Chapter 3

Current Electricity

Solutions

SECTION - A

Objective Type Questions (One option is correct)

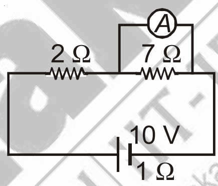
1. A voltmeter has resistance 2000 Ω and range 0-5 V. For increasing its range upto 20 V, a resistance of

   (1) 8000 Ω should be connected in series
   (2) 6000 Ω should be connected in series
   (3) 8000 Ω should be connected in parallel
   (4) 6000 Ω should be connected in parallel

Sol. Answer (2)

$i = \frac{5}{2000} = \frac{20}{2000 + x}$ $\Rightarrow$ x = 8000 – 2000 = 6000 Ω (connected in series)

2. In the situation shown in figure, an ideal ammeter is connected across 7 Ω resistors. Select the correct statement from the following

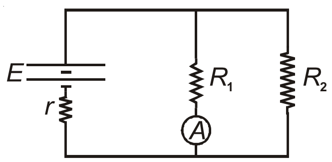


   (1) The current drawn by the battery is 1 A
   (2) The currents through 2 Ω and 7 Ω are equal
   (3) The rate of heat production in 7 Ω is less than that in 2 Ω
   (4) Both (1) & (2)

Sol. Answer (3)

As ideal ammeter has zero resistance thus 7Ω resistance will be shorted and all the current will pass through the ammeter.

3. In the circuit shown below, the ammeter reading will be independent of R_2 when

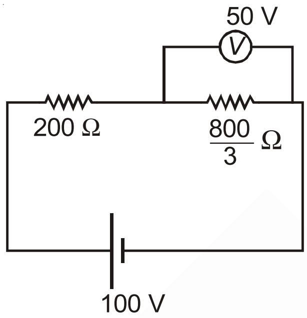


   (1) $R_1 + R_2 = r$
   (2) $R_1 = 2r$
   (3) $r = R_1 - R_2$
   (4) $r = 0$

Sol. Answer (4)

If $r = 0$, potential difference across $R_1 = E$ = constant. Hence, in this case current through R_1 does not depend on R_2.

4. What is the resistance of voltmeter shown in the circuit?

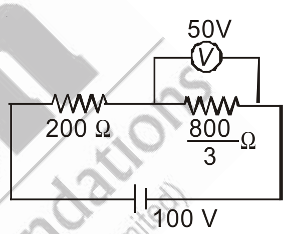


(1) $\frac{800}{3}\ \Omega$ (2) 800 Ω (3) 1000 Ω (4) 200 Ω

Sol. Answer (2)

Voltage across 200 Ω = 50 V

So, equivalent resistance across voltmeter is also 200 Ω



i.e., $\dfrac{\frac{800}{3}.R}{\frac{800}{3}+R} = 200$

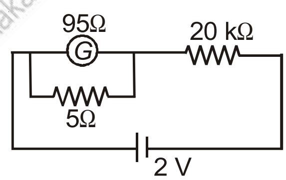
$\Rightarrow$ R = 800 Ω

5. A galvanometer of resistance 95 Ω, shunted by a resistance of 5 Ω, gives a deflection of 50 divisions, when joined in series with a resistance of 20 kΩ and a 2.0 V accumulator. The current sensitivity of the ammeter, in divisions per μA, is

(1) $\frac{1}{2}$ (2) 1 (3) 5 (4) 10

Sol. Answer (1)

Equivalent resistance of circuit $\simeq$ 20 kΩ

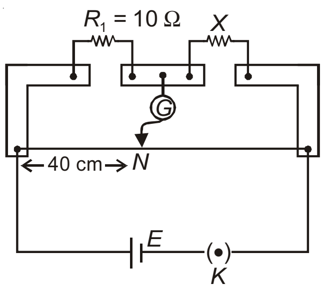


$\therefore \quad i = \dfrac{2\text{ V}}{20000\ \Omega} = 10^{-4}$ A

$\therefore$ Current sensitivity $= \dfrac{50 \text{ divisions}}{100\ \mu\text{A}} = \dfrac{1}{2}$ divisions/μA

