17

Current Electricity

TOPIC 1

Ohm's Law and Resistance

01 A square shaped wire with resistance of each side 3Ω is bent to form a complete circle. The resistance between two diametrically opposite points of the circle in unit of Ω will be **[2021, 31 Aug Shift-I]**

Ans. *(3)*

Let the sides of square be a.

$\therefore$ Total length or perimeter of square $= 4a$

If the radius of shape of circle be r, then

$$\therefore \quad 2\pi r = 4a$$

$$\Rightarrow \quad r = \frac{4a}{2\pi}$$

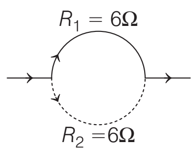
$$\Rightarrow \quad r = \frac{2a}{\pi}$$

Since, resistance of each side of square $= 3\,\Omega$

$\therefore$ Total resistance of square $= 4 \times 3 = 12\Omega$

i.e. resistance of length $2\pi r = 12\,\Omega$

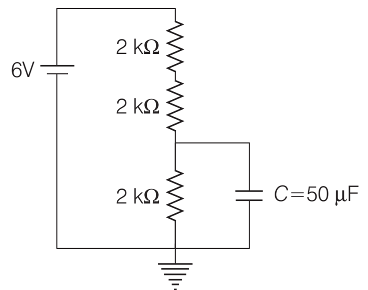
$\Rightarrow$ Resistance of $\pi r = 6\,\Omega$



Now, equivalent resistance of circle diametrically opposite

$$(R_{eq}) = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 6}{6 + 6} = 3\Omega$$

02 A capacitor of $50\,\mu F$ is connected in a circuit as shown in figure. The charge on the upper plate of the capacitor is .... μC.



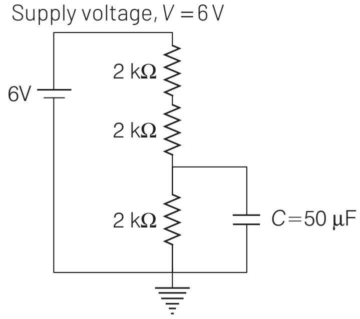
[2021, 31 Aug Shift-I]

Ans. *(100)*

According to given circuit diagram,

Capacitance $= 50\,\mu F = 50 \times 10^{-6} F$

Supply voltage, $V = 6\,V$



In steady state, capacitor will act as open circuit,

$\therefore$ Equivalent resistance

$$R_{eq} = (2 + 2 + 2)\,k\Omega = 6\,k\Omega$$

Circuit current, $I = \dfrac{V}{R_{eq}}$

$$= \frac{6}{6 \times 1000} = 10^{-3} A$$

$\therefore$ Voltage across $2\,k\Omega = I \times 2$

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

$$= 2V$$

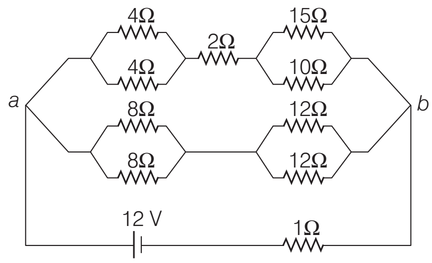
Now, charge on capacitor,

$$q = CV = 50 \times 10^{-6} \times 2$$

$$= 100 \times 10^{-6}\ C$$

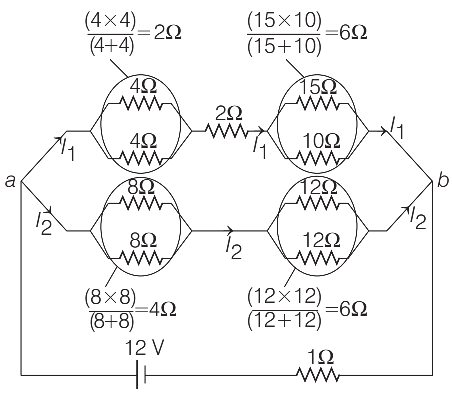
$$= 100\,\mu C$$

03 The voltage drop across 15Ω resistance in the given figure will be .... V. **[2021, 31 Aug Shift-I]**



Ans. *(6)*

According to given circuit diagram,



As we know that, parallel equivalent resistance,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

and series equivalent resistance,

$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

Let the net resistance across a and b be R'

$$\therefore \quad \frac{1}{R'} = \frac{1}{2 + 2 + 6} + \frac{1}{4 + 6}$$

$$a = \frac{1}{10} + \frac{1}{10} = \frac{2}{10}$$

$$R' = 5\,\Omega$$

Hence, total resistance,

$$R = R' + 1 = 5 + 1 = 6\,\Omega$$

According to current division rule, current in upper branch,

$$I_1 = I\cdot\frac{4+6}{(2+2+6)+(4+6)}$$

$$= I\cdot\frac{10}{20} = \frac{I}{2} = \frac{1}{2}\cdot\frac{V}{R} = \frac{1}{2}\times\frac{12}{6} = 1\text{ A}$$

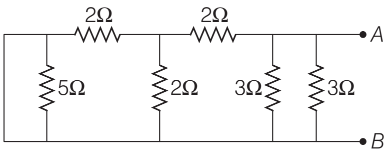
Again, according to current division rule, current in $15\,\Omega$ resistor,

$$I_{15} = I_1\cdot\frac{10}{10+15} = 1\times\frac{2}{5} = 0.4\text{ A}$$

$\therefore$ Voltage drop across 15Ω resistor,

$$V_{15} = I_{15}\times 15 = 0.4\times 15 = 6\text{ V}$$

04 The equivalent resistance of the given circuit between the terminals A and B is **[2021, 31 Aug Shift-II]**



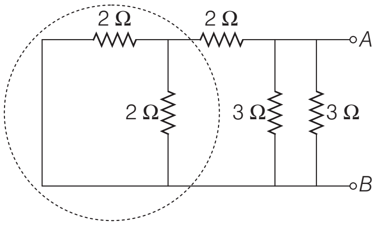
(a) 0 (b) $3\,\Omega$

(c) $9/2\,\Omega$ (d) $1\,\Omega$

Ans. *(d)*

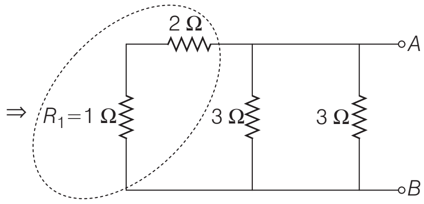
In the given circuit, $5\,\Omega$ resistance is shorted. So, it can be discarded.

Now, we get a resolved circuit as shown below



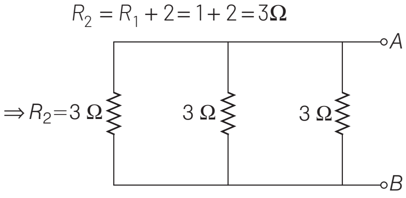
In parallel,

$$R_1 = \frac{2\times 2}{2+2} = 1\,\Omega$$



In series,

$$R_2 = R_1 + 2 = 1 + 2 = 3\Omega$$

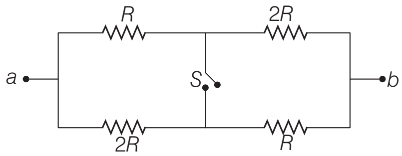


Here, all the three resistances $(3\,\Omega)$ are parallel.

$\therefore$ Equivalent resistance across A and B,

$$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1 \Rightarrow R_{eq} = 1\,\Omega$$

05 The ratio of the equivalent resistance of the network (shown in figure) between the points a and b when switch is open and switch is closed is $x:8$. The value of x is **[2021, 27 Aug Shift-II]**



Ans. *(9)*

According to given circuit diagram

When switch is open, then combination R_1 and R_2 will be in series and also combination R_3 and R_4 will be in series and these branches will be in parallel.

$\therefore$ Equivalent resistance

$$(R_{eq}) = \frac{3R\cdot 3R}{3R+3R} = \frac{9R^2}{6R} = \frac{3}{2}R \qquad \text{...(i)}$$

When switch is closed, then combination R_1 and R_3 will be in parallel and also, combination R_2 and R_4 will be in parallel. After that, both will be in series.

$\therefore$ Equivalent resistance,

$$(R'_{eq}) = \frac{R\cdot 2R}{R+2R} + \frac{R\cdot 2R}{R+2R} = \frac{2R^2}{3R} + \frac{2R^2}{3R}$$

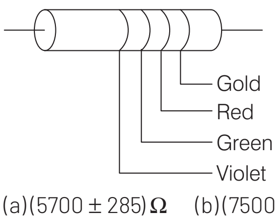
$$= \frac{2R}{3} + \frac{2R}{3} = \frac{4R}{3} \qquad \text{...(ii)}$$

Now, dividing Eq. (i) by Eq. (ii), we get

$$\frac{R_{eq}}{R_{eq}'} = \frac{3\frac{R}{2}}{4\frac{R}{3}} = \frac{9}{8}$$

$$x = 9$$

06 The colour coding on a carbon resistor is shown in the given figure. The resistance value of the given resistor is **[2021, 27 Aug Shift-II]**

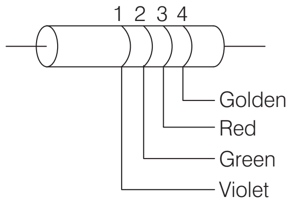


(a) $(5700\pm 285)\,\Omega$ (b) $(7500\pm 750)\,\Omega$

(c) $(5700\pm 375)\,\Omega$ (d) $(7500\pm 375)\,\Omega$

Ans. *(d)*

According to given colour coded resistor



According to resistor colour chart,

Violet	Green	Red	Golden
↓	↓	↓	↓
7	5	2	5%

$\therefore$ Resistance of resistor $= 75\times 10^2 \pm 5\%$

$$= 7500 \pm 5\% = (7500\pm 375)\,\Omega$$

07 First, a set of n equal resistors of 10 Ω each are connected in series to a battery of emf 20 V and internal resistance 10 Ω. A current I is observed to flow. Then, the n resistors are connected in parallel to the same battery. It is observed that the current is increased 20 times, then the value of n is .... **[2021, 27 Aug Shift-I]**

Ans. *(20)*

Given, value of each resistance, $R = 10\,\Omega$

Emf of battery, $e = 20\text{V}$

Internal resistance of battery, $r = 10\,\Omega$

Current in parallel connection is 20 times current in series combination, $i_p = 20 i_s$.

Net resistance in parallel combination will be given as

$$R_p = r + \left[\frac{1}{\frac{1}{R}+\frac{1}{R}+\frac{1}{R}...+n}\right] = r + \frac{R}{n}$$

$$R_p = 10 + \frac{10}{n}$$

$$(\because r = 10\,\Omega \text{ and } R = 10\,\Omega\,)\text{...(i)}$$

In series combination,

The net resistance of circuit will be equivalent to sum of all resistances as all are connected in series.

$$R_s = [R + R + ... + n] + r = nR + r$$

$$R_s = 10n + 10$$

$$(\because r = 10\,\Omega \text{ and } R = 10\,\Omega)\text{...(ii)}$$

By Ohm's law, current flowing in circuit is given as

$$i = V/R$$

As, $i_p = 20 i_s$

$$\frac{V_p}{R_p} = 20\frac{V_s}{R_s}$$

$$\Rightarrow \frac{20}{10+\frac{10}{n}} = \frac{20\times 20}{10\,n+10} \quad [\because V_p = V_s = e = 20\text{ V}]$$

$$\Rightarrow \frac{20n}{10n+10} = \frac{400}{10n+10} \Rightarrow 20n = 400$$

$$n = 20$$

Thus, the value of number of resistances n is 20.

08 If you are provided a set of resistances $2\Omega, 4\Omega, 6\Omega$ and 8Ω. Connect these resistances, so as to obtain an equivalent resistance of $\frac{46}{3}\Omega$. **[2021, 26 Aug Shift-II]**

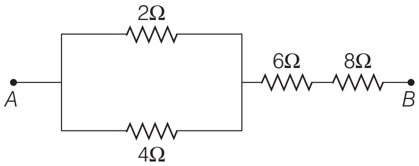
(a) $4\,\Omega$ and $6\,\Omega$ are in parallel with $2\,\Omega$ and $8\,\Omega$ in series.
(b) $6\,\Omega$ and $8\,\Omega$ are in parallel with $2\,\Omega$ and $4\,\Omega$ in series.
(c) $2\,\Omega$ and $6\,\Omega$ are in parallel with $4\,\Omega$ and $8\,\Omega$ in series.
(d) $2\,\Omega$ and $4\,\Omega$ are in parallel with $6\,\Omega$ and $8\,\Omega$ in series.

Ans. *(d)*

The given value of resistances are 2Ω, 4Ω, 6Ω and 8Ω. The required value of combination is $46/3\Omega$.

In order to achieve the above mentioned values of resistance from given resistances, we will connect 2Ω and 4Ω resistance in parallel, then join $6\,\Omega$ and $8\,\Omega$ resistance in series with the combination.

The circuit diagram for connection is shown below.



$$R_{eq} = (2\|4) + 6 + 8 = \frac{2\times 4}{2+4} + 14 = \frac{46}{3}\Omega$$

Thus, resistance of 2Ω and 4Ω are in parallel with
6Ω and 8Ω in series combination.

09 What equal length of an iron wire and a copper-nickel alloy wire, each of 2 mm diameter connected parallel to give an equivalent resistance of 3Ω?

(Given, resistivities of iron and copper-nickel alloy wire are $12\,\mu\Omega$ cm and $51\,\mu\Omega$ cm respectively)

[2021, 26 Aug Shift-I]

(a) 82 m (b) 97 m (c) 110 m (d) 90 m

Ans. (b) Let the resistance of iron wire be R_1 and that of copper nickel alloy wire be R_2

$$r_1 = r_2 = 1\text{ mm} = 10^{-3}\text{ m}$$
$$\rho_1 = 12\mu\Omega\text{ cm} = 12\times 10^{-6}\ \Omega\text{cm} = 12\times 10^{-8}\ \Omega\text{m}$$
$$\rho_2 = 51\mu\Omega\text{ cm} = 51\times 10^{-6}\ \Omega\text{cm} = 51\times 10^{-8}\ \Omega\text{m}$$

For parallel combination,

$$R_{eq} = \frac{R_1R_2}{R_1+R_2}$$

$$3 = \frac{\frac{\rho_1 l}{\pi r_1^2}\,\frac{\rho_2 l}{\pi r_2^2}}{\frac{\rho_1 l}{\pi r_1^2} + \frac{\rho_2 l}{\pi r_2^2}}$$

$$\Rightarrow \quad 3 = \frac{\frac{(12\times 10^{-8})\,l}{\pi\times 10^{-6}} \times \frac{51\times 10^{-8}\,l}{\pi\times 10^{-6}}}{\frac{12\times 10^{-8}\,l}{\pi\times 10^{-6}} + \frac{51\times 10^{-8}\,l}{\pi\times 10^{-6}}}$$

On solving, $\quad l = 97\text{ m}$

10 The resistance of a conductor at 15°C is $16\,\Omega$ and at 100°C is $20\,\Omega$. What will be the temperature coefficient of resistance of the conductor? **[2021, 27 July Shift-II]**

(a) 0.010°C^{-1} (b) 0.033°C^{-1}
(c) 0.003°C^{-1} (d) 0.042°C^{-1}

Ans. *(c)*

Given,

Resistance of conductor at 15°C = $16\,\Omega$

and resistance of conductor at 100°C $= 20\,\Omega$

$\because$ We know that,

$$R_t = R_0[1+\alpha(\Delta T)] \quad \text{...(i)}$$

where, R_t = resistance of conductor at t°C,

R_0 = resistance of conductor at 0°C,

α = temperature coefficient of resistance

and ΔT = temperature difference.

$\therefore$ Using Eq. (i), we can write

$$16 = R_0[1+\alpha(15 - T_0)] \quad \text{...(ii)}$$

and $$20 = R_0[1+\alpha(100 - T_0)] \quad \text{...(iii)}$$

Assume that T_0 to be 0°C as per general convention and divide Eq. (ii) by Eq. (iii), we get

$$\frac{16}{20} = \frac{R_0(1+\alpha\times 15)}{R_0(1+\alpha\times 100)}$$

$$\Rightarrow \quad \frac{4}{5} = \frac{1+15\alpha}{1+100\alpha}$$

$$\Rightarrow \quad 4 + 400\,\alpha = 5 + 75\alpha$$

$$\Rightarrow \quad 400\alpha - 75\alpha = 5 - 4 \Rightarrow 325\alpha = 1$$

$$\Rightarrow \quad \alpha = \frac{1}{325} = 0.003°\text{ C}^{-1}$$

11 In Bohr's atomic model, the electron is assumed to revolve in a circular orbit of radius 0.5 Å. If the speed of electron is 2.2×16^6 m/s, then the current associated with the electron will be .... $\times 10^{-2}$ mA. [Take, π as $\frac{22}{7}$] **[2021, 27 July Shift-I]**

Ans. *(112)*

Radius of circular orbit,

$$r = 0.5\text{ Å} = 0.5\times 10^{-10}\text{ m}$$

Velocity of electron, $v = 2.2\times 10^6\text{ ms}^{-1}$

$\because$ We know that,

$$\text{Current, } I = \frac{q}{t}$$

where, q = charge and t = time taken.

$$\Rightarrow \quad I = \frac{e}{t} \quad \text{...(i)} \{\because q = e\}$$

As electron is moving in circular orbit, so it means electron is tracing a distance of $2\pi r$.

$$\because \quad \text{Time} = \frac{\text{Distance}}{\text{Speed}} \Rightarrow t = \frac{2\pi r}{v} \quad \text{...(ii)}$$

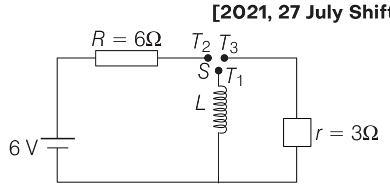
From Eqs. (i) and (ii), we get

$$I = \frac{e}{\frac{2\pi r}{v}} \Rightarrow I = \frac{ev}{2\pi r}$$

$$\Rightarrow \quad I = \frac{1.6\times 10^{-19}\times 2.2\times 10^6}{2\times\frac{22}{7}\times 0.5\times 10^{-10}}$$

$$= 112\times 10^{-2}\text{ mA}$$

12 Consider an electrical circuit containing a two way switch S. Initially S is open and then T_1 is connected to T_2. As the current in $R = 6\,\Omega$ attains a maximum value of steady state level, T_1 is disconnected from T_2 and immediately connected to T_3. Potential drop across $r = 3\,\Omega$ resistor immediately after T_1 is connected to T_3 is .... V. (Round off to the nearest integer) **[2021, 27 July Shift-I]**



Ans. *(3)*

According to given circuit diagram in question, when T_1 and T_2 are connected, the steady state current in the inductor,

$$I = \frac{V}{R} = \frac{6}{6} = 1\text{A}$$

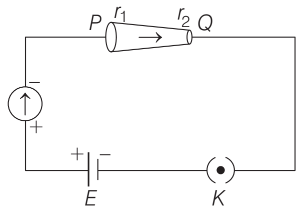
When T_1 and T_3 are connected, the steady state current through inductor remains same.

Therefore, potential difference,

$$V = Ir = 1 \times 3 = 3\text{ V}$$

13 In the given figure, a battery of emf E is connected across a conductor PQ of length l and different area of cross-sections having radii r_1 and $r_2 (r_2 < r_1)$.

[2021, 27 July Shift-I]

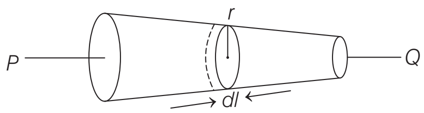


Choose the correct option as one moves from P to Q.

(a) Drift velocity of electron increases
(b) Electric field decreases
(c) Electron current decreases
(d) All of the above

Ans. *(a)*

If we consider only conductor PQ as follows



Let dl be the small element of conductor PQ.

$\because$ Current passing through PQ is constant.

So, resistance of this small element dl will be given as

$$dR = \frac{\rho dl}{A} \quad \text{...(i)}$$

where, ρ = resistivity,

dl = small element of conductor PQ

and A = area of cross-section.

$\because$ Current, $I = \dfrac{dV}{dR}$

$$\Rightarrow \quad dV = IdR \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$dV = \frac{I\rho dl}{A} \Rightarrow dV = \frac{I\rho dl}{\pi r^2} \quad \text{...(iii)} \{\because A = \pi r^2\}$$

$\because$ We know that,

$$\text{Electric field, } E = \frac{dV}{dl} \quad \text{...(iv)}$$

From Eqs. (iii) and (iv), we get

$$\Rightarrow \quad E = \frac{I\rho dl}{\pi r^2 dl}$$

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

$$\Rightarrow \quad E \propto \frac{1}{r^2} \quad \text{...(v)}$$

Also, we know that, drift velocity,

$$v_d = \frac{eE\tau}{m}$$

$$\Rightarrow \quad v_d \propto E \quad \text{...(vi)}$$

$\therefore$ From Eqs. (v) and (vi), we can say

If r decreases, E will increase and due to this, v_d will increase.

14 For the circuit shown, the value of current at time $t = 3.2$ s will be .... A. **[2021, 27 July Shift-II]**

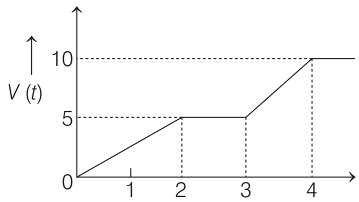


Fig. (1)

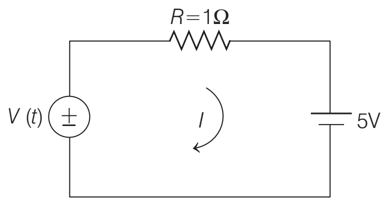
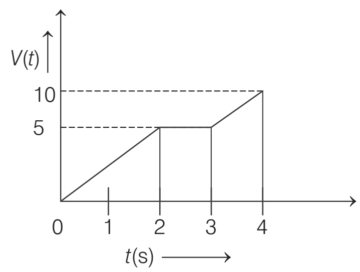


Fig. (2)

[Voltage distribution $V(t)$ is shown by Fig. (1) and the circuit is shown in Fig. (2).]

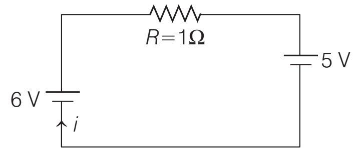
Ans. *(1)*

Consider the given figure 1,



From the above graph, we can say that voltage at $t = 3.2$ s is 6 V.

Now, consider figure 2,



$\therefore$ The value of I in the above figure will be

$$I = \frac{6\text{V} - 5\text{V}}{1\Omega} \Rightarrow I = \frac{1\text{V}}{1\Omega} \Rightarrow I = 1\text{A}$$

15 A 16 Ω wire is bend to form a square loop. A 9 V supply having internal resistance of 1 Ω is connected across one of its sides. The potential drop across the diagonals of the square loop is ...... $\times 10^{-1}$ V. **[2021, 25 July Shift-II]**

Ans.

(45) Given, resistance of wire = 16 Ω.

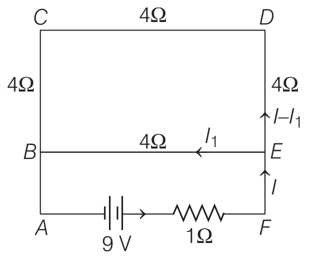
Let, length of wire = 4 L

Hence, side of square $a = L$

Resistance of one side $= \dfrac{16}{4} = 4\Omega$

Supply voltage $V = 9$ V and internal resistance = 1 Ω

Current flowing through circuit be I and voltage across diagonal be V'.



There $4l$ resistance are in series with 4Ω and 1 Ω resistance in parallel.

$$\text{Equivalent resistance } (R_{eq}) = \frac{12 \times 4}{12 + 4} + 1$$

$$= \frac{48}{16} + 1 = 4\Omega$$

As we know that,

By Ohm's law, $V = IR$

$$\Rightarrow \quad I = \frac{V}{R} \Rightarrow I = \frac{9}{4}\text{A}$$

Now current through BE be I_1 and $EDCB$ is $(I - I_1)$.

$\because$ In parallel connection,

Voltage across BE (V_1) = Voltage across $EDCB$ (V_2)

$$\therefore \quad I_1 \times 4 = \left(\frac{9}{4} - I_1\right)12$$

$$I_1 = \left(\frac{9}{4} - I_1\right)3$$

$\Rightarrow \quad 4I_1 = (9 - 4I_1)3$

$\Rightarrow \quad 16I_1 = 27$

$\Rightarrow \quad I_1 = \frac{27}{16}\text{ A}$

Equivalent resistance across diagonal,

$$\frac{1}{R_d} = \frac{1}{4+4} + \frac{1}{4+4} = \frac{1}{8} + \frac{1}{8}$$

$$R_d = \frac{8}{2} = 4l$$

and $\quad I_2 = I - I_1 = \frac{9}{4} - \frac{27}{16} = \frac{9}{16}\text{ A}$

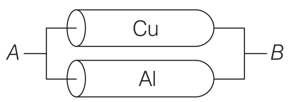
$\therefore \quad V' = (4+4)\, I_2 = 8 \times \frac{9}{16} = 4.5\text{ V}$

$= 45 \times 10^{-1}\text{ V}$

16 A copper (Cu) rod of length 25 cm and cross-sectional area 3 mm^2 is joined with a similar aluminium (Al) rod as shown in figure. Find the resistance of the combination between the ends *A* and *B*.

