2} - 1} = \sqrt{2}$

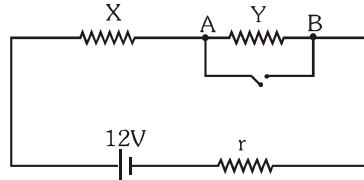


22.



So current in FC=0

23.



$\frac{12}{X + Y + r} = 1 \text{ A} \Rightarrow V_x = 1 \times X \Rightarrow X = 1\Omega$

When Y shorted $I = \frac{12}{1 + r}$



$$10 = 12 - Ir \Rightarrow 10 = 12 - \frac{12}{(1+r)}r$$

$$\Rightarrow 10 + 10r = 12 + 12 - 12r$$

$$\Rightarrow 10r = 2 \Rightarrow r = 0.2 \Omega$$

24. $\frac{E_1 + E_2}{r_1 + r_2 + R} < \frac{E_1}{r_1 + R}; (E_1 + E_2)(r_1 + R) < E_1(r_1 + r_2 + R)$

$$E_1R + E_2R + E_1r_1 < E_1r_2 + E_1R; R(E_1 + E_2) < E_1r_2$$

On solving we get $E_1r_2 > E_2(R + r_1)$

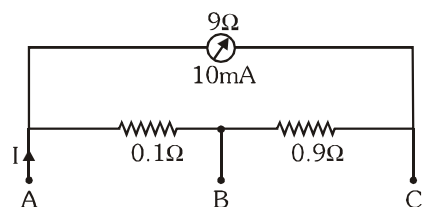
25. If all were in series all of them would have been getting discharged. But since, 2 are in opposite polarity, they will be getting charged.

$$V = E + iR \text{ getting charged } i = \frac{V}{R} = \frac{(nE - 4)}{nR}$$

as $(nE - 4)$ as 4 batteries will be cancelled out

$$= E + \left(\frac{nE - 4}{nR}\right)R, = E + \left(E - \frac{4}{n}\right) = 2\left(1 - \frac{2}{n}\right)E$$

26.



Between A and B

$$(9 + 0.9) \times 10 \times 10^{-3} = (I - 10\text{mA}) \times 0.1$$

$$\Rightarrow 990 \text{ mA} = I - 10\text{mA} \Rightarrow I = 1000 \text{ mA} = 1\text{A}$$

27. When S_2 open (

Assume resistance of AB = R

Resistance of wire per unit length.

$$x = \frac{R}{L}$$

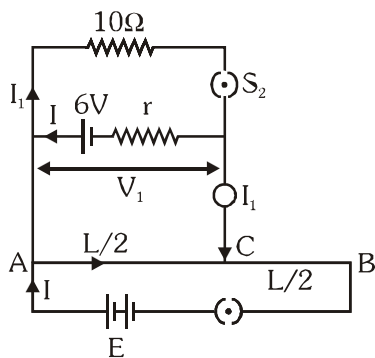
$$I = \frac{E}{R}$$

Now in AC

$$\frac{E}{R} \times \frac{R}{L} \times \frac{L}{2} = 6$$

$$E = 12\text{V}$$

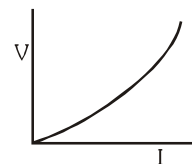
When S_2 closed



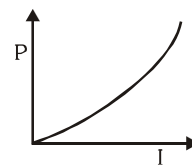
$$V_1 = \frac{E}{R} \times \frac{R}{L} \times \frac{5L}{12} = \frac{5E}{12} = \frac{5 \times 12}{12} = 5\text{V}$$

$$\Rightarrow 6 - I_1r = 5 \Rightarrow 6 - \left(\frac{5}{10}\right)r = 5 \Rightarrow r = 2\Omega$$

28.



$$R = \frac{V}{I} = \text{slope } \uparrow$$



So $R \uparrow$

$$P = I^2R$$

$$R \uparrow \quad P \uparrow$$

$$P \propto I^2$$

29. Rearranged circuit between A & B is :



(due to symmetry)

Total resistance of circuit

$$= \frac{7}{3} + \frac{2}{3} = 3 \Omega \cdot i = \frac{9}{3} = 3 \text{ A}$$

Heat produced in cell

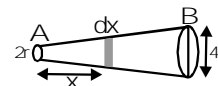
$$= I^2 r = (3)^2 \times \left(\frac{2}{3}\right) = 6\text{W}$$

Current in resistance connected directly between

$$A \& B = \frac{7}{15} \times 3 = \frac{7}{5} = 1.4 \text{ A}$$

$$= \frac{7}{15} \times 3 = \frac{7}{5} = 1.4 \text{ A}$$

30.



$$r_x = r + rx = r(1 + x) \Rightarrow dR_x = \frac{\rho dx}{\pi r_x^2} = \frac{\rho dx}{\pi r^2 (1 + x)^2}$$

$$R_1 = \int_0^l \frac{\rho dx}{\pi r^2 (1 + x)^2} = \frac{\rho}{\pi r^2} \left[1 - \frac{1}{1 + l} \right]$$

$$R_2 = \int_l^1 \frac{\rho dx}{\pi r^2 (1 + x)^2} = \frac{\rho}{\pi r^2} \left[\frac{1}{1 + l} - \frac{1}{1 + 1} \right]$$

For null point

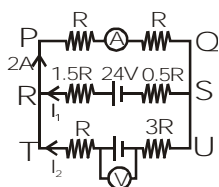


$$\frac{R_1}{R_2} = \frac{10}{10} \Rightarrow R_1 = R_2$$

$$\Rightarrow 1 - \frac{1}{1+l} = \frac{1}{1+l} - \frac{1}{2} \Rightarrow \frac{3}{2} = \frac{2}{1+l}$$

$$\Rightarrow 3 + 3l = 4 \Rightarrow l = \frac{1}{3} \text{ m}$$

31. $V_p - V_o = 2(2R) \Rightarrow 4R = 24 - (2R)I_1$



$$\Rightarrow I_1 R = 12 - 2R, E - I_2(4R) = 4R, I_1 + I_2 = 2$$

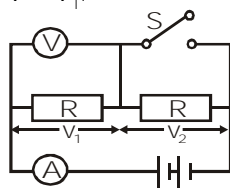
$$\Rightarrow E = 20R - 48$$

EXERCISE -III

Match the column

- For potentiometer short circuit = $x l_1$
 x Depends only on primary circuit
- (A) $E_1 \uparrow \Rightarrow x \uparrow \Rightarrow l_1 \downarrow$ if secondary circuit remain same
- (B) $R \uparrow \Rightarrow x \downarrow \Rightarrow l_1 \uparrow$ if secondary circuit remain same
- (C) S.C $\uparrow = l_1 \uparrow$ if x remain same

- After closing the switch net resistance decreases therefore there will be increases in the current. After closing the switch V_2 becomes zero hence $V = V_1$.



After short circuiting current in the resistance becomes zero therefore power become zero.

Comprehension-1

- Power through fuse
 $P = I^2 R = h \times 2\pi r l$
 h = heat energy lost per unit area per unit time
 I = current.

$$I^2 = \frac{h \times 2\pi r l}{\frac{\rho l}{\pi r^2}} \propto r^3 \Rightarrow I \propto r^{3/2}$$

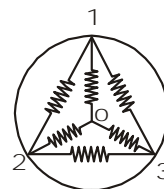
$$\left(\frac{I_1}{I_2}\right) = \left(\frac{r_1}{r_2}\right)^{3/2} = \left(\frac{4}{1}\right)^{3/2} = \frac{8}{1}$$

- $P = VI \quad 20\text{kw} \Rightarrow 2000 = \frac{V^2}{20}$
 $\Rightarrow V = 200 \text{ volt} \Rightarrow V < 200 \text{ volt}$

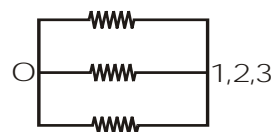
- At maximum power delivery $R = r$, so $\eta = 50\%$

Comprehension-2

- As potential of 1, 2 and 3 are same potential difference across them 'zero'.