[Meter Bridge, Potentiometer]

6. In the meterbridge experiment, the null point is obtained at N. The value of unknown resistance X will be



(1) 60 Ω (2) 40 Ω (3) 6 Ω (4) 15 Ω

Sol. Answer (4)

$$\frac{10}{40}=\frac{x}{60} \Rightarrow x = 3 \times 5\ \Omega = 15\ \Omega$$

7. In a potentiometer experiment, the balancing length for a cell was found to be 1.20 m. Now, a resistance of 10 Ω is connected across the terminals of this cell and the balancing length becomes 80 cm. The internal resistance of this cell is

(1) 2 Ω (2) 5 Ω (3) 1.5 Ω (4) 15 Ω

Sol. Answer (2)

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

$$\frac{\varepsilon}{1.2}=\frac{\varepsilon-ir}{0.8}$$

On solving r = 5 Ω.

8. Two cells when connected in series are balanced on 6 m on a potentiometer. If the polarity of one of these cell is reversed, they balance on 2 m. The ratio of e.m.f. of the two cells is

(1) 3 : 1 (2) 2 : 3 (3) 4 : 3 (4) 2 : 1

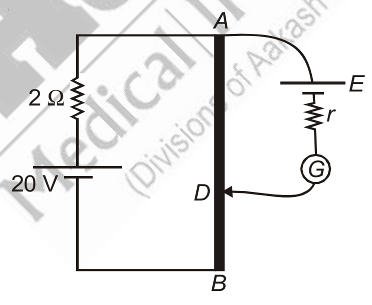
Sol. Answer (4)

$$\frac{\varepsilon_1+\varepsilon_2}{6}=\frac{\varepsilon_1-\varepsilon_2}{2}$$

$$\frac{\varepsilon_1}{\varepsilon_2}+1=3\frac{\varepsilon_1}{\varepsilon_2}-3$$

$$\frac{\varepsilon_1}{\varepsilon_2}=\frac{2}{1}$$

9. In the potentiometer circuit shown, the galvanometer shows no deflection for AD = 35 cm. The resistance of wire AB is 18 Ω and its length is 50 cm. Calculate the emf E of the cell.



(1) 10 V (2) 14 V (3) 12.6 V (4) 12 V

Sol. Answer (3)

Current through the wire AB,

$$i=\frac{20\ \text{V}}{(18+2)\ \Omega}=1\text{A}$$

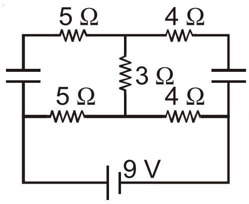
$$\frac{R_{AD}}{R_{AB}}=\frac{35}{50}$$

$\Rightarrow \quad R_{AD} = \frac{7}{10} \times 18$

$\therefore \quad E = i.R_{AD} = \frac{7 \times 18}{10} \times 1 \;=\; 12.6 \text{ V}$

[RC Circuit]

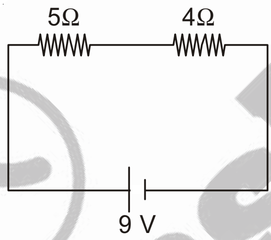
10. The power consumption by the circuit shown in figure at steady state is



(1) 18 W (2) 4.5 W (3) 36 W (4) 9 W

Sol. Answer (4)

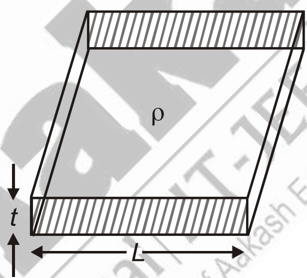
At steady state, capacitor behaves as open circuit.