(Take, resistivity of copper $= 1.7 \times 10^{-8}\ \Omega$-m, resistivity of aluminium $= 2.6 \times 10^{-8}\ \Omega$-m)

[2021, 22 July Shift-II]



(a) 2.170 m Ω (b) 1.420 m Ω
(c) 0.0858 m Ω (d) 0.858 m Ω

Ans. *(d)*

Given, length of copper and aluminium,

$$l = 25\text{ cm} = 25 \times 10^{-2}\text{ m}$$

Area of cross-section,

$$A = 3\text{ mm}^2 = 3 \times 10^{-6}\text{ m}^2$$

and their resistivities of copper (ρ_{Cu}) and aluminium (ρ_{Al}) be $1.7 \times 10^{-8}\ \Omega$-m and $2.6 \times 10^{-8}\ \Omega$-m respectively.

According to given diagram, both copper rod and aluminium rods are in parallel and we know that,

in parallel combination, equivalent resistance $\left(\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}\right)$

We know that, $R = \rho l / A$

$\therefore$ Resistance of copper (R_{Cu})

$$= \frac{1.7 \times 10^{-8} \times 25 \times 10^{-2}}{3 \times 10^{-6}}$$

$$= 14.167 \times 10^{-4}\ \Omega$$

Resistance of aluminium

$$(R_{Al}) = \frac{2.6 \times 10^{-8} \times 25 \times 10^{-2}}{3 \times 10^{-6}}$$

$$= 21.67 \times 10^{-4}\ \Omega$$

Hence,

$$\frac{1}{R_{eq}} = \frac{1}{R_{Cu}} + \frac{1}{R_{Al}}$$

$$\Rightarrow \quad R_{eq} = \frac{R_{Cu} \cdot R_{Al}}{R_{Cu} + R_{Al}}$$

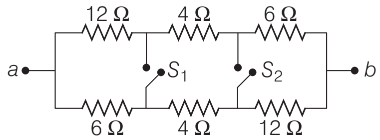
$$\Rightarrow \quad R_{eq} = \frac{14.167 \times 10^{-4} \times 21.67 \times 10^{-4}}{10^{-4}(14.167 + 21.67)}$$

$$= \frac{14.167 \times 21.67 \times 10^{-4}}{35.837}$$

$$= 0.857 \times 10^{-3} = 0.857\text{ m}\Omega$$

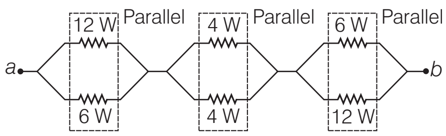
$$\simeq 0.858\text{ m}\Omega$$

17 In the given figure, switches S_1 and S_2 are in open condition. The resistance across *ab* when the switches S_1 and S_2 are closed is ...... Ω. **[2021, 20 July Shift-II]**



Ans. *(10)*

When switches S_1 and S_2 are closed, then the given figure will be represented as follows



$\therefore$ The resistance across *ab* will be given as

$$R_{ab} = \frac{12 \times 6}{12 + 6} + \frac{4 \times 4}{4 + 4} + \frac{6 \times 12}{6 + 12}$$

$$\Rightarrow \quad R_{ab} = \frac{72}{18} + 2 + \frac{72}{18}$$

$$\Rightarrow \quad R_{ab} = 4 + 2 + 4 = 10\ \Omega$$

18 A current of 5 A is passing through a non-linear magnesium wire of cross-section 0.04 m^2. At every point, the direction of current density is at an angle of 60° with the unit vector of area of cross-section. The magnitude of electric field at every point of the conductor is

(Take, resistivity of magnesium, $\rho = 44 \times 10^{-8}\ \Omega$-m)

[2021, 20 July Shift-I]

(a) 11×10^{-2} V/m (b) 11×10^{-7} V/m
(c) 11×10^{-5} V/m (d) 11×10^{-3} V/m

Ans. *(c)*

Given, current, $I = 5$ A

Area of cross-section of wire, $A = 0.04\text{ m}^2$

We know that, $J = \frac{I}{A}$

$\Rightarrow \quad I = JA$

or $\quad \mathbf{I} = \mathbf{J} \cdot \mathbf{A}$ or $I = JA\cos\theta$

where, $\quad J =$ current density.

$\Rightarrow \quad 5 = J\left(\frac{4}{100}\right) \times \cos(60°)$

$[\because \text{Given, } \theta = 60°]$

$$J = 500 \times \frac{1}{2}\left[\because \cos 60° = \frac{1}{2}\right]$$

$\Rightarrow \quad J = 250\text{ Am}^{-2}$

The relation between electric field, current density and resistivity can be given as

$$\mathbf{E} = \rho \cdot \mathbf{J}$$

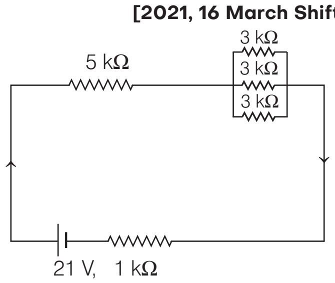
$$= 44 \times 10^{-8} \times 250$$

$[\because \text{Resistivity, } \rho = 44 \times 10^{-8}\ \Omega\text{-m}]$

$$= 11 \times 10^{-5}\text{ V/m}$$

19 In the figure given, the electric current flowing through the 5 kΩ resistor is *x* mA.

[2021, 16 March Shift-I]



The value of *x* to the nearest Integer is ....

Ans. *(3)*

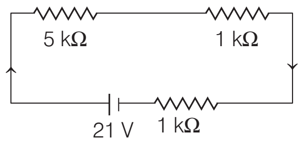
According to the figure given in question, all 3 Ω resistances are in parallel combination. So, their equivalent resistance is

$$\frac{1}{R_{parallel}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$$\frac{1}{R_{parallel}} = \frac{3}{3}$$

$$\Rightarrow \quad R_{parallel} = 1\text{k}\Omega$$

Equivalent circuit



5 kΩ and 1 kΩ resistance are in series to the equivalent of all 3 Ω resistances.

$\therefore \quad R_{net} = 5 + 1 + R_{parallel}$ ...(i)

$\Rightarrow \quad R_{net} = (5 + 1 + 1)k\Omega = 7k\Omega = 7 \times 10^3 \Omega$

$\therefore$ The value of electric current flowing through $5k\Omega$ resistor will be

$$I = \frac{V}{R_{net}} = \frac{21}{7 \times 10^3} = 3 \times 10^{-3}\text{ A} = 3\text{ mA}$$

Comparing with the given value in the question i.e., x mA, the value of $x = 3$.

20 Two wires of same length and thickness having specific resistances $6\,\Omega$- cm and $3\,\Omega$-cm respectively are connected in parallel. The effective resistivity is ρ Ω-cm. The value of ρ to the nearest integer, is ....

[2021, 18 March Shift-II]

Ans. *(4)*

Given, specific resistance for wire 1,

$$\rho_1 = 6\,\Omega\text{-cm}$$

Specific resistance for wire 2,

$$\rho_2 = 3\,\Omega\text{-cm}$$

Resistance,

$$R = \frac{\rho l}{A}$$

For parallel connections,

$$R_{net} = \frac{R_1 R_2}{R_1 + R_2}$$

$$\Rightarrow \quad \frac{\rho l}{2A} = \frac{\frac{\rho_1 l}{A} \times \frac{\rho_2 l}{A}}{\frac{\rho_1 l}{A} + \frac{\rho_2 l}{A}}$$

$$\Rightarrow \quad \frac{\rho}{2} = \frac{\rho_1 \rho_2}{\rho_1 + \rho_2}$$

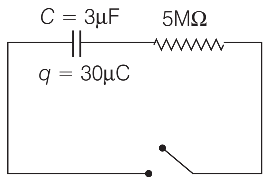
$$\Rightarrow \quad \frac{\rho}{2} = \frac{6 \times 3}{6 + 3}$$

$$\rho = 4\,\Omega\text{-cm}$$

Hence, the value of ρ to the nearest integer is 4.

21 The circuit shown in the figure consists of a charged capacitor of capacity $3\,\mu$F and a charge of 30 μC. At time $t = 0$, when the key is closed, the value of current flowing through the 5 MΩ resistor is $x\,\mu$A. The value of x to the nearest integer is ....

[2021, 18 March Shift-I]



Ans. *(2)*

According to given circuit diagram,

At $t = 0$, the key is in closed position.

Current through the resistor will be maximum.

Using Ohm's law,

$$I_{max} = \frac{V}{R}$$

$$\Rightarrow \quad I_{max} = \left(\frac{Q}{C}\right) \times \frac{1}{R}$$

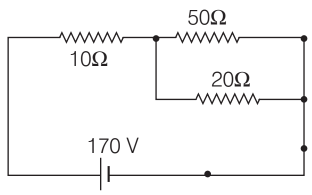
$$\Rightarrow \quad I_{max} = \left(\frac{30 \times 10^{-6}}{3 \times 10^{-6}}\right) \times \frac{1}{5 \times 10^6}$$

$$I_{max} = 2 \times 10^{-6}\text{ A}$$

$$I_{max} = 2\,\mu\text{A}$$

The value of the current flowing through the 5 Ω resistor is $2\,\mu$A. Hence, the value of the x to the nearest integer is 2.

22 The voltage across the 10Ω resistor in the given circuit is x volt.

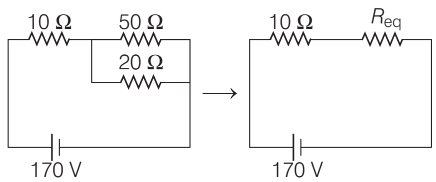


The value of x to the nearest integer is ....

[2021, 18 March Shift-I]

Ans. *(70)*

Electrical circuit is shown in the diagram. Now, let's draw the equivalent circuit.



Equivalent resistance of the circuit,

$$R_{eq} = \frac{50 \times 20}{50 + 20}$$

$$R_{eq} = \frac{100}{7}\,\Omega$$

According to voltage division rule, voltage across the 10 Ω resistance of the circuit,

$$V_{10\,\Omega} = 170 \times \left(\frac{10}{10 + \frac{100}{7}}\right)$$

$$V_{10\,\Omega} = 70\text{ V}$$

The value of the x to the nearest integer is 70.

23 A current of 10 A exists in a wire of cross sectional area of 5 mm^2 with a drift velocity of $2 \times 10^{-3}\text{ ms}^{-1}$. The number of free electrons in each cubic metre of the wire is

[2021, 17 March Shift-I]

(a) 2×10^6 (b) 625×10^{25}

(c) 2×10^{25} (d) 1×10^{23}

Ans. *(b)*

Given, current, $I = 10$ A

Cross-sectional area,

$$A = 5\text{ mm}^2 = 5 \times 10^{-6}\text{ m}^2$$

Drift velocity, $v_d = 2 \times 10^{-3}\text{ ms}^{-1}$

The value of current flowing through a conductor can be given by

$$I = neAv_d \quad \text{...(i)}$$

where, n = number of free electrons

and e = charge on an electron

Putting all the given values in Eq. (i) we get

$$10 = n \times 1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}$$

$$\Rightarrow \quad n = \frac{10}{1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}}$$

$$= 0.625 \times 10^{28} = 625 \times 10^{25}$$

24 The equivalent resistance of series combination of two resistors is s. When they are connected in parallel, the equivalent resistance is p. If $s = np$, then the minimum value for n is ....

(Round off to the nearest integer)

[2021, 17 March Shift-I]

Ans. *(4)*

Let two resistors have resistances R_1 and R_2, respectively.

As per question, equivalent resistance of series combination is s

$$\Rightarrow \quad s = R_1 + R_2 \quad \text{...(i)}$$

and equivalent resistance of parallel combination is p

$$\Rightarrow \quad p = \frac{R_1 R_2}{R_1 + R_2} \quad \text{...(ii)}$$

According to the question,

$$s = np \quad \text{...(iii)}$$

From Eqs. (i),(ii) and (iii), we get

$$R_1 + R_2 = n\frac{R_1 R_2}{(R_1 + R_2)}$$

$$\Rightarrow \quad n(R_1 R_2) = (R_1 + R_2)^2 \Rightarrow n = \frac{(R_1 + R_2)^2}{R_1 R_2}$$

For n to be minimum, $R_1 = R_2 = R$

$$\Rightarrow \quad n = \frac{(R + R)^2}{R \cdot R} = \frac{(2R)^2}{R^2} = \frac{4R^2}{R^2}$$

$$\Rightarrow \quad n = 4$$

25 A conducting wire of length l, area of cross-section A and electric resistivity ρ is connected between the terminals of a battery. A potential difference V is developed between its ends, causing an electric current. If the length of the wire of the same material is doubled and the area of cross-section is halved, the resultant current would be **[2021, 16 March Shift-I]**

(a) $\frac{1}{4}\frac{VA}{\rho l}$ (b) $\frac{3}{4}\frac{VA}{\rho l}$

(c) $\frac{1}{4}\frac{\rho l}{VA}$ (d) $4\frac{VA}{\rho l}$

Ans. *(a)*

Initially, the resistance of wire is

$R_1 = \rho L/A$

In second case,

Length, $l' = 2l$

Area, $A' = \frac{A}{2}$

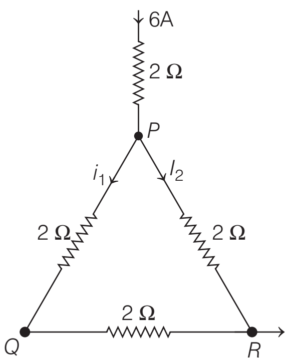
$\therefore \quad R_2 = \frac{\rho l'}{A'} = \frac{\rho(2l)}{(A/2)} = \frac{4\rho l}{A}$

According to Ohm's law, $I = \frac{V}{R_2}$

$\Rightarrow \quad I = \frac{V}{4\rho l/A} = \frac{1}{4}\frac{VA}{\rho l}$

This is the required value of resultant current.

26 A current of 6 A enters one corner P of an equilateral triangle PQR having three wires of resistance 2 Ω each and leaves by the corner R. The currents i_1 in ampere is .... **[2021, 25 Feb Shift-II]**



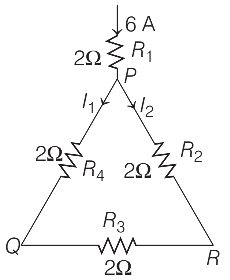
Ans. *(2)*

Let resistances be R_1, R_2, R_3 and R_4 and I_1 current is passing through R_4 as shown in figure

$\therefore I_2 = (6 - I_1)$ is passing through R_2

As, same current is flowing through R_4 and R_3.

$\therefore R_4$ and R_3 are in series.



and series equivalent resistance,

$R_{eq} = R_4 + R_3$

$\therefore \quad R_{eq} = 2 + 2 = 4\,\Omega$

Voltage through R_{eq} and R_2 will be same.

$\Rightarrow \quad I_1 R_{eq} = I_2 R_2 \Rightarrow I_1 4 = (6 - I_1)2$

$\Rightarrow \quad 2I_1 = 6 - I_1 \Rightarrow I_1 = 2\text{A}$

27 A cylindrical wire of radius 0.5 mm and conductivity 5×10^7 S/m is subjected to an electric field of 10 mV/m. The expected value of current in the wire will be $x^3\pi$ mA. The value of x is .... **[2021, 24 Feb Shift-II]**

Ans. *(5)*

Given, radius of cylindrical wire, $r = 0.5$ mm $= 0.5 \times 10^{-3}$ m

Conductivity, $\sigma = 5 \times 10^7$ S/m

Electric field, $E = 10$ mV/m $= 10 \times 10^{-3}$ V/m

We know that current density,

$\therefore \quad J = \sigma E$

$= 5 \times 10^7 \times 10 \times 10^{-3}$

$= 5 \times 10^5$ A/m^2

Also, $J = I/A \Rightarrow I = JA$

$\Rightarrow \quad I = 5 \times 10^5 \times \pi \times (0.5 \times 10^{-3})^2$

$= 5 \times 10^5 \times \pi \times 25 \times 10^{-8}$

$= 125\,\pi \times 10^{-3}$

$\Rightarrow \quad x^3\,\pi\text{mA} = 125\,\pi\,\text{mA}$

$\Rightarrow \quad x^3 = 5^3$

$\Rightarrow \quad x = 5$

28 A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$, where $\alpha_0 = 20$ A/s and $\beta = 8$ As^{-2}. Find the charge crossed through a section of the wire in 15 s. **[2021, 24 Feb Shift-I]**

(a) 260 C (b) 2100 C

(c) 11250 C (d) 2250 C

Ans. *(c)*

Given, $\quad i = \alpha_0 t + \beta t^2$

where, $\alpha_0 = 20$ A/s, $\beta = 8$ A/s^2

We know that, $\quad i = \frac{dq}{dt}$

$\Rightarrow \frac{dq}{dt} = i = \alpha_0 t + \beta t^2 = 20t + 8t^2$

$\Rightarrow \quad dq = (20t + 8t^2)dt$

On integrating both sides, we get

$\int_0^q dq = \int_0^{15} (20t + 8t^2)dt$

$q = \left[\frac{20t^2}{2} + \frac{8t^3}{3}\right]_0^{15} = 10 \times (15)^2 + \frac{8}{3} \times (15)^3$

$\therefore q = 11250$C

29 Consider four conducting materials copper, tungsten, mercury and aluminium with resistivity ρ_C, ρ_T, ρ_M and ρ_A, respectively. Then, **[2020, 2 Sep Shift-I]**

(a) $\rho_A > \rho_T > \rho_C$

(b) $\rho_A > \rho_M > \rho_C$

(c) $\rho_C > \rho_A > \rho_T$

(d) $\rho_M > \rho_A > \rho_C$

Ans. *(d)*

Aluminium is more resistive than copper and mercury is most resistive of all.

So, $\rho_M > \rho_A > \rho_C$

Hence, correct option is (d).

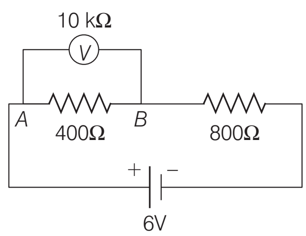
30 Two resistors 400 Ω and 800 Ω are connected in series across a 6 V battery. The potential difference measured by a voltmeter of 10 kΩ across 400 Ω resistor is close to **[2020, 3 Sep, Shift-II]**

(a) 1.95 V (b) 2 V

(c) 1.8 V (d) 2.05 V

Ans. *(a)*

The circuit diagram is



The equivalent resistance across AB,

$R_{AB} = \frac{10000 \times 400}{10000 + 400}$

$= \frac{10000 \times 400}{10400}$

$= \frac{40000}{104}$

$= 384.6\ \Omega$

$\approx 385\ \Omega$

$\therefore$ Total circuit resistance

$= 385 + 800 = 1185\ \Omega$

Hence, circuit current is

$I = \frac{V}{R_{eq}} = \frac{6}{1185}$

$= 5.06 \times 10^{-3}$ A

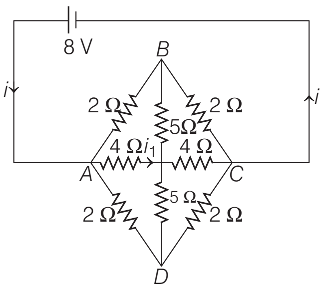
Now, potential drop across points A and B is

$V_{AB} = I \cdot R_{AB}$

$= 5.06 \times 10^{-3} \times 385$

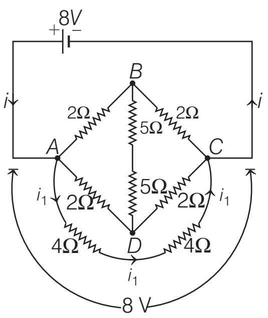
$= 1.946\text{V} \simeq 1.95\text{V}$

31 The value of current i_1 flowing from A to C in the circuit diagram is **[2020, 4 Sep Shift-II]**



(a) 1 A (b) 5 A (c) 2 A (d) 4 A

Ans. *(a)*



From the given circuit diagram,

Potential drop across $AC, V = 8$ V

Resistance of mentioned wire,

$R = 4 + 4 = 8\ \Omega$

So, the current flowing from A to C,

$i_1 = \frac{V}{R} = \frac{8\text{V}}{8\Omega} = 1$ A

Hence, option (a) is correct.

32 A circuit to verify Ohm's law uses ammeter and voltmeter in series or parallel connected correctly to the resistor. In the circuit, **[2020, 6 Sep Shift-II]**

(a) ammeter is always used in parallel and voltmeter in series

(b) Both ammeter and voltmeter must be connected in parallel

(c) ammeter is always connected in series and voltmeter in parallel

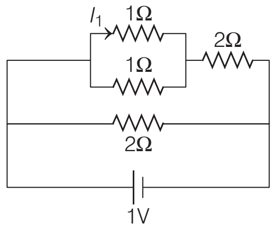
(d) Both ammeter and voltmeter must be connected in series

Ans. *(c)*

In the circuit to verify Ohm's law, the ammeter is connected in series as it measures the current through the resistance, while the voltmeter is connected in parallel as it measures the potential difference across the ends of resistor.

Hence, correct option is (c).

33 The current I_1 (in ampere) flowing through 1Ω resistor in the following circuit is **[2020, 7 Jan Shift-I]**

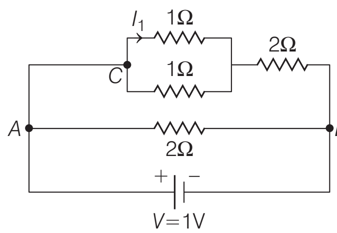


(a) 0.25 (b) 0.4

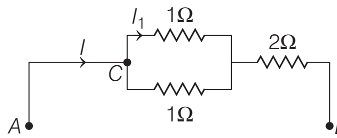
(c) 0.5 (d) 0.2

Ans. *(d)*

Given circuit is



In given circuit $V_{AB} = 1$V, so upper branch of circuit is as shown below figure.



Equivalent resistance of upper branch,

$R_{eq} = (1\Omega \,||\, 1\Omega) + 2\Omega$

$= \frac{1}{2} + 2 = \frac{5}{2}\ \Omega$

So, current in upper branch,

$I = \frac{V}{R} = \frac{V_{AB}}{R_{eq}}$

$= \frac{1}{5/2} = \frac{2}{5}$ A

At point C, this current is equally divided into two parts.

So, $I_1 = \frac{1}{2}\left(\frac{2}{5}\right) = 0.2$ A

34 A 200 Ω resistor has a certain colour code. If one replaces the red colour by green in the code, the new resistance will be

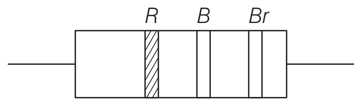
(a) 100 Ω (b) 400 Ω

(c) 300 Ω (d) 500 Ω

[2019, 8 April Shift-I]

Ans. *(d)*

Given, resistance is $200\ \Omega = 20 \times 10^1\ \Omega$

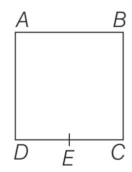


So, colour scheme will be red, black and brown.

Significant figure of red band is 2 and for green is 5. When red (2) is replaced with green (5), new resistance will be

200 ohm $\longrightarrow$ 500 ohm.

35 A wire of resistance R is bent to form a square $ABCD$ as shown in the figure. The effective resistance between E and C is [E is mid-point of arm CD] **[2019, 9 April Shift-I]**



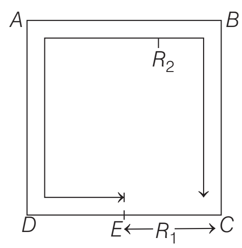
(a) $\frac{7}{64}R$ (b) $\frac{3}{4}R$

(c) R (d) $\frac{1}{16}R$

Ans. *(a)*

Let the length of each side of square $ABCD$ is a.

$\therefore$ Resistance per unit length of each side $= \frac{R}{4a}$

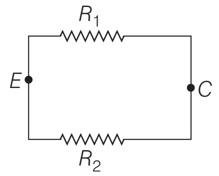


Now, $R_1 = \frac{R}{4a}[EC] = \frac{R}{4a} \times \frac{a}{2} = \frac{R}{8}$

Similarly,

$$R_2 = \frac{R}{4a}[EDABC]$$
$$= \frac{R}{4a} \times \frac{7a}{2} = \frac{7R}{8}$$

Now, effective resistance between E and C is the equivalent resistance of R_1 and R_2 that are connected in parallel as shown below.