- As 1, 2 and 3 are having same potential therefore we can draw it.



$$R_{01} = R/3 \quad ; \quad R_{02} = R/3 \quad ; \quad R_{03} = R/3$$

- As point 1,2,3 are equipotential $\Delta V = I R_{12}$
 $\Rightarrow \Delta V = 0$ therefore $I = 0$ for R_{12}, R_{23}, R_{31}

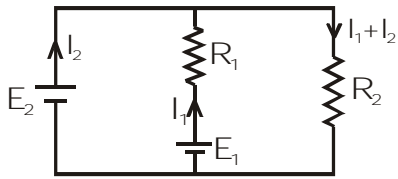
Comprehension-3

- Current is maximum when resistance in the circuit is minimum. i.e. when S_1, S_3, S_5 are closed because then all resistances will be shortcircuited $I_{\text{max}} = \frac{V_0}{R}$.
- After regular closing of switches, total resistance decreases gradually.

- $P_1 = \frac{V_0^2}{R}, P_2 = \frac{V_0^2}{\frac{37}{7}R}$ so $\frac{P_1}{P_2} = \frac{7}{37}$

Comprehension-4

- $I_1 = \frac{E_1 - E_2}{R_1}, I_1 + I_2 = \frac{E_2}{R_2} \Rightarrow I_2 = \frac{E_2}{R_2} - \frac{E_1 - E_2}{R_1}$



$$\Rightarrow I_1 = \left(\frac{-1}{R_1}\right) E_2 + \frac{E_1}{R_1} \quad \& \quad I_2 = \left(\frac{1}{R_1} + \frac{1}{R_2}\right) E_2 - \frac{E_1}{R_1}$$

$$\Rightarrow \frac{1}{R_1} = \frac{0.3}{6} \Rightarrow R_1 = 20\Omega$$

and $\frac{1}{R_1} + \frac{1}{R_2} = \frac{0.3}{4} \Rightarrow R_2 = 40\Omega$

Now as $\frac{E_1}{R_1} = 0.3 \Rightarrow E_1 = 0.3 \times 20 = 6V$

Comprehension-5

1. In balancing condition, current in the circuit should be zero which happens at $l=20$ cm according to graph.

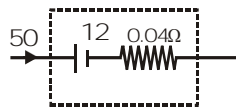
2. At balance point $\epsilon = \frac{l}{100} V = \frac{20}{100} \times 6 = 1.2V$

3. At $l = 0$, applying kirchhoff's 2nd law in the circuit containing cell, $\epsilon = IR$

where I is the current at $l = 0$, & ϵ is the emf of the cell. $\Rightarrow R = \frac{\epsilon}{I} = \frac{1.2}{40 \times 10^{-3}} = 30\Omega$

Comprehension-6

1. $V = E + ir$
 $= 12 + (0.04) (50)$
 $= 12 + 2 \Rightarrow 14 V$



2. **Ans. (A)**

Loss in power
 $= i^2 r = (50)^2 (0.04) = 100 W$

3. **Ans. (C)**

Total input
 - Loss in power (
 = Useful power (
 Input power = $14 (50) = 700 w$
 Loss in power = $100 w$, Rate of conversion = $600 watt$

EXERCISE -IV A

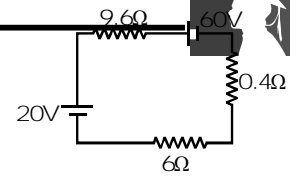
1. $I = \frac{40}{16} = \frac{10}{4} = 2.5 A$



$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I$$

$$I_1 = \left(\frac{48}{60}\right) 2.5 = 2A \Rightarrow I_2 = 0.5$$

$$\Rightarrow V = 0.5(7) = 3.5 \text{ volt}$$

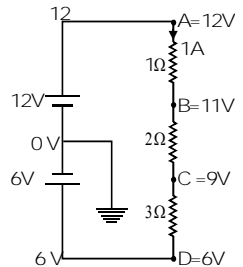


2. $\Delta V = IR$

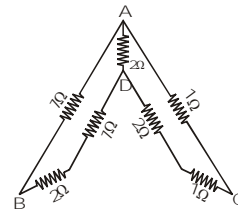
$$\Delta V_{AB} = 1V$$

$$\Delta V_{BC} = 2V$$

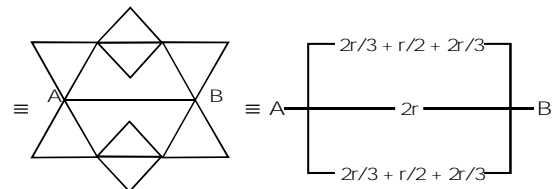
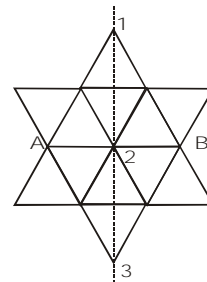
$$\Delta V_{CD} = 3V$$



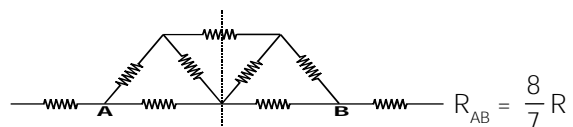
3. By symmetric path method Points E, F and B, C are Equipotential $\Rightarrow R_{AD} = 1\Omega$



4. By perpendicular Axis symmetry all points 1, 2, 3 are at same potential therefore junction on this line can be redrawn as $R_{AB} = \frac{22}{35} R$.

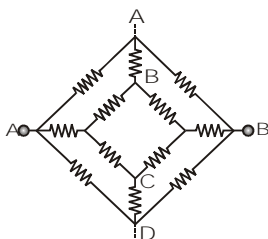


5. By applying perpendicular Axis- Symmetry

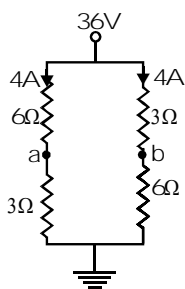




6. By applying perpendicular axis symmetry. Points lying on the line 'AD' have same potential therefore Resistance between AB and CD can be removed $R_{AB} = 9\Omega$.

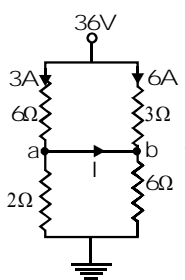


7. (i) When switch S is open



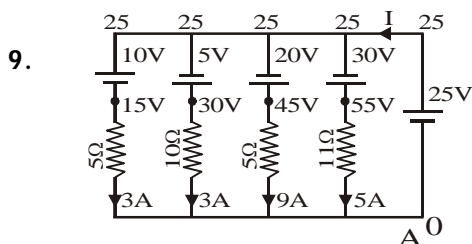
$$V_a - V_b = (36 - 6 \times 4) - (36 - 3 \times 4) = -12V$$

- (ii) Total current through circuit = $\frac{36V}{4\Omega} = 9A$



Therefore $I = 3A$

8. (i) Chemical energy consumed = 3 watt
 (ii) Rate of energy dissipation = $i^2R = 0.4$ watt
 (iii) Rate of energy dissipation in resistor = $(E - ir) = 2.6$ watt
 (iv) The output energy to the source = 2.6 watt



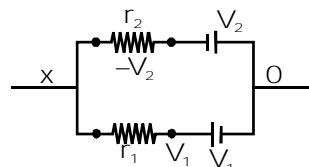
Taking point 'A' as reference potential and its potential to be '0': $I = 20A$

- 9.

