HINTS & SOLUTIONS

EXERCISE - 1
Single Choice

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

$\frac{4I}{\pi d^2} = nev \ldots$**(i)** $\quad \frac{16I}{\pi d^2} = nev' \ldots$**(ii)**

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

2. $j \to$ Current density $\quad n \to$ Charge density

$j = -nev_d \qquad v_{d_1} = \frac{j}{n_1 e}$

$v_{d_2} = \frac{j}{n_2 e}, \frac{n_1}{n_2} = \frac{1}{4} \Rightarrow n_2 = 4n_1$

$\frac{v_{d_1}}{v_{d_2}} = \frac{n_2}{n_1} = \frac{4n_1}{n_1} = 4:1$

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

4. $v_d = \frac{i}{Ane}$ As $A\uparrow$ so $v_d\downarrow \Rightarrow v_P > v_Q$

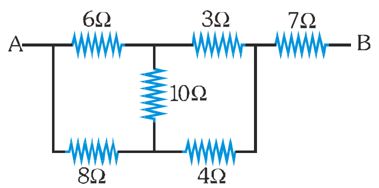
5. $R = \frac{\rho L}{A}\frac{L}{L} = \frac{\rho L^2}{V} \Rightarrow R \propto L^2$

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

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

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

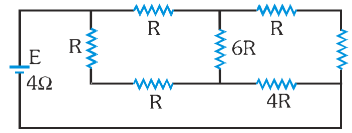
7.

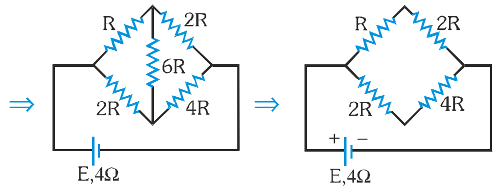


Balanced Wheatstone Bridge

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

8.

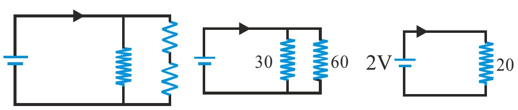




This is balanced wheat stone bridge
From maximum power transfer theorem
Internal resistance = External resistance

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

9.



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

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

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

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

Power across $P_X = P_Y = \left(\frac{\varepsilon^2}{4R}\right)R$

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 $\propto i^2R$ 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.

12. $R_1 = \frac{\rho \ell}{A_1}, R_2 = \frac{\rho \ell}{A_2}$ As $A_1 < A_2$ So $R_1 > R_2$

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

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

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

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

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

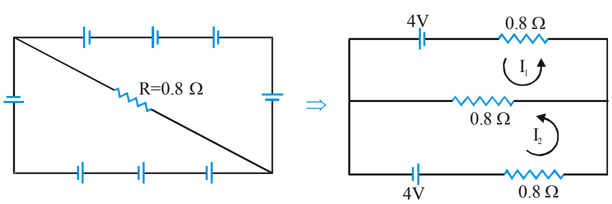
14. $V = \varepsilon + i(r) \Rightarrow 12.5 = \varepsilon + \frac{1}{2}(1) \Rightarrow \varepsilon = 12$ V

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

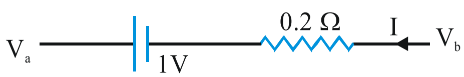
15. $V = IR \Rightarrow 0.2 = I(20)$
$I_g = 0.01$ A (through the galvanometer)
$I_g G = (i - i_g)S \Rightarrow (0.01)(20) = (10 - 0.01)S$
$\Rightarrow S = 0.020\ \Omega$

16. The correct answer is R = 0

17.



$1.6\, I_1 - 0.8\, I_2 = 4$ ...**(i)**
$1.6\, I_2 - 0.8\, I_1 = 4$ ...**(ii)**
from eq. $I_1 = I_2 = 5$
voltage difference across any of the battery.



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

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

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

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

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

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

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

22. $\frac{P}{S} = \frac{Q}{625} \Rightarrow \frac{P}{Q} = \frac{S}{625}$ ...**(i)**

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

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

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

23. Potential gradient

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

Effective emf of E_1 and E_2

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

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

24. Potential gradient

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

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

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

According to question

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

26. **(25W– 220V)**

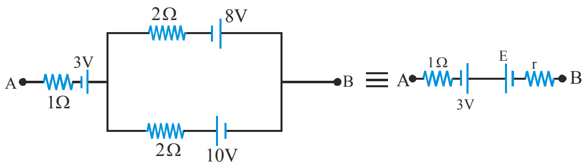
$P_1 = \frac{V_1^2}{R_1}, R_1 = \frac{(220)^2}{25} = 1936\Omega$

(100W–220V)

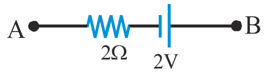
$P_2 = \frac{V_2^2}{R_2}, R_2 = \frac{(220)^2}{100} = 484\ \Omega$

In Series (I same)
$H = I^2Rt$, $H \propto R$ so if $R_1 > R_2$ then $H_1 > H_2$
R_1 is likely to fuse

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

28. 

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

$r=\frac{r_1 r_2}{r_1+r_2}=1\Omega$. Therefore 

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

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

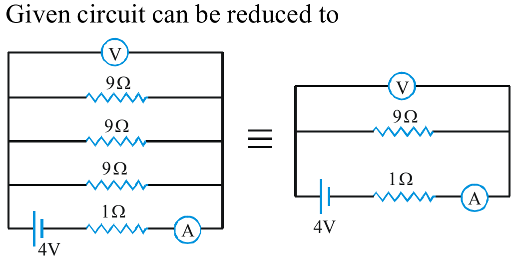
from eq. (i) & (ii) $P' = \frac{10}{9}P$

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

$\Rightarrow \frac{1}{9}\times 100 \Rightarrow 11.11\%$

30. 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.

31. Given circuit can be reduced to



Reading of ammeter $=\frac{4}{3+1}=1A$

Reading of voltmeter = 3 × 1 = 3V

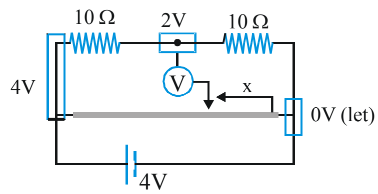
32. **Ans. (A)**

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

Potential difference across voltmeter,

$V = Ir - 2$

$\Rightarrow$ 2 sinπt = 0.2 × 50 x –2 $\Rightarrow$ 2 πcosπt = 10 V

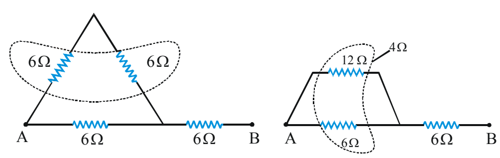


$\Rightarrow$ V = 20 π (cosπt) cm/s

34. Total length of wire = 90 + 90 = 180 m ; Total resistance of wire = 180/5 = 12 Ω.

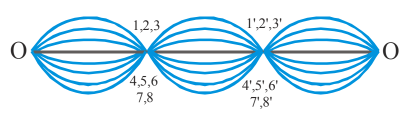
As $I = \frac{nE}{R+nr} \Rightarrow 0.25 = \frac{n\times 1.4}{12+5+n\times 2} \Rightarrow n = 4.7$

$\Rightarrow$ Total number of cells required = 5

35. 

$\Rightarrow$ 

$\Rightarrow R_{eq}=10\ \Omega$

36. 

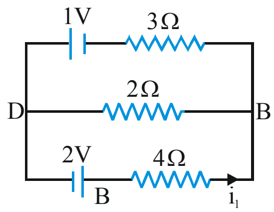
Points 1, 2, 3.........8 are of same potential and 1', 2', 3'.........8' are of same potential.

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

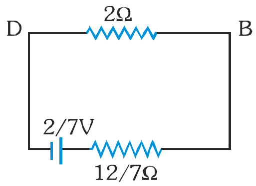
EXERCISE - 2

Part # I : Multiple Choice

1. $E_{eq} = \dfrac{E_1r_2 - E_2r_1}{r_1 + r_2} = \dfrac{2\times3 - 1\times4}{3+4} = \dfrac{2}{7}$



$r_{eq} = \dfrac{3\times4}{3+4} = \dfrac{12}{7}$; $i = \dfrac{2/7}{2+\dfrac{12}{7}} = \dfrac{1}{13}$A



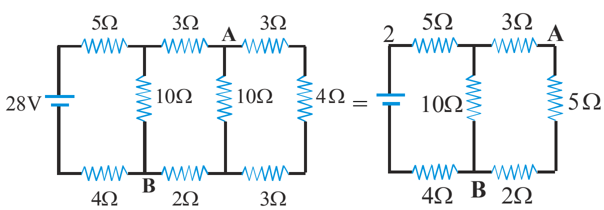
$V_B > V_D = 2\left(\dfrac{1}{13}\right)$; $V_D - V_B = -\dfrac{2}{13}$V

From Figure 1 :

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

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

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

2. 

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

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

4. $I = \dfrac{dq}{dt} = 2 - 16t$

Power : $P = I^2R = (2-16t)^2R$

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

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

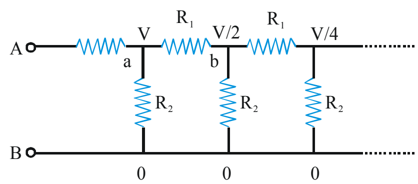
5. Both '4Ω' and '6Ω' resistors are short circuited therefore R_{eq} of the circuit in 2Ω is 10 A.