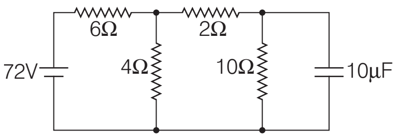
$$R_{EC} = \frac{R_1 R_2}{R_1 + R_2}$$
$$= \frac{(R/8)\times(7R/8)}{(R/8)+(7R/8)}$$
$$= \frac{7R^2}{64} \times \frac{8}{8R} = \frac{7}{64}R$$

36 Determine the charge on the capacitor in the following circuit **[2019, 9 April Shift-I]**

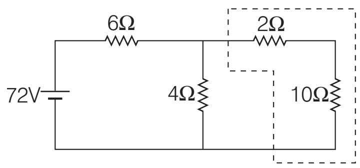
(a) $2\,\mu C$ (b) $200\,\mu C$
(c) $10\,\mu C$ (d) $60\,\mu C$

Ans. ***(b)***

Given circuit is

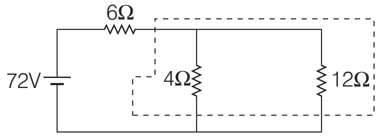


To find charge on capacitor, we need to determine voltage across it. In steady state, capacitor will acts as open circuit and circuit can be reduced as

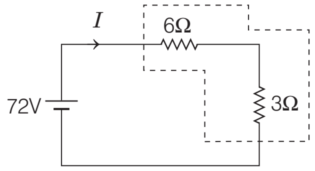


In series, $R_{eq} = 2\,\Omega + 10\,\Omega$
$= 12\,\Omega$

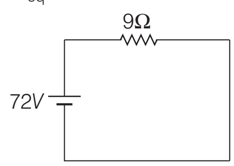
$\Downarrow$



In parallel, $R_{eq} = \dfrac{4\times 12}{4+12} = 3\,\Omega$



In series, $R_{eq} = 6\,\Omega + 3\,\Omega = 9\,\Omega$

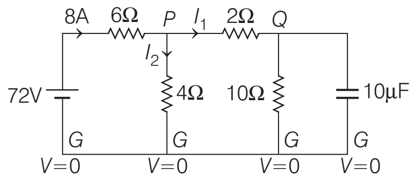


So, current in steady state,

$$I = \frac{V}{R} = \frac{72}{9} = 8\text{A}$$

Now, by using current division, at point P, current in $6\,\Omega$ branch is

$$\frac{72 - V_P}{6\,\Omega} = 8\text{A} \Rightarrow V_P = 72 - 48 = 24\,\text{V}$$



Current in $4\,\Omega$ branch is,

$$i_2 = \frac{V_P - 0}{4} = \frac{24-0}{4} = 6\,\Omega$$

So, current in $2\,\Omega$ resistance is

$$I_1 = 8 - I_2 \qquad [\because I = I_1 + I_2]$$
$$= 8 - 6 = 2\text{A}$$

$\therefore$Potential difference across $10\,\Omega$ resistor is

$$V_{0G} = 2\text{A} \times 10\,\Omega = 20\,\text{V}$$

Same potential difference will be applicable over the capacitor (parallel combination).

So, charge stored in the capacitor will be

$$Q = CV = 10 \times 10^{-6} \times 20$$
$$\Rightarrow \qquad Q = 2 \times 10^{-4}\,\text{C} = 200\,\mu\text{C}$$

37 In a conductor, if the number of conduction electrons per unit volume is $8.5 \times 10^{28}\ \text{m}^{-3}$ and mean free time is 25 fs(femto second), it's approximate resistivity is (Take, $m_e = 9.1\times 10^{-31}$ kg) **[2019, 9 April Shift-II]**

(a) $10^{-7}\,\Omega$-m (b) $10^{-5}\,\Omega$-m
(c) $10^{-6}\,\Omega$-m (d) $10^{-8}\,\Omega$-m

Ans. ***(d)***

Resistivity of a conductor is

$$\rho = \frac{m_e}{ne^2\tau} \qquad \ldots(\text{i})$$

where, m_e = mass of electron
$= 9.1\times 10^{-31}$ kg,
n = free charge density $= 8.5\times 10^{28}\,\text{m}^{-3}$,
τ = mean free time $= 25\,\text{fs} = 25\times 10^{-15}$ s
and e = charge of electron $= 1.6\times 10^{-19}$ C

Substituting values in Eq. (i), we get

$$\rho = \frac{9.1\times 10^{-31}}{8.5\times 10^{28} \times (1.6\times 10^{-19})^2 \times 25\times 10^{-15}}$$
$$= \frac{9.1\times 10^{-6}}{8.5\times 2.56\times 25} = 0.016\times 10^{-6}$$
$$= 1.6\times 10^{-8}\ \Omega\text{-m} \simeq 10^{-8}\ \Omega\text{-m}$$

38 A metal wire of resistance $3\,\Omega$ is elongated to make a uniform wire of double its previous length. This new wire is now bent and the ends joined to make a circle. If two points on this circle make an angle 60º at the centre, the equivalent resistance between these two points will be **[2019, 9 April Shift-II]**

(a) $\dfrac{7}{2}\Omega$ (b) $\dfrac{5}{2}\Omega$
(c) $\dfrac{12}{5}\Omega$ (d) $\dfrac{5}{3}\Omega$

Ans. ***(d)***

Initial resistance of wire is $3\,\Omega$. Let its length is l and area is A.

Then, $\qquad R_{\text{initial}} = \rho\dfrac{l}{A} = 3\,\Omega \qquad \ldots(\text{i})$

When wire is stretched twice its length, then its area becomes A', on equating volume, we have

$$Al = A'2l \Rightarrow A' = \frac{A}{2}$$

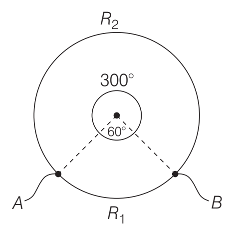
So, after stretching, resistance of wire will be

$$R' = R_{\text{final}} = \rho\frac{l'}{A'} = 4\rho\frac{l}{A} = 12\,\Omega$$

[using Eq. (i)]

Now, this wire is made into a circle and connected across two points A and B (making 60º angle at centre) as

Now, above arrangement is a combination of two resistances in parallel,



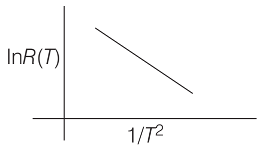
$$R_1 = \frac{60 \times R'}{360} = \frac{1}{6} \times 12 = 2\,\Omega$$

and $\quad R_2 = \frac{300}{360} \times R' = \frac{5}{6} \times 12 = 10\,\Omega$

Since, R_1 and R_2 are connected in parallel.

So, $\quad R_{AB} = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \times 2}{12} = \frac{5}{3}\,\Omega$

39 In an experiment, the resistance of a material is plotted as a function of temperature (in some range). As shown in the figure, it is a straight line. **[2019, 10 April Shift-I]**



One may conclude that

(a) $R(T) = R_0 e^{-T^2/T_0^2}$

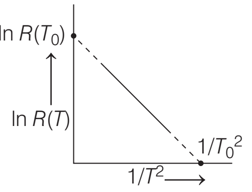
(b) $R(T) = R_0 e^{T^2/T_0^2}$

(c) $R(T) = R_0 e^{-T_0^2/T^2}$

(d) $R(T) = \frac{R_0}{T^2}$

Ans. ***(c)***

From the given graph,



We can say that, $\ln R(T) \propto -\frac{1}{T^2}$

Negative sign implies that the slope of the graph is negative.

or $\ln R(T) = \text{constant}\left(-\frac{1}{T^2}\right)$

$$\Rightarrow \quad R(T) = \frac{\exp(\text{const.})}{\exp\left(\frac{1}{T^2}\right)}$$

$$\Rightarrow \quad R(T) = R_0 \exp\left(-\frac{T_0^2}{T^2}\right)$$

Alternate Solution

From graph, $\quad \frac{\frac{1}{T^2}}{\frac{1}{T_0^2}} + \frac{\ln R(T)}{\ln R(T_0)} = 1$

$$\Rightarrow \quad \ln R(T) = [\ln R(T_0)] \cdot \left[1 - \frac{T_0^2}{T^2}\right]$$

or $\quad R(T) = R_0 \exp\left(\frac{-T_0^2}{T^2}\right)$

40 A current of 5 A passes through a copper conductor (resistivity $= 1.7 \times 10^{-8}\,\Omega$-m) of radius of cross-section 5 mm. Find the mobility of the charges, if their drift velocity is 1.1×10^{-3} m/s. **[2019, 10 April Shift-I]**

(a) $1.5\,\text{m}^2/\text{V-s}$ (b) $1.3\,\text{m}^2/\text{V-s}$

(c) $1.0\,\text{m}^2/\text{V-s}$ (d) $1.8\,\text{m}^2/\text{V-s}$

Ans. ***(c)***

Given, $\quad I = 5\text{A}$,

$\rho = 1.7 \times 10^{-8}\,\Omega\text{-m}$,

$r = 5\,\text{mm} = 5 \times 10^{-3}\,\text{m}$,

$v_d = 1.1 \times 10^{-3}\,\text{m/s}$

Mobility of charges in a conductor is given by

$$\mu = \frac{v_d}{E} \quad \text{...(i)}$$

and resistivity is given by

$$\rho = \frac{E}{J} = \frac{E}{I/A} \quad \left(\because J = \sigma E = \frac{1}{\rho} \times E\right)$$

$$\Rightarrow \quad \rho = \frac{EA}{I}$$

or $\quad E = \frac{\rho I}{A} \quad \text{...(ii)}$

From Eqs. (i) and (ii), we get

$$\mu = \frac{v_d A}{\rho I}$$

Substituting the given values, we get

$$= \frac{1.1 \times 10^{-3} \times \pi \times (5 \times 10^{-3})^2}{1.7 \times 10^{-8} \times 5}$$

$$= \frac{86.35 \times 10^{-9}}{8.5 \times 10^{-8}} = 10.1 \times 10^{-1}$$

$$\Rightarrow \quad \mu \approx 1\,\text{m}^2/\text{V-s}$$

41 Space between two concentric conducting spheres of radii a and $b (b > a)$ is filled with a medium of resistivity ρ. The resistance between the two spheres (in ohm) will be **[2019, 10 April Shift-II]**

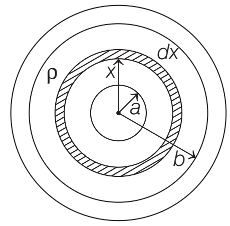
(a) $\frac{\rho}{2\pi}\left(\frac{1}{a} + \frac{1}{b}\right)$ (b) $\frac{\rho}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$

(c) $\frac{\rho}{2\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$ (d) $\frac{\rho}{4\pi}\left(\frac{1}{a} + \frac{1}{b}\right)$

Ans. ***(b)***

Key Idea Resistance between surface of inner shell and a circumferential point of outer shell can be formed by finding resistance of a thin (differentially thin) shell in between these two shells. Then, this result can be integrated (summed up) to get resistance of the complete arrangement.

For a elemental shell of radius x and thickness dx,



Resistance, $dR = \rho \frac{l}{A}$

$$\Rightarrow \quad dR = \rho \frac{dx}{4\pi x^2}$$

So, resistance of complete arrangement is

$$R = \int_a^b dR = \int_a^b \rho \frac{dx}{4\pi x^2} = \frac{\rho}{4\pi}\int_a^b x^{-2} dx$$

$$\Rightarrow R = \frac{\rho}{4\pi}\left(\frac{x^{-1}}{-1}\right)_a^b = \frac{\rho}{4\pi}\left(-\frac{1}{x}\right)_a^b$$

$$= \frac{\rho}{4\pi}\left(-\frac{1}{b} - \left(-\frac{1}{a}\right)\right)$$

$$= \frac{\rho}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)\text{ohm}$$

42 Drift speed of electrons, when 1.5 A of current flows in a copper wire of cross-section $5\,\text{mm}^2$ is v. If the electron density in copper is $9 \times 10^{28}/\text{m}^3$, the value of v (in mm/s) is close to (Take, charge of electron to be $= 1.6 \times 10^{-19}$ C) **[2019, 9 Jan Shift-I]**

(a) 0.02 (b) 0.2 (c) 2 (d) 3

Ans. ***(a)***

Relation between current (I) flowing through a conducting wire and drift velocity of electrons (v_d) is given as

$$I = neAv_d$$

where, n is the electron density and A is the area of cross-section of wire.

$$\Rightarrow \quad v_d = \frac{I}{neA}$$

Substituting the given values, we get

$$v=\frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times5\times10^{-6}}$$

$$v=\frac{1.5\times10^{-3}}{72}\text{ m/s}=0.2\times10^{-4}\text{ m/s}$$

or $\quad v=0.02\text{ mm/s}$

43 A copper wire is stretched to make it 0.5% longer. The percentage change in its electrical resistance, if its volume remains unchanged is **[2019, 9 Jan Shift-I]**

(a) 2.0% (b) 1.0% (c) 0.5% (d) 2.5%

Ans. ***(b)***

Electrical resistance of wire of length 'l', area of cross-section 'A' and resistivity 'ρ' is given as

$$R=\rho\frac{l}{A} \qquad \text{...(i)}$$

Since we know, volume of the wire is

$$V=A\times l \qquad \text{...(ii)}$$

$\therefore$ From Eqs. (i) and (ii), we get

$$R=\rho\frac{l^2}{V} \quad \text{...(iii)}$$

As, the length has been increased to 0.5%.

$\therefore$ New length of the wire,

$$l'=l+0.5\%\text{ of }l=l+0.005\,l=1.005\,l$$

But V and ρ remains unchanged.

So, new resistance,

$$R'=\frac{\rho[(1.005)\,l]^2}{V} \qquad \text{...(iv)}$$

Dividing Eq. (iv) and Eq. (iii), we get

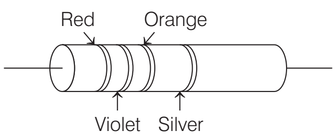
$$\frac{R'}{R}=(1.005)^2$$

$\Rightarrow$ % change in the resistance

$$=\left(\frac{R'}{R}-1\right)\times100$$

$$=[(1.005)^2-1]\times100=1.0025\%\simeq1\%$$

44 A resistance is shown in the figure. Its value and tolerance are given respectively by **[2019, 9 Jan Shift-I]**



(a) 270 Ω, 5%
(b) 27 kΩ, 20%
(c) 27 kΩ, 10%
(d) 270 kΩ, 10%

Ans. ***(c)***

The value of a carbon resistor is given as,

$$R=AB\times C\pm D\% \qquad \text{...(i)}$$

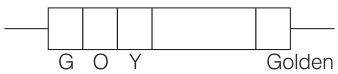
where, color band A and B (first two colors) indicate the first two significant figures of resistance in ohms, C (third color) indicates the decimal multiplier and D (forth color) indicates the tolerance in % as per the indicated value. The table for color code of carbon resistor is given below,

Color Codes	Values (A, B)	Multiplier (C)	Tolerance (D)(%)
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Grey	8	10^8	
White	9	10^9	
Gold			$\pm5\%$
Silver			$\pm10\%$
No colour			$\pm20\%$

$\therefore$ Comparing the colors given in the question and the table and writing in the manner of Eq. (i), we get

$$R=27\times10^3\ \Omega,\pm10\%=27\text{ k}\Omega,\pm10\%$$

45 A carbon resistance has a following color code. What is the value of the resistance? **[2019, 9 Jan Shift-II]**



(a) 5.3 M$\Omega\pm5\%$ (b) 64 k$\Omega\pm10\%$
(c) 6.4 M$\Omega\pm5\%$ (d) 530 k$\Omega\pm5\%$

Ans. ***(d)***

The value of a carbon resistor is given as

$$R=AB\times C\pm D\% \qquad \text{...(i)}$$

where, colour band A and B (first two colour) indicates the first two significant figures of resistance in Ohms.

C (third colour) indicate the decimal multiplies and D (fourth colour) indicates the tolerance in % as per the indicated value.

The table for colour code,

Colour code	Values (AB)	Multiplier (C)	Tolerance
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Voilet	7	10^7	
Grey	8	10^8	
White	9	10^9	
Gold	-	-	$\pm5\%$
Silver	-	-	$\pm10\%$
No colour	-	-	$\pm20\%$

$\because$ Comparing the colours given in the question and table and writing in the manner of Eq. (i), we get

$$R=53\times10^4\pm5\%\ \Omega$$

or $\quad R=530\times10^3\ \Omega\pm5\%$

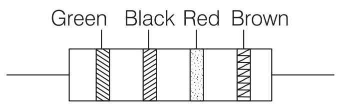
or $\quad R=530\text{ k}\Omega\pm5\%$

46 A 2 W carbon resistor is color coded with green, black, red and brown respectively. The maximum current which can be passed through this resistor is **[2019, 10 Jan Shift-I]**

(a) 0.4 mA (b) 63 mA
(c) 20 mA (d) 100 mA

Ans. ***(c)***

Colour code of carbon resistance is shown in the figure below



So, resistance value of resistor using colour code is

$$R=502\times10$$
$$=50.2\times10^2\ \Omega$$

Here, we must know that for given carbon resistor first three colours give value of resistance and fourth colour gives multiplier value.

Now using power, $P=i^2R$

we get, $\quad i=\sqrt{\frac{P}{R}}=\sqrt{\frac{2}{50.2\times10^2}}$

$$\approx20\times10^{-3}\text{A}$$
$$=20\text{ mA.}$$

47 A uniform metallic wire has a resistance of 18 Ω and is bent into an equilateral triangle. Then, the resistance between any two vertices of the triangle is **[2019, 10 Jan Shift-I]**

(a) 12 Ω (b) 8 Ω (c) 2 Ω (d) 4 Ω

Ans. *(d)*

Resistance of each arm of equilateral triangle will be

$$R = \frac{18}{3} = 6\,\Omega$$

So we have following combination will be

Equivalent resistance is

$$\therefore \quad R_{AB} = \frac{12 \times 6}{12 + 6} = \frac{12 \times 6}{18} = 4\,\Omega$$

48 The temperature dependence of resistances of Cu and undoped Si in the temperature range 300-400 K, is best described by **[JEE Main 2016]**

(a) linear increase for Cu, linear increase for Si

(b) linear increase for Cu, exponential increase for Si

(c) linear increase for Cu, exponential decrease for Si

(d) linear decrease for Cu, linear decrease for Si

Ans. *(c)*

As, we know Cu is a conductor, so increase in temperature, resistance will increase. Then, Si is semiconductor, so with increase in temperature, resistance will decrease.

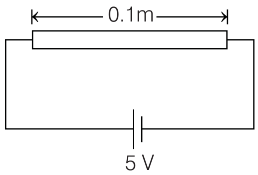
49 When 5V potential difference is applied across a wire of length 0.1m, the drift speed of electrons is $2.5 \times 10^{-4}\,\text{ms}^{-1}$. If the electron density in the wire is $8 \times 10^{28}\,\text{m}^{-3}$ the resistivity of the material is close to **[JEE Main 2015]**

(a) $1.6 \times 10^{-8}\,\Omega\text{m}$ (b) $1.6 \times 10^{-7}\,\Omega\text{m}$

(c) $1.6 \times 10^{-6}\,\Omega\text{m}$ (d) $1.6 \times 10^{-5}\,\Omega\text{m}$

Ans. *(d)*

According to the question,



$$v_d = 2.5 \times 10^{-4}\,\text{m/s}$$

$$\Rightarrow \quad n = 8 \times 10^{28}\,/\,\text{m}^3$$

We know that

$$J = nev_d \text{ or } I = nev_d A$$

where, symbols have their usual meaning.

$$\Rightarrow \quad \frac{V}{R} = nev_d A \text{ or } \frac{V}{\frac{\rho L}{A}} = nev_d A$$

$$\text{or} \quad \frac{V}{\rho L} = nev_d \text{ or } \rho = \frac{V}{nev_d L}$$

$$= \frac{5}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 2.5 \times 10^{-4} \times 0.1}$$

or $\rho = 1.6 \times 10^{-5}\,\Omega\text{m}$

50 If 400Ω of resistance is made by adding four 100Ω resistance of tolerance 5%, then the tolerance of the combination is **[AIEEE 2011]**

(a) 20% (b) 5%

(c) 10% (d) 15%

Ans. *(b)*

Resistance of combination, $R_e = 4R$

$$\Rightarrow \quad \frac{\Delta R_e}{R_e} = \frac{\Delta R}{R} = \frac{5 \times 100}{100} = 5\%$$

51 If a wire is stretched to make it 0.1% longer, its resistance will **[AIEEE 2011]**

(a) increase by 0.2%

(b) decrease by 0.2%

(c) decrease by 0.05%

(d) increase by 0.05%

Ans. *(d)*

$$R = \frac{\rho l}{A} = \frac{\rho l^2}{V} \qquad [\because V = \text{volume}]$$

$$\therefore \quad \frac{\Delta R}{R} = 2\frac{\Delta l}{l} = +\,0.2\%$$

52 Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly **[AIEEE 2010]**

(a) $\frac{\alpha_1 + \alpha_2}{2}, \alpha_1 + \alpha_2$

(b) $\alpha_1 + \alpha_2, \frac{\alpha_1 + \alpha_2}{2}$

(c) $\alpha_1 + \alpha_2, \frac{\alpha_1 \alpha_2}{\alpha_1 + \alpha_2}$

(d) $\frac{\alpha_1 + \alpha_2}{2}, \frac{\alpha_1 + \alpha_2}{2}$

Ans. *(d)*

Let R_0 be the initial resistance of both conductors.

$\therefore$ At temperature θ, their resistances will be

$$R_1 = R_0(1 + \alpha_1\theta)$$

and $R_2 = R_0(1 + \alpha_2\theta)$

For series combination,

$$R_s = R_1 + R_2$$

$$R_{s0}(1 + \alpha_s\theta) = R_0(1 + \alpha_1\theta) + R_0(1 + \alpha_2\theta)$$

where, $R_{s0} = R_0 + R_0 = 2R_0$

$$\therefore 2R_0(1 + \alpha_s\theta) = 2R_0 + R_0\theta(\alpha_1 + \alpha_2)$$

$$\text{or} \quad \alpha_s = \frac{\alpha_1 + \alpha_2}{2}$$

For parallel combination,

$$R_p = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_{p0}(1 + \alpha_p\theta) = \frac{R_0(1 + \alpha_1\theta)R_0(1 + \alpha_2\theta)}{R_0(1 + \alpha_1\theta) + R_0(1 + \alpha_2\theta)}$$

where, $R_{p0} = \frac{R_0 R_0}{R_0 + R_0} = \frac{R_0}{2}$

$$\therefore \frac{R_0}{2}(1 + \alpha_p\theta) = \frac{R_0^2(1 + \alpha_1\theta + \alpha_2\theta + \alpha_1\alpha_2\theta^2)}{R_0(2 + \alpha_1\theta + \alpha_2\theta)}$$

As α_1 and α_2 are small quantities.

$\therefore$ $\alpha_1\alpha_2$ is negligible.

$$\text{or} \quad \alpha_p = \frac{\alpha_1 + \alpha_2}{2 + (\alpha_1 + \alpha_2)\theta}$$

$$= \frac{\alpha_1 + \alpha_2}{2}\left[1 - \left(\frac{\alpha_1 + \alpha_2}{2}\right)\theta\right]$$

As $(\alpha_1 + \alpha_2)^2$ is negligible.

$$\therefore \quad \alpha_p = \frac{\alpha_1 + \alpha_2}{2}$$

53 This question contains Statement I and Statement II. Of the four choices given after the statements, choose the one that best describes the two statements. **[AIEEE 2009]**

Statement I The temperature dependence of resistance is usually given as $R = R_0(1 + \alpha\Delta t)$. The resistance of a wire changes from $100\,\Omega$ to $150\,\Omega$ when its temperature is increased from 27°C to 227°C. This implies that $\alpha = 2.5 \times 10^{-3}\,/°\text{C}$.

Statement II $R = R_i(1 + \alpha\Delta T)$ is valid only when the change in the temperature ΔT is small and $\Delta R = (R - R_0) << R_0$.

(a) Statement I is true, Statement II is false

(b) Statement I is true, Statement II is true; Statement II is the correct explanation of Statement I

(c) Statement I is true, Statement II is true; Statement II is not the correct explanation of Statement I

(d) Statement I is false, Statement II is true

Ans. *(d)*

$$R = R_t\,(1+\alpha\,\Delta t)$$

Given, $R_t = 100\ \Omega$, $R = 150\ \Omega$, $\Delta t = 200°\text{C}$

$\therefore \quad 150 = 100\,(1+\alpha\,200)$

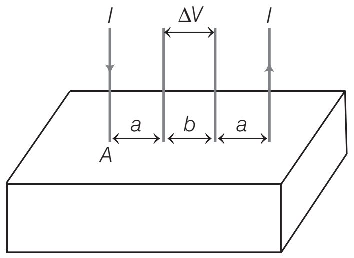
$\Rightarrow \quad 0.5 = 200\,\alpha$

$\Rightarrow \quad \alpha = \dfrac{0.5}{200} = \dfrac{1}{400}$

$= 25\times 10^{-4}/°\text{C}$

Directions (Q. Nos. 54 to 55) are based on the following paragraph.