Power supplied by 20 V cell

$$= -20 \times 1 = -20 W$$

10. By applying node Analysis



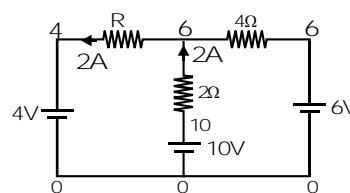
$$\frac{x + V_2}{r_2} + \frac{x - V_1}{r_1} = 0 \Rightarrow x \left[\frac{1}{r_2} + \frac{1}{r_1} \right] = \frac{V_2 r_1 - V_1 r_2}{r_1 r_2}$$

$$x = \frac{V_2 r_1 - V_1 r_2}{r_1 + r_2}, \quad r_{eq} = r_1 + r_2$$

11. $P_1 = P_2 \Rightarrow \frac{\epsilon^2 R_1}{(R_1 + r)^2} = \frac{\epsilon^2 R_2}{(R_2 + r)^2}$

$$\frac{R_2 + r}{R_1 + r} = \sqrt{\frac{R_2}{R_1}}, \quad r = \sqrt{R_1 R_2}$$

12. By taking 'O' as a reference potential as current through '4Ω' is zero there should be no potential drop across it



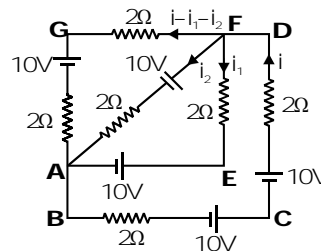
Value of 'R' for this condition = 1Ω

13. '2R' and 'R_x' are in series therefore $R = 2R + R_x$ and it is in parallel with

$$'R' \Rightarrow R_{eq} = \frac{(2R + R_x)(R)}{(R + 2R + R_x)} = R_x$$

By solving above equation $R_x = (\sqrt{3} - 1)R$

14. In loop ABCDEA $20 - 4i - 2i_1 - 10 = 0$
 $\Rightarrow -2i - i_1 = -5 \Rightarrow i_1 = -2i + 5$



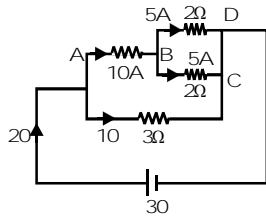
In loop ABCDFA $20 - 4i - 10 - 2i_2 = 0 \Rightarrow i_2 = -2i + 5$

In loop ABCDFGA $20 - 4i - 10 - 4(i - i_1 - i_2) = 0$



Put the values of i_1 & i_2
 $\Rightarrow 10 - 4i - 4(1 + 2i - 5 + 2i - 5) = 0$
 $\Rightarrow 10 - 4i - 20i + 40 = 0 \Rightarrow i = \frac{25}{12} \text{ A}$

15. Circuit can be redrawn as



$$R_{eq} = \frac{3}{2} \Omega; I = \frac{V}{R_{eq}} = 20 \text{ A}$$

Current In $I_{CD} = I_{AC} + I_{B'}$; $I_{CD} = 15 \text{ A}$

16. (i) $i = \frac{-i_0}{T_0} t + i_0$; $\int dq = \int -\frac{i_0 t}{T_0} dt + \int i_0 dt$

$$Q = -\frac{i_0 T_0}{2} + i_0 T_0 = \frac{i_0 T_0}{2}$$

(ii) $i = i_0 \left(1 - \frac{t}{T_0} \right)$

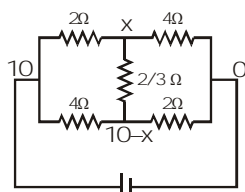
(iii) Heat = $i^2 R dt$ [$\because i = i_0 \left(\frac{1-t}{T_0} \right)$]

$$= \int \frac{i_0^2}{T_0^2} t^2 + \int i_0^2 dt - \int_0^{T_0} \frac{2i_0^2}{T_0} t dt$$

$$= \frac{i_0^2}{T_0^2} \frac{T_0^3}{3} + i_0^2 T_0 - i_0^2 T_0$$

$$\text{Heat} = \frac{i_0^2 T_0}{3}$$

17. Submission of current at the Node 'X' is



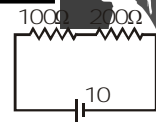
$$\frac{x-10}{2} + \frac{x-0}{4} + 3 \left(\frac{2x-10}{2} \right) = 0$$

$$\Rightarrow 15x - 20 - 60 = 0 \Rightarrow x = \frac{80}{15}$$

$$\text{Current} = \frac{\Delta V}{R} = \left[\frac{10}{15} \times \frac{3}{2} \right] = 1 \text{ A}$$

18. Potential difference across voltmeter is same as that of 200Ω

$$V_1 = \left(\frac{200}{300} \right) 10 = \frac{20}{3} \text{ V}$$



19. $5 - ir = 4 \Rightarrow i = 1 \text{ A}$
 $1 \times R = 4 \text{ V} \Rightarrow R = 4 \Omega$

20. $\frac{R_1}{R_2} = \frac{40}{60} = \frac{4}{6} \dots (i)$; $\frac{R_1(R_2 + 10)}{R_2 \times 10} = 1$

$$R_1 R_2 + 10 R_1 = R_2 \times 10 \dots (ii)$$

By solving (i) and (ii) $R_1 = \frac{10}{3} \Omega$; $R_2 = 5 \Omega$

21. (i) Current due to primary circuit

$$i = \frac{1E_p}{R_{pm} + r} = \frac{10}{10} = 1 \text{ Amp}$$

$$\Delta V = IR_{PM} \Rightarrow \Delta V = 9 \text{ volt}$$

$$\text{Potential gradient} = \frac{9}{12}$$

$$\left(\frac{9}{12} \right) (\ell_1) = 4.5 \Rightarrow \ell_1 = 6 \text{ m}$$

(ii) $i = \frac{E_p}{R_{PM} + r + R_{ext}} = \frac{10}{9 + 1 + 10} = \frac{1}{2} \text{ A}$

$$\Delta V = iR_{PM} = \frac{1}{2} \times 9R = 4.5 \text{ volt}$$

$$\text{Potential gradient } x = \frac{\Delta V}{L} = \frac{4.5}{12}$$

$$\text{S.C} = x\ell_1 = \left(\frac{4.5}{12} \right) \times 8 = 3 \text{ V}$$

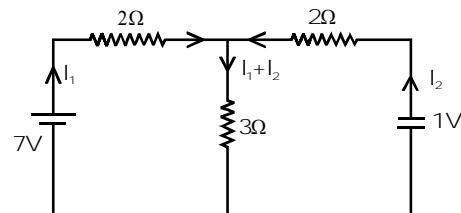
$$V = E - ir, iR = 3 \Rightarrow i = \frac{3}{2}$$

$$= 4.5 - \left(\frac{3}{2} \right) r = 3 \Rightarrow r = 1 \Omega$$

22. Power developed in it is maximum when external resistance = internal resistance.

$$\frac{nr}{324/n} = R \Rightarrow \frac{9n^2}{324} = 4 \Rightarrow n = 12$$

23. Applying KVL



$$7 = 2I_1 + 3(I_1 + I_2), 1 = 2I_2 + 3(I_1 + I_2)$$

$$\Rightarrow I_1 = 2 \text{ A}, I_2 = -1 \text{ A}$$

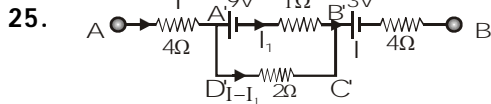
$$\text{Power supplied by } E_1 = a = E_1 I_1 = 14 \text{ W}$$