Power = VI = 200 watt

Potential difference across both 'A' and 'B' = 0

6. It is the concept of potentiometer.

7. By applying node analysis at point b



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

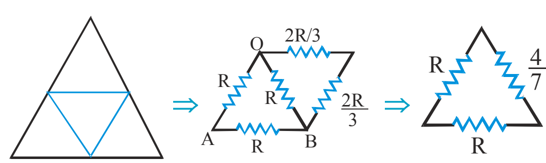
8. For wheat stone Bridge condition is $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

Therefore null point is independent of the battery voltage.

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

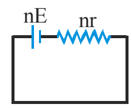
10. $V = E - ir \Rightarrow V = -ri + E$

Slope of graph 'V' and 'i' gives 'r' intercept of graph 'V' and 'i' gives E $\Rightarrow \tan\theta = \dfrac{y}{x} = r$.

11. 

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

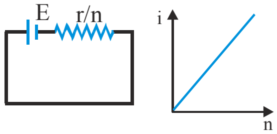
12. If n batteries are in series than the circuit can be made as

$i = \dfrac{nE}{nr} \Rightarrow \dfrac{E}{r}$ 

i.e. independent of n.

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

as $i = \dfrac{nE}{r}$



i is directly proportional to n .

14. Slope of 'V' vs 'i' graph give internal resistance

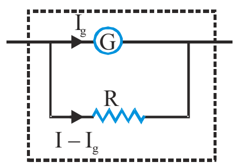
$\therefore r = 5\,\Omega$

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

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

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. 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 $I_g(R + G) = V$

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

$\Rightarrow R + G = 200\,k\Omega$

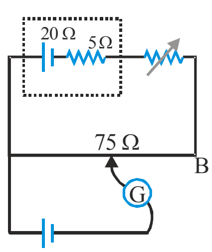
$\Rightarrow R \cong 200 k\Omega$

17. 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 $= i^2RT \Rightarrow (36)(2) = 72$ W

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

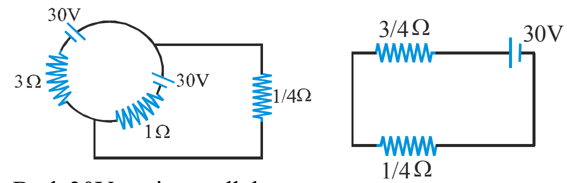
$i_{max} = \dfrac{20}{R_{max}} = \dfrac{20}{250} = \dfrac{2}{25}$ Amp



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

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

19.



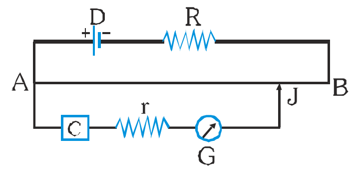
Both 30V are in parallel

$30 - \dfrac{1}{4}i - \dfrac{3}{4}i = 0 \Rightarrow i = 30\,A$

20. 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.



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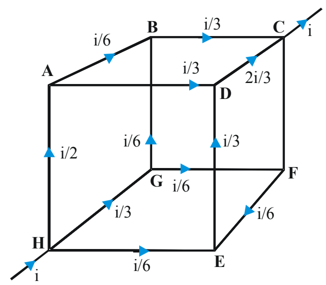


So current in FC=0

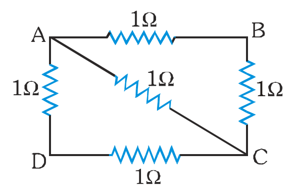
22. Assume DE $\Rightarrow R_1\Omega$

EC $\Rightarrow R_2\Omega$

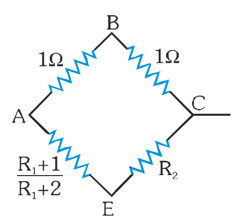
$R_1 + R_2 = 1\Omega$

$V_B = V_E$

Means balance wheat stone bridge



$\dfrac{P}{Q} = \dfrac{R}{S}; \dfrac{1}{1} = \dfrac{\frac{R_1+1}{R_1+2}}{R_2}$



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

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

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

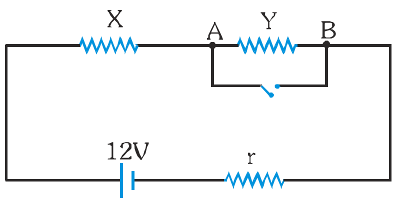
$\dfrac{CE}{ED} = \dfrac{R_2}{R_1} = \dfrac{2-\sqrt{2}}{\sqrt{2}-1} = \sqrt{2}$

23. $\dfrac{E_1+E_2}{r_1+r_2+R} < \dfrac{E_1}{r_1+R}$;$(E_1+E_2)(r_1+R) < E_1(r_1+r_2+R)$

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

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

24.



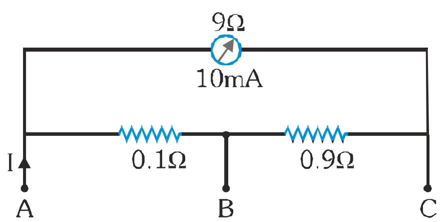
$\dfrac{12}{X+Y+r} = 1A \Rightarrow V_x = 1 = 1 \times X \Rightarrow X = 1\Omega$

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

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

$\Rightarrow 10 + 10r = 12 + 12 - 12r \Rightarrow 10r = 2 \Rightarrow r = 0.2\,\Omega$

25.



Between A and B

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

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

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

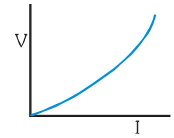
26. If all were in series all of them would have being getting discharged. But since, 2 are in opposite polarity, they will be getting charged.

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

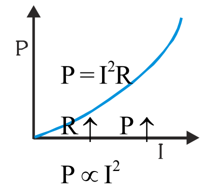
as (nE–4) as 4 batteries will be cancelled out

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

27.



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



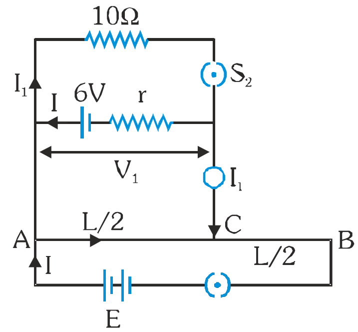
So $R\uparrow$

28. When S_2 open

Assume resistance of AB = R

Resistance of wire per unit length.

$x = \dfrac{R}{L}$ $\quad I = \dfrac{E}{R}$



Now in AC

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

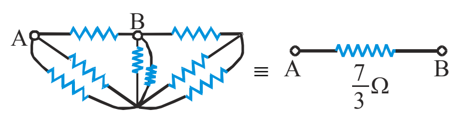
E = 12V

When S_2 closed

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

$\Rightarrow 6 - I_1 r = 5 \Rightarrow 6 - \left(\dfrac{5}{10}\right)r = 5 \Rightarrow r = 2\,\Omega$

29. Rearranged circuit between A & B is :



(due to symmetry)

Total resistance of circuit

$= \dfrac{7}{3} + \dfrac{2}{3} = 3\,\Omega$. $i = \dfrac{9}{3} = 3\,A$

Heat produced in cell

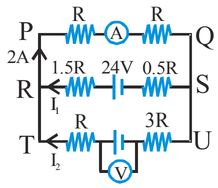
$= I^2 r = (3)^2 \times \left(\dfrac{2}{3}\right) = 6W$

Current in resistance connected directly between

$A \,\&\, B = \dfrac{7}{15} \times 3 = \dfrac{7}{5} = 1.4A$

$= \dfrac{7}{15} \times 3 = \dfrac{7}{5} = 1.4A$)

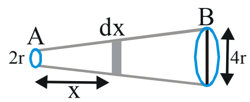
30. $V_P - V_Q = 2(2R) \Rightarrow 4R = 24 - (2R)I_1$



$\Rightarrow I_1R = 12 - 2R,\ E - I_2(4R) = 4R,\ I_1 + I_2 = 2$

$\Rightarrow\ E = 20R - 48$

31.



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

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

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

For null point

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

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

$$\Rightarrow 3 + 3\ell = 4 \Rightarrow \ell = \frac{1}{3}\,m$$

Part # II : Assertion & Reason

1. C **2.** B **3.** E **5.** A **6.** A **7.** B
8. A **9.** C **10.** D

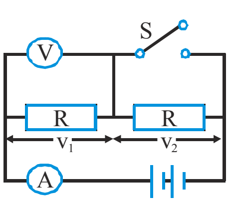
EXERCISE - 3

Part # I : Matrix Match Type

1. $A \to P$; $B \to Q, S$; $C \to S$; $D \to P, R, S$

2. $A \to Q$; $B \to P$; $C \to P$; $D \to Q$

3. 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.

4. For potentiometer short circuit = x ℓ_1
x Depends only on primary circuit
(A) $E_1\uparrow \Rightarrow x\uparrow \Rightarrow \ell_1\downarrow$ if secondary circuit remain same
(B) $R\uparrow \Rightarrow x\downarrow \Rightarrow \ell_1\uparrow$ if secondary circuit remain same
(C) S.C$\uparrow = \ell_1\uparrow$ if x remain same

Part # II : Comprehension

Comprehension–1

1. (A) **2.** (D) **3.** (D)

Comprehension–2

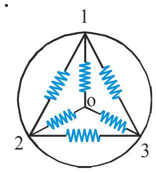
1. (B) **2.** (B) **3.** (D)

Comprehension–3

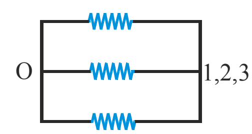
1. (C) **2.** (B)

Comprehension–4

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



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



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

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–5

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

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

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

2. $P = VI \quad 20kw \Rightarrow 2000 = \dfrac{V^2}{20}$

$\Rightarrow V = 200$ volt $\Rightarrow V < 200$ volt

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

Comprehension–6

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

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

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

where I is the current at ℓ = 0, & ε is the emf of the cell.