Consider a block of conducting material of resistivity ρ shown in the figure. Current I enters at A and leaves from D. We apply superposition principle to find voltage ΔV developed between B and C. The calculation is done in the following steps



(a) Take current I entering from A and assume it to spread over a hemispherical surface on the block.
(b) Calculate field $E(r)$ at distance r from A by using Ohm's law $= \rho J$, where J is the current per unit area at r.
(c) From the r dependence of $E(r)$, obtain the potential $V(r)$ at r.
(d) Repeat steps (i), (ii) and (iii) for current I leaving D and superpose results for A and D.

54 ΔV measured between B and C is **[AIEEE 2008]**

(a) $\dfrac{\rho I}{\pi a} - \dfrac{\rho I}{\pi(a+b)}$ (b) $\dfrac{\rho I}{a} - \dfrac{\rho I}{(a+b)}$

(c) $\dfrac{\rho I}{2\pi a} - \dfrac{\rho I}{2\pi(a+b)}$ (d) $\dfrac{\rho I}{2\pi(a-b)}$

Ans. *(c)*

Electric field at a distance r from A is

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

$\Rightarrow \quad \int dV = -\int E\,dr$

$\Rightarrow \quad V_C - V_B = \Delta V$

$$= -\int_a^{a+b}\frac{\rho I}{2\pi}\times\frac{dr}{r^2}$$

or $\quad \Delta V = \dfrac{\rho I}{2\pi}\left[\dfrac{1}{a} - \dfrac{1}{a+b}\right]$

55 For current entering at A, the electric field at a distance r from A is **[AIEEE 2008]**

(a) $\dfrac{\rho I}{8\pi r^2}$ (b) $\dfrac{\rho I}{r^2}$

(c) $\dfrac{\rho I}{2\pi r^2}$ (d) $\dfrac{\rho I}{4\pi r^2}$

Ans. *(c)*

As $E = \dfrac{V}{l} = \dfrac{IR}{l} = \dfrac{I}{t}\dfrac{el}{A} = \rho J$

[$\because$ current density, $J = I/A$]

From $E = \rho J = \dfrac{\rho I}{2\pi r^2}$

56 The resistance of a wire is $5\ \Omega$ at $50°$C and $6\ \Omega$ at $100°$C. The resistance of the wire at $0°$C will be **[AIEEE 2007]**

(a) $2\ \Omega$ (b) $1\ \Omega$
(c) $4\ \Omega$ (d) $3\ \Omega$

Ans. *(c)*

From $R_t = R_0(1+\alpha t)$

$\therefore \quad 5 = R_0(1+50\alpha)$ ...(i)

and $\quad 6 = R_0(1+100\alpha)$ ...(ii)

$\therefore \quad \dfrac{5}{6} = \dfrac{1+50\alpha}{1+100\alpha}$

or $\quad \alpha = \dfrac{1}{200}$

Putting the value of α in Eq. (i), we get

$$5 = R_0\left(1+50\times\frac{1}{200}\right) \text{ or } R_0 = 4\ \Omega$$

57 A material B has twice the specific resistance of A. A circular wire made of B has twice the diameter of a wire made of A. Then, for the two wires to have the same resistance, the ratio l_B/l_A of their respective lengths must be **[AIEEE 2006]**

(a) 1 (b) 1/2
(c) 1/4 (d) 2

Ans. *(d)*

Let (ρ_A, l_A, r_A, A_A) and (ρ_B, l_B, r_B, A_B) be specific resistances, lengths, radii and areas of wires A and B, respectively.

Resistance of $A = R_A = \dfrac{\rho_A l_A}{A_A} = \dfrac{\rho_A l_A}{\pi r_A^2}$

Resistance of $B = R_B = \dfrac{\rho_B l_B}{A_B} = \dfrac{\rho_B l_B}{\pi r_B^2}$

From given information,

$$\rho_B = 2\rho_A$$

$$r_B = 2r_A$$

and $\quad R_A = R_B$

$\therefore \quad \dfrac{\rho_A l_A}{\pi r_A^2} = \dfrac{\rho_B l_B}{\pi r_B^2}$

or $\quad \dfrac{\rho_A l_A}{\pi r_A^2} = \dfrac{2\rho_A\times l_B}{\pi(2r_A)^2}$

or $\quad \dfrac{l_B}{l_A} = \dfrac{2}{1} = 2:1$

58 The resistance of a bulb filament is $100\ \Omega$ at a temperature of $100°$C. If its temperature coefficient of resistance is 0.005 per °C, its resistance will become $200\ \Omega$ at a temperature of **[AIEEE 2006]**

(a) 300°C (b) 400°C (c) 500°C (d) 200°C

Ans. *(b)*

Let resistance of bulb filament be R_0 at $0°$C, then from expression,

$$R_\theta = R_0[1+\alpha\Delta\theta]$$

We have, $\quad 100 = R_0[1+0.005\times 100]$

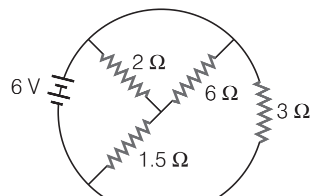
and $\quad 200 = R_0[1+0.005\times x]$

where, x is temperature in °C at which resistance become $200\ \Omega$.

Dividing the above two equations, we get

$$\frac{200}{100} = \frac{1+0.005x}{1+0.005\times 100} \Rightarrow x = 400°\text{C}$$

59 The total current supplied to the circuit by the battery is **[AIEEE 2004]**

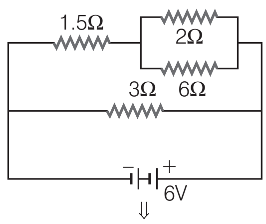


(a) 1 A (b) 2 A
(c) 4 A (d) 6 A

Ans. *(c)*

The equivalent circuit can be drawn as $6\ \Omega$ and $2\ \Omega$ are in parallel.

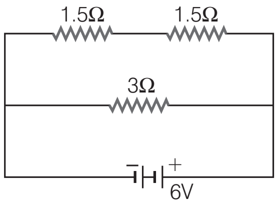
$$R' = \frac{2\times 6}{8} = 1.5\ \Omega$$



$\Downarrow$

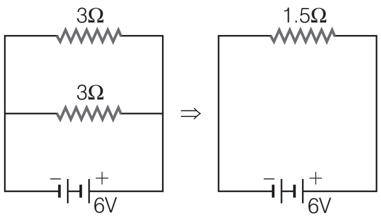
As $1.5\ \Omega$ and $1.5\ \Omega$ are in series.

$$R'' = 1.5+1.5 = 3\ \Omega$$



As $3\,\Omega$ and $3\,\Omega$ are in parallel.

$$R_{eq} = \frac{3\times 3}{6} = 1.5\,\Omega$$



Hence, current supplied by the battery is

$$I = \frac{V}{R_{eq}} = \frac{6}{1.5} = 4\text{ A}$$

60 The resistance of the series combination of two resistances is S. When they are joined in parallel, the total resistance is P. If $S = nP$, then the minimum possible value of n is **[AIEEE 2004]**

(a) 4 (b) 3
(c) 2 (d) 1

Ans. *(a)*

Let resistances be R_1 and R_2. Then,

$$S = R_1 + R_2$$

and $$P = \frac{R_1R_2}{R_1 + R_2}$$

$$\therefore \quad (R_1 + R_2) = \frac{n \times R_1R_2}{R_1 + R_2} \qquad [\because S = nP]$$

or $(R_1 + R_2)^2 = nR_1R_2$

$$\Rightarrow \quad n = \left[\frac{R_1^2 + R_2^2 + 2R_1R_2}{R_1R_2}\right]$$

$$= \left[\frac{R_1}{R_2} + \frac{R_2}{R_1} + 2\right]$$

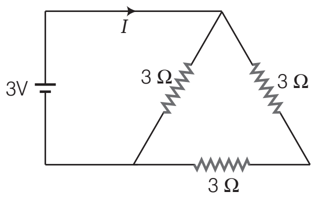
We know,
Arithmetic Mean ≥ Geometric Mean

$$\frac{\frac{R_1}{R_2} + \frac{R_2}{R_1}}{2} \geq \sqrt{\frac{R_1}{R_2} \times \frac{R_2}{R_1}}$$

$$\Rightarrow \quad \frac{R_1}{R_2} + \frac{R_2}{R_1} \geq 2$$

So, n(minimum value) $= 2 + 2 = 4$

61 A 3 V battery with negligible internal resistance is connected in a circuit as shown in the figure. **[AIEEE 2003]**

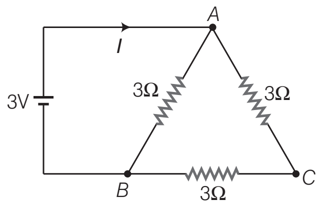


The current I in the circuit will be

(a) 1 A (b) 1.5 A
(c) 2 A (d) $\frac{1}{3}$ A

Ans. *(b)*

Resistance in the arms AC and BC are in series.



$$\therefore \quad R' = 3 + 3 = 6\,\Omega$$

Now, R' and $3\,\Omega$ are in parallel.

$$\therefore \quad R_{eq} = \frac{6\times 3}{6+3} = 2\,\Omega$$

Now, $\quad V = IR \Rightarrow I = \frac{3}{2} = 1.5\text{ A}$

62 The length of a given cylindrical wire is increased by 100%. Due to the consequent decrease in diameter, the change in the resistance of the wire will be **[AIEEE 2003]**

(a) 200% (b) 100%
(c) 50% (d) 300%

Ans. (*d*)

Given, $\quad l' = l + 100\%\, l = 2l$

Initial volume = Final volume

i.e., $\quad \pi r^2 l = \pi r'^2 l'$

or $\quad r'^2 = \frac{r^2 l}{l'} = r^2 \times \frac{l}{2l}$

or $\quad r'^2 = \frac{r^2}{2}$

$$\therefore \quad R' = \rho\frac{l'}{A'} = \rho\frac{2l}{\pi r'^2} \quad \left[\because R = \frac{\rho l}{A}\right]$$

$$= \frac{\rho \cdot 4l}{\pi r^2} = 4R$$

Thus, $\quad \Delta R = R' - R = 4R - R = 3R$

$$\therefore \quad \%\,\Delta R = \frac{3R}{R} \times 100\% = 300\%$$

Alternate Solution

By the shortcut formula,

$$\%\text{ Change} = x + y + \frac{xy}{100}$$

Valid only for 2 variables in terms of percentage.

As $\quad R \propto l^2\%$

Increase in resistance

$$= 100 + 100 + \frac{100\times 100}{100} = 300\%$$

TOPIC 2
Heating Effect of Current

63 A uniform heating wire of resistance $36\,\Omega$ is connected across a potential difference of 240 V. The wire is then cut into half and potential difference of 240 V is applied across each half separately. The ratio of power dissipation in first case to the total power dissipation in the second case would be $1 : x$, where x is .... **[2021, 1 Sep Shift-II]**

Ans. *(4)*

For case I,

The potential difference of the uniform wire, $V = 240$ V

The resistance of the uniform wire, $R_1 = 36\,\Omega$

The power dissipation in the first case,

$$P_1 = \frac{V^2}{R_1} = \frac{(240)^2}{36}$$

For case II,

The resistance of each half,

$$R_2 = \frac{R_1}{2} = \frac{36}{2} = 18\,\Omega$$

$$P_2 = \frac{V^2}{R_2} + \frac{V^2}{R_2} = \frac{(240)^2}{18} + \frac{(240)^2}{18} = \frac{(240)^2}{9}$$

Thus, the ratio of the total power dissipation in the first case to the second case

$$\frac{P_1}{P_2} = \frac{(240)^2/36}{(240)^2/9}$$

$$\Rightarrow \quad \frac{P_1}{P_2} = \frac{1}{4}$$

Comparing with, $\frac{P_1}{P_2} = \frac{1}{x}$

The value of the $x = 4$.

64 A resistor dissipates 192 J of energy in 1 s when a current of 4 A is passed through it. Now, when the current is doubled, the amount of thermal energy dissipated in 5 s is .... J. **[2021, 31 Aug Shift-II]**

Ans. *(3840)*

Given that, initial current, $I_1 = 4\,A$

Final current, $I_2 = 2I_1 = 8\,A$

Initial heat dissipated, $H_1 = 192\,J$

Initial time, $t_1 = 1\,s$

Final time, $t_2 = 5\,s$

Let final heat dissipated $= H_2$

By Joule's law of heating, $H \propto I^2 RT$

Since resistance remains same at initial and final condition,

$$\therefore \quad \frac{H_2}{H_1} = \frac{I_2^2 Rt_2}{I_1^2 Rt_1} = \frac{I_2^2 t_2}{I_1^2 t_1}$$

Substituting the given values, we get

$$\frac{H_2}{192} = \left(\frac{8}{4}\right)^2 \times \frac{5}{1}$$

$$\Rightarrow \quad H_2 = 3840\,J$$

65 An electric bulb of 500 W at 100 V is used in a circuit having a 200 V supply. Calculate the resistance R to be connected in series with the bulb, so that the power delivered by the bulb is 500 W. **[2021, 26 Aug Shift-II]**

(a) 20 Ω (b) 30 Ω (c) 5 Ω (d) 10 Ω

Ans. *(a)*

Given, power rating of bulb, $P_B = 500\,W$

Voltage across bulb, $V_B = 100\,V$

Supply voltage, $V_S = 200\,V$

If a resistance R is attached in series with the bulb, then the voltage across resistance will be 100 V.

Now, current flowing in circuit when bulb delivers power of 500 W is given as

$$P_B = V_B I$$

$$\Rightarrow \quad 500 = 100 \times I$$

$$\Rightarrow \quad I = 5\,A$$

Same amount of current will flow from the resistance as it is connected in series.

Using Ohm's law,

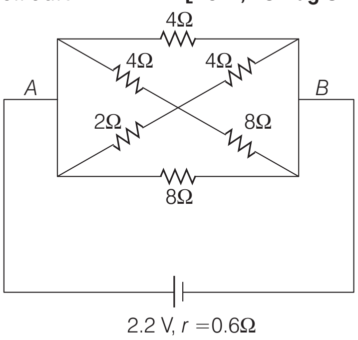
$$V = IR$$

$$\Rightarrow \quad 100 = 5 \times R$$

$$\Rightarrow \quad R = 20\,\Omega$$

Thus, the resistance connected in series is $20\,\Omega$.

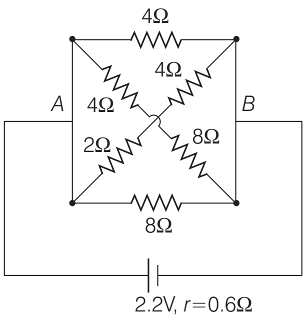
66 In the given figure, the emf of the cell is 2.2 V and if internal resistance is $0.6\,\Omega$. Calculate the power dissipated in the whole circuit **[2021, 26 Aug Shift-I]**



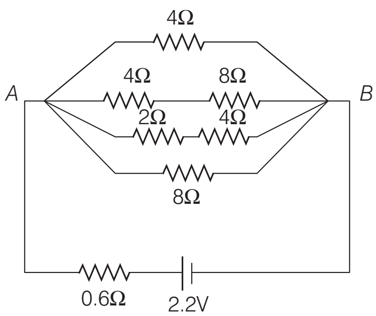
(a) 1.32 W (b) 0.65 W
(c) 2.2 W (d) 4.4 W

Ans. *(c)*

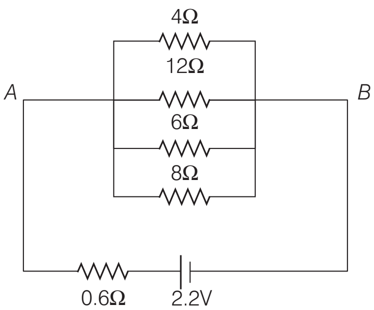
The given circuit diagram can be drawn as



Redrawing the above circuit diagram as



$$\Downarrow$$



Equivalent resistance of the circuit between point A and B is given as

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

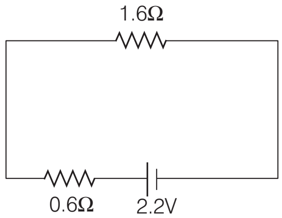
$$= \frac{1}{4} + \frac{1}{12} + \frac{1}{6} + \frac{1}{8}$$

$$= \frac{6+2+4+3}{24}$$

$$= \frac{15}{24}$$

$$= \frac{24}{15}\,\Omega$$

$$= 1.6\,\Omega$$



$$R_{total} = 1.6 + 0.6 = 2.2\,\Omega$$

$$P = \frac{V^2}{R_{total}} = \frac{2.2 \times 2.2}{2.2}$$

$$= 2.2\,W$$

67 The energy dissipated by a resistor is 10 mJ in 1s when an electric current of 2 mA flows through it. The resistance is .... Ω.

(Round off to the nearest integer)

[2021, 16 March Shift-II]

Ans. *(2500)*

Given, energy dissipated by a resistor,

$$H = 10\,mJ$$

$$= 10 \times 10^{-3}\,J$$

Time, $t = 1\,s$

Electric current, $I = 2\,mA$

$$= 2 \times 10^{-3}\,A$$

Resistance, $R = ?$

According to Joule's law of heating,

$$H = I^2 Rt$$

$$\Rightarrow \quad R = \frac{H}{I^2 T} \quad \text{...(i)}$$

Substituting the given values in Eq. (i), we get

$$R = \frac{10 \times 10^{-3}}{(2 \times 10^{-3})^2 \times 1}$$

$$\Rightarrow \quad R = \frac{10^{-2}}{4 \times 10^{-6}}$$

$$\Rightarrow \quad R = 0.25 \times 10^4$$

$$\Rightarrow \quad R = 2500\,\Omega$$

68 A resistor develops 500 J of thermal energy in 20 s, when a current of 1.5 A is passed through it. If the current is increased from 1.5 A to 3 A, what will be the energy developed in 20 s? **[2021, 16 March Shift-II]**

(a) 1500 J (b) 1000 J (c) 500 J (d) 2000 J

Ans. *(d)*

Given,

$$\text{Heat energy}, H_1 = 500\text{ J}$$

Initial current, $I_1 = 1.5$ A, final current,

$$I_2 = 3\text{ A}$$

and time, $t = 20$ s

According to Joule's law of heating,

$$H = I^2Rt$$

$$\Rightarrow \quad H_1 = I_1^2Rt \quad \text{...(i)}$$

$$\text{and} \quad H_2 = I_2^2Rt \quad \text{...(ii)}$$

[∵ Resistance and time being the same in both cases]

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

$$\Rightarrow \quad \frac{H_1}{H_2} = \frac{I_1^2Rt}{I_2^2Rt} \Rightarrow \frac{H_1}{H_2} = \left(\frac{I_1}{I_2}\right)^2$$

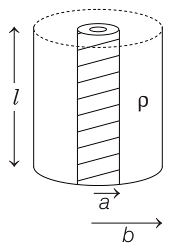
$$\Rightarrow \quad \frac{H_1}{H_2} = \left(\frac{1.5}{3}\right)^2 = \left(\frac{15}{30}\right)^2 \Rightarrow \frac{H_1}{H_2} = \left(\frac{1}{2}\right)^2$$

$$\Rightarrow \quad \frac{H_1}{H_2} = \frac{1}{4} \Rightarrow \frac{500}{H_2} = \frac{1}{4}$$

$$\Rightarrow \quad H_2 = 500 \times 4$$

$$\Rightarrow \quad H_2 = 2000\text{ J}$$

69 A torch battery of length l is to be made up of a thin cylindrical bar of radius a and a concentric thin cylindrical shell of radius b is filled in between with an electrolyte of resistivity ρ (see figure). If the battery is connected to a resistance R, the maximum joule's heating in R will takes place for **[2020, 3 Sep Shift-I]**

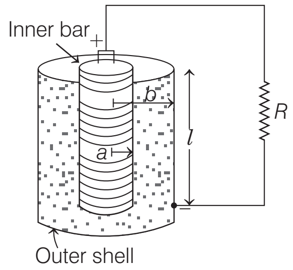


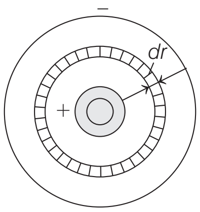
(a) $R = \frac{\rho}{2\pi l}\left(\frac{b}{a}\right)$ (b) $R = \frac{\rho}{2\pi l}\ln\left(\frac{b}{a}\right)$

(c) $R = \frac{\rho}{\pi l}\ln\left(\frac{b}{a}\right)$ (d) $R = \frac{2\rho}{\pi l}\ln\left(\frac{b}{a}\right)$

Ans. *(b)*

By maximum power theorem, maximum joule's heating in external resistance R takes place when internal resistance of battery is equal to external resistance R.





Now, resistance of a elemental cylinder of radius r and thickness dr is

$$(dR)_{\text{internal}} = \frac{\rho \cdot dr}{2\pi rl}$$

$$\Rightarrow \quad R_{\text{internal}} = \int (dR)_{\text{internal}}$$

$$= \int_{r=a}^{r=b} \frac{\rho dr}{2\pi rl} = \frac{\rho}{2\pi l}\int_a^b \frac{dr}{r}$$

$$= \frac{\rho}{2\pi l}[\ln r]_a^b$$

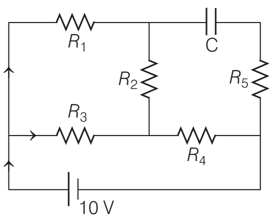
$$= \frac{\rho}{2\pi l}(\ln b - \ln a) = \frac{\rho}{2\pi l}\cdot \ln\left(\frac{b}{a}\right)$$

So, the maximum joule's heating in R will takes place when its value is

$$= R_{\text{internal}} = \frac{\rho}{2\pi l}\cdot \ln\left(\frac{b}{a}\right)$$

Hence, option (b) is correct.

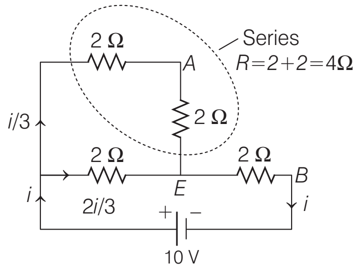
70 An ideal cell of emf 10 V is connected in circuit shown in figure. Each resistance is 2 Ω. The potential difference (in V) across the capacitor when it is fully charged is ....

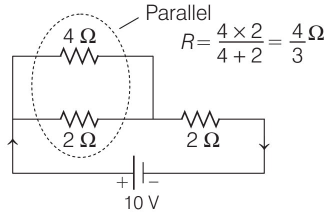


[2020, 2 Sep Shift-II]

Ans. *(8)*

When capacitor is fully charged, circuit is reduced to as shown below,





So,

Total resistance is $R_{\text{eq}} = \frac{4}{3} + 2 = \frac{10}{3}\,\Omega$

Current in circuit, $i = \frac{V}{R_{\text{eq}}} = \frac{10}{10/3} = 3$ A

Hence, potential difference across capacitor

= potential difference across AEB

$= 2i/3 + 2 \times i = 2 \times \frac{3}{3} + 2 \times 3 = 8$ V

71 A battery of 3.0 V is connected to a resistor dissipating 0.5 W of power. If the terminal voltage of the battery is 2.5 V, the power dissipated within the internal resistance is **[2020, 4 Sep Shift-I]**

(a) 0.072 W (b) 0.125 W

(c) 0.50 W (d) 0.10 W

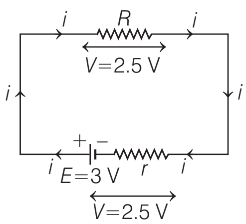
Ans. *(d)*

Using Kirchhoff 's loop law,

$$V = E - ir$$

$$2.5 = 3 - ir$$

$$ir = 0.5 \quad \text{...(i)}$$



Now, from Ohm's law,

$$V = iR, 2.5 = iR, iR = 2.5 \quad \text{...(ii)}$$

and given that

$$P_R = 0.5, i^2R = 0.5 \quad \text{...(iii)}$$

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

$$\frac{ir}{iR} = \frac{0.5}{2.5} \Rightarrow \frac{r}{R} = \frac{1}{5} \quad \text{...(iv)}$$

Now, $\frac{P_r}{P_R} = \frac{i^2 r}{i^2 R} \Rightarrow \frac{P_r}{0.5} = \frac{r}{R} \Rightarrow \frac{P_r}{0.5} = \frac{1}{5}$

$\Rightarrow \quad P_r = 0.1\,\text{W} = 0.10\,\text{W}$

Hence, correct option is (d).