Power supplied by $E_2 = b = E_2 I_2 = -1W$

Therefore $a + b = 14 - 1 = 13W$

24. Heat developed will be maximum for the resistor '4' because (P.D.) will be maximum for the branch containing '5Ω' and '4Ω'



By applying K.V.L

$$V_A - 4I - 9 - I_1 - 3 - 4I = V_B$$

$$16 = +8I + I_1 + 12$$

$$8I + I_1 = 4V \dots(i)$$

By applying K.V.L. in loop A'B'C'D'A'

$$-9 - I_1 + 2(I - I_1) = 0$$

$$-3I_1 + 2I = 9 \dots(ii)$$

By solving (i) and (ii) Current in 2Ω resistance is 3.5A.

26.(i) $I = \int \vec{J} \cdot \vec{d}_A = J_0 \int_0^R \left(1 - \frac{r}{R}\right) 2\pi r dr = J_0 2\pi \left[\int_0^R r dr - \int_0^R \frac{r^2}{R} dr \right]$

$$= J_0 2\pi \left[\frac{R^2}{2} - \frac{R^2}{3} \right] = J_0 \left(\frac{2\pi R^2}{6} \right) = \frac{J_0 A}{3}$$

(ii) $J = \int_0^R J_0 \left(\frac{r}{R}\right) 2\pi r dr = \frac{J_0 2\pi}{R} \int_0^R r^2 dr = \frac{J_0 2\pi R^2}{3} = \frac{2J_0 A}{3}$

27. Potential gradient = $x = 0.2$

$$E_2 = x l_1$$

$$1.5 = (0.2) l_1$$

$$l_1 = 7.5m$$

(a) $i = \frac{2}{35}, V = ir \Rightarrow x = \frac{12}{70}$

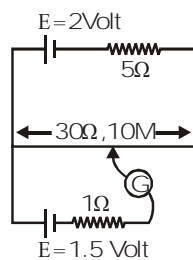
$x l_1 = S.C.$

$$\Rightarrow \frac{12}{70} l_1 = \frac{15}{10} \Rightarrow l_1 = \frac{15 \times 7}{12} = 8.75m$$

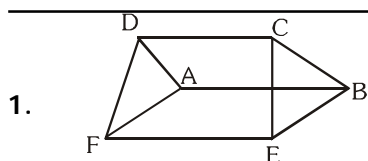
(b) $S.C. = \left(\frac{E}{R+r_1}\right) R = \left(\frac{1.5}{6}\right) 5 = 1.25$

$$S.C. = x l_2$$

$$1.25 = 0.2 (l_2) \Rightarrow l_2 = 6.25m$$



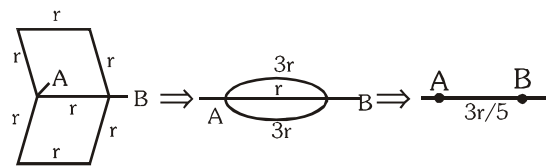
EXERCISE -IV B



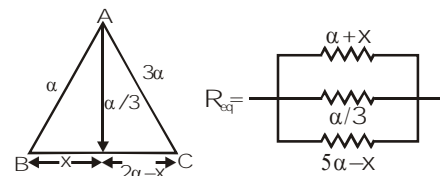
By symmetry D and F are at same potential and C

and E .

And by symmetry C and E are at same potential. So we can removed DF and CE



- 2.



$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{(\alpha+x)} + \frac{3}{\alpha} + \frac{1}{(5\alpha-x)}$$

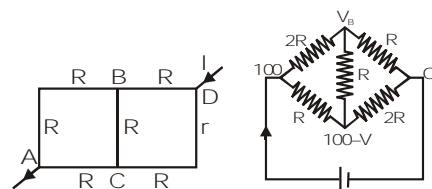
$$= \frac{\alpha(5\alpha-x) + 3(\alpha+x)(5\alpha-x) - 2(\alpha+x)}{\alpha(\alpha+x)(5\alpha-x)}$$

$$\frac{1}{R_{eq}} = \frac{5\alpha^2 - \alpha x + \alpha^2 + \alpha x + 15\alpha^2 - 3x^2 + 12\alpha x}{\alpha(\alpha+x)(5\alpha-x)}$$

$$R_{eq} = \frac{\alpha(\alpha+x)(5\alpha-x)}{21\alpha^2 + 12\alpha x - 3x^2} \Rightarrow \frac{dR_{eq}}{dx} = 0$$

$$R_{eq} (\max) = \frac{3}{11} \alpha$$

3. By applying nodal analysis at note 'B' and 'C'.
(: 3 2 B 7 C 4 : 3 7 < 9 5 7 5 9)



$$\frac{V-100}{2R} + \frac{2V-100}{R} + \frac{V-0}{R} = 0$$

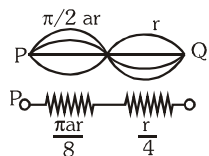
$$\Rightarrow 7V - 300 = 0 \Rightarrow V_B = \frac{300}{7} \text{ and } V_C = \frac{400}{7}$$

$$I_{BC} = \frac{V_B - V_C}{R} = \frac{100}{7R}$$

$$I = \frac{200}{7R} + \frac{300}{7R} = \frac{500}{7R} = \frac{5}{7} \left(\frac{100}{R}\right)$$

i.e. times the length of any side.

4. By path symmetry potential of points A,B,C,D is same.)



$$R_{eq} = \frac{ra}{4} \left(\frac{\pi}{2} + 1 \right) \Rightarrow R_{eq} = \frac{ra}{8} (\pi + 2)$$

5. $I = I_0 \sin\left(\frac{2\pi t}{T}\right)$

As $\frac{dq}{dt} = I$ so $Q = 2 \int_0^{T/2} I_0 \sin\left(\frac{2\pi t}{T}\right) dt = \frac{2I_0 T}{\pi}$

Total heat generated

$$= \int_0^T I^2 R dt = \int_0^T I_0^2 R \sin^2\left(\frac{2\pi t}{T}\right) dt$$

$$= \frac{I_0^2 R}{2} \int_0^T \left(1 - \cos\frac{4\pi t}{T}\right) dt = \frac{I_0^2 R}{2} (T)$$

$$= \left(\frac{Q\pi}{2T}\right)^2 \left(\frac{RT}{2}\right) = \frac{Q^2 \pi^2 R}{8T}$$