$\Rightarrow R = \frac{\varepsilon}{I} = \frac{1.2}{40 \times 10^{-3}} = 30\Omega$

Comprehension–7

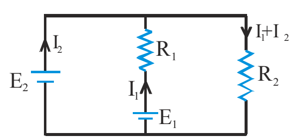
1. Current is maximum when resistance in the circuit is minimum. i.e. when S_1, S_3, S_5 are closed because then all resistances will be short circuited $I_{max} = \frac{V_0}{R}$.

2. After regular closing of switches, total resistance decreases gradually.

3. $P_1 = \frac{V_0^2}{R}$, $P_2 = \frac{V_0^2}{\frac{37}{7}R}$ So $\frac{P_1}{P_2} = \frac{7}{37}$

Comprehension–8

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



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

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

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

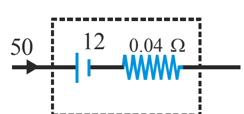
Now as $\frac{E_1}{R_1} = 0.3 \Rightarrow E_1 = 0.3 \times 20 = 6V$

Comprehension–9

1. V = E + ir

= 12 + (0.04) (50)

= 12 + 2 ⇒ 14 V



2. Loss in power

$= i^2 r = (50)^2 (.04) = 100$ W

3. Total input

– Loss in power

= Useful power

Input power = 14 (50) = 700 w

Loss in power = 100 w,

Rate of conversion = 600 watt

EXERCISE - 4

Subjective Type

Section (A)

1. 31 C, $\frac{31}{3}$ A

2. $\frac{1.5 \times 63.5 \times 10^{-3}}{1.6 \times 6 \times 9} = 1.1 \times 10^{-3}$ ms^{-1}

or 1.1 mm s^{-1}

3. **(i)** Q = 1200 C **(ii)** n = 75 x 10^{20}

Section (B)

4. **(a)** $n = \frac{2}{1.6} \times 10^{17} = 1.25 \times 10^{17}$

(b) $\frac{1}{2\pi} \times 10^6$ A/m^2.

5. 10 A. **6.** **(i)** 41°C **(ii)** $\frac{\ell n 2}{273}$ °C^{-1}.

7. T_2 **8.** 0.2 %

9. **(i)** $R = \frac{0.35}{2} = 0.175\,\Omega$ **(ii)** R = 7 x 10^{-5} Ω

Section (C)

10. **(a)** E = 10 V each

(b) **(A)** act as a source and **(B)** act as load

(c) $V_A = 9V$, $V_B = 11$ V

(d) $P_A = 9$ W, $P_B = 11$ W

(e) Heat rate = 1 W each

(f) 10 W each

(g) 9V, 11V

(h) –9W, 11 W

11. $\frac{125}{9}$ V

12. **(a)** all equal **(b)** b, then a and c equal
(c) a, c equal, b

13. **(a)** 7.5 V, **(b)** 24 mA **(c)** greater than 12 V.

14. **(a)** $\frac{50}{11} = 4.55$ A **(b)** $\frac{22 \times 11}{5} = 48.4\,\Omega$
(c) 1000 W **(d)** 240 cal s^{-1} **(e)** 80/3 gm

15. $\frac{125}{4} = 31.25$ watt

16. $P_A = 8$ W & $P_B = 32$ W, A is more likely to fail his examinations

17. **(a)** $V_A = V_B = V_C = V_D = 0$ V,
$V_E = V_F = V_G = V_H = 10$ V, $V_I = V_J = V_K = 15$ V
(b) $V_1 = 15$ V, $V_2 = 5$V, $V_3 = 15$ V
(c) each act as a source
(d) 17.5 A(↑), 15A(↓) 2.5 A(↑), 5A(↓) from left to right in given circuit.
(e) 1 Ω resistance
(f) left most battery.

18. $\frac{25}{9}$ V = 2.78 V, $\frac{5}{18}$ A = 0.278 A

19. 19V

20. **(a)** 10 Ω. **(b)** 3200 J

21. 5 A, 74 V, 49 V(+ve terminal is connected at point B)

Section (D)

22. $R_f = 2\Omega$.

23. **(a)** R = 10 Ω **(b)** 1A in each
(c) $V_3 = 3$V, $V_2 = 2$V, $V_4 = 4$V **(d)** 10 W **(e)** 1 W **(f)** 9W
(g) 9V **(h)** 4 Ω resistance **(i)** 3 W.

24. **(a)** R = 3 Ω **(b)** $i = 2$A, $i_1 = \frac{1}{2}$ A, $i_2 = 1$A, $i_3 = \frac{1}{2}$ A
(c) V = 4V in each **(d)** 12 W **(e)** 4W **(f)** 8 W
(g) 4Ω **(h)** 4W

25. **(a)** 3.7 V **(b)** 3.7 V

26. **(i)** $R_{AB} = 5/6\,\Omega$ **(ii)** $R_{CD} = 1.5\,\Omega$
(iii) $R_{EF} = 1.5\,\Omega$ **(iv)** $R_{AF} = 5/6\,\Omega$
(v) $R_{AC} = 4/3\,\Omega$

27. **(ii)** 1.5 A

28. **(i)** $\frac{150}{7} = 21.43$ V, **(ii)** 1600 Ω

29. CE : ED = $\sqrt{2} : 1$

30. 12.5 Ω, 170 Ω.

31. **(a)** 1 A **(b)** 2/3 A **(c)** 1/3 A

32. **(a)** 0.1 A **(b)** 0.3 A

Section (E)

33. **(i)** $\frac{12}{8.59} = 1.4$ A, **(ii)** $\frac{12 \times 8.5}{8.59} = 11.9$ V

34. **(i)** $\frac{1}{2} = 0.5$ A **(ii)** $\frac{1}{12} = 0.0833$ A
(iii) $1.5 + \frac{1}{2} \times 0.4 = 1.7$ V

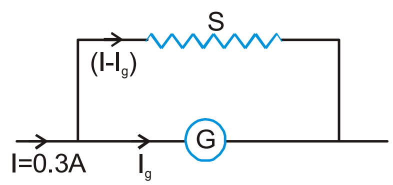
35. $V_B - V_A = 21/5 = 4.2$ V, I = 35/2 mA = 17.5 mA
(B to A)

36. zero in the upper 4 Ω resistor and 0.2 A in the rest two.

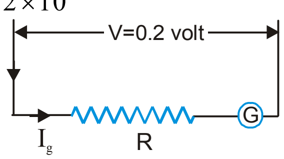
37. **(a)** $\frac{1.2}{2.1} = 0.57$ **(b)** 1 **(c)** $\frac{10.5}{6} = 1.75$

Section (F)

38.



(a) $S = \frac{30 \times 2 \times 10^{-3}}{0.3 - 2 \times 10^{-3}} = 0.2013\,\Omega$



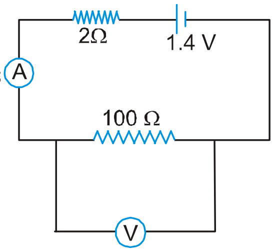
(b) R = 70 Ω

39. (a) 24 V, (b) 28 V

40. $V = \varepsilon / (\eta + 1) = 2.0$ V.

41. $\frac{20}{3}$V

42. **(i)**



(ii) 200 Ω

(iii) $1.1-\frac{4}{3}=-0.23$ V

43. $\left(\frac{70}{60}-1\right)\times 9.5=\frac{9.5}{6}$ ohm

44. **(a)** 1.25 V, **(b)** saving of galvanometer from damage and to prevent the cell discharging fast

(c) No, **(d)** Yes, **(e)** No, **(f)** No

45. $x=\frac{20}{7}\ \Omega,\ Y=\frac{20}{3}\ \Omega$

EXERCISE - 5

Part # I : AIEEE/JEE-MAIN

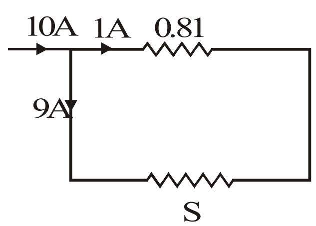
1. In order to convert an ammeter into a voltmeter, one has to connect a high resistance in series with it.