72 In a building, there are 15 bulbs of 45 W, 15 bulbs of 100 W, 15 small fans of 10 W and 2 heaters of 1 kW. The voltage of electric main is 220 V. The minimum fuse capacity (rated value) of the building will be

[2020, 7 Jan Shift-II]

(a) 25 A (b) 10 A (c) 20 A (d) 15 A

Ans. *(c)*

Power of 15 bulbs (each of 45 W),

$$P_1 = 15 \times 45 = 675\,\text{W}$$

Power of 15 bulbs (each of 100 W),

$$P_2 = 15 \times 100 = 1500\,\text{W}$$

Power of 15 fans (each of 10 W),

$$P_3 = 15 \times 10 = 150\,\text{W}$$

Power of 2 heaters (each of 1 kW),

$$P_4 = 2 \times 1000 = 2000\,\text{W}$$

Total power usage of building,

$$P = P_1 + P_2 + P_3 + P_4 = 4325\,\text{W}$$

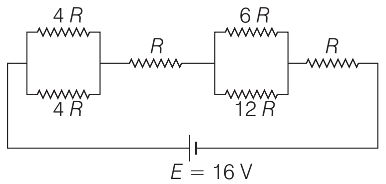
Using $P = VI$, current drawn from mains supply of 220 V,

$$I = \frac{P}{V} = \frac{4325}{220} = 19.66\,\text{A}$$

$\therefore$ Minimum fuse capacity required is 20 A.

73 The resistive network shown below is connected to a DC source of 16 V. The power consumed by the network is 4 W. The value of R is

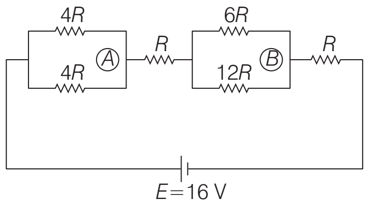
[2019, 12 April Shift-I]



(a) 6 Ω (b) 8 Ω (c) 1 Ω (d) 16 Ω

Ans. *(b)*

Given circuit is



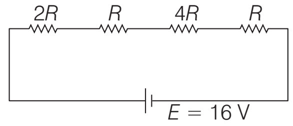
Equivalent resistance of part A,

$$R_A = \frac{4R \times 4R}{4R + 4R} = 2R$$

Equivalent resistance of part B,

$$R_B = \frac{6R \times 12R}{6R + 12R} = \frac{72}{18} R = 4R$$

$\therefore$ Equivalent circuit is



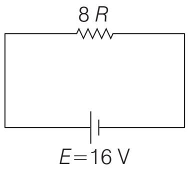
$\therefore$ Total resistance of the given network is

$$R_s = 2R + R + 4R + R = 8R$$

As we know, power of the circuit,

$$P = \frac{E^2}{R_s} = \frac{(16)^2}{8R} = \frac{16 \times 16}{8R} \quad \text{...(i)}$$

According to question, power consumed by the network, $P = 4\,\text{W}$



From Eq. (i), we get

$$\therefore \quad \frac{16 \times 16}{8R} = 4$$

$$\Rightarrow \quad R = \frac{16 \times 16}{8 \times 4} = 8\Omega$$

74 A current of 2 mA was passed through an unknown resistor which dissipated a power of 4.4 W. Dissipated power when an ideal power supply of 11 V is connected across it is **[2019, 10 Jan Shift-II]**

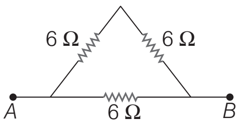
(a) 11×10^{-4} W (b) 11×10^{-5} W

(c) 11×10^{5} W (d) 11×10^{-3} W

Ans. *(b)*

Power dissipated by any resistor R, when I current flows through it is,

$$P = I^2 R \quad \text{...(i)}$$



Given $I = 2\,\text{mA} = 2 \times 10^{-3}\,\text{A}$ and $P = 4.4\,\text{W}$

Using Eq. (i), we get

$$4.4 = (2 \times 10^{-3})^2 \times R$$

$$\text{or} \quad R = \frac{.4}{4 \times 10^{-6}} \cdot \Omega \quad \text{...(ii)}$$

When this resistance R is connected with 11 V supply then power dissipated is

$$P = \frac{V^2}{R}$$

$$\text{or} \quad P = \frac{(11)^2}{4.4} \times 4 \times 10^{-6}$$

[$\because$ Using Eq. (ii)]

$$\Rightarrow \quad P = \frac{11 \times 11 \times 4 \times 10^{-6}}{44 \times 10^{-1}}\,\text{W}$$

$$\text{or} \quad P = 11 \times 10^{-5}\,\text{W}$$

75 Two equal resistances when connected in series to a battery consume electric power of 60 W. If these resistances are now connected in parallel combination to the same battery, the electric power consumed will be

[2019, 11 Jan Shift-I]

(a) 60 W (b) 30 W

(c) 240 W (d) 120 W

Ans. *(c)*

Let P_1 and P_2 be the individual electric powers of the two resistances, respectively.

In series combination, power is

$$P_0 = \frac{P_1 P_2}{P_1 + P_2} = 60\,\text{W}$$

Since, the resistances are equal and the current through each resistor in series combination is also same. Then,

$$P_1 = P_2 = 120\,\text{W}$$

In parallel combination, power is

$$P = P_1 + P_2 = 120 + 120 = 240\,\text{W}$$

Alternate Solution

Let R be the resistance.

$\therefore$ Net resistance in series $= R + R = 2R$

$$P = \frac{V^2}{2R} = 60\,\text{W} \Rightarrow \frac{V^2}{R} = 120\,\text{W}$$

New resistance in parallel $= \frac{R \times R}{R + R} = R/2$

$$P' = \frac{V^2}{R/2} = 2\left(\frac{V^2}{R}\right) = 240\,\text{W}$$

76 Two electric bulbs rated at 25 W, 220 V and 100 W, 220 V are connected in series across a 220 V voltage source. If the 25 W and 100 W bulbs draw powers P_1 and P_2 respectively, then

[2019, 12 Jan Shift-I]

(a) $P_1 = 16\,\text{W}, P_2 = 4\,\text{W}$

(b) $P_1 = 4\,\text{W}, P_2 = 16\,\text{W}$

(c) $P_1 = 9\,\text{W}, P_2 = 16\,\text{W}$

(d) $P_1 = 16\,\text{W}, P_2 = 9\,\text{W}$

Ans. *(a)*

Resistance of a bulb of power P and with a voltage source V is given by

$$R=\frac{V^2}{P}$$

Resistance of the given two bulbs are

$$R_1=\frac{V^2}{P_1}=\frac{(220)^2}{25}$$

and $$R_2=\frac{V^2}{P_2}=\frac{(220)^2}{100}$$

Since, bulbs are connected in series. This means same amount of current flows through them.

$\therefore$ Current in circuit is

$$i=\frac{V}{R_{\text{total}}}=\frac{220}{\frac{(220)^2}{25}+\frac{(220)^2}{100}}=\frac{1}{11}\text{ A}$$

Power drawn by bulbs are respectively,

$$P_1=i^2R_1=\left(\frac{1}{11}\right)^2\times\frac{220\times220}{25}=16\text{ W.}$$

and $$P_2=i^2R_2=\left(\frac{1}{11}\right)^2\times\frac{220\times220}{100}=4\text{ W.}$$

77 In a large building, there are 15 bulbs of 40 W, 5 bulbs of 100 W, 5 fans of 80 W and 1 heater of 1 kW. The voltage of the electric mains is 220 V. Then, the minimum current should be **[JEE Main 2014]**

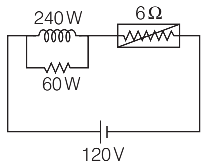
(a) 8 A (b) 10 A (c) 12 A (d) 14 A

Ans.*(c)*

Total power (P) consumed

$=(15\times40)+(5\times100)+(5\times80)+(1\times1000)$

$=2500$ W



As, we know that

$$P=VI$$

$$\Rightarrow \quad I=\frac{2500}{200}=\frac{125}{11}=11.3\text{ A}$$

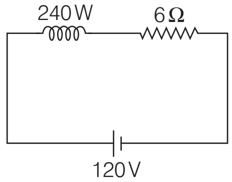
Hence, minimum capacity should be 12 A.

78 The supply voltage to room is 120 V. The resistance of the lead wires is 6 Ω. A 60 W bulb is already switched on. What is the decrease of voltage across the bulb, when a 240 W heater is switched on in parallel to the bulb? **[JEE Main 2013]**

(a) Zero (b) 2.9 V (c) 13.3 V (d) 10.04 V

Ans. *(d)*

$$P=\frac{V^2}{R}$$



Resistance of the bulb,

$$R=\frac{120\times120}{60}=240\ \Omega$$

$$R_{\text{eq}}=240+6=246\ \Omega$$

$$\Rightarrow \quad I_1=\frac{V}{R_{\text{eq}}}=\frac{120}{246}$$

$$V_1=I_1R_1=\frac{120}{246}\times240$$

$$=117.073\text{ V}$$

Resistance of the heater

$$=\frac{V^2}{P}=\frac{120\times120}{240}=60\ \Omega$$

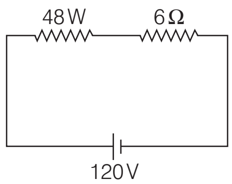
As bulb and heater are connected in parallel.

Net resistance $=\frac{240\times60}{300}=48\ \Omega$

Total resistance, $R_2=48+6=54\ \Omega$

Total current, $I_2=V/R_2=120/54$

Potential across heater $=$ Potential across bulb



$$V_2=\frac{120}{54}\times48=106.66\text{ V}$$

$$V_1-V_2=117.073-106.66$$

$$=10.04\text{ V}$$

79 Two electric bulbs marked 25 W-220 V and 100 W-220 V are connected in series to a 440 V supply. Which of the bulbs will fuse? **[AIEEE 2012]**

(a) Both (b) 100 W
(c) 25 W (d) None of these

Ans. *(c)*

As the rated power of 25 W is less than 100 W, it implies that 25 W bulb has higher resistance. As in series connection, current through both the bulbs is same but heating in 25 W bulb is more than that of 100 W bulb. So, 25 W bulb will get fused.

80 An electric bulb is rated 220 V-100 W. The power consumed by it when operated on 110 V will be **[AIEEE 2006]**

(a) 75 W (b) 40 W (c) 25 W (d) 50 W

Ans. *(c)*

Resistance of electric bulb, $R=\frac{V^2}{P}$,

where subscripts denote for rated parameters.

$$\Rightarrow \quad R=\frac{(220)^2}{100}$$

Power consumed at 110 V,

$$P_{\text{consumed}}=\frac{V^2}{R}$$

$$\therefore P_{\text{consumed}}=\frac{(110)^2}{(220)^2/100}=25\text{ W}$$

81 A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be **[AIEEE 2005]**

(a) doubled (b) four times
(c) one-fourth (d) halved

Ans. *(a)*

Is heat generated

$$H_1=\frac{V^2}{R}t \quad \text{and } H_2=\frac{V^2}{(R/2)}t$$

$$\therefore \quad \frac{H_2}{H_1}=2 \quad \text{or } H_2=2H_1$$

82 The resistance of hot tungsten filament is about 10 times the cold resistance. What will be the resistance of 100 W and 200 V lamp, when not in use? **[AIEEE 2005]**

(a) 40 Ω (b) 20 Ω (c) 400 Ω (d) 200 Ω

Ans. *(a)*

$$P=V^2/R$$

$$\therefore \quad R_{\text{hot}}=\frac{V^2}{P}=\frac{200\times200}{100}$$

$$=400\ \Omega$$

$$R_{\text{cold}}=\frac{400}{10}=40\ \Omega$$

83 The thermistors are usually made of **[AIEEE 2004]**

(a) metals with low temperature coefficient of resistivity
(b) metals with high temperature coefficient of resistivity
(c) metal oxides with high temperature coefficient of resistivity
(d) semiconducting materials having low temperature coefficient of resistivity

Ans. *(c)*

Thermistors are the resistors made up of semiconductors whose resistance decreases with the increase in temperature. This implies that they have negative and high temperature coefficient of resistivity.

They are usually made of metal oxides with high temperature coefficient of resistivity.

84 Time taken by a 836 W heater to heat 1 L of water from 10°C to 40°C is **[AIEEE 2004]**

(a) 50 s (b) 100 s
(c) 150 s (d) 200 s

Ans. *(c)*

Let time taken in boiling the water by the heater be t second. Then,

$$Q = ms\,\Delta T$$

$$\Rightarrow \quad \frac{Pt}{J} = ms\,\Delta T$$

$$\therefore \quad \frac{836}{4.2} t = 1 \times 1000(40 - 10)$$

$$\text{or} \quad \frac{836}{4.2} t = 1000 \times 30$$

$$\text{or} \quad t = \frac{1000 \times 30 \times 4.2}{836} = 150 \text{ s}$$

85 A 220 V–1000 W bulb is connected across a 110 V mains supply. The power consumed will be **[AIEEE 2003]**

(a) 750 W (b) 500 W
(c) 250 W (d) 1000 W

Ans. *(c)*

$$R = \frac{V^2}{P} = \frac{(220)^2}{1000}$$

where, V and P are denoting rated voltage and power, respectively.

$$\therefore \quad P_{\text{consumed}} = \frac{V_{\text{applied}}^2}{R}$$

$$= \frac{110 \times 110}{220 \times 220} \times 1000$$

$$= 250 \text{ W}$$

86 A wire when connected to 220 V mains supply has power dissipation P_1. Now, the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then, $P_2 : P_1$ is **[AIEEE 2002]**

(a) 1 (b) 4
(c) 2 (d) 3

Ans. *(b)*

Case I

Using the formula, $P = \dfrac{V^2}{R}$ ...(i)

where, R is resistance of wire, V is voltage across wire and P is power dissipation in wire

and $R = \dfrac{\rho l}{A}$ ...(ii)

From Eqs. (i) and (ii), we have

$$P_1 = \frac{V^2}{\rho l / A}$$

$$\text{or} \quad P_1 = \frac{V^2}{\rho l} \cdot A \quad \text{...(iii)}$$

Case II

Let R_2 be net resistance of two wires in parallel, then

$$R_2 = \frac{R \times R}{R + R} = \frac{R}{2}$$

where, R is the resistance of half wire.

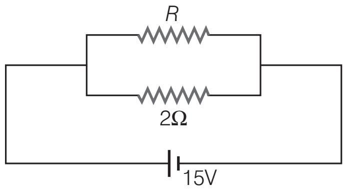
$$\Rightarrow \quad R_2 = \frac{\rho \cdot \left(\frac{l}{2}\right)}{A \cdot 2} = \frac{\rho l}{4A}$$

$$\text{or} \quad P_2 = \frac{V^2}{\rho l} \cdot 4A \quad \text{...(iv)}$$

Hence, from Eqs. (iii) and (iv), we get

$$\frac{P_1}{P_2} = \frac{1}{4} \Rightarrow \frac{P_2}{P_1} = \frac{4}{1}$$

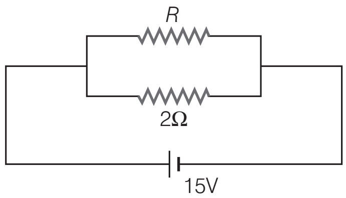
87 If in the circuit, power dissipation is 150 W, then R is **[AIEEE 2002]**



(a) 2 Ω (b) 6 Ω
(c) 5 Ω (d) 4 Ω

Ans. *(b)*

$$P = \frac{V^2}{R_{\text{net}}}$$



$$\therefore \quad 150 = \frac{(15)^2}{\dfrac{R \cdot 2}{2 + R}}$$

$$\Rightarrow \quad R = 6\,\Omega$$

TOPIC 3
Cells and its Combination and Kirchhoff's Rules

88 Five identical cells each of internal resistance 1 Ω and emf 5V are connected in series and in parallel with an external resistance R. For what value of R, current in series and parallel combination will remain the same? **[2021, 27 Aug Shift-I]**

(a) 1 Ω (b) 25 Ω
(c) 5 Ω (d) 10 Ω

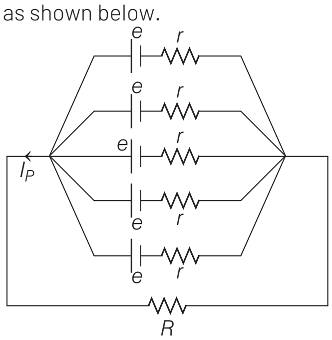
Ans. *(a)*

Given, number of cells, $n = 5$

Internal resistance of each cell, $r = 1\,\Omega$

Emf of each cell, $e = 5$ V

When all cells are connected in parallel as shown below.



Potential will remain same as, $V_P = 5$ V

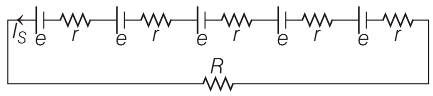
Net resistance in parallel combination will be given as

$$R_p = R + \left[\frac{1}{\frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \frac{1}{r}}\right]$$

$$= R + \frac{r}{5}$$

$$R_p = R + \frac{1}{5} \quad (\because r = 1\,\Omega) \text{...(i)}$$

When all cells are connected in series as shown below



The net potential will increase as cells are connected in series,

$V_s = 5 + 5 + 5 + 5 + 5 = 25$ V

The net resistance of circuit will be equivalent of sum of all resistances as all are connected in series.

$$R_s = r + r + r + r + r + R = 5r + R$$

$$R_s = 5 + R \quad (\because r = 1\,\Omega) \text{...(ii)}$$

By Ohm's law, current flowing in circuit is given as

$$I = V / R$$

As current in both series and parallel combination is same,

$$\frac{V_p}{R_p} = \frac{V_s}{R_s}$$

$\Rightarrow \quad \dfrac{5}{R + \frac{1}{5}} = \dfrac{25}{5 + R}$ [From Eqs. (i) and (ii)]

$\Rightarrow \quad 25 + 5R = 25R + 5 \Rightarrow R = 1\,\Omega$

89 In an electric circuit, a cell of certain EMF provides a potential difference of 1.25 V across a load resistance of 5 Ω. However, it provides a potential difference of 1 V across a load resistance of 2 Ω. The emf of the cell is given by $\frac{x}{10}$ V. Then, the value of x is ....

[2021, 22 July Shift-II]

Ans. *(15)*

Let emf of cell $= \varepsilon$

Potential difference across the terminal of cell

$$V_1 = 1.25\text{ V}$$

Load resistance, $R_{L_1} = 5\Omega$

when load resistance, $R_{L_2} = 2\Omega$,

then $V_2 = 1\text{ V}$

I_1, I_2 be the current through load in the two above mentioned cases and r be internal resistance of cell.

As we know that,

By using Kirchhoff's voltage law,

$$\varepsilon - V = I_1 R_{L_1}$$
$$\varepsilon = I_1 R_{L_1} + V$$
$$\varepsilon = I_1 (R_{L_1} + r) \quad [\because V = I_1 r]$$

$\Rightarrow \quad I_1 = \dfrac{\varepsilon}{R_{L_1} + r} = \dfrac{\varepsilon}{5 + r}$

$\because \quad V_1 = I_1 R_{L_1}$

$\therefore \quad 1.25 = \dfrac{\varepsilon}{5 + r} \times 5$

$\Rightarrow \quad \dfrac{\varepsilon}{5 + r} = 0.25 = \dfrac{25}{100} = \dfrac{1}{4}$

$\Rightarrow \quad 4\varepsilon = 5 + r \quad$ ...(i)

and $V_2 = I_2 R_{L_2} = \dfrac{\varepsilon}{2 + r} 2 = 1$

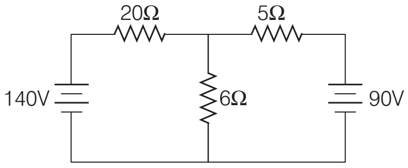
$\Rightarrow \quad 2\varepsilon = 2 + r \quad$ ...(ii)

On subtracting Eq. (i) and Eq. (ii), we get

$$2\varepsilon = 3$$
$$\varepsilon = \frac{3}{2} = 1.5\text{ V} = \frac{15}{10}\text{ V}$$

Hence, $x = 15$

90 The value of current in the $6\,\Omega$ resistance is **[2021, 20 July Shift-I]**

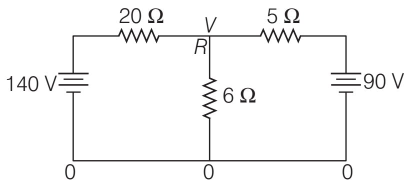


(a) 4 A (b) 8 A

(c) 10 A (d) 6 A

Ans. *(c)*

The given figure can be represented as



From the above figure, it can be clearly seen that the voltage across point R is assumed as V.

Therefore, applying Kirchhoff's current law at point R, we can write

$$\frac{V - 0}{6} + \frac{V - 90}{5} + \frac{V - 140}{20} = 0$$

$\Rightarrow \quad \dfrac{V}{6} + \dfrac{V - 90}{5} + \dfrac{V - 140}{20} = 0$

$\Rightarrow \quad \dfrac{10V + 12V - 1080 + 3V - 420}{60} = 0$

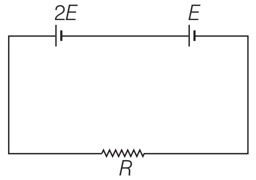
$\Rightarrow \quad 25V = 1500$

$\Rightarrow \quad V = 60\text{ V}$

Therefore, current through 6Ω resistor is

$$I = \frac{V}{R} = \frac{60}{6} = 10\text{ A}$$

91 Two cells of emf $2E$ and E with internal resistance r_1 and r_2 respectively are connected in series to an external resistor R (see figure). The value of R, at which the potential difference across the terminals of the first cell becomes zero is **[2021, 17 March Shift-II]**

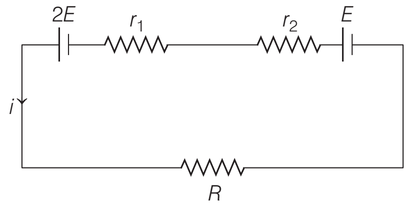


(a) $r_1 + r_2$ (b) $\frac{r_1}{2} - r_2$

(c) $\frac{r_1}{2} + r_2$ (d) $r_1 - r_2$

Ans. *(b)*

The given circuit can be drawn as



Since in series combination, the current through each resistance remains same. So, equivalent resistance of the circuit is given as

$$R_{\text{equivalent}} = R + r_1 + r_2$$

and equivalent emf,

$$E_{\text{equivalent}} = 2E + E = 3E$$

From Ohm's law, $I = \dfrac{E_{\text{equivalent}}}{R_{\text{equivalent}}}$

$\Rightarrow \quad I = \dfrac{3E}{R + r_1 + r_2}$

When potential difference is zero across the first cell, then potential positive terminal is equal to the potential at negative terminal.

$$V_P = V_N$$
$$2E = I r_1$$

Substituting the values in the above equation, we get

$$2E = \frac{3E}{R + r_1 + r_2} r_1$$

$$2R + 2r_1 + 2r_2 = 3r_1$$

$\Rightarrow \quad R = \dfrac{r_1 - 2r_2}{2}$

$\Rightarrow \quad R = \dfrac{r_1}{2} - r_2$

92 In an electrical circuit, a battery is connected to pass 20 C of charge through it in a certain given time. The potential difference between two plates of the battery is maintained at 15 V. The work done by the battery is .... J.

[26 Feb 2021 Shift-I]

Ans. *(300)*

Given, charge passing through circuit,

$$q = 20\text{ C}$$

Potential difference between two plates,

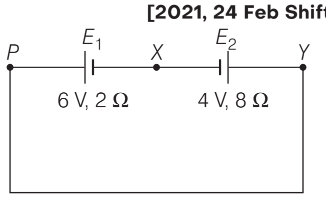
$$V = 15\text{ V}$$

Let W be the amount of work done by battery.

$\therefore \quad W = qV = 20 \times 15$
$= 300\text{ J}$

93 A cell E_1 of emf 6 V and internal resistance $2\,\Omega$ is connected with another cell E_2 of emf 4 V and internal resistance $8\,\Omega$ (as shown in the figure). The potential difference across points X and Y is

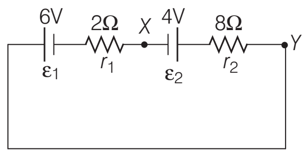
[2021, 24 Feb Shift-I]



(a) 2.0 V (b) 3.6 V (c) 5.6 V (d) 10.0 V

Ans. *(c)*

The circuit can be shown as below



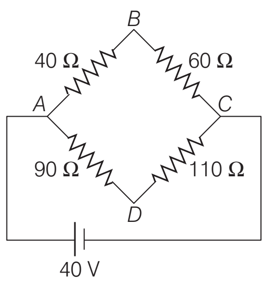
The current through the circuit,

$$I = \frac{\varepsilon_1 - \varepsilon_2}{r_1 + r_2} = \frac{6-4}{10} = \frac{1}{5}\text{ A}$$

$\therefore$ Potential difference across points X and Y is

$$V_{XY} = E_2 + Ir_2 = 4 + \frac{1}{5} \times 8 = 5.6\text{ V}$$

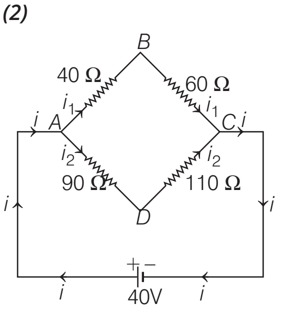
94



Four resistances $40\,\Omega$, $60\,\Omega$, $90\,\Omega$ and $110\,\Omega$ make the arms of a quadrilateral $ABCD$. Across AC is a battery of emf 40 V and internal resistance negligible. The potential difference across BD (in volt) is ....