6. $R = \rho \frac{\ell}{A}$

$$\int_0^R dR = \int_0^L \frac{\rho_0 e^{-x/L} dx}{A}$$

$$R = \frac{\rho_0 L}{A} \left(1 - \frac{1}{e}\right) = \frac{\rho_0 L (e-1)}{Ae}$$

$$I = \frac{V}{R} = \frac{V_0 A}{\rho_0 L} \left(\frac{e}{e-1}\right)$$

7. Current with both switches opened is -

$$\frac{V}{R_{eq}} = \frac{1.5}{450} = \frac{1}{300} = i$$

After closing the switch

$$V_1 + V_2 = V$$

$$\frac{1}{3} + V_2 = \frac{3}{2}$$

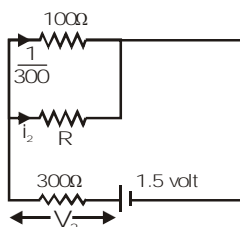
$$V_2 = \frac{9-2}{6} = \frac{7}{6}$$

$$i = \frac{7}{1800}$$

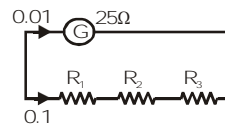
By kirchoffs first law

$$i_2 = \frac{7}{1800} - \frac{1}{300} = \frac{1}{1800}; \quad i_2 R = i_1 R_1$$

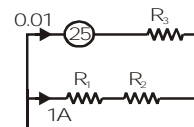
$$R = 1800 \left(\frac{1}{3}\right) = 600\Omega$$



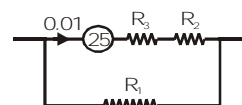
8. $(0.01)G = 0.1(R_1 + R_2 + R_3)$
 $G = 10(R_1 + R_2 + R_3) \dots (i)$



$(0.01)G = 1(R_1 + R_2) \dots (ii)$



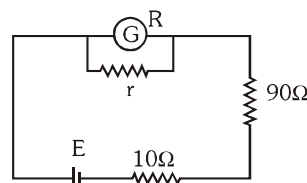
$(0.01)G = 10R_1 \dots (iii)$



By solving Equation (i), (ii) and (iii)

$$R_1 = 0.0278\Omega; \quad R_2 = 0.25\Omega; \quad R_3 = 2.5\Omega$$

9.



Assume 1 division have x ampere When $r=10\Omega$

$$\frac{E}{90 + 10 + 10R / (10 + R)} = 9x \dots (i) \text{ When } r=50\Omega$$

$$\frac{E}{90 + 10 + 50R / (50 + R)} = 30x \dots (ii)$$

(i) divided by (ii)

$$\frac{(10 + R)}{100(10 + R) + 10R} \times \frac{100(50 + R) + 50R}{(50 + R)} = \frac{9}{30}$$

$$\frac{(10 + R)(500 + 15R)}{(100 + 11R)(50 + R)} = \frac{9}{30}$$

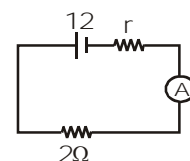
After solving $R = 233.3 \Omega$

10. $R_A = \frac{S \times G}{S + G}; \quad R_A = \frac{99 \times 1}{100} = 0.99\Omega$

$$3(2 + r + 0.99) = 12$$

$$\Rightarrow 2 + r + 0.99 = 4$$

$$\Rightarrow r = 1.01 \Omega$$



$$I_g(R + G) = V; \quad I_g S = (I - I_g)G; \quad I_g (S + G) = 4IG$$



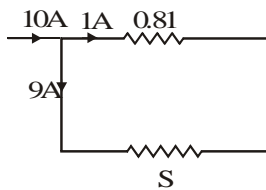
By solving the above equation we get the answers.

EXERCISE -V-A

- In order to convert an ammeter into a voltmeter, one has to connect a high resistance in series with it.
- The emf of the standard cell $E \propto 100$
The emf of the secondary cell $e \propto 30$

$$\frac{E}{e} = \frac{100}{30} \Rightarrow e = \frac{30E}{100}$$

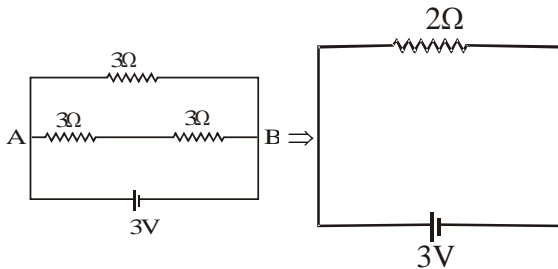
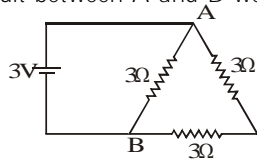
- $I_g = 1A$; $G = 0.81\Omega$; $I = 10A$



$$S = \left(\frac{I_g}{I - I_g} \right) G ; S = \frac{1}{9} \times 0.81 = 0.09\Omega$$

- On redrawing the circuit between A and B we get

$$I = \frac{3V}{2\Omega} = 1.5A$$



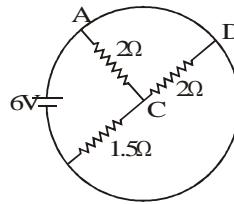
- For a given volume, the resistance of the wire is expressed as

$$R = \frac{\rho l^2}{\text{Volume}} \Rightarrow R \propto l^2$$

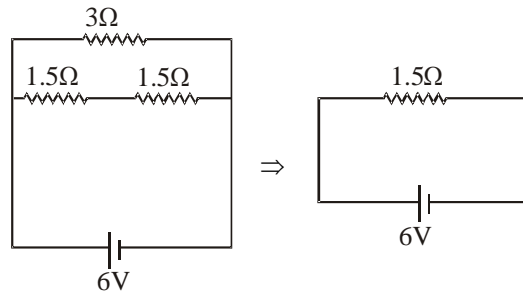
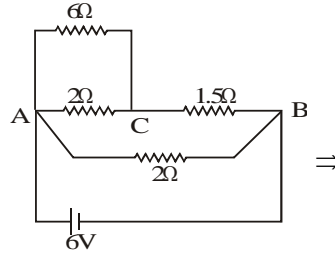
$$\frac{R_2}{R_1} = \left(\frac{2l}{l} \right)^2 = 4 \Rightarrow \frac{R_2 - R_1}{R_1} = 3$$

So, the change in resistance of wire will be 300%

7.



On redrawing the diagram, we get $I = \frac{6}{1.5} = 4A$



- Let resistances be R_1 and R_2

then $S = R_1 + R_2$ and $P = \frac{R_1 R_2}{R_1 + R_2}$

$$n = \frac{S}{P} = \frac{(R_1 + R_2)^2}{R_1 R_2} = \frac{R_1}{R_2} + \frac{R_2}{R_1} + 2$$

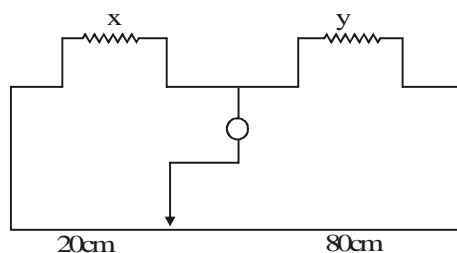
$$= \left(\sqrt{\frac{R_1}{R_2}} - \sqrt{\frac{R_2}{R_1}} \right)^2 + 4 \Rightarrow n_{\min} = 4$$

- Given that $\frac{l_1}{l_2} = \frac{4}{3}$ & $\frac{r_1}{r_2} = \frac{2}{3} \Rightarrow \frac{A_1}{A_2} = \frac{r_1^2}{r_2^2} = \frac{4}{9}$

In parallel : $I_1 R_2 = I_2 R_1$

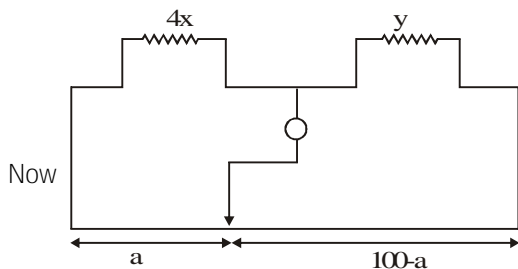
hence $\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{l_2}{A_2} \times \frac{A_1}{l_1} = \frac{3}{4} \times \frac{4}{9} = \frac{1}{3}$

10.