3. The emf of the standard cell $E \propto 100$

The emf of the secondary cell $e \propto 30$

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

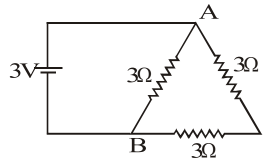
4. I_g=1A; G=0.81Ω; I=10A

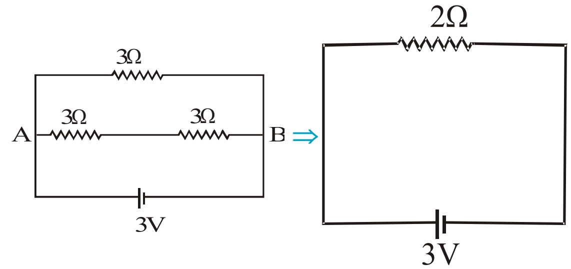


$$S=\left(\frac{I_g}{I-I_g}\right)G\ ;\ S=\frac{1}{9}\times 0.81=0.09\Omega$$

5. On redrawing the circuit between A and B we get

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





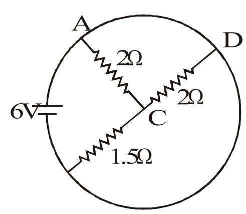
6. For a given volume, the resistance of the wire is expressed as

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

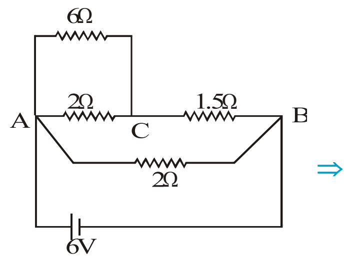
$$\frac{R_2}{R_1}=\left(\frac{2\ell}{\ell}\right)^2=4 \Rightarrow \frac{R_2-R_1}{R_1}=3$$

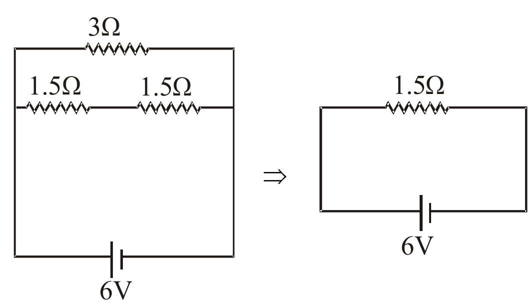
So, the change in resistance of wire will be 300%

7.



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





8. Let resistances be R_1 and R_2

then $S = R_1 + R_2$ and $P = \dfrac{R_1R_2}{R_1 + R_2}$

$$n = \frac{S}{P} = \frac{(R_1+R_2)^2}{R_1R_2} = \frac{R_1}{R_2} + \frac{R_1}{R_2} + 2$$

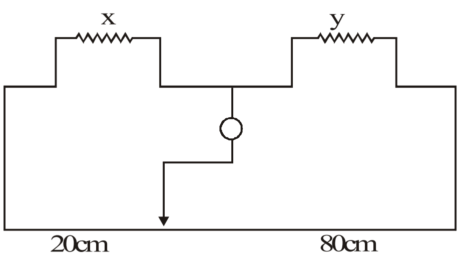
$$= \left(\sqrt{\frac{R_1}{R_1}} - \sqrt{\frac{R_2}{R_1}}\right)^2 + 4 \Rightarrow n_{min} = 4$$

9. Given that $\dfrac{\ell_1}{\ell_2} = \dfrac{4}{3}$ & $\dfrac{r_1}{r_2} = \dfrac{2}{3} \Rightarrow \dfrac{A_1}{A_2} = \dfrac{r_1^2}{r_2^2} = \dfrac{4}{9}$

In parallel : $I_1R_2 = I_2R_2$

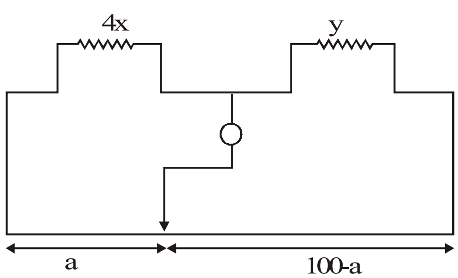
hence $\dfrac{I_1}{I_2} = \dfrac{R_2}{R_1} = \dfrac{\ell_2}{A_2} \times \dfrac{A_1}{l_1} = \dfrac{3}{4} \times \dfrac{4}{9} = \dfrac{1}{3}$

10.



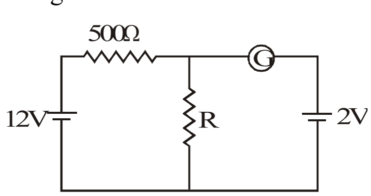
$$\frac{x}{20} = \frac{y}{80} \Rightarrow \frac{x}{y} = \frac{1}{4}$$

Now



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

12. Voltage across R=2V
Hence, voltage across 500Ω=10V

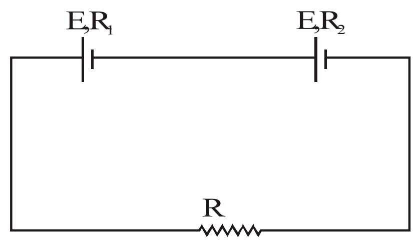


Current through 500 Ω $= \dfrac{10}{500} = \dfrac{1}{50}$ A $= \dfrac{10}{500} = \dfrac{1}{50}$ A

As 500Ω and RΩ are in series value of

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

13.



Current in the circuit $= \dfrac{2E}{R_1 + R_2 + R}$

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

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

If r>>R; $I = \dfrac{E}{r}$

which will be constant

15. The internal resistance of a cell

$$r = \left(\frac{e}{v_T} - 1\right)R = \left(\frac{l_1}{l_2} - 1\right)R = \left(\frac{240}{120} - 1\right)2 = 2\Omega$$

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 $(\rho_B) = 2\rho_A$; diameter $d_B = 2d_A$

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

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

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

18. Given that

$R_{100°C} = 100\Omega$

$R_{T°C} = 200\Omega$

T=?

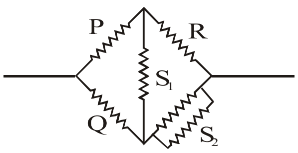
$R_{100}=R_0[1+\alpha(100)]$ ...**(i)**

$R_T=R_0[1+\alpha T]$ ...**(ii)**

On dividing eq. **(ii)** by eq. **(i)**, we get

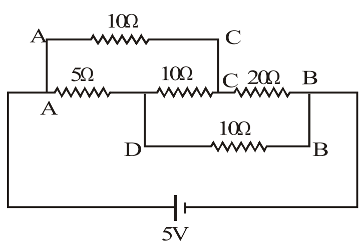
$$\frac{R_T}{R_{100}} = \frac{1+\alpha T}{1+100\alpha}$$

On solving, we get T=400°C

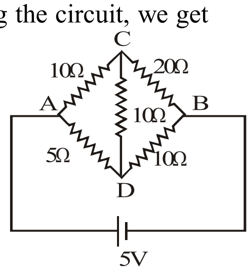
19. 

Under balanced condition

$$\frac{P}{Q} = \frac{R}{\frac{S_1S_2}{S_1+S_2}} \Rightarrow \frac{P}{Q} = \frac{R(S_1+S_2)}{S_1S_2}$$

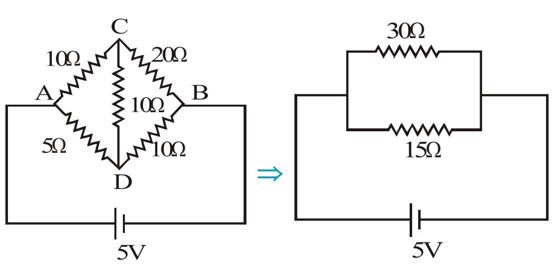
20. 

On redrawing the circuit, we get



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

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



The current delivered by the source is

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

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

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

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

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

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

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

$$\alpha = \frac{1}{200}/°C$$

On replacing $\alpha = \frac{1}{200}/°C$ 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,

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

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

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

27. For series combination

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

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

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

For parallel combination

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

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

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

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

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. $R = \rho\frac{\ell}{A} \Rightarrow R \;\alpha\; \ell^2$

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

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

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

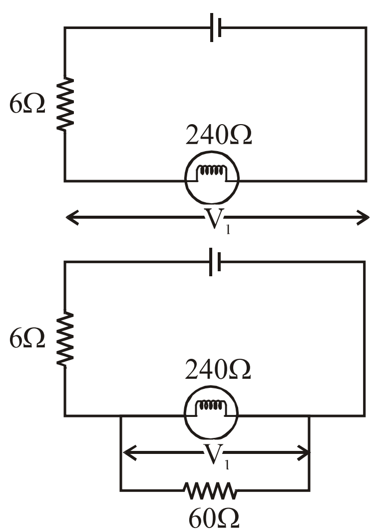
For combination $\frac{\Delta R}{R}\times 100 = \frac{20}{400}\times 100 = 5\%$

30. $i = 0.2$ A, $\rho = 4 \times 10^{-7}$ Ω-m, $A = 8 \times 10^{-7}$ 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 $H = I^2R$
25W get fused.

32.



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

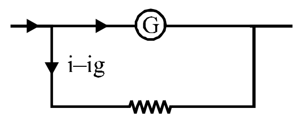
$$V_1 = \frac{120}{246}\times 240 = 117.07$$

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

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

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.



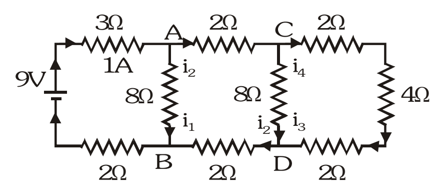
Part # II : IIT-JEE ADVANCED

Single Choice

1. Net resistance of the circuit is 9Ω.

∴ current drawn from the battery,

$i = \frac{9}{9}$ =1A = current through 3Ω 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

$V_C - V_D = (V_A - V_B) - i_2(2+2) = 4 - 4i_2 = 4 - 4(0.5) = 2V = 8i_3$

$\therefore i_3 = 0.25$ A

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.