[2020, 4 Sep Shift-II]

Ans. *(2)*



The resistors $40\,\Omega$ and $60\,\Omega$ are connected in series combination. Similarly, the resistors $90\,\Omega$ and $110\,\Omega$ are also connected in series combination.

So, $i_1 = \dfrac{V_{AC}}{R_{AB} + R_{BC}} = \dfrac{40}{40 + 60} = \dfrac{40}{100} = \dfrac{2}{5}\text{ A}$

and $i_2 = \dfrac{V_{AC}}{R_{AD} + R_{DC}} = \dfrac{40}{90 + 110}$

$= \dfrac{40}{200} = \dfrac{1}{5}\text{ A}$

For path BAD, using KVL (Kirchhoff's voltage law),

$$V_B + i_1 \times 40 - i_2 \times 90 = V_D$$

$$V_B + \frac{2}{5} \times 40 - \frac{1}{5} \times 90 = V_D$$

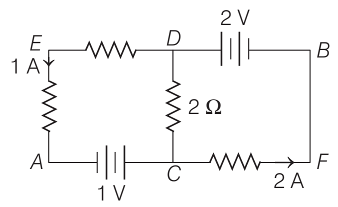
$$V_B + 16 - 18 = V_D$$

$$V_B - 2 = V_D$$

$$V_B - V_D = 2\text{ V}$$

So, the potential difference across BD (in volt) is $= 2$.

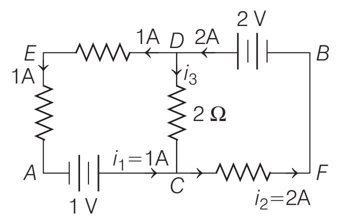
95 In the given circuit, currents in different branches and value of one resistor are shown. Then, potential at point B with respect to the point A is **[2020, 5 Sep Shift-II]**



(a) +2 V (b) −2 V
(c) −1V (d) +1V

Ans. *(d)*

The given circuit can be drawn as,



Current in branch DC (using KCl at point C),

$$i_1 + i_3 = i_2$$

$$2 - 1 - i_3 = 0$$

$$i_3 = 1\text{A}$$

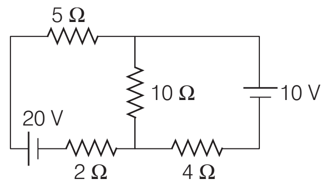
Now, while moving from A to B *via* C and D, the potential along $ACDB$,

$$V_A + 1 + 2 \times i_3 - 2 = V_B$$

$$\Rightarrow \quad V_B - V_A = 1\text{ V}$$

Hence, correct option is (d).

96



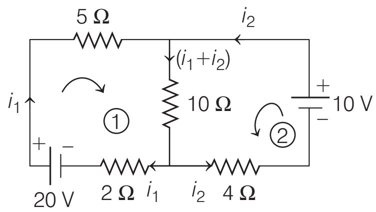
In above figure shown, the current in the 10 V battery is close to

[2020, 6 Sep Shift-II]

(a) 0.71 A from positive to negative terminal
(b) 0.42 A from positive to negative terminal
(c) 0.21 A from positive to negative terminal
(d) 0.36 A from negative to positive terminal

Ans. *(c)*

Assume the current in branches as shown in figure,



Applying KVL in loop 1,

$$+20 - 5i_1 - 10(i_1 + i_2) - 2i_1 = 0$$

$$17i_1 + 10i_2 = 20 \qquad \text{...(i)}$$

Applying KVL in loop 2,

$$+10 - 10(i_1 + i_2) - 4i_2 = 0$$

$$5i_1 + 7i_2 = 5 \qquad \text{...(ii)}$$

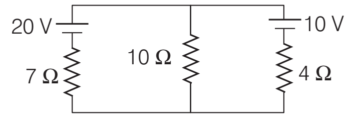
On solving Eqs. (i) and (ii), we get

$$i_2 = -0.214\text{ A or } i_2 \simeq -0.21\text{ A}$$

It means the direction of current is from positive to negative terminal of battery inside it.

Alternate solution

The circuit can be reduced to

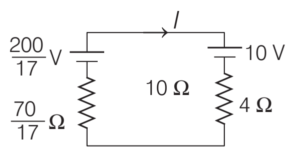


Using voltage division rule, voltage across $10\,\Omega$ resistor,

$$V' = \frac{20 \times 10}{10 + 7} = \frac{200}{17}\text{ V}$$

and resistance, $R' = \dfrac{7 \times 10}{7 + 10} = \dfrac{70}{17}\,\Omega$

Now, circuit becomes



$$\therefore I = \frac{V_{eq}}{R_{eq}} = \frac{\frac{200}{17} - 10}{\frac{70}{17} + 4} = \frac{30}{138}\text{ A} = 0.21\text{ A}$$

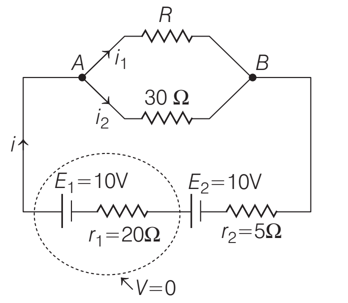
Hence, correct option is (c).

97 The series combination of two batteries, both of the same emf 10 V, but different internal resistance of 20 Ω and 5 Ω, is connected to the parallel combination of two resistors 30 Ω and R Ω. The voltage difference across the battery of internal resistance 20 Ω is zero, the value of R(in Ω) is ....

[2020, 8 Jan Shift-II]

Ans. *(30)*

Given arrangement of batteries and resistances is shown below.



Let i = circuit current, then it is given that potential difference across battery of 10V and 20 Ω is zero.

i.e. $E_1 - ir_1 = 0 \Rightarrow 10 - i(20) = 0$

$\Rightarrow \quad i = \frac{1}{2} = 0.5\text{A}$

Now, potential drop across combination of resistors,

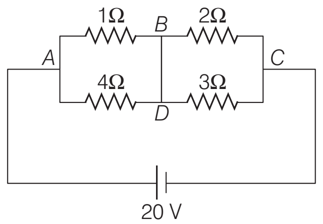
$$V_{AB} = (E_1 + E_2) - i(r_1 + r_2)$$
$$= 20 - 0.5 \times (25) = 7.5\text{ V}$$

Now, at junction B,

$$i = i_1 + i_2 \Rightarrow 0.5 = \frac{7.5}{R} + \frac{7.5}{30}$$

On solving, we get, $R = 30\,\Omega$

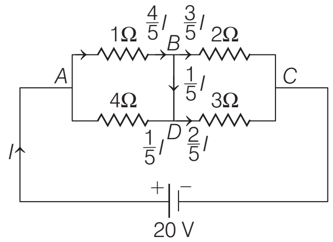
98 In the given circuit diagram, a wire is joining points B and D. The current in this wire is **[2020, 9 Jan Shift-I]**



(a) 0.4 A (b) zero (c) 2A (d) 4A

Ans. *(c)*

In given circuit, current distribution following Kirchhoff's law will be as shown in the figure.



Since, the current flows in inverse ratio of the resistance of branch.

Now, total circuit resistance,

$$R_{eq} = (1\Omega \,||\, 4\Omega) + (2\Omega \,||\, 3\Omega)$$
$$= \left(\frac{1 \times 4}{1+4}\right) + \left(\frac{2 \times 3}{2+3}\right)$$
$$= \frac{4}{5} + \frac{6}{5}$$
$$= \frac{10}{5}\,\Omega = 2\Omega$$

So, current drawn from cell,

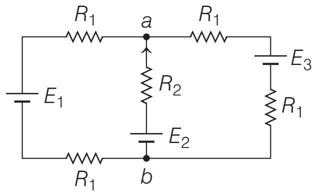
$$I = \frac{V}{R_{eq}} = \frac{20\text{V}}{2\Omega} = 10\text{ A}$$

Hence, current through BD arm is (refer to circuit diagram),

$$I_{BD} = \frac{I}{5} = \frac{10}{5}$$
$$= 2\text{A}$$

99 For the circuit shown with $R_1 = 1.0\Omega$, $R_2 = 2.0\Omega$, $E_1 = 2$ V and $E_2 = E_3 = 4$ V, the potential difference between the points a and b is approximately (in volt)

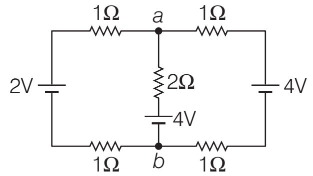
[2019, 8 April Shift-I]



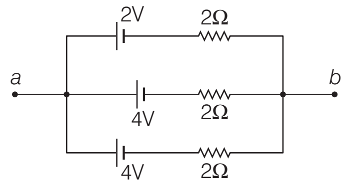
(a) 2.7 (b) 2.3
(c) 3.7 (d) 3.3

Ans. *(d)*

Given circuit is



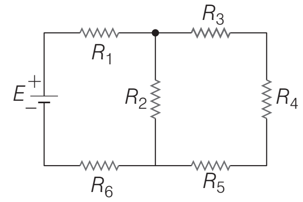
Above circuit can be viewed as



This is a parallel combination of three cells or in other words, a parallel grouping of three cells with internal resistances.

$$\text{So, } V_{ab} = E_{eq} = \frac{I_{eq}}{r_{eq}} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$
$$= \frac{\frac{2}{2} + \frac{4}{2} + \frac{4}{2}}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2}} = \frac{10}{3}\text{ V} \approx 3.3\text{ V}$$

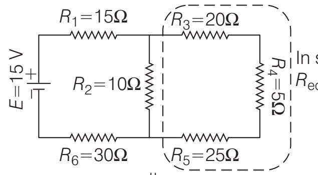
100 In the figure shown, what is the current (in ampere) drawn from the battery? You are given $R_1 = 15\,\Omega$, $R_2 = 10\,\Omega$, $R_3 = 20\,\Omega$, $R_4 = 5\,\Omega$, $R_5 = 25\,\Omega$, $R_6 = 30\,\Omega$, $E = 15$ V **[2019, 8 April Shift-II]**



(a) 13/24 (b) 7/18 (c) 20/3 (d) 9/32

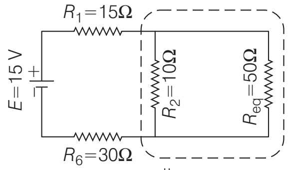
Ans. *(d)*

Given circuit is redrawn and can be simplified as



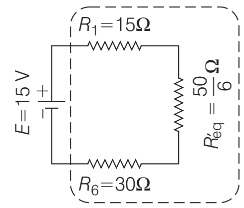
In series,
$R_{eq} = R_3 + R_4 + R_5$
$= 20 + 5 + 25$
$= 50\Omega$

⇓



In parallel,
$$R'_{eq} = \frac{R_{eq} \times R_2}{R_{eq} + R_2} = \frac{50 \times 10}{50 + 10} = \frac{50}{6}\,\Omega$$

⇓



In series,
$$R''_{eq} = R_1 + R'_{eq} + R_6$$
$$= 30 + \frac{50}{6} + 15$$
$$= \frac{320}{6} = \frac{160}{3}\,\Omega$$

So, current drawn through cell is

$$i = \frac{\text{Voltage}}{\text{Net resistance of the circuit}}$$

$$= \frac{V}{R''_{eq}}$$

$$= \frac{15}{(160/3)}$$

$$= \frac{9}{32}\text{ A}$$

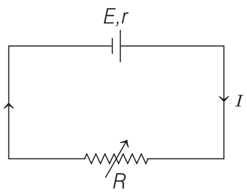
101 A cell of internal resistance r drives current through an external resistance R. The power delivered by the cell to the external resistance will be maximum when

[2019, 8 April Shift-II]

(a) $R = 2r$ (b) $R = r$
(c) $R = 0.001\,r$ (d) $R = 1000\,r$

Ans. *(b)*

Given circuit is shown in the figure below



Net current, $I = \frac{E}{R + r}$ ...(i)

Power across R is given as

$$P = I^2 R = \left(\frac{E}{R + r}\right)^2 \cdot R \quad \text{[using Eq. (i)]}$$

For the maximum power,

$$\frac{dP}{dR} = 0$$

$$\Rightarrow \frac{dP}{dR} = \frac{d}{dR}\left(\left(\frac{E}{R + r}\right)^2 \cdot R\right)$$

$$= E^2 \frac{d}{dR}\left(\frac{R}{(R + r)^2}\right)$$

$$= E^2\left[\frac{(R + r)^2 \times 1 - 2R \times (R + r)}{(R + r)^4}\right] = 0$$

$\Rightarrow \quad (R + r)^2 = 2R(R + r)$

or $\quad R + r = 2R$

$\Rightarrow \quad r = R$

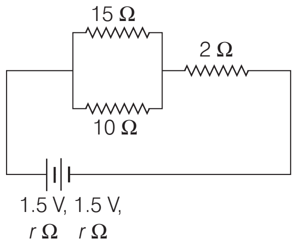
$\therefore$ The power delivered by the cell to the external resistance is maximum when $R = r$.

Alternate Solution

From maximum power theorem, power dissipated will be maximum when internal resistance of source will be equals to external load resistance, i.e. $r = R$.

102 In the given circuit, an ideal voltmeter connected across the $10\,\Omega$ resistance reads 2 V. The internal resistance r, of each cell is

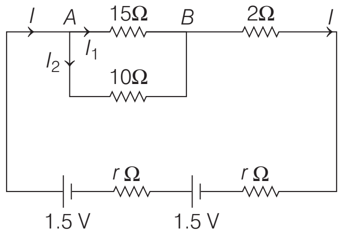
[2019, 10 April Shift-I]



(a) $1.5\,\Omega$ (b) $0.5\,\Omega$ (c) $1\,\Omega$ (d) $0\,\Omega$

Ans. *(b)*

For the given circuit



Given, $V_{AB} = 2\text{V}$

$\therefore$ Current in circuit,

$$I = I_1 + I_2$$

$$= \frac{2}{15} + \frac{2}{10} \quad [\because V = IR \text{ or } I = V/R]$$

$$= \frac{4 + 6}{30} = \frac{1}{3}\text{A} \quad \text{...(i)}$$

Also, voltage drop across $(r + r)$ resistors is

= voltage of the cell
− voltage drop across AB
$= 3 - 2 = 1\text{V}$

Using $V = IR$ over the entire circuit

$\Rightarrow \quad 1 = I(2 + 2r)$

$= \frac{1}{3}(2 + 2r)$ [using Eq. (i)]

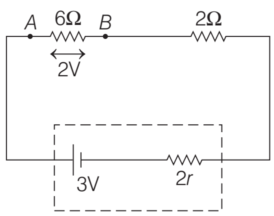
$\Rightarrow \quad 3 = 2 + 2r$ or $2r = 1\,\Omega$

or $\quad r = \frac{1}{2}\Omega = 0.5\,\Omega$

Alternate Solution

Equivalent resistance between A and B is

$$\frac{1}{R_{AB}} = \frac{1}{10} + \frac{1}{15} = \frac{1}{6} \Rightarrow R_{AB} = 6\,\Omega$$



$\therefore$ Equivalent resistance of the entire circuit is, $R_{eq} = 6\,\Omega + 2\,\Omega + 2\,r = 8 + 2r$

Now, current passing through the circuit is given

as, $\quad I = \frac{E_{net}}{R + r_{eq}} = \frac{E_{net}}{R_{eq}}$

where, R is external resistance, r_{eq} is net internal resistance and E_{net} is the emf of the cells.

Here, $\quad E_{net} = 1.5 + 1.5 = 3\text{ V}$

$$r_{eq} = r + r = 2r \Rightarrow I = \frac{3}{8 + 2r}$$

Also, reading of the voltmeter,

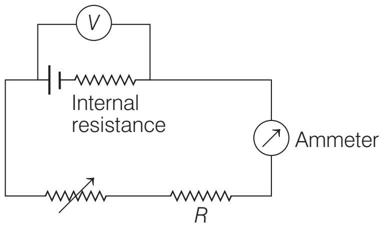
$$V = 2\text{V} = I \cdot R_{AB}$$

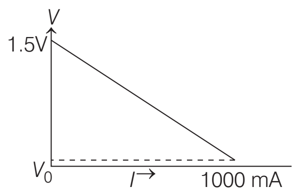
$$2 = \left(\frac{3}{8 + 2r}\right) \times 6 \Rightarrow 8 + 2r = 9$$

or $\quad r = \frac{1}{2} = 0.5\,\Omega$

103 To verify Ohm's law, a student connects the voltmeter across the battery as shown in the figure. The measured voltage is plotted as a function of the current and the following graph is obtained

[2019, 12 April Shift-I]





If V_0 is almost zero, then identify the correct statement.

(a) The emf of the battery is 1.5 V and its internal resistance is $1.5\,\Omega$
(b) The value of the resistance R is $1.5\,\Omega$
(c) The potential difference across the battery is 1.5 V when it sends a current of 1000 mA
(d) The emf of the battery is 1.5 V and the value of R is $1.5\,\Omega$

Ans. *(a)*

Given circuit in a series combination of internal resistance of cell (r) and external resistance R.

$\therefore$ Effective resistance in the circuit,

$$R_{eff} = r + R$$

$\therefore$ Current in the circuit,

$$I = \frac{E}{R+r} \text{ or } E = IR + Ir$$

Voltage difference across resistance R is V, so

$$E = V + Ir \quad \text{...(i)}$$

Now, from graph at $I = 0$, $V = 1.5$ V

From Eq. (i) at $I = 0$, $E = V = 1.5$ V ...(ii)

At $I = 1000$ mA (or 1 A), $V = 0$

From Eq. (i) at $I = 1$ A and $V = 0$

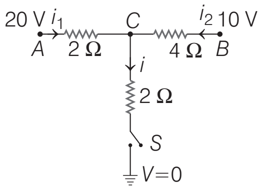
$$\Rightarrow \quad E = I \times r = r \quad \text{...(iii)}$$

From Eqs. (ii) and (iii), we can get

$$r = E = V = 1.5\text{V}$$

$$\therefore \quad r = 1.5\,\Omega$$

104 When the switch S in the circuit shown is closed, then the value of current i will be



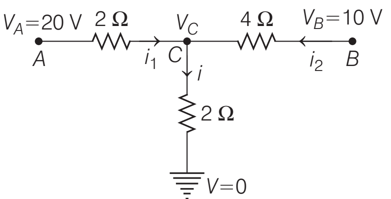
[2019, 9 Jan Shift-I]

(a) 4A (b) 3A

(c) 2A (d) 5A

Ans. *(d)*

When the switch 'S' is closed the circuit, hence formed is given in the figure below,



Then, according to Kirchhoff's current law, which states that the sum of all the currents directed towards a point in a circuit is equal to the sum of all the currents directed away from that point.

Since, in the above circuit, that point is 'C'

$$\therefore \quad i_1 + i_2 = i$$

$$\Rightarrow \quad \frac{V_A - V_C}{2} + \frac{V_B - V_C}{4} = \frac{V_C - V}{2}$$

($\because$ using Ohm's law, $V = iR$)

$$\text{or} \quad \frac{20 - V_C}{2} + \frac{10 - V_C}{4} = \frac{V_C - 0}{2}$$

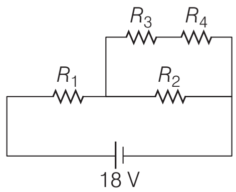
$$\Rightarrow \quad 20 - V_C + (10 - V_C)2 = V_C$$

$$\Rightarrow \quad 40 = V_C + 3V_C$$

$$40 = 4V_C \text{ or } V_C = 10 \text{ V}$$

$$\therefore \quad \text{The current, } i = \frac{V_C}{2} = \frac{10}{2} = 5\text{A}$$

105 In the given circuit, the internal resistance of the 18 V cell is negligible. If $R_1 = 400\,\Omega$, $R_3 = 100\,\Omega$ and $R_4 = 500\,\Omega$ and the reading of an ideal voltmeter across R_4 is 5 V, then the value of R_2 will be **[2019, 9 Jan Shift-II]**

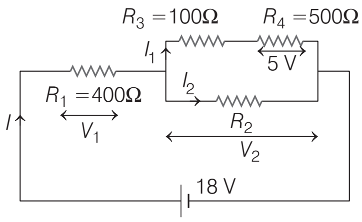


(a) 550 Ω (b) 230 Ω

(c) 300 Ω (d) 450 Ω

Ans. *(c)*

According to question, the voltage across R_4 is 5 volt, then the current across it



According to Ohm's law,

$$\Rightarrow \quad V = IR$$

$$\Rightarrow \quad 5 = I_1 \times R_4$$

$$\Rightarrow \quad 5 = I_1 \times 500$$

$$I_1 = \frac{5}{500} = \frac{1}{100}\text{A}$$

The potential difference across series combination of R_3 and R_4

$$\Rightarrow \quad V_2 = (R_3 + R_4)I = 600 \times \frac{1}{100} = 6\text{V}$$

So, potential difference (across R_1)

$$V_1 = 18 - 6 = 12\text{V}$$

Current through R_1 is,

$$I = \frac{V_1}{R_1} = \frac{12}{400} = \frac{3}{100}\text{A}$$

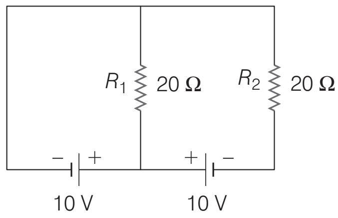
So current through R_2 is,

$$I_2 = I - I_1 = \frac{3}{100} - \frac{1}{100}\text{A} = \frac{2}{100}\text{A}$$

Now, from $V = IR$, we have,

$$R_2 = \frac{V_2}{I_2} = \frac{6}{(2/100)} = 300\,\Omega.$$

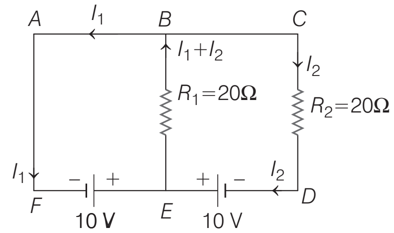
106 In the given circuit, the cells have zero internal resistance. The currents (in Ampere) passing through resistances R_1 and R_2 respectively are **[2019, 10 Jan Shift-I]**



(a) 0.5, 0 (b) 1, 2 (c) 2, 2 (d) 0, 1

Ans. *(a)*

By Kirchhoff's loop rule in the given loop $ABEFA$, we get



$$10 - (I_1 + I_2)R_1 = 0$$

$$\Rightarrow \quad 10 - (I_1 + I_2)\,20 = 0 \text{ or } I_1 + I_2 = \frac{1}{2} \quad \text{...(i)}$$

and from loop $BCDEB$, we get

$$10 - (I_1 + I_2)R_1 - I_2R_2 = 0$$

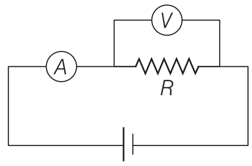
$$\Rightarrow \quad 10 - (I_1 + I_2 + I_2)\,20 = 0$$

$$\Rightarrow \quad I_1 + 2I_2 = \frac{1}{2} \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$I_2 = 0 \quad \text{and} \quad I_1 = 0.5\text{ A}$$

107 The actual value of resistance R, shown in the figure is 30 Ω. This is measured in an experiment as shown using the standard formula $R = \frac{V}{I}$, where V and I are the readings of the voltmeter and ammeter, respectively. If the measured value of R is 5% less, then the internal resistance of the voltmeter is **[2019, 10 Jan Shift-II]**



(a) 600 Ω (b) 570 Ω (c) 350 Ω (d) 35 Ω

Ans. *(b)*

Measured value of R = 5% less than actual value of R.

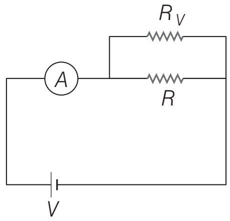
Actual values of $R = 30\,\Omega$

So, measured value of R is

$$R' = 30 - (5\% \text{ of } 30) = 30 - \frac{5}{100} \times 30$$

$$\Rightarrow \quad R' = 28.5\,\Omega \quad \text{...(i)}$$

Now, let us assume that internal resistance of voltmeter R_V. Replacing voltmeter with its internal resistance, we get following circuit.



It is clear that the measured value, R' should be equal to parallel combination of R and R_V. Mathematically,

$$R' = \frac{RR_V}{R + R_V} = 28.5\,\Omega$$

Given, $\quad R = 30\,\Omega \Rightarrow \dfrac{30R_V}{30 + R_V} = 28.5$

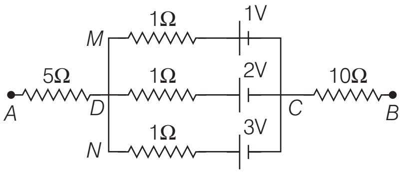
$\Rightarrow \quad 30R_V = (28.5 \times 30) + 28.5\,R_V$

$\Rightarrow \quad 1.5R_V = 28.5 \times 30$

$\Rightarrow \quad R_V = \dfrac{28.5 \times 30}{1.5} = 19 \times 30$

or $\quad R_V = 570\,\Omega$

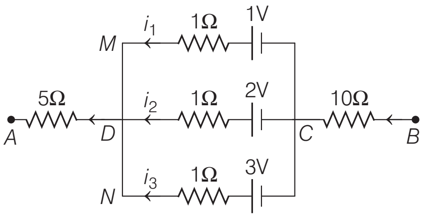
108 In the circuit shown, the potential difference between A and B is **[2019, 11 Jan Shift-II]**



(a) 3 V (b) 1 V (c) 6 V (d) 2 V

Ans. *(d)*

In the given circuit, let's assume currents in the arms are i_1, i_2 and i_3, respectively.