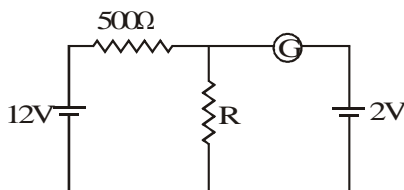
$$\frac{x}{20} = \frac{y}{80} \Rightarrow \frac{x}{y} = \frac{1}{4}$$



$$\frac{4x}{a} = \frac{y}{100-a} \Rightarrow a = 50 \text{ cm}$$

12. Voltage across $R=2V$

Hence, voltage across $500\Omega=10V$

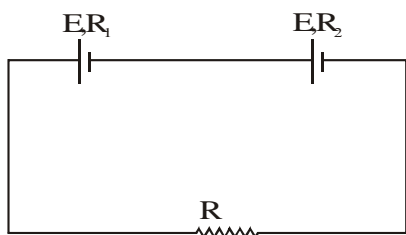


$$\text{Current through } 500\Omega = \frac{10}{500} = \frac{1}{50} \text{ A}$$

As 500Ω and $R\Omega$ are in series value of

$$R = \frac{V_R}{I_R} = \frac{2}{1/50} = 100\Omega$$

- 13.



Current in the circuit $= \frac{2E}{R_1 + R_2 + R}$
 potential difference across cell with R_2 resistance

$$= E - IR_2 = E - \frac{2E}{R_1 + R_2 + R} \times R_2$$

But potential difference = 0

$$\Rightarrow E = \frac{2E}{R_1 + R_2 + R} \times R_2 \Rightarrow R = R_2 - R_1$$

14. Current supplied by the source to the external resistance

$$I = \frac{E}{R+r}$$

$$\text{If } () r \gg R; I = \frac{E}{r}$$

which will be constant

15. The internal resistance of a cell

$$r = \left(\frac{e}{V_T} - 1 \right) R = \left(\frac{I_1}{I_2} - 1 \right) R = \left(\frac{240}{120} - 1 \right) 2 = 2\Omega$$

16. Kirchoff's first law is based on law of conservation of charge. Kirchoff's second law is based on law of conservation of energy.

17. Specific resistance (ρ_B) = $2\rho_A$; diameter $d_B = 2d_A$

$$\frac{\ell_B}{\ell_A} = ? \text{ for } \frac{(\text{Resistance})_B}{(\text{Resistance})_A} = 1$$

$$\frac{\rho_B \ell_B}{A_B} = \frac{\rho_A \ell_A}{A_A} \quad \frac{\ell_B}{\ell_A} = \frac{\rho_A A_B}{\rho_B A_A}$$

$$\frac{\ell_B}{\ell_A} = \frac{\rho_A (\text{dia}_B)^2}{\rho_B (\text{dia}_A)^2} = \frac{1}{2} \times 2^2 = 2$$

18. Given that

$$R_{100^\circ\text{C}} = 100\Omega$$

$$R_{T^\circ\text{C}} = 200\Omega$$

$$T = ?$$

$$R_{100} = R_0 [1 + \alpha(100)] \dots (i)$$

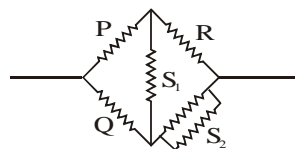
$$R_T = R_0 [1 + \alpha T] \dots (iii)$$

On dividing eq. (2) by eq. (1), we get

$$\frac{R_T}{R_{100}} = \frac{1 + \alpha T}{1 + 100\alpha}$$

On solving, we get $T = 400^\circ\text{C}$

- 19.

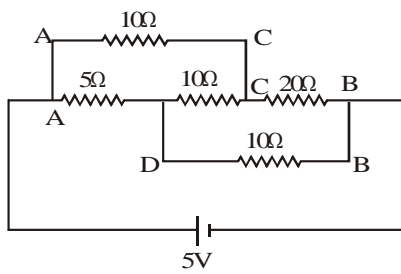


Under balanced condition

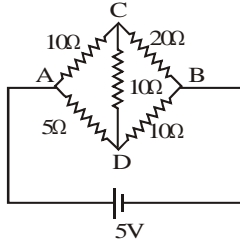
$$\frac{P}{Q} = \frac{R}{\frac{S_1 S_2}{S_1 + S_2}} \Rightarrow \frac{P}{Q} = \frac{R(S_1 + S_2)}{S_1 S_2}$$



20.

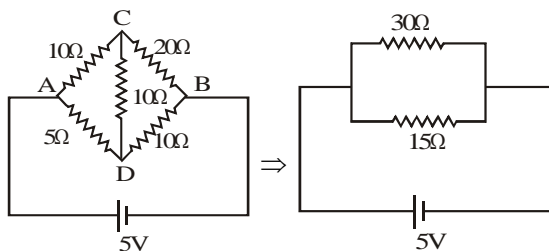


On redrawing the circuit, we get



It is a balanced Wheatstone bridge having R_{eff} as

$$R_{\text{eff}} = \frac{30 \times 15}{45} = 10\Omega$$



The current delivered by the source is

$$I = \frac{V}{R} = \frac{5}{10} = 0.5\text{A}$$

21. Let the resistance of the wire at 0°C is R_0 also let the temperature coefficient of resistance is α .

$$R_{50} = R_0[1 + \alpha(50 - 0)] \dots (i)$$

$$\text{Similarly } R_{100} = R_0[1 + \alpha(100 - 0)] \dots (ii)$$

On dividing equation (ii) by equation (i), we get

$$\frac{R_{100}}{R_{50}} = \frac{1 + 100\alpha}{1 + 50\alpha}; \quad \frac{6}{5} = \frac{1 + 100\alpha}{1 + 50\alpha}$$

$$\Rightarrow 6 + 300\alpha = 5 + 500\alpha \Rightarrow 1 = 200\alpha$$

$$\alpha = \frac{1}{200} / ^\circ\text{C}$$

On replacing $\alpha = \frac{1}{200} / ^\circ\text{C}$ in equation (i), we get

$$5 = R_0 \left[1 + \frac{1}{200} 50 \right] \Rightarrow 5 = R_0 \left[1 + \frac{1}{4} \right]$$

$$\Rightarrow 5 = R_0 \left[\frac{5}{4} \right] \Rightarrow R_0 = 4\Omega$$

22. $\frac{55}{20} = \frac{R}{80} \Rightarrow R = \frac{55 \times 8}{2} = 220\Omega$

24. Choosing A as origin,

$$E = \rho j = \rho \frac{l}{2\pi r^2}$$

25. $V_C - V_B = -\frac{\rho l}{2\pi} \int_a^{(a+b)} \frac{1}{r^2} dr = \frac{\rho l}{2\pi} \left[\frac{1}{(a+b)} - \frac{1}{a} \right]$

$$V_B - V_C = -\frac{\rho l}{2\pi} \left[\frac{1}{a} - \frac{1}{(a+b)} \right]$$

27. For series combination

$$\alpha_s = \frac{\alpha_1 R_{01} + \alpha_2 R_{02}}{R_{01} + R_{02}}$$

$$R_{01} = R_{02} = R_0 \text{ (given)}$$

$$\alpha_s = \frac{\alpha_1 + \alpha_2}{2}$$

For parallel combination

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow \frac{1}{R_{\text{eq}}} = \frac{1}{R_0(1 + \alpha_1 t)} + \frac{1}{R_0(1 + \alpha_2 t)}$$

$$\frac{1}{\frac{R_0}{2}(1 + \alpha_p t)} = \frac{1}{R_0(1 + \alpha_1 t)} + \frac{1}{R_0(1 + \alpha_2 t)}$$

$$2(1 + \alpha_p t)^{-1} = (1 + \alpha_1 t)^{-1} + (1 + \alpha_2 t)^{-1}$$

using binomial expansion

$$2 - 2\alpha_p t = 1 - \alpha_1 t + 1 - \alpha_2 t \Rightarrow \alpha_p = \frac{\alpha_1 + \alpha_2}{2}$$