Therefore, $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow R_1R_4 = R_2R_3$

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

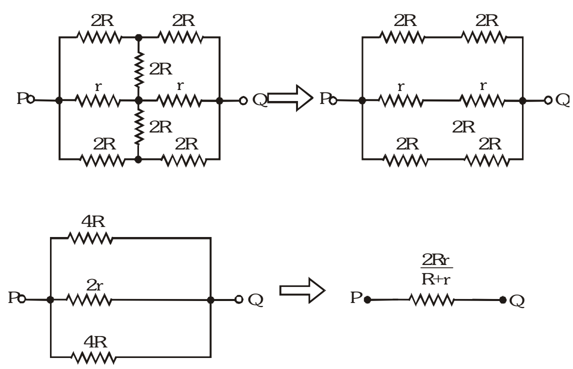
When length of the wire is doubled, resistance and mass both are doubled. Therefore, in the second case

$\frac{(NE)^2}{2R}.t = (2m)s\Delta T$ ....**(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, $R = \frac{V^2}{P}$

$\therefore R_1 = \frac{V^2}{100}$ & $R_2 = R_3 = \frac{V^2}{60}$

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

and $W_2 = \frac{(250)^2}{(R_1+R_2)^2} \cdot R_2$ 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. $P = i^2R$ 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 $\frac{3r}{2}$

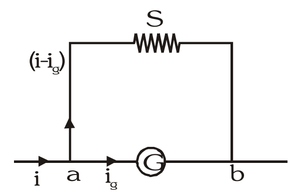
$R_{III} < R_{II} < R_{IV} < R_I$ $\therefore$ $P_{III} < P_{II} < P_{IV} < P_I$

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



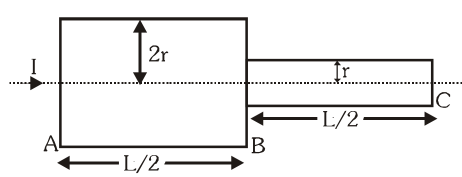
Substituting the values, we get i=100.1 mA

13. W=0. Therefore, from first law of thermodynamics,

$\Delta U = \Delta Q = i^2Rt = (1)^2(100)(5 \times 60)\ J = 30\ kJ$

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.

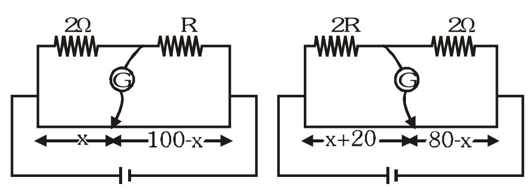
15. $H = I^2Rt$ $I \rightarrow$ same



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

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

16.



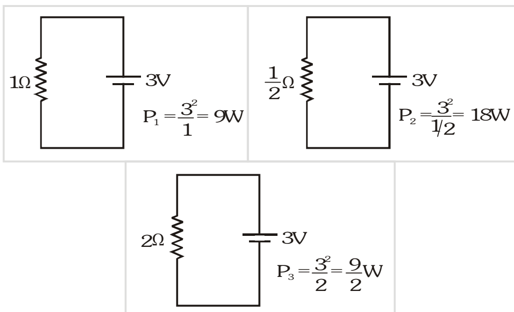
$R > 2\Omega \quad \therefore \; 100 - x > x$

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

We have $\frac{2}{R} = \frac{x}{100-x}$ ..(i) $\quad \frac{R}{2} = \frac{x+20}{80-x}$ ...(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 $100W > 60W > 40W$

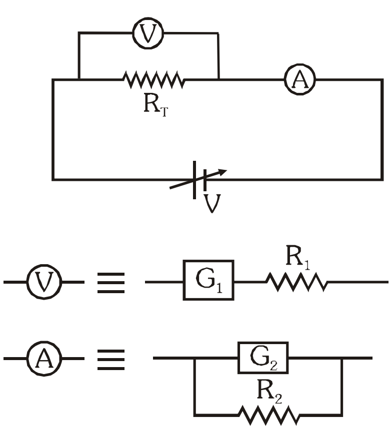
$\Rightarrow \frac{V^2}{R_{100}} > \frac{V^2}{R_{60}} > \frac{V^2}{R_{40}} \Rightarrow \frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

[**Note :** Although 100 = 60 +40 so at room tempeature

$\frac{V^2}{R_{100}} = \frac{V^2}{R_{60}} + \frac{V^2}{R_{40}} \Rightarrow \frac{1}{R_{100}} = \frac{1}{R_{60}} + \frac{1}{R_{40}}$

(Applicable Only at room temperature)]

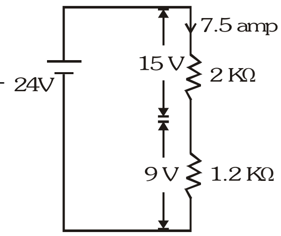
19.



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

Multiple Choice

1. $I = \frac{V}{R_{eq}}$



$\left[R_p = \frac{1.5 \times 6}{7.5}\right]$

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

(A) Current I is 7.5 mA

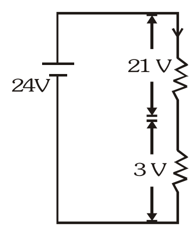
(B) Voltage drop across R_L is 9 volt

(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

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

$\frac{P_1}{P_2} = \frac{V_1^2}{R_L} \frac{R_L}{(v_2)^2} \Rightarrow \left(\frac{v_1}{v_2}\right)^2$



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

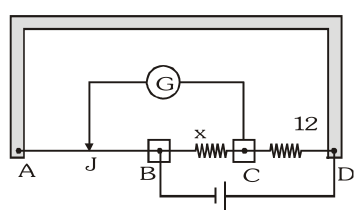
Assertion - Reason

1. **Ans. D**

Subjective Problems

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

(ii)



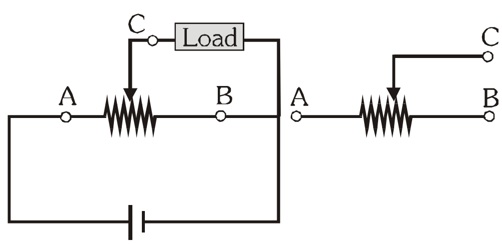
(iii) AJ = 60 cm $\therefore$ BJ = 40 cm

If no deflection is taking place. Then, the Wheatstone's bridge is said to be balanced,

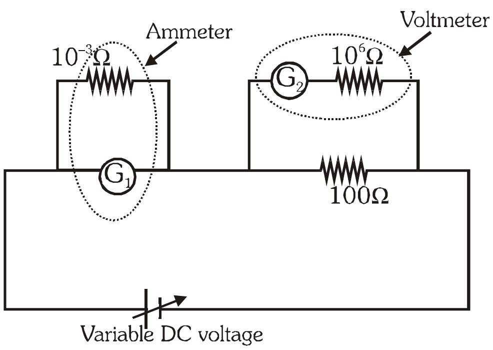
Hence, $\frac{X}{12} = \frac{R_{BJ}}{R_{AJ}} \Rightarrow \frac{X}{12} = \frac{40}{60} = \frac{2}{3}$

$\Rightarrow$ x = 8Ω

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

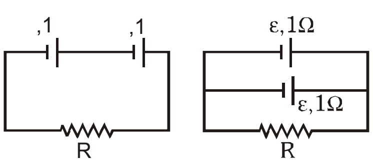


3.



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.



$$J_1 = \left(\frac{2\varepsilon}{R+2}\right)^2 R$$

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

So $\frac{4\varepsilon^2}{(R+2)} = 2.25 \frac{4\varepsilon^2}{(1+2R)^2} \Rightarrow R = 4\Omega$

MOCK TEST

1. $i = \frac{7\,V}{7\,\Omega} = 1$ A.

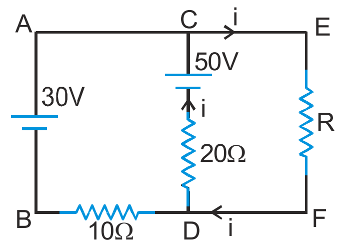
Current flows in anticolockwise direction in the loop.

Therefore $0 - 1 \times 2 - 1 \times 2 - 5 = V_1$

$V_1 = -9$ V.

2. $i = \frac{50}{20+R}$

Potential drop across R = Potential drop across AB



$\Rightarrow \frac{50}{20+R}.R = 30 \Rightarrow R = 30\ \Omega$

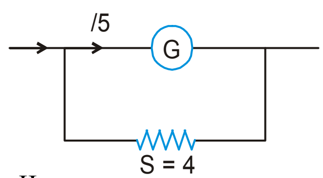
3. $I_G = 10$ mA $\Rightarrow$ G = 10Ω

$S(I - I_G) = I_G G$ where S is shunt is parallel

S = 0.1Ω

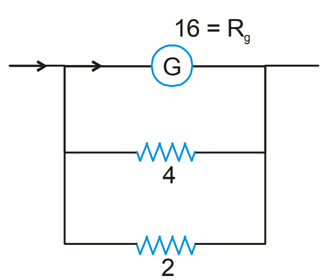
4. Case I

$R_g \times \frac{I}{5} = \left(I - \frac{I}{5}\right) \times 4 \quad \Rightarrow R_g = 16\ \Omega$



Case II

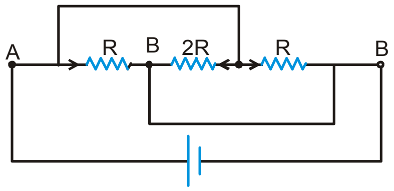
$16\,I_1 = \frac{4 \times 2}{6}(I - I_1) \Rightarrow I_1 = I/13$



so decrease in current to previous current

$= \frac{I/5 - I/13}{I/5} = \frac{8}{13}$ **Ans.**

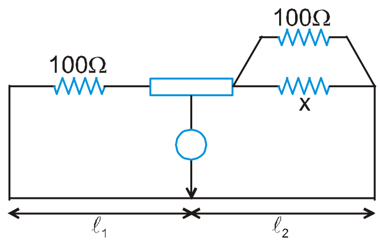
5. In figure all resistance are connected in parallel.