Now, $\quad i_1 = \dfrac{V_1}{R_1} = \dfrac{1}{1} = 1\text{ A}$

Similarly, $\quad i_2 = \dfrac{2}{1} = 2\text{ A}$ and $i_3 = \dfrac{3}{1} = 3\text{ A}$

Total current in the arm DA is

$$i = i_1 + i_2 + i_3 = 6\text{ A}$$

As all three resistors between D and C are in parallel.

$\therefore$ Equivalent resistance between terminals D and C is

$$\frac{1}{R_{DC}} = \left(\frac{1}{1} + \frac{1}{1} + \frac{1}{1}\right)$$

$\therefore \quad R_{DC} = \dfrac{1}{3}\,\Omega$

So, potential difference across D and C is

$$V_{DC} = iR_{DC} = 6 \times \frac{1}{3} \Rightarrow V_{DC} = 2\text{ V}$$

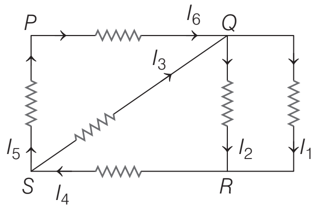
Now, $\quad V_{AD}$ and $V_{CB} = 0$

(In case of open circuits, $I = 0$)

So, $\quad V_{AB} = V_{AD} + V_{DC} + V_{CB} = V_{DC}$

So, $\quad V_{AB} = 2\text{V}$

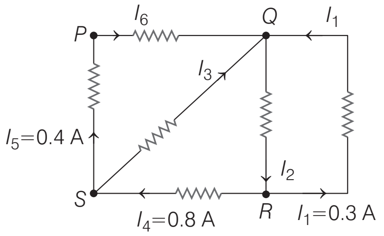
109 In the given circuit diagram, the currents $I_1 = -0.3$ A, $I_4 = 0.8$ A and $I_5 = 0.4$ A, are flowing as shown. The currents I_2, I_3 and I_6 respectively, are **[2019, 12 Jan Shift-II]**



(a) 1.1 A, 0.4 A, 0.4 A
(b) 1.1 A, −0.4 A, 0.4 A
(c) 0.4 A, 1.1 A, 0.4 A
(d) −0.4 A, 0.4 A, 1.1 A

Ans. *(a)*

Given circuit with currents as shown in the figure below, [In the question $I_1 = 0.3$ A is given, due to it we change the direction of I_1, in this figure]



From Kirchoff's junction rule, $\Sigma I = 0$

At junction S, $\quad I_4 = I_5 + I_3$

$\Rightarrow \quad 0.8 = 0.4 + I_3 \Rightarrow I_3 = 0.4\text{ A}$

At junction P, $\quad I_5 = I_6 \Rightarrow I_6 = 0.4\text{ A}$

At junction Q, $\quad I_2 = I_1 + I_3 + I_6$

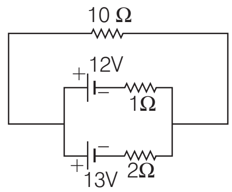
$$= 0.3 + 0.4 + 0.4 = 1.1\text{ A}$$

110 Two batteries with emf 12 V and 13 V are connected in parallel across a load resistor of 10 Ω. The internal resistances of the two batteries are 1 Ω and 2 Ω, respectively. The voltage across the load lies between **[JEE Main 2018]**

(a) 11.6 V and 11.7 V (b) 11.5 V and 11.6 V
(c) 11.4 V and 11.5 V (d) 11.7 V and 11.8 V

Ans. *(b)*

For parallel combination of cells,



$$E_{eq} = \frac{\dfrac{E_1}{r_1} + \dfrac{E_2}{r_2}}{\dfrac{1}{r_1} + \dfrac{1}{r_2}} \quad \therefore E_{eq} = \frac{\dfrac{12}{1} + \dfrac{13}{2}}{\dfrac{1}{1} + \dfrac{1}{2}} = \frac{37}{3}\text{ V}$$

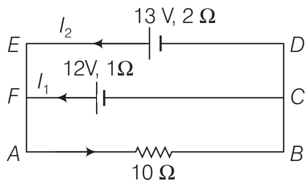
Potential drop across 10 Ω resistance,

$$V = \left(\frac{E}{R_{\text{total}}}\right) \times 10 = \frac{37/3}{\left(10 + \dfrac{2}{3}\right)} \times 10$$

$$= 11.56\text{ V}$$

$\therefore \quad V = 11.56\text{ V}$

Alternate Solution



Applying KVL, in loop $ABCFA$,

$$-12 + 10\,(I_1 + I_2) + 1 \times I_1 = 0$$

$\Rightarrow \quad 12 = 11I_1 + 10I_2 \quad$ ...(i)

Similarly,

In loop $ABDEA$,

$$-13 + 10\,(I_1 + I_2) + 2 \times I_2 = 0$$

$\Rightarrow \quad 13 = 10I_1 + 12I_2 \quad$ ...(ii)

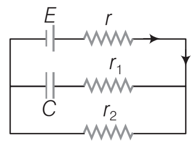
Solving Eqs. (i) and (ii), we get

$$I_1 = \frac{7}{16}\text{ A},\ I_2 = \frac{23}{32}\text{ A}$$

$\therefore$ Voltage drop across 10 Ω resistance is

$$V = 10\left(\frac{7}{16} + \frac{23}{32}\right) = 11.56\text{ V}$$

111 In the given circuit diagram, when the current reaches steady state in the circuit, the charge on the capacitor of capacitance C will be **[JEE Main 2017]**



(a) $CE\dfrac{r_1}{(r_2 + r)}$ (b) $CE\dfrac{r_2}{(r + r_2)}$

(c) $CE\dfrac{r_1}{(r_1 + r)}$ (d) CE

Ans. *(b)*

In steady state, no current flows through the capacitor. So, resistance r_p becomes ineffective.
So, the current in circuit,

$$I = \frac{E}{r + r_2 \text{ (Total Resistance)}}$$

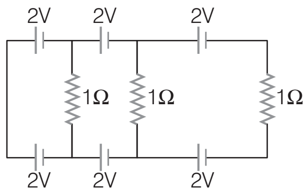
$\because$ Potential drop across capacitor = Potential drop

across $r_2 = Ir_2 = \frac{Er_2}{r + r_2}$

$\therefore$ Stored charge of capacitor,

$$Q = CV = CE\frac{r_2}{r + r_2}$$

112 In the below circuit, the current in each resistance is **[JEE Main 2017]**

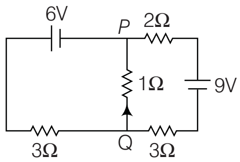


(a) 0.25 A (b) 0.5 A (c) 0 A (d) 1 A

Ans. *(c)*

Each resistance is converted with two cells combined in opposite direction, so potential drop across each resistor is zero. Hence, the current through each of resistor is zero.

113 In the circuit shown below, the current in the 1Ω resistor is **[JEE Main 2015]**

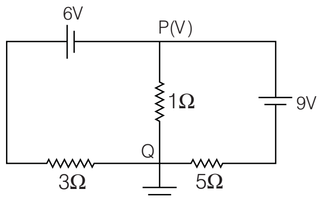


(a) 1.3 A, from P to Q
(b) 0 A
(c) 0.13 A, from Q to P
(d) 0.13 A, from P to Q

Ans. *(c)*

Key Idea Connect point Q to ground and apply KCL.

Consider the grounded circuit as shown below.



Applying KCL of point Q we can write
Incoming current at Q = outgoing current from Q

$$\Rightarrow \quad \frac{V+6}{3} + \frac{V}{1} = \frac{9-V}{5}$$

or $$V\left[\frac{1}{3} + \frac{1}{5} + 1\right] = \frac{9}{5} - 2$$

or $$V\left[\frac{5+3+15}{15}\right] = \frac{9-10}{5}$$

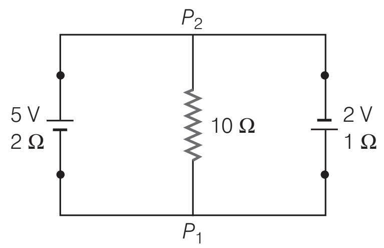
or $$V\left[\frac{23}{15}\right] = \frac{-1}{5}$$

or $$V = \frac{-3}{23}$$

$$= -0.13\text{ V}$$

Thus, current in the 1 Ω resistance is 0.13 A, from Q to P.

114 A 5 V battery with internal resistance 2 Ω and a 2 V battery with internal resistance 1 Ω are connected to a 10 Ω resistor as shown in the figure.



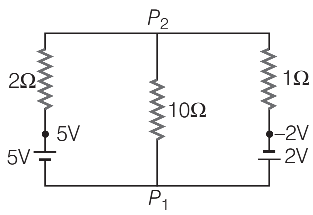
The current in the 10 Ω resistor is **[AIEEE 2008]**

(a) 0.27 A, P_2 to P_1 (b) 0.03 A, P_1 to P_2
(c) 0.03 A, P_2 to P_1 (d) 0.27 A, P_1 to P_2

Ans. *(c)*

Let potential at P_1 be 0 V and potential at P_2 be V_0.
Now apply KCL at P_2,

$$\Sigma I = 0$$



$$\frac{V_0 - 5}{2} + \frac{V_0 - 0}{10} + \frac{V_0 - (-2)}{1} = 0$$

or $$V_0 = \frac{5}{16}$$

So, current through 10 Ω resistor is $\frac{V_0}{10}$ from P_2 to P_1.

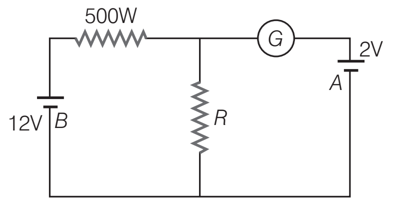
115 The Kirchhoff's first law $(\Sigma i = 0)$ and second law $(\Sigma iR = \Sigma E)$ where, the symbols have their usual meanings, are respectively based on **[AIEEE 2006]**

(a) conservation of charge, conservation of momentum
(b) conservation of energy, conservation of charge
(c) conservation of momentum, conservation of charge
(d) conservation of charge, conservation of energy

Ans. *(d)*

Kirchhoff's Ist law or KCL states that the algebraic sum of current meeting at any junction is equal to zero. In other words, we can say that "The sum of all the currents directed towards a junction in a circuit is equal to the sum of all the currents directed away from that junction."
Thus, no charge has been accumulated at any junction *i.e.*, charge is conserved and hence we can say that KCL $(\Sigma i = 0)$ is based on conservation of charge.
Kirchhoff's IInd law or KVL states that algebraic sum of changes in potential around any closed resistor loop must be zero. In other words, "Around any closed loop, voltage drops are equal to voltage rises". No energy is gained or lost in circulating a charge around a loop, thus we can say that KVL is based on conservation of energy.

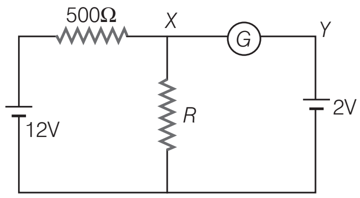
116 In the circuit, the galvanometer G shows zero deflection. If the batteries A and B have negligible internal resistance, the value of the resistor R will be **[AIEEE 2005]**



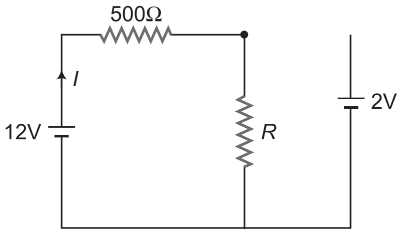
(a) 200 Ω (b) 100 Ω (c) 500 Ω (d) 1000 Ω

Ans. *(b)*

The galvanometer shows zero deflection *i.e.*, current through XY is zero



As a result potential drop across R is 2 V. Circuit can be redrawn as



$$I = \frac{12}{500 + R}$$

Voltage across $R, V = IR$

$$\Rightarrow \quad 2 = \frac{12}{500 + R} \times R$$

or $\quad 1000 + 2R = 12R$

or $\quad R = 100\ \Omega$

117 Two sources of equal emf are connected to an external resistance R. The internal resistances of the two sources are R_1 and R_2, $(R_2 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then **[AIEEE 2005]**

(a) $R = \frac{R_2 \times (R_1 + R_2)}{(R_2 - R_1)}$

(b) $R = R_2 - R_1$

(c) $R = \frac{R_1 R_2}{(R_1 + R_2)}$

(d) $R = \frac{R_1 R_2}{(R_2 - R_1)}$

Ans. (*b*)

As R_1, R_2 and R in series.

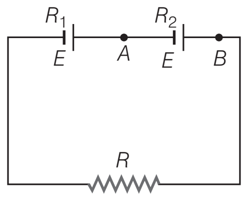
$$R_{eq} = R_1 + R_2 + R$$

$\therefore$ Net current, $I = \frac{2E}{R_1 + R_2 + R}$

According to the question,

$$-(V_A - V_B) = E - IR_2$$

$$\therefore \quad 0 = E - IR_2$$



or $\quad E = IR_2$ or $E = \frac{2E}{R_1 + R_2 + R} R_2$

or $\quad R_1 + R_2 + R = 2R_2$ or $R = R_2 - R_1$

118 An energy source will supply a constant current into the load, if its internal resistance is **[AIEEE 2005]**

(a) equal to the resistance of the load

(b) very large as compared to the load resistance

(c) zero

(d) non-zero but less than the resistance of the load

Ans. *(c)*

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

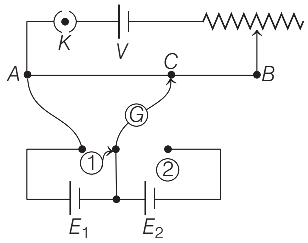
$$I = \frac{E}{R} = \text{constant}$$

where, R = external resistance

r = internal resistance = 0

TOPIC 4
Measuring Instruments

119 In the given potentiometer circuit arrangement, the balancing length AC is measured to be 250 cm. When the galvanometer connection is shifted from point (1) to point (2) in the given diagram, the balancing length becomes 400 cm. The ratio of the EMF of two cells, $\frac{\varepsilon_1}{\varepsilon_2}$ is **[2021, 25 July Shift-II]**



(a) $\frac{5}{3}$ (b) $\frac{8}{5}$

(c) $\frac{4}{3}$ (d) $\frac{3}{2}$

Ans. *(a)*

Given, balancing length for emf (ε_1),

$$l_1 = 250 \text{ cm} = 250 \times 10^{-2} \text{ m}$$

and for balancing emf $(\varepsilon_1 + \varepsilon_2)$, length,

$$l_2 = 400 \text{ cm} = 400 \times 10^{-2} \text{ m}$$

As we know that,

$$\frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} = \frac{l_1}{l_2}$$

$$\Rightarrow \quad \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} = \frac{250 \times 10^{-2}}{400 \times 10^{-2}}$$

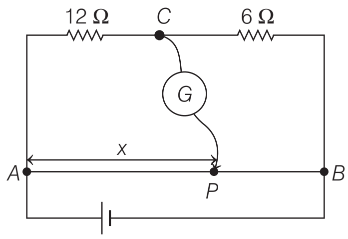
$$\Rightarrow \quad \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} = \frac{250}{400} = \frac{5}{8}$$

$$\Rightarrow \quad 8\varepsilon_1 = 5\varepsilon_1 + 5\varepsilon_2$$

$$\Rightarrow \quad 3\varepsilon_1 = 5\varepsilon_2$$

$$\Rightarrow \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{5}{3}$$

120 Consider a 72 cm long wire AB as shown in the figure. The galvanometer jockey is placed at P on AB at a distance x cm from A. The galvanometer shows zero deflection.



The value of x, to the nearest integer, is .... **[2021, 18 March Shift-II]**

Ans. *(48)*

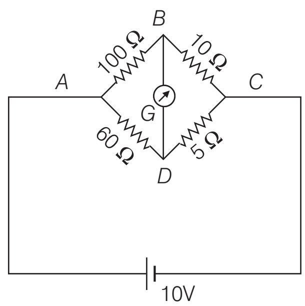
At the balanced condition of the Wheatstone bridge,

$$\frac{R}{S} = \frac{L_1}{L - L_1} \Rightarrow \frac{12}{6} = \frac{x}{72 - x} \Rightarrow x = 48 \text{ cm}$$

$\therefore$ The galvanometer jockey is placed at P on AB at a distance of 48 cm from the A.

So, the value of the x to the nearest integer is 48.

121 The four arms of a Wheatstone bridge have resistances as shown in the figure. A galvanometer of 15 Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across AC. **[2021, 17 March Shift-II]**



(a) 2.44 μA (b) 2.44 mA

(c) 4.87 mA (d) 4.87 μA

Ans. *(c)*

As, A is directly connected to the positive terminal of the battery, $V_A = 10\text{V}$ and $V_C = 0$

By nodal analysis at B,

$$\frac{V_B - 10}{100} + \frac{V_B - V_D}{15} + \frac{V_B - 0}{10} = 0$$

$$53V_B - 20V_D = 30 \quad \dots \text{(i)}$$

By nodal analysis at D,

$$\frac{V_D - 10}{60} + \frac{V_D - V_B}{15} + \frac{V_D - 0}{5} = 0$$

$$-4V_B + 17V_D = 10 \quad \dots \text{(ii)}$$

Solving Eqs. (i) and (ii) by substitution method, we get

$$V_D = 0.792\,\text{V} \Rightarrow V_B = 0.865\,\text{V}$$

The current through the galvanometer,

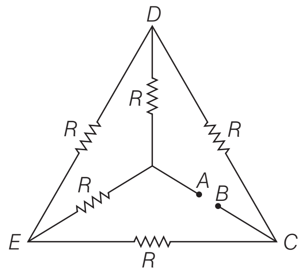
$$I = \frac{V_B - V_D}{R}$$

Substituting the values in the above equation, we get

$$I = \frac{0.865 - 0.792}{15}$$

$$\Rightarrow \quad I = 4.87\,\text{mA}$$

122 Five equal resistances are connected in a network as shown in figure. The net resistance between the points A and B is **[2021, 26 Feb Shift-I]**

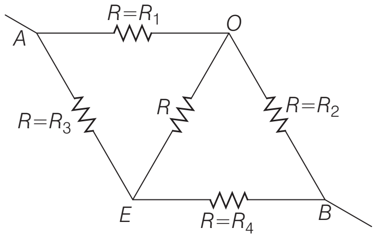


(a) $2R$ (b) $\frac{R}{2}$ (c) $\frac{3R}{2}$ (d) R

Ans. *(d)*

Given all resistances have same resistance R.

Now, we can redraw the circuit as below



Let resistances be R_1, R_2, R_3 and R_4.

$$\because \quad \frac{R_1}{R_3} = \frac{R_2}{R_4}$$

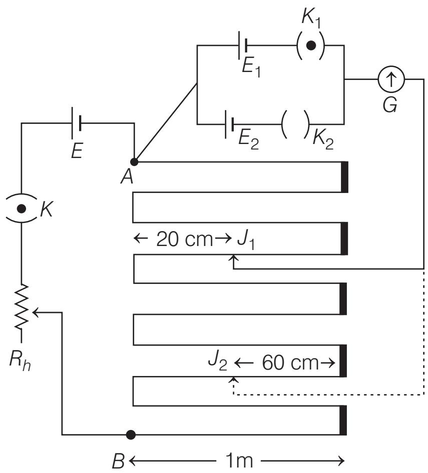
So, circuit will behave as a Wheatstone bridge and no current will flow through middle resistor.

$$\therefore \quad R_{eq} = \frac{(R_1 + R_2)(R_3 + R_4)}{(R_1 + R_2) + (R_3 + R_4)}$$

$$= \frac{(R + R)(R + R)}{(R + R) + (R + R)}$$

$$= R$$

123 In the given circuit of potentiometer, the potential difference E across AB (10 m length) is larger than E_1 and E_2 as well. For key K_1 (closed), the jockey is adjusted to touch the wire at point J_1, so that there is no deflection in the galvanometer. Now, the first battery (E_1) is replaced by second battery (E_2) for working by making K_1 open and K_2 closed. The galvanometer gives then null deflection at J_2. The value of $\frac{E_1}{E_2}$ is $\frac{a}{b}$, where $a = \dots\dots\dots$. **[2021, 25 Feb Shift-I]**



Ans. *(1)*

Given, length of $AB = 10\text{ m} = 1000\text{ cm}$

Length of one arm $= \frac{1000}{10} = 100\text{ cm}$

For no deflection,

In first case, $l_1 = 3 \times 100 + 80 = 380\text{ cm}$

In 2nd case, $l_2 = 7 \times 100 + 60 = 760\text{ cm}$

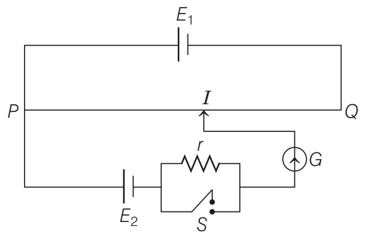
As we know that in balanced potentiometer,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$\Rightarrow \quad \frac{a}{b} = \frac{380}{760} = \frac{1}{2}$$

$$\therefore \quad a = 1$$

124 A potentiometer wire PQ of 1 m length is connected to a standard cell E_1. Another cell E_2 of emf 1.02 V is connected with a resistance r and switch S (as shown in figure). With switch S open, the null position is obtained at a distance of 49 cm from Q. The potential gradient in the potentiometer wire is **[2020, 2 Sep Shift-II]**

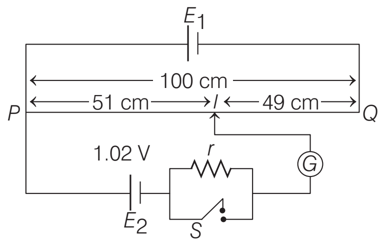


(a) 0.02 V/cm (b) 0.01 V/cm
(c) 0.03 V/cm (d) 0.04 V/cm

Ans. *(a)*

Resistance r limits current through E_2 when there is no balance situation.

But at balance point no current flows through galvanometer G and E_2, so r does not affects the position of balance point as shown in figure.



Now, 1.02 V is balanced against 51 cm length, so potential gradient of wire PQ is,

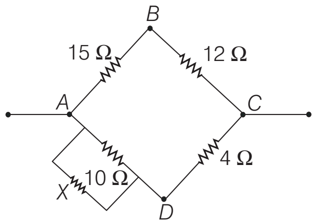
Potential gradient = Fall of potential per unit length $= \frac{1.02}{51}\frac{\text{V}}{\text{cm}} = 0.02\,\text{V/cm}$

Hence, correct option is (a).

125 Four resistances of 15 Ω, 12 Ω, 4 Ω and 10 Ω respectively in cyclic order to form Wheatstone's network. The resistance that is to be connected in parallel with the resistance of 10 Ω to balance the network is .... Ω . **[2020, 8 Jan Shift-I]**

Ans. *(10)*

Cyclic order and resistance X Ω which is connected to obtain balance condition is as shown in the figure

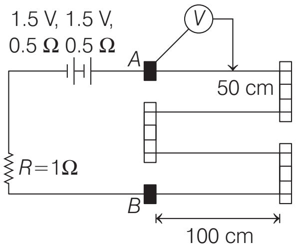


For balance,

$$\frac{15}{12}=\frac{\left(\frac{10X}{10+X}\right)}{4} \Rightarrow \frac{10X}{10+X}=5$$

$\Rightarrow \qquad X = 10\ \Omega$

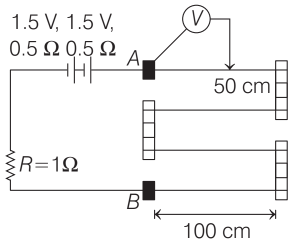
126 In the circuit shown, a four-wire potentiometer is made of a 400 cm long wire, which extends between A and B. The resistance per unit length of the potentiometer wire is $r = 0.01\ \Omega/\text{cm}$. If an ideal voltmeter is connected as shown with jockey J at 50 cm from end A, the expected reading of the voltmeter will be **[2019, 8 April Shift-II]**



(a) 0.20 V (b) 0.75 V
(c) 0.25 V (d) 0.50 V

Ans. *(c)*

In given potentiometer, resistance per unit length is $x = 0.01\ \Omega\ \text{cm}^{-1}$.