28. $R = \rho \frac{l}{A} \Rightarrow R \propto l^2$

$$\frac{\Delta R}{R} = \frac{\Delta R}{R} = \frac{2\Delta l}{l} = 2[0.1] = 0.2\% \text{ increase.}$$

29. $R = R_1 + R_2 + R_3 + R_4 \Rightarrow \Delta R = \frac{5}{100} \times 100 = 5\Omega$

$$\Delta R = \Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4 = 20$$

For combination $\frac{\Delta R}{R} \times 100 = \frac{20}{400} \times 100 = 5\%$

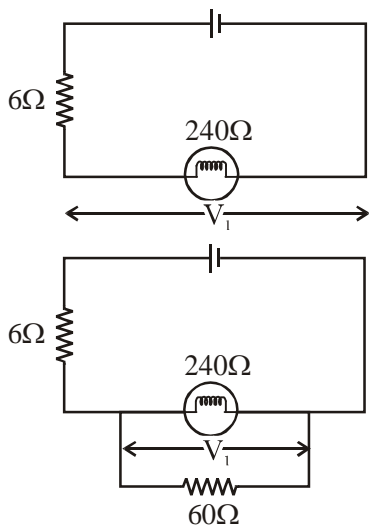
30. $i = 0.2\text{A}, \rho = 4 \times 10^{-7} \Omega\text{-m}, A = 8 \times 10^{-7} \text{m}^2$

$$x = \frac{i\rho}{A} = \frac{0.02 \times 4 \times 10^{-7}}{8 \times 10^{-7}} = 0.1 \text{V/m}$$

31. Due to greater heating as $H = I^2 R$
25W get fused.



32.



$$R_{\text{bulb}} = \frac{(120)^2}{60} = 240\Omega$$

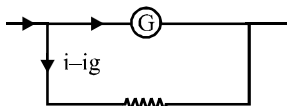
$$V_1 = \frac{120}{246} \times 240 = 117.07$$

$$R_{\text{heater}} = \frac{(120)^2}{240} = 60\Omega$$

$$V_2 = \frac{120}{54} \times 48 = 106.6$$

So change in voltage = $V_1 - V_2 \approx 10.4$ Volt

33. To increase the range of ammeter, resistance should be decreased (So additional shunt connected in parallel) so total resistance to ammeter decreases.



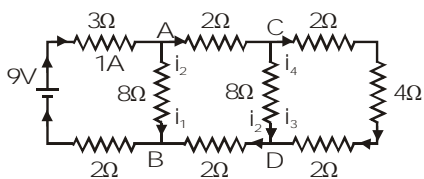
EXERCISE -V-B

Single Choice

1. Net resistance of the circuit is 9Ω .

\therefore current drawn from the battery,

$$i = \frac{9}{9} = 1A = \text{current through } 3\Omega \text{ resistor}$$



Potential difference between A and B is

$$V_A - V_B = 9 - (3+2) = 4V = 8i_1$$

$$\therefore i_1 = 0.5 A \quad \therefore i_2 = 1 - i_1 = 0.5 A$$

Similarly, potential difference between C and D

$$V_C - V_D = (V_A - V_B) - i_2(2+2) = 4 - 4i_2 = 4 - 4(0.5) = 2V = 8i_3 \quad \therefore i_3 = 0.25 A$$

$$\text{Therefore, } i_4 = i_2 - i_3 = 0.5 - 0.25 \Rightarrow i_4 = 0.25 A$$

2. As there is no change in the reading of galvanometer with switch S open or closed. It implies that bridge is balanced. Current through S is zero and

$$I_R = I_G, I_P = I_Q.$$

3. Current I can be independent of R_6 only when R_1, R_2, R_3, R_4 and R_6 form a balanced wheatstone's bridge.

$$\text{Therefore, } \frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow R_1 R_4 = R_2 R_3$$

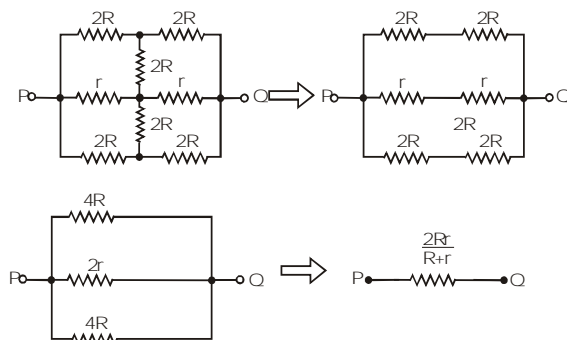
4. In the first case $\frac{(3E)^2}{R} t = ms\Delta T$..(i) $\left[H = \frac{V^2}{R} t \right]$

When length of the wire is doubled, resistance and mass both are doubled. Therefore, in the second case $t = (2m)s\Delta T$..(ii)

Dividing eq. (ii) by (i), we get

$$\frac{N^2}{18} = 2 \Rightarrow N^2 = 36 \Rightarrow N = 6$$

5. The circuit can be redrawn as follows



6. $P = \frac{V^2}{R}$ so, $R = \frac{V^2}{P} \therefore R_1 = \frac{V^2}{100}$ & $R_2 = R_3 = \frac{V^2}{60}$

$$\text{Now, } W_1 = \frac{(250)^2}{(R_1 + R_2)^2} \cdot R_1 \text{ and}$$

$$W_2 = \frac{(250)^2}{(R_1 + R_2)^2} \cdot R_2 \text{ and } W_3 = \frac{(250)^2}{R_3}$$

$$W_1 : W_2 : W_3 = 15 : 25 : 64 \Rightarrow W_1 < W_2 < W_3$$

7. Ammeter is always connected in series and voltmeter in parallel.

8. The ratio $\frac{AC}{CB}$ will remain unchanged.

9. $P = i^2 R$ Current is same, so $P \propto R$.

In the first case it is $3r$, in second case it is $(2/3)r$, in III



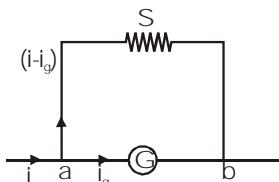
case it is $\frac{r}{3}$ & in IV case the net resistance is $\frac{3r}{2}$

$$R_{III} < R_{II} < R_{IV} < R_1 \therefore P_{III} < P_{II} < P_{IV} < P_1$$

10. $R_{PQ} = \frac{5}{11}r$, $R_{QR} = \frac{4}{11}r$ and $R_{PR} = \frac{3}{11}r$
 $\therefore R_{PQ}$ is maximum

11. BC, CD and BA are known resistance. The unknown resistance is connected between A and D.

12. $V_{ab} = i_g G = (i - i_g)S \therefore i = \left(1 + \frac{G}{S}\right) i_g$

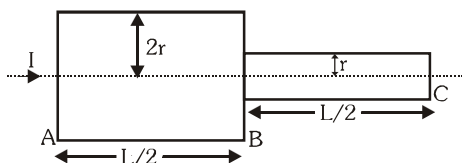


Substituting the values, we get $i = 100.1 \text{ mA}$

13. $W=0$. Therefore, from first law of thermodynamics, $\Delta U = \Delta Q = i^2 R t = (1)^2 (100) (5 \times 60) \text{ J} = 30 \text{ kJ}$

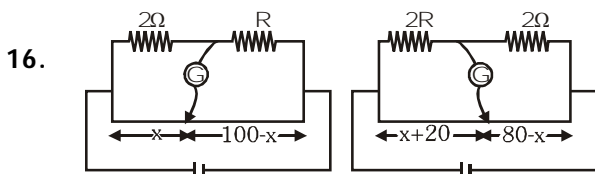
14. Current in the respective loop will remain confined in the loop itself. Therefore, current through 2Ω resistance = 0. Current always flow in closed path.