So $R_{eq} = \dfrac{2R \times R/2}{2R + R/2}$ and current in all resistance flow from positive terminal of battery (means A end) to negative terminal of battery (means B end).

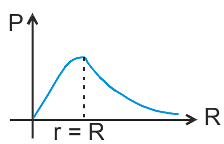
6. $\because$ wheat stone bridge is in balanced condition

So $\dfrac{100}{\ell_1} = \dfrac{\dfrac{100\,x}{100 + x}}{\ell_2}$



$\because \dfrac{\ell_1}{\ell_2} = 2 \Rightarrow x = 100\ \Omega$

7.



Power maximum when $r = R$.
So, power consumed by it will decrease. for $R > r$.

8. $V = E - ir = -\dfrac{Er}{R + r} = E\left[\dfrac{R + r - r}{R + r}\right]$

$V = \dfrac{ER}{(R + r)} \Rightarrow \quad V = 0$ at $R = 0$

$V = E$ at $R = \infty$

So (B) is correct option.

9. Voltage across each bulb will be

$V_1 = iR = \dfrac{V}{nR} \cdot R = (V/n)$

so power developed by each bulb =

$$iV_1 = \frac{V}{nR} \cdot \frac{V}{n} = \frac{V^2}{n^2 R} \;\&\; P = \frac{V^2}{R}$$

So power consumed by one bulb = $\dfrac{P}{n^2}$

10. For maximum current, net resistance of cells must be equal to 2.5Ω

i.e. $\dfrac{n\,(0.5)}{m} = 2.5$ ....**(1)**

& $m \times n = 45$ ....**(2)**

solving, we get $n = 15$, $m = 3$

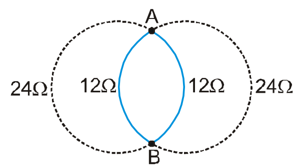
11. From the figure.

$AC_1 = AC_2 = C_1C_2 = $ radius

$\therefore \angle AC_1B = 120°$

Hence the resistance of four sections are

Hence equivalent resistance R across AB is



$\dfrac{1}{R} = \dfrac{1}{24} + \dfrac{1}{12} + \dfrac{1}{12} + \dfrac{1}{24}$ or $R = 4\Omega$

$\therefore$ Power $= \dfrac{V^2}{R} = \dfrac{(20)^2}{4} = 100$ watt.

12. In potentiometer wire potential difference is directly proportional to length

Let potential drop per unit length a potentiometer wire be K.

For zero deflection the current will flow independently in two closed circuits

$IR = K \times 10$ .... **(1)**

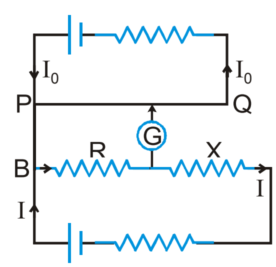
$IR + IX = K \times 30$ .... **(2)**

(2) – (1)

$\Rightarrow IX = k \times 20$ .... **(3)**

Divide (1) & (3)

$\dfrac{R}{X} = \dfrac{1}{2} \Rightarrow x = 2R$



13. $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$,

where λ is the linear charge density on the inner cylinder.

and $V = \displaystyle\int_a^b E.d\ell = \frac{\lambda}{2\pi\varepsilon_0} \ell n\left(\frac{b}{a}\right)$ .... **(1)**

Now ; $I = \int \vec{J}.\vec{dA} = \sigma \int \vec{E}.\vec{dA} = \sigma \frac{\lambda}{2\pi\varepsilon_0 r}.2\pi r \ell$

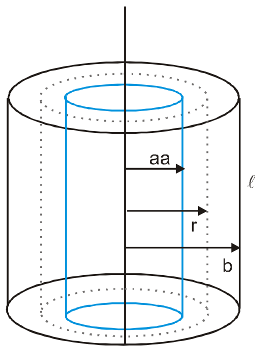
Current per unti length will be :

$I = \frac{\sigma\lambda}{\varepsilon_0}$ .... (2)

From (1)

$I = \frac{2\sigma\pi\varepsilon_0}{\varepsilon_0 \ell n(b/a)} V$

$= \frac{2\pi\sigma}{\ell n(b/a)} V$



Alternate

$I_b = \frac{V}{R}$

$R = \int_{x=a}^{b} \frac{1}{\sigma}\frac{dx}{2\pi x.1} = \frac{1}{2\pi\sigma}\ell n\left(\frac{b}{a}\right)$ $\therefore$ $I = \frac{2\pi\sigma V}{\ell n(b/a)}$

14. $50 = 10[R + r]$

$R + r = 5\,\Omega$

$\eta = \frac{R}{R+r} \Rightarrow 0.25 = \frac{R}{R+r}$

$R + r = 4R$

$r = 3R$

then $R = \frac{5}{4} = 1.25\,\Omega$, and $r = 3.75\,\Omega$.

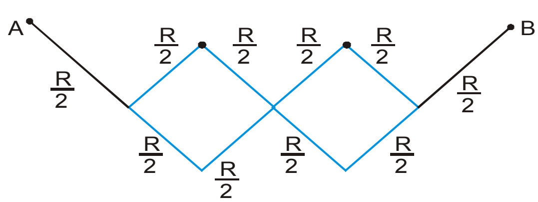
15. $P = VI$, $50 = 5 \times I$

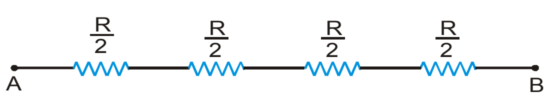
$I = 10\,A$

Power lost in cable $= I^2R = 10 \times 10 \times 0.02 = 2\,W$

Power supplied to T.R. = 50 W – 2 W = 48 W

16. The circuit can be folded about B and redrawn as





Hence equivalent resistance between A and B is 2R.

17. $R = \frac{1}{\sigma} \times \frac{t}{4\pi r^2}$

Using values $R = 5 \times 10^{-11}\,\Omega$

$R = 5 \times 10^{-11}\,\Omega$

18. Since current $I = neAv_d$ through both rods is same

$2(n)\,e\,A\,v_L = n\,e\,(2A)\,v_R$ or $\frac{v_L}{v_R} = 1$

19. $i = \frac{dq}{dt}$ = slope of q - t graph

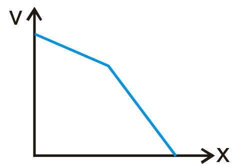
= – 5 (which is constant)

Amount of heat generated in time t

$H = i^2RT$

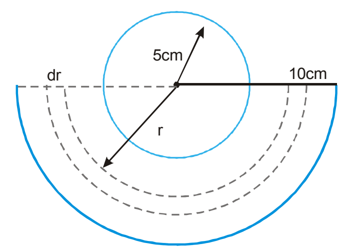
$H \propto t$.

20. From relation $E = \rho J$, the magnitude of electric field is greater in right rod as compared to left rod. There fore magnitude of potential gradient in the right rod is greater. (remember potential is continuous).



Therefore the variation is shown by figure.

21. The arrangement is shown in figure. Consider the hemi-spherical shell of radius r and thickness dr as shown. Resistance of this shell is :



$dR = \frac{dr}{\sigma \times 2\pi r^2}$

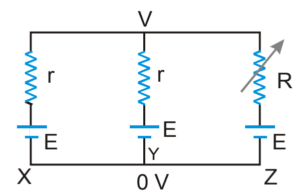
$R = \frac{1}{2\pi\sigma} \times \int_{r=5cm}^{r=10cm} \frac{dr}{r^2} = 1591.6\,\Omega.$

22. Redrawing the given circuit diagram as shown below:

Using point potential theory,

$\frac{V-E}{r} + \frac{V-E}{r} + \frac{V-E}{R} = 0$

$\Rightarrow (V-E)\left(\frac{2}{r} + \frac{1}{R}\right) = 0$



As $\frac{2}{r} + \frac{1}{R} \neq 0$

So $V - E = 0$

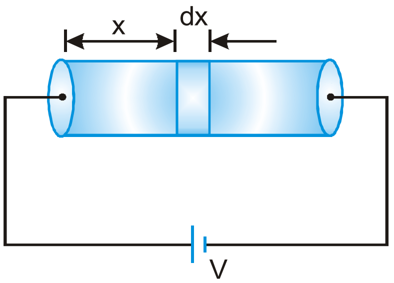
So, current through R, $i = \frac{V-E}{R} = 0$

whatever be the value of R.

23. Consider an elemental part of solid at a distance x from left end of width dx.

Resistance of this elemental part is,

$$dR = \frac{\rho dx}{\pi a^2} = \frac{\rho_0 x dx}{\pi a^2} \Rightarrow R = \int dR = \int_0^L \frac{\rho_0 x dx}{\pi a^2} = \frac{\rho_0 L^2}{2\pi a^2}$$



Current through cylinder is, $I = \frac{V}{R} = \frac{V \times 2\pi a^2}{\rho_0 L^2}$

Potential drop across element is, $dV = IdR = \frac{2V}{L^2}$ x dx

$$E(x) = \frac{dV}{dx} = \frac{2V}{L^2} x.$$

24. **(A)** p.d. across each cell = $V_P - V_Q$

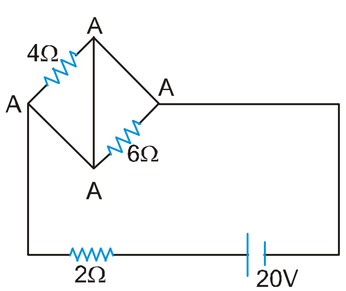
(B) If i is clockwise then E_2 is source and for anti–clockwise current E_1 is source.