Length of potentiometer wire is

$$L = 400\ \text{cm}$$

Net resistance of the wire AB is

R_{AB} = resistance per unit length × length of $AB = 0.01 \times 400$

$\Rightarrow \qquad R_{AB} = 4\ \Omega$

Net internal resistance of the cells connected in series,

$$r = 0.5 + 0.5 = 1\Omega$$

$\therefore$ Current in given potentiometer circuit is

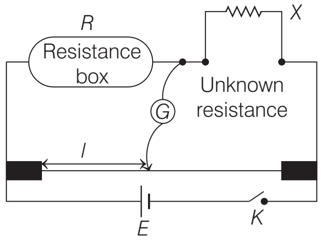
$$I = \frac{\text{Net emf}}{\text{Total resistance}} = \frac{\text{Net emf}}{r + R + R_{AB}}$$

$$= \frac{3}{1+1+4} = 0.5\ \text{A}$$

Reading of voltmeter when the jockey is at 50 cm (l') from one end A,

$$V = IR = I(xl') = 0.5 \times 0.01 \times 50 = 0.25\ \text{V}$$

127 In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure **[2019, 10 April Shift-I]**



S. No.	$R(\Omega)$	l(cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

Which of the readings is inconsistent?

(a) 3 (b) 2 (c) 1 (d) 4

Ans. *(d)*

Unknown resistance 'X' in meter bridge experiment is given by

$$X = \left(\frac{100 - l}{l}\right) R$$

Case I When $R = 1000\ \Omega$ and $l = 60$ cm, then

$$X = \frac{(100-60)}{60} \times 1000 = \frac{40 \times 1000}{60}$$

$$\Rightarrow \qquad X = \frac{2000}{3}\ \Omega \approx 667\ \Omega$$

Case II When $R = 100\ \Omega$ and $l = 13$ cm, then

$$X = \left(\frac{100-13}{13}\right) \times 100 = \frac{100 \times 87}{13}$$

$$= \frac{8700}{13}\ \Omega \approx 669\ \Omega$$

Case III When $R = 10\ \Omega$ and $l = 1.5$ cm, then

$$X = \left(\frac{100 - 1.5}{1.5}\right) \times 10$$

$$= \frac{98.5}{1.5} \times 10 = \frac{9850}{15}\ \Omega \approx 656\ \Omega$$

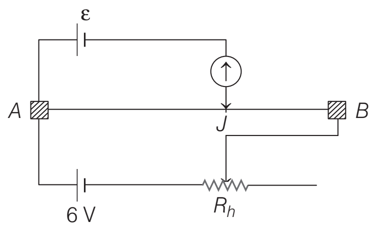
Case IV When $R = 1\ \Omega$ and $l = 1.0$ cm, then

$$X = \left(\frac{100-1}{1}\right) \times 1$$

$\therefore \qquad X = 99\ \Omega$

Thus, from the above cases, it can be concluded that, value calculated in case (IV) is inconsistent.

128 The resistance of the meter bridge AB in given figure is 4Ω. With a cell of emf $\varepsilon = 0.5$ V and rheostat resistance $R_h = 2\Omega$. The null point is obtained at some point J. When the cell is replaced by another one of emf $\varepsilon = \varepsilon_2$, the same null point J is found for $R_h = 6\Omega$. The emf ε_2 is **[2019, 11 Jan Shift-I]**



(a) 0.6 V (b) 0.3 V
(c) 0.5 V (d) 0.4 V

Ans. *(b)*

Let length of null point 'J' be 'x' and length of the potentiometer wire be 'L'.

In first case, current in the circuit

$$I_1 = \frac{6}{4+2} = 1\ \text{A}$$

$\therefore$ Potential gradient,

$$= I \times R = \frac{1 \times 4}{L}$$

$\Rightarrow$ Potential difference in part 'AJ'

$$= \frac{1 \times 4}{L} \times x = \varepsilon_1$$

Given, $\varepsilon_1 = 0.5 = \dfrac{4x}{L}$

or $\qquad \dfrac{x}{L} = \dfrac{1}{8} \qquad$ ...(i)

In second case, current in the circuit

$$I_2 = \frac{6}{4+6} = 0.6\ \text{A}$$

$\therefore$ Potential gradient $= \dfrac{0.6 \times 4}{L}$

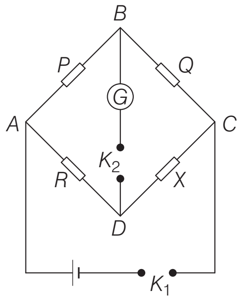
$\Rightarrow$ Potential difference in part 'AJ'

$$= \frac{0.6 \times 4}{L} \times x = \varepsilon_2$$

$\Rightarrow \qquad \varepsilon_2 = \dfrac{0.6 \times 4}{L} \times \dfrac{L}{8}$ [using Eq. (i)]

$\Rightarrow \qquad \varepsilon_2 = 0.3\ \text{V}$

129 In a Wheatstone bridge (see figure), resistances P and Q are approximately equal. When $R = 400\,\Omega$, the bridge is balanced. On interchanging P and Q, the value of R for balance is $405\,\Omega$. The value of X is close to **[2019, 11 Jan Shift-I]**



(a) $404.5\,\Omega$ (b) $401.5\,\Omega$
(c) $402.5\,\Omega$ (d) $403.5\,\Omega$

Ans. *(c)*

For a balanced Wheatstone bridge,

$$\frac{P}{R} = \frac{Q}{X}$$

In first case when $R = 400\,\Omega$, the balancing equation will be

$$\frac{P}{R} = \frac{Q}{X}$$

$$\Rightarrow \quad \frac{P}{400\,\Omega} = \frac{Q}{X}$$

$$\Rightarrow \quad P = \frac{400 \times Q}{X} \quad \text{...(i)}$$

In second case, P and Q are interchanged and $R = 405\,\Omega$

$$\therefore \quad \frac{Q}{R} = \frac{P}{X}$$

$$\Rightarrow \quad \frac{Q}{405} = \frac{P}{X} \quad \text{...(ii)}$$

Substituting the value of P from Eq. (i) in Eq. (ii), we get

$$\frac{Q}{405} = \frac{Q \times 400}{X^2}$$

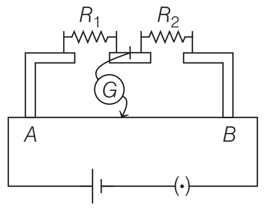
$$\Rightarrow \quad X^2 = 400 \times 405$$

$$\Rightarrow \quad X = \sqrt{400 \times 405}$$

$$= 402.5$$

The value of X is close to $402.5\,\Omega$.

130 In the experimental set up of meter bridge shown in the figure, the null point is obtained at a distance of 40 cm from A. If a $10\,\Omega$ resistor is connected in series with R_1, the null point shifts by 10 cm. The resistance that should be connected in parallel with $(R_1 + 10)\,\Omega$ such that the null point shifts back to its initial position is **[2019, 11 Jan Shift-II]**



(a) $60\,\Omega$ (b) $20\,\Omega$ (c) $30\,\Omega$ (d) $40\,\Omega$

Ans. *(a)*

For meter bridge, if balancing length is l cm, then in first case, $\frac{R_1}{R_2} = \frac{l}{(100 - l)}$

It is given that, $l = 40$ cm;

So; $\quad \frac{R_1}{40} = \frac{R_2}{100 - 40}$ or $\frac{R_1}{R_2} = \frac{2}{3}$ ...(i)

In second case, $R_1' = R_1 + 10$, and balancing length is now 50 cm then

$$\frac{R_1 + 10}{50} = \frac{R_2}{(100 - 50)}$$

or $\quad R_1 + 10 = R_2 \quad$ ...(ii)

Substituting value of R_2 from (ii) to (i) we get,

or $\quad \frac{R_1}{10 + R_1} = \frac{2}{3}$

$$\Rightarrow \quad 3R_1 = 20 + 2R_1 \text{ or } R_1 = 20\,\Omega$$

$$\Rightarrow \quad R_2 = 30\,\Omega$$

Let us assume the parallel connected resistance is x.

Then equivalent resistance is $\frac{x(R_1 + 10)}{x + R_1 + 100}$

So, this combination should be again equal to R_1.

$$\frac{(R_1 + 10)x}{R_1 + 10 + x} = R_1 \Rightarrow \frac{30x}{30 + x} = 20$$

or $\quad 30x = 600 + 20x$ or $x = 60\,\Omega$

131 An ideal battery of 4 V and resistance R are connected in series in the primary circuit of a potentiometer of length 1 m and resistance $5\,\Omega$. The value of R to give a potential difference of 5 mV across 10 cm of potentiometer wire is **[2019, 12 Jan Shift-I]**

(a) $395\,\Omega$ (b) $495\,\Omega$ (c) $490\,\Omega$ (d) $480\,\Omega$

Ans. *(a)*

Given, potential difference of 5 mV is across 10 m length of potentiometer wire. So potential drop per unit length is

$$= \frac{5 \times 10^{-3}}{10 \times 10^{-2}} = 5 \times 10^{-2} \left(\frac{\text{V}}{\text{m}}\right)$$

Hence, potential drop across 1 m length of potentiometer wire is

$$V_{AB} = 5 \times 10^{-2} \left(\frac{\text{V}}{\text{m}}\right) \times 1 = 5 \times 10^{-2} \text{ V}$$

Now, potential drop that must occurs across resistance R is

$$V_R = 4 - 5 \times 10^{-2} = \frac{395}{100} \text{ V}$$

Now, circuit current is $i = \frac{V}{R_{\text{total}}} = \frac{4}{R + 5}$

Hence, for resistance R, using $V_R = iR$, we get

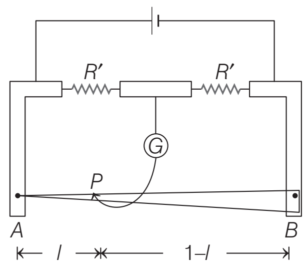
$$\frac{395}{100} = \frac{4}{R + 5} \times R$$

$$395(R + 5) = 400R$$

$$395 \times 5 = (400 - 395)R$$

$$\Rightarrow \quad R = 395\,\Omega$$

132 In a meter bridge, the wire of length 1m has a non-uniform cross-section such that the variation $\frac{dR}{dl}$ of its resistance R with length l is $\frac{dR}{dl} \propto \frac{1}{\sqrt{l}}$. Two equal resistance are connected as shown in the figure. The galvanometer has zero deflection when the jockey is at point P. What is the length AP? **[2019, 12 Jan Shift-I]**



(a) 0.3 m (b) 0.25 m (c) 0.2 m (d) 0.35 m

Ans. *(b)*

As, galvanometer shows zero deflection. This means, the meter bridge is balanced.

$$\frac{R'}{R_{AP}} = \frac{R'}{R_{PB}} \Rightarrow R_{AP} = R_{PB} \quad \text{...(i)}$$

Now, for meter bridge wire, $\frac{dR}{dl} = \frac{k}{\sqrt{l}}$

where, 'k' is the constant of proportionality.

$\Rightarrow \qquad dR = \frac{k}{\sqrt{l}} dl$

Integrating both sides, we get

$\Rightarrow \qquad R = \int \frac{k}{\sqrt{l}} dl$

So, $\qquad R_{AP} = \int_0^l \frac{k}{\sqrt{l}} dl = k(2\sqrt{l})\Big|_0^l = 2k\sqrt{l}$

and $\qquad R_{PB} = \int_l^1 \frac{k}{\sqrt{l}} dl = 2k(\sqrt{l})\Big|_l^1$

$= 2k(\sqrt{1} - \sqrt{l}) = 2k(1 - \sqrt{l})$

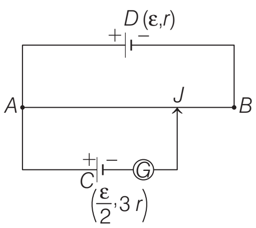
Substituting values of R_{AP} and R_{PB} in Eq. (i), we get

$R_{AP} = R_{PB}$

$\Rightarrow \qquad 2k\sqrt{l} = 2k(1 - \sqrt{l})$

$\Rightarrow \qquad \sqrt{l} = \frac{1}{2}$ or $l = \frac{1}{4} = 0.25\,\text{m}$

133 A potentiometer wire AB having length L and resistance $12r$ is joined to a cell D of EMF ε and internal resistance r. A cell C having emf $\frac{\varepsilon}{2}$ and internal resistance $3r$ is connected. The length AJ at which the galvanometer as shown in figure shows no deflection is **[2019, 10 Jan Shift-I]**



(a) $\frac{5}{12}L$ (b) $\frac{11}{12}L$

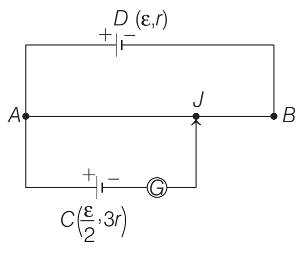
(c) $\frac{13}{24}L$ (d) $\frac{11}{24}L$

Ans. ***(c)***

Given, length of potentiometer wire $(AB) = L$

Resistance of potentiometer wire $(AB) = 12\,r$

EMF of cell D of potentiometer $= \varepsilon$



Internal resistance of cell 'D' $= r$

EMF of cell 'C' $= \frac{\varepsilon}{2}$

Internal resistance of cell 'C' $= 3r$

Current in potentiometer wire

$$i = \frac{\text{EMF of cell of potentiometer}}{\text{Total resistance of potentiometer circuit}}$$

$\Rightarrow \; i = \frac{\varepsilon}{r + 12r} = \frac{\varepsilon}{13r}$

Potential drop across the balance length AJ of potentiometer wire is

$V_{AJ} = i \times R_{AJ}$

$\Rightarrow V_{AJ} = i$ (Resistance per unit length of potentiometer wire $\times$ length AJ)

$\Rightarrow V_{AJ} = i\left(\frac{12r}{L} \times x\right)$

where, x = balance length AJ.

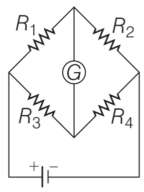
As null point occurs at J so potential drop across balance length AJ = EMF of the cell 'C'.

$\Rightarrow \qquad V_{AJ} = \frac{\varepsilon}{2}$

$\Rightarrow \qquad i\left(\frac{12r}{L} \times x\right) = \frac{\varepsilon}{2}$

$\Rightarrow \qquad \frac{\varepsilon}{13r} \times \frac{12r}{L} \times x = \frac{\varepsilon}{2} \Rightarrow x = \frac{13}{24}L$

134 The Wheatstone bridge shown in figure here, gets balanced when the carbon resistor is used as R_1 has the color code (orange, red, brown). The resistors R_2 and R_4 are $80\,\Omega$ and $40\,\Omega$, respectively.



Assuming that the color code for the carbon resistors gives their accurate values, the color code for the carbon resistor is used as R_3 would be **[2019, 10 Jan Shift-II]**

(a) brown, blue, black
(b) brown, blue, brown
(c) grey, black, brown
(d) red, green, brown

Ans. ***(b)***

The value of R_1 (orange, red, brown)

$\Rightarrow \qquad = 32 \times 10 = 320\,\Omega$

Given, $\qquad R_2 = 80\,\Omega$ and $R_4 = 40\,\Omega$

In balanced Wheatstone bridge condition,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$\Rightarrow \qquad R_3 = R_4 \times \frac{R_1}{R_2}$

$\Rightarrow \qquad R_3 = \frac{40 \times 320}{80}$

or $\qquad R_3 = 160\,\Omega = 16 \times 10^1$

Comparing the value of R_3 with the colours assigned for the carbon resistor, we get

$R_3 = 16 \times 10^1$

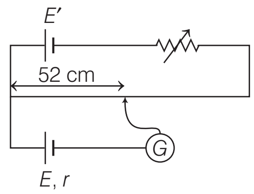
Brown Blue Brown

135 In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of $5\,\Omega$, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell. **[JEE Main 2018]**

(a) $1\,\Omega$ (b) $1.5\,\Omega$ (c) $2\,\Omega$ (d) $2.5\,\Omega$

Ans. ***(b)***

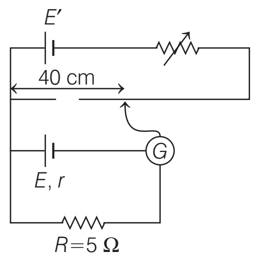
With only the cell,



On balancing, $\quad E = 52 \times x \qquad$ ...(i)

where, x is the potential gradient of the wire.

When the cell is shunted,



Similarly, on balancing,

$$V = E - \frac{Er}{(R + r)} = 40 \times x \qquad \text{...(ii)}$$

Solving Eqs. (i) and (ii), we get

$$\frac{E}{V} = \frac{1}{1 - \frac{r}{R + r}} = \frac{52}{40}$$

$$\Rightarrow \quad \frac{E}{V}=\frac{R+r}{R}=\frac{52}{40} \Rightarrow \frac{5+r}{5}=\frac{52}{40}$$

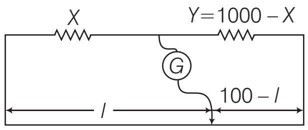
$$\Rightarrow \quad r=\frac{3}{2}\,\Omega \quad r=1.5\,\Omega$$

136 On interchanging the resistances, the balance point of a meter bridge shifts to the left by 10 cm. The resistance of their series combination is $1\,\text{k}\Omega$. How much was the resistance on the left slot before interchanging the resistances? **[JEE Main 2018]**

(a) $990\,\Omega$ (b) $505\,\Omega$ (c) $550\,\Omega$ (d) $910\,\Omega$

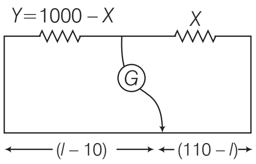
Ans. ***(c)***

We have, $X+Y=1000\,\Omega$



Initially, $\dfrac{X}{l}=\dfrac{1000-X}{100-l}$ ...(i)

When X and Y are interchanged, then



$$\frac{1000-X}{l-10}=\frac{X}{100-(l-10)}$$

or $\dfrac{1000-X}{l-10}=\dfrac{X}{110-l}$ ...(ii)

From Eqs. (i) and (ii), we get

$$\frac{100-l}{l}=\frac{l-10}{110-l}$$

$$(100-l)\,(110-l)=(l-10)l$$

$$11000-100l-110l+l^2=l^2-10l$$

$\Rightarrow \quad 11000=200l$

$\therefore \quad l=55\,\text{cm}$

Substituting the value of l in Eq. (i), we get

$$\frac{X}{55}=\frac{1000-55}{100-55} \Rightarrow 20X=11000$$

$\therefore \quad X=550\,\Omega$

137 Which of the following statements is false? **[JEE Main 2017]**

(a) In a balanced Wheatstone bridge, if the cell and the galvanometer are exchanged, the null point is disturbed

(b) A rheostat can be used as a potential divider

(c) Kirchhoff's second law represents energy conservation

(d) Wheatstone bridge is the most sensitive when all the four resistances are of the same order of magnitude

Ans. ***(a)***

In a balanced Wheatstone bridge, there is no effect on position of null point, if we exchange the battery and galvanometer. So, option (a) is incorrect.

138 The current in the primary circuit of a potentiometer is 0.2 A. The specific resistance and cross-section of the potentiometer wire are $4\times10^{-7}\ \Omega$- m and $8\times10^{-7}\ \text{m}^2$, respectively. The potential gradient will be equal to **[AIEEE 2011]**

(a) 0.2 V/m (b) 1 V/m
(c) 0.3 V/m (d) 0.1 V/m

Ans. ***(d)***

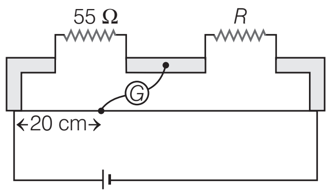
Potential gradient of a potentiometer,

$$K=\frac{V}{l}$$

$$K=\frac{I\rho}{A}=\frac{0.2\times4\times10^{-7}}{8\times10^{-7}}$$

$$=0.1\ \text{V/m}$$

139 Shown in the figure adjacent is a meter-bridge set up with null deflection in the galvanometer. The value of the unknown resistor R is **[AIEEE 2008]**



(a) $13.75\,\Omega$ (b) $220\,\Omega$
(c) $110\,\Omega$ (d) $55\,\Omega$

Ans. ***(b)***

When bridge is balanced, ratio of resistance in opposite arms is equal.

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

Given, $P=55\,\Omega$, $Q=R$

As $\quad R\propto l$

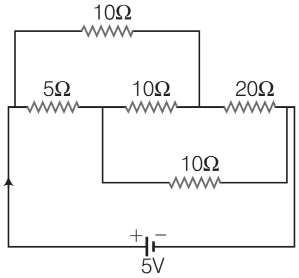
$R\propto l_1$, where $l_1=20$ cm

$S\propto l_2$, where $l_2=100-20=80$ cm

$$\frac{R}{S}=\frac{l_1}{l_2}=\frac{20}{80}$$

$\therefore \quad \dfrac{55}{R}=\dfrac{20}{80}$ or $R=220\,\Omega$

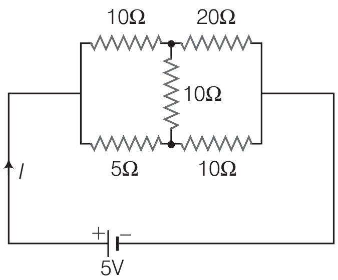
140 The current I drawn from the 5 V source will be **[AIEEE 2006]**



(a) 0.33 A (b) 0.5 A
(c) 0.67 A (d) 0.17 A

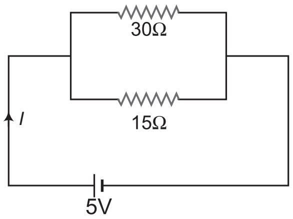
Ans. ***(b)***

The given circuit can be redrawn as



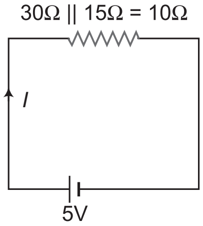
Which is a balanced Wheatstone's bridge and hence no current flows in the middle resistor, so equivalent circuit would be as shown below.

$\Rightarrow$



30Ω || 15Ω = 10Ω

$\Rightarrow$



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

141 In a Wheatstone's bridge, three resistances P, Q and R are connected in the three arms and the fourth arm is formed by two resistances S_1 and S_2 connected in parallel. The condition for the bridge to be balanced will be **[AIEEE 2006]**

(a) $\frac{P}{Q}=\frac{2R}{S_1+S_2}$ (b) $\frac{P}{Q}=\frac{R(S_1+S_2)}{S_1S_2}$

(c) $\frac{P}{Q}=\frac{R(S_1+S_2)}{2S_1S_2}$ (d) $\frac{P}{Q}=\frac{R}{S_1+S_2}$

Ans. ***(b)***

For balanced Wheatstone's bridge,

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

Here, $S=S_1 \,||\, S_2=\frac{S_1S_2}{S_1+S_2}$

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

142 In a potentiometer experiment, the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is **[AIEEE 2005]**

(a) 1 Ω (b) 0.5 Ω

(c) 4 Ω (d) 2 Ω

Ans. ***(d)***

The internal resistance of the cell,

$$r=\left(\frac{l_1-l_2}{l_2}\right)R=\left(\frac{240-120}{120}\right)\times 2=2\,\Omega$$

143 In a meter bridge experiment, null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If $X<Y$, then where will be the new position of the null point from the same end, if one decides to balance a resistance of $4X$ against Y? **[AIEEE 2004]**

(a) 50 cm (b) 80 cm

(c) 40 cm (d) 70 cm

Ans. ***(a)***

Meter bridge is an arrangement which works on Wheatstone's principle, so the balancing condition is

$$\frac{R}{S}=\frac{l_1}{l_2}$$

where, $l_2=100-l_1$

Case I $R=X, S=Y, l_1=20$ cm,

$l_2=100-20=80$ cm

$\therefore$ $\frac{X}{Y}=\frac{20}{80}$ ...(i)

Case II Let the position of null point be obtained at a distance l from same end.

$\therefore$ $R=4X,\ \ S=Y,$

$l_1=l, l_2=100-l$

So, from Eq. (i), we get

$$\frac{4X}{Y}=\frac{l}{100-l}$$

$$\frac{X}{Y}=\frac{l}{4(100-l)} \quad \text{...(ii)}$$

Therefore, from Eqs. (i) and (ii), we get

$$\frac{l}{4(100-l)}=\frac{20}{80}$$

$\Rightarrow$ $\frac{l}{4(100-l)}=\frac{1}{4}$

or $l=100-l$ or $2l=100$

Hence, $l=50$ cm

144 The length of a wire of a potentiometer is 100 cm and the emf of its stand and cell is E volt. It is employed to measure the emf of a battery whose internal resistance is 0.5 Ω. If the balance point is obtained at $l=30$ cm from the positive end, the emf of the battery is **[AIEEE 2003]**

(a) $\frac{30E}{100.5}$

(b) $\frac{30E}{100-0.5}$

(c) $\frac{30(E-0.5I)}{100}$, where I is the current in the potentiometer wire

(d) $\frac{30E}{100}$

Ans. ***(d)***

$V \propto l$

$\therefore$ $\frac{V}{E}=\frac{l}{L}$

where, l = balance point distance

L = length of potentiometer wire

or $V=\frac{l}{L}E$

or $V=\frac{30\times E}{100}=\frac{30}{100}E$