15. $H = I^2 R t$ $I \rightarrow$ same



So $H \propto R$ $R = \frac{\rho l}{\pi r^2}$ ρ, l same.

So $H \propto R \propto \frac{1}{r^2}$ $H_{BC} = 4H_{AB}$



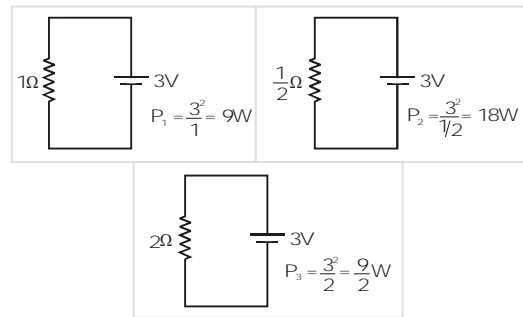
$R > 2\Omega \therefore 100 - x > x$

Applying $\frac{P}{Q} = \frac{R}{S}$

We have $\frac{2}{R} = \frac{x}{100-x} \dots(i)$ $\frac{R}{2} = \frac{x+20}{80-x} \dots(ii)$

Solving eq. (i) and (ii) we get $R = 3\Omega$

17. Given circuits can be reduced to



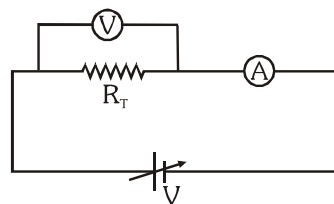
18. $P = \frac{V^2}{R}$ and $100W > 60W >$

$40W \Rightarrow \frac{V^2}{R_{100}} > \frac{V^2}{R_{60}} > \frac{V^2}{R_{40}} \Rightarrow \frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

Note : Although $100 = 60 + 40$ so at room temperature

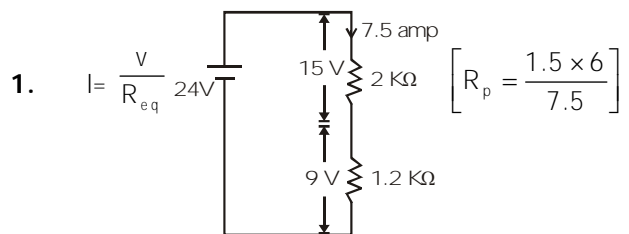
$\frac{V^2}{R_{100}} = \frac{V^2}{R_{60}} + \frac{V^2}{R_{40}} \Rightarrow \frac{1}{R_{100}} = \frac{1}{R_{60}} + \frac{1}{R_{40}}$ (Applicable Only at room temperature)

- 19.



20. $R = \frac{\rho L}{A} = \frac{\rho L}{L t} = \frac{\rho}{t} \Rightarrow$ independent of L

Multiple Choice



$I = \frac{240}{32} \Rightarrow \frac{60}{8} = 7.5 \text{ mA}$

(A) Current I is 7.5 mA

(B) Voltage drop across R_L is 9 volt



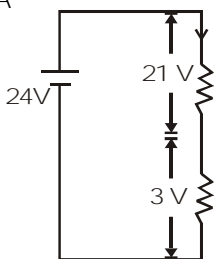
$$(C) \frac{P_1}{P_2} = \frac{V_1^2}{R_1} \times \frac{R_2}{V_2^2} = \frac{225 \times 1.2}{2 \times 81} \Rightarrow 1.6$$

(D) After interchanging the two resistor R_1 and R_2

$$I = \frac{V}{R_{eq}} = \frac{2.4}{(48)} \times 7 = 3.5 \text{ mA}$$

$$\frac{P_1}{P_2} = \frac{V_1^2}{R_L} \frac{R_L}{(V_2)^2} \Rightarrow \left(\frac{V_1}{V_2}\right)^2$$

$$\Rightarrow \left[\frac{9}{3}\right]^2 = 9$$

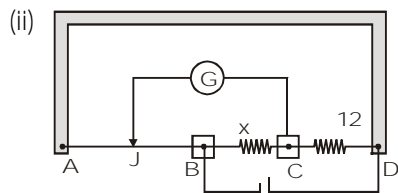


Assertion - Reason

1. **Ans. D**

Subjective Problems

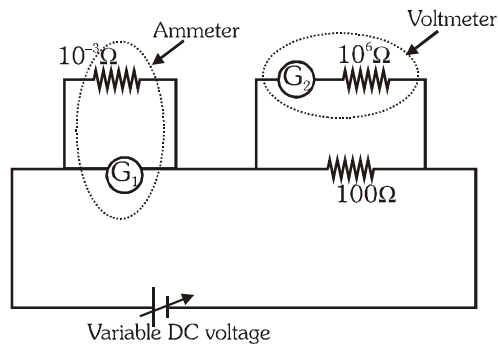
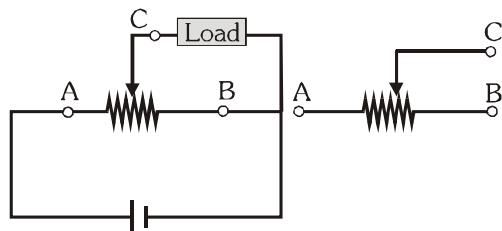
1. (i) There are no positive and negative terminals on the galvanometer because only zero deflection is needed.



(iii) $AJ = 60 \text{ cm} \therefore BJ = 40 \text{ cm}$
If no deflection is taking place. Then, the Wheatstone's bridge is said to be balanced,

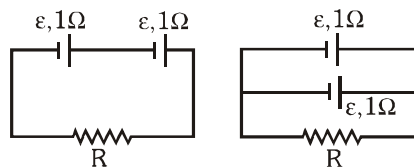
$$\text{Hence, } \frac{X}{12} = \frac{R_{BJ}}{R_{AJ}} \Rightarrow \frac{X}{12} = \frac{40}{60} = \frac{2}{3} \Rightarrow x = 8\Omega$$

2. The rheostat is as shown in figure. Battery should be connected between A and B and the load between C and B



3.

4. Slide wire bridge is most sensitive when the resistance of all the four arms of bridge is same. Hence, B is the most accurate answer.



5.

$$J_1 = \left(\frac{2\epsilon}{R+2}\right)^2 R \text{ and } J_2 = \left(\frac{\epsilon}{R+1/2}\right)^2 R \text{ as } \frac{J_1}{J_2} = 2.25$$

$$\text{so } \frac{4\epsilon^2}{(R+2)^2} = 2.25 \frac{4\epsilon^2}{(1+2R)^2} \Rightarrow R = 4\Omega$$