(C) P.D. = E – ir (when battery supplies energy) = E + ir (when battery consumes energy).

By KVL $i = \frac{E_1 - E_2}{r_1 + r_2}$ (Anticlockwise)

$$\therefore V_P - V_Q = E_1 - i r_1 = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

25. there is zero potential difference across 4 Ω and 6 Ω resistance.

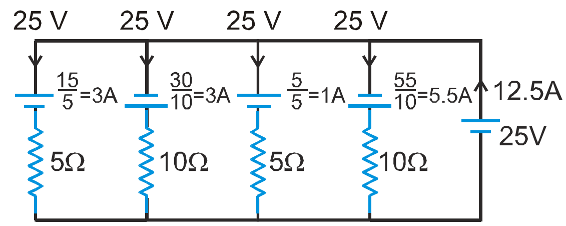


$i = \frac{20}{2} = 10$ A power by battery

$p_b = \varepsilon i = 20 \times 10 = 200$ W **Ans.**

26. The area of cross-section of conductor at point A is less than that at point B. So current density at A is higher. Hence, the electric field at A is more than at B and the thermal power generated at A is more than at B in an element of small same width. since resistance at A is greater

27.



Power supplied by 20 V cell = (–1) (20) = – 20 W

as the cell is not supplying the power, it is eating the power (getting charged)

28. As the length is doubled, the cross section area of the wire becomes half. Thus the resistance of the wire $R = \rho\frac{L}{A}$ becomes four times the previous value. Hence after the wire is elongated the current becomes one fourth. Electric field is potential difference per unit length and hence becomes half the initial value.

The power delivered to resistance is $P = \frac{V^2}{R}$ and hence becomes one fourth.

29. Total charge $= \int Idt$ = Area under the curve

$= 10$ C

Average current $= \frac{\int Idt}{\int dt} = 5$A

Total heat produced $= \int I^2 Rdt = \int_0^2 (-5t + 10)^2 .1$

$dt = \frac{200}{3}$ J

Maximum Power = I^2R when I is maximum current.

= 100 x 1 = 100 W

30. Let a be the radius of left end side cross–section, then radius of cross–section at distance x from left end is a + bx where b is a constant.

From $J = \sigma E \Rightarrow \frac{i}{A} = \sigma E \Rightarrow E = \frac{i}{A} \times \frac{1}{\sigma}$ as i and σ are same for all cross–section

$$E \propto \frac{1}{A} = \frac{1}{\pi(a + bx)^2}$$

Rate of heat generation per unit length, $H = \dfrac{i^2\rho}{A}$,

So $H \propto \dfrac{1}{A} \Rightarrow \dfrac{H}{E} = \dfrac{i^2\rho}{A} \times \dfrac{A}{i\rho} = i$ = constant

$$dV = -\vec{E}\cdot d\vec{x} \Rightarrow \int_{\varepsilon}^{V} dV = \int_{0}^{X} \frac{\rho\ i\ dx}{\pi(a+bx)^2}$$

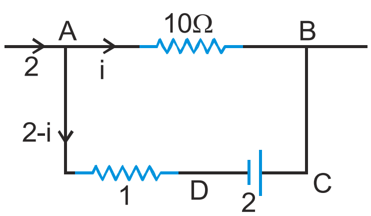
$$\Rightarrow V = \varepsilon + \frac{\rho i}{\pi b}\left[\frac{1}{a+bx} - \frac{1}{a}\right] = \varepsilon - \frac{\rho i}{\pi ab}\left(\frac{bx}{a+bx}\right).$$

31. Resistance absorbs energy at the rate of 2W.
Potential difference across AB $\Rightarrow V_{AB}.I = 50$ W

$V_{AB} = 50$ V

Drop across resistor is 2V, therefore EMF of E is 48 V. As AB is absorbing energy at the rate of 50 W, 48 W is being absorbed by E. Thus E is on charging mode i.e. current is entering from +ve terminal of E.

32. Let the currents be as shown in the figure
KVL along ABCDA



$\Rightarrow -10\,i - 2 + (2 - i)1 = 0$ $\therefore i = 0$

Potential difference across S = (2 – i)1 = 2 × 1 = 2 V.

33. Both statements 1 and 2 are true. In statement-1 R is varied while in statement-2 R is kept constant. Hence both statements are independent.

34. From relation $\vec{J} = \sigma\vec{E}$, the current density $\vec{J}$ at any point in ohmic resistor is in direction of electric field $\vec{E}$ at that point. In space having non-uniform electric field, charges released from rest may not move along ELOF. Hence statement 1 is true while statement 2 is false.

35. As the length of wire is doubled, the cross-section area of wire becomes half. Therefore resistance of wire becomes four times and current becomes $\dfrac{1}{4}$th of the initial value.

also $v_d = \dfrac{I}{neA}$

Since current becomes one fourth and cross-section area of wire becomes half, therefore from above equation the drift velocity of electron becomes half. Hence statement I is false.

36. The potential difference across the resistance is always $|E_1 - E_2|$ in magnitude. Hence statement 1 and 2 are true and statement 2 is correct explanation of statement 1.

37. Just after switching ON the bulb, the filament of bulb is cold and its resistance is low. But after some time as filament gets hot, its resistance increases and hence withdraws less power from the source as compared to initial duration.

38. The points A and B are at same potential, then under given conditions points A and B on the circuit can be connected by a conducting wire. Hence the circuit can be redrawn as shown in figure 2.

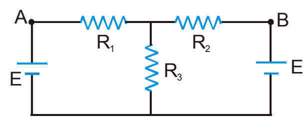
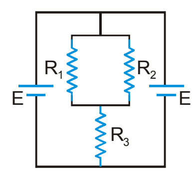


Fig-1



(fig.2)

Therefore statement 1 is true. Statement 2 is obviously false.

39. $R_A = \dfrac{R\,.\,R_V}{R + R_V} < R$

40. $R_B = R + R_G > R$

41. % error in case A.

$$\frac{R_A - R}{R} \times 100 = \left(\frac{R_V}{R+R_V} - 1\right) \times 100$$

$$= \frac{-R}{R+R_V} \times 100 \approx -1\%$$

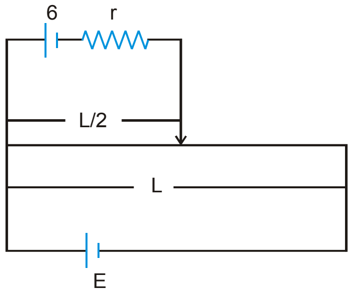
% error in case B

$$\frac{R_B - R}{R} \times 100 = \frac{R_G}{R} \times 100 \approx 10\%$$

Hence percentage error in circuit B is more than that in A.

42. **(C)**

43. Case-I S_2 is open

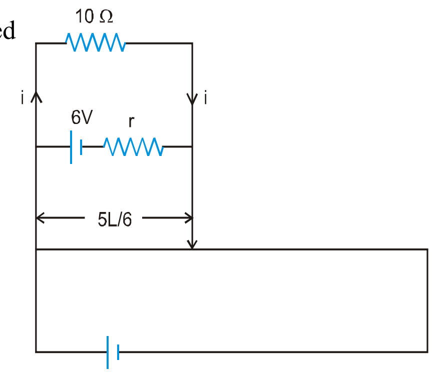


Potential gradient $= \frac{E}{L}$

So $6 = \frac{E}{L}\,\frac{L}{2}$

$E = 12\text{ V}$

Case-II S_2 is closed



$i = \frac{6}{10+r}$

$6 - ir = \frac{E}{L}\,\frac{5L}{12}$

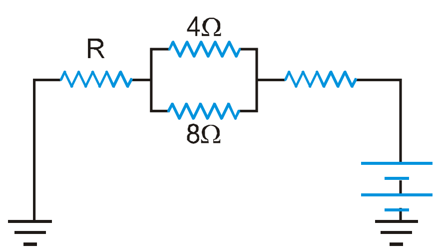
$6 - \frac{6}{10+r}\,r = 5$

$\frac{6r}{r+10} = 1$

$6r = r + 10$

$r = 2\Omega$

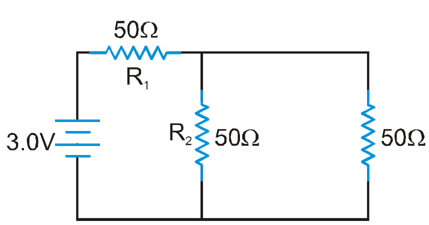
44.



Current in 4Ω resistance = 4A

Total current = 4 + 2 = 6A

45. The equivalent circuit can be redrawn as shown in figure1. From figure 1 it is obivious that power dissipated by R_1 is maximum.



Potential difference across R_2 is $= \frac{25}{25+50} \times 3\text{ volt} = 1\text{ volt}$

Therefore potential difference across R_3 or R_4

$= \frac{20}{20+30} \times 1\text{ volt} = 0.4\text{ volt}$

The equivalent resistance of circuit across the cell is 50+25 = 75 ohms

Therefore current drawn through cell is

$\frac{3}{75} \times 1000\text{ mA} = 40\text{ mA}.$

48. (A) Since current in both rods is same.

$\therefore\ n_1 e v_1 A_1 = n_2 e v_2 A_2$

$\therefore\ \frac{v_1}{v_2} = \frac{n_2 A_2}{n_1 A_1} = \frac{1}{2} \times \frac{2}{1} = 1$

(B) $\because\ E = \rho J = \rho \frac{I}{A}$

$\therefore\ \frac{E_1}{E_2} = \frac{\rho_1}{\rho_2} \times \frac{A_2}{A_1} = \frac{2}{1} \times \frac{2}{1} = 4$

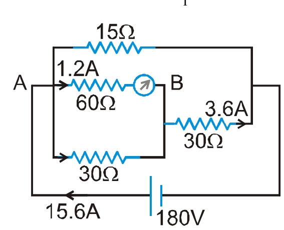
(C) $\frac{\text{p.d. across rod I}}{\text{p.d. across rod II}} = \frac{E_1 \times AB}{E_2 \times BC} = 4$

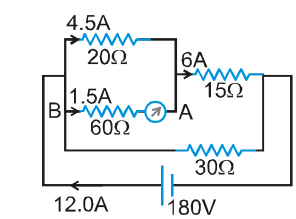
(D) $\frac{\text{Average time taken by free electron to move from A to B}}{\text{Average time taken by free electron to move from B to C}}$

$= \frac{AB}{v_1} \times \frac{v_2}{BC} = 1$

49. When switch S is opened then right side resistance R which was short circuited earlier contributes to equivalent resistance. Hence, equivalent resistance across the battery increases, power dissipated by left resistance R decreases, voltmeter reading decreases and ammeter reading decreases.

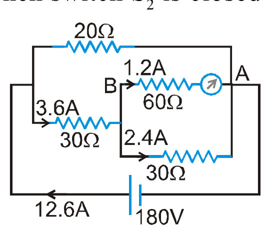
50. When switch S_1 is closed

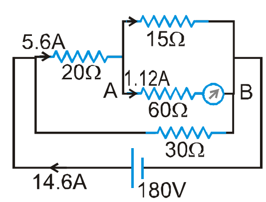




When switch S_2 is closed

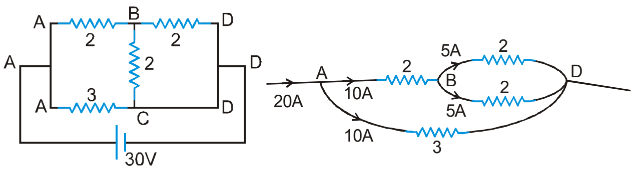
When switch S_3 is closed





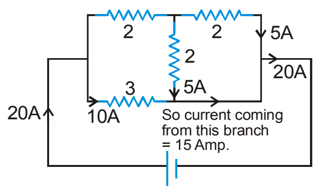
When switch S_4 is closed

51.

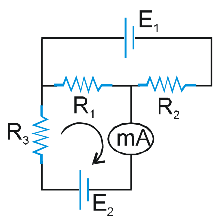


$\Rightarrow R_{eq} = 3/2i = \dfrac{30}{3/2} = 20$ Amp.

From figure current through B $\rightarrow$ D branch = 5 Amp.



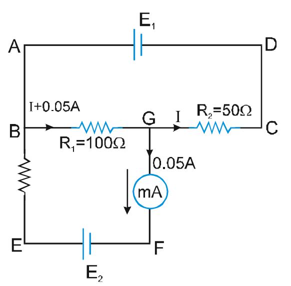
52. Applying KVL in loop ABCD



$E_1 = (I + 0.05) R_1 + IR_2$

$\Rightarrow$ $I = -20$ mA

$\therefore$ Current through R_1 = 30 mA towards right

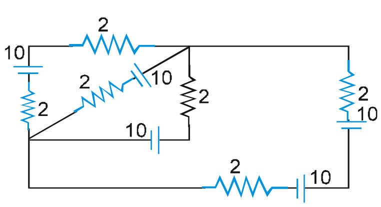


Current through R_2 = 20 mA towards left

Applying KVL in loop BGFE

$E_2 = (I + 0.05)\ 100 + (0.05)20 = 4$ volts

53. The simplified circuit is.



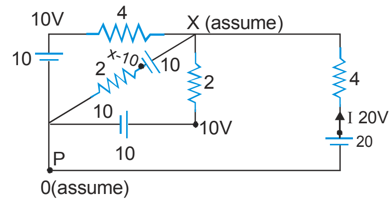
We have to find I.

Let potential of point 'P' be '0'. Potential at other points are shown in the figure apply kirchoff's current law at point x.

$$\frac{x-10}{4} + \frac{x-10}{2} + \frac{x-20}{4} + \frac{(x-10)-0}{2} = 0$$

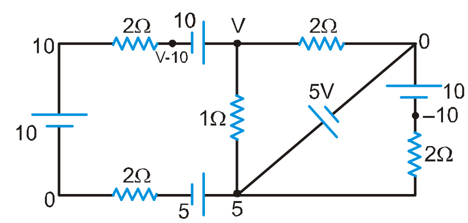
$\Rightarrow x - 10 + 2x - 20 + x - 20 + 2x - 20 = 0$

$\therefore 6x = 70 \Rightarrow x = \dfrac{35}{3}$ volt.



$\therefore\ I = \dfrac{20 - \dfrac{35}{3}}{4} = \dfrac{25}{12}$ A.

54. $\dfrac{5}{2}$ A



$$\frac{v-20}{2} + \frac{v}{2} + v - 5 = 0\ ;\ v - 20 + v + 2(v-5) = 0$$

$\Rightarrow 4v - 20 - 10 = 0$

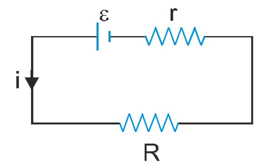
$$v = \frac{30}{4} = \frac{15}{2}\ ;\quad v - 5 = \frac{15}{2} - 5 = \frac{15-10}{2} = \frac{5}{2}$$

$\Rightarrow i = \dfrac{5/2}{1} = \dfrac{5}{2}$ amp. Ans.

55. Efficiency $= \eta = \dfrac{\text{out put power}}{\text{input power}}$

$\Rightarrow \eta = \dfrac{i^2R}{\varepsilon i} \qquad \because i = \dfrac{\varepsilon}{R + r}$

$\eta = \dfrac{R}{R+r}$



$0.6 = \dfrac{R}{R+r}$

$\Rightarrow$ $3R + 3r = 5R$ or $2R = 3r$

$\therefore$ new efficiency $\eta = \dfrac{6R}{6R + r} = 0.9 = 90\%$ **Ans.**

56. V = Potential difference across the cell = Electric field × width of the cell

$= 8 \times 0.1 = 0.8$ volt **....Ans.**

ε = emf of the cell = $10 \times 0.1 = 1.0$ volt **....Ans.**

Also r is the internal resistance and i is the current drawn from the cell

$V = \varepsilon - ir$ or $0.8 = 1 - 1r \Rightarrow r = 0.2\ \Omega$ **....Ans.**

57. (a) When Jockey is not connected.

$I = \dfrac{E}{13r}$ ....**(i)**

Resistance per unit length

$\lambda = \dfrac{12r}{300}\ \Omega/\text{cm}$

$\therefore$ Let ℓ be the length when we get zero deflection.

$\therefore \left(\dfrac{E}{2}\right) = (\lambda\,\ell) \Rightarrow \dfrac{E}{2} = \dfrac{E}{13r} \times \dfrac{12r}{300} \times \ell$

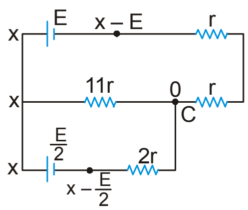
$\therefore$ $\ell = 157.5$ cm

(b) Let potential at C is zero

Then apply Kirchoff's Ist law

$$\frac{x-0}{11r} + \frac{x - \frac{E}{2} - 0}{2r} + \frac{(x - E - 0)}{2r} = 0$$

$\Rightarrow$ $x = \dfrac{11E}{16}$



$$I_g = \frac{x - \frac{E}{2}}{2r} = \frac{\left(\frac{11\varepsilon}{16}\right) - \frac{E}{2}}{2r} = \frac{3E}{32r}$$

Alternate method

$\ell = 300$ cm $\therefore$ $r' = (275) \times \dfrac{12r}{300}$

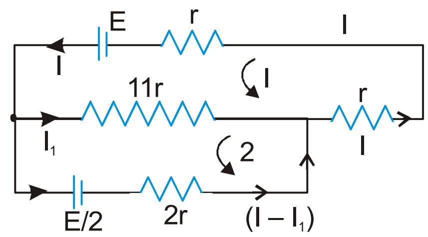
$r' = 11r$

Using KVL in loop (i)

$E - I_1 .11r - Ir - Ir = 0$ ....**(i)**

and in loop (ii)

$-I_1\,11r + (I - I_1)2r + \dfrac{E}{2} = 0$ ....**(ii)**



Solving equation **(i)** and **(ii)** we have

$I_1 = \dfrac{E}{16r}$ and $I = \dfrac{5E}{32r}$

So current in galvanometer

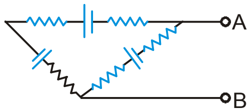
Branch $= (I - I_1) = \dfrac{5E}{32r} - \dfrac{E}{16r} = \dfrac{3E}{32r}$

$\Rightarrow I_g = \dfrac{3E}{32r}$

(a) 157.5 cm **(b)** $\dfrac{3E}{32r}$

58. $R = 100\,\Omega$, $\varepsilon = 3V$

In open circuit



$i = \dfrac{3+3-3}{5 \times 200}$ So $V_{AB} = \varepsilon + ir$

$= 3 + \dfrac{3}{5 \times 200} \times 400$

$V_{AB} = 4.2\,V$ **Ans.** In short circuit