$P = \frac{V^2}{R} = \frac{9^2}{9} = 9\text{W}$

(Previous Year Questions)

11. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is



(1) Directly proportional to L (2) Directly proportional to t

(3) Independent of L (4) Independent of t

Sol. Answer (3)

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

$= \rho \frac{L}{tL}$

$= \frac{\rho}{t} \qquad \Rightarrow$ Resistance is independent of L.

12. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with the increase in temperature. If at room temperature, 100 W, 60 W and 40 W bulbs have filament resistance R_{100}, R_{60} and R_{40}, respectively, the relation between these resistance is

(1) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ (2) $R_{100} = R_{40} + R_{60}$ (3) $R_{100} > R_{50} > R_{40}$ (4) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

Sol. Answer (4)

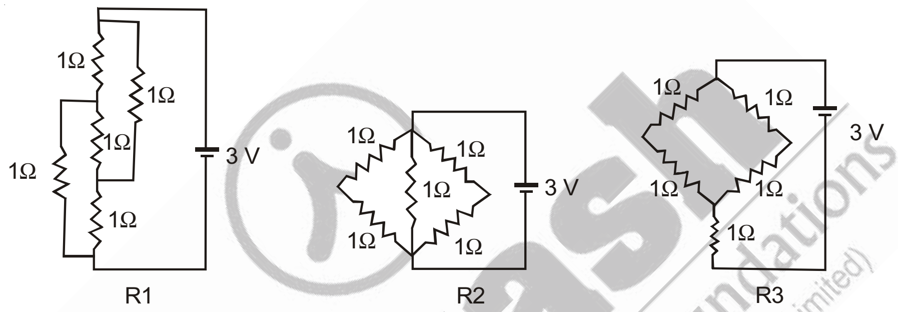
$$P = \frac{V^2}{R}$$

$$\Rightarrow \frac{1}{R} \propto P$$

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

Normally $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ could have been correct. But small change in resistance due to temperature change can destroy the equality.

13. Figure shows three resistor configurations R1, R2 and R3 connected to 3 V battery. If the power dissipated by the configuration R1, R2 and R3 is P1, P2 and P3, respectively, then



(1) P1 > P2 > P3 (2) P1 > P3 > P2 (3) P2 > P1 > P3 (4) P3 > P2 > P1

Sol. Answer (3)

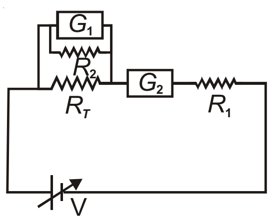
$R_1 = 1\ \Omega$ (Balanced Wheatstone bridge)

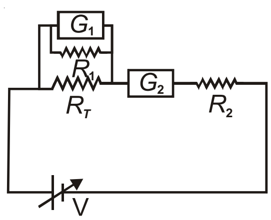
$R_2 = 0.5\ \Omega$

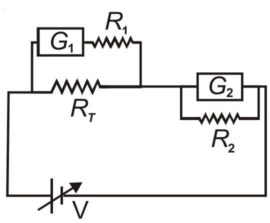
$R_3 = 2\ \Omega$

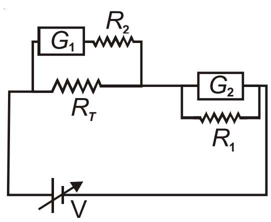
As $P = \frac{V^2}{R} \Rightarrow P \propto \frac{1}{R}$

14. To verify Ohm's law, a student is provided with a test resistor R_T, a high resistance R_1, a small resistance R_2, two identical galvanometers G_1 and G_2, and a variable voltage source V. The correct circuit to carry out the experiment is

(1)


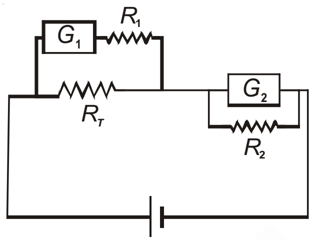
(2)


(3)


(4)


Sol. Answer (3)

G_1 is used as voltmeter by connecting it in series with high resistance and applying it across R_T in parallel G_2 is used as ammeter by shunting it with small resistance and connecting in series with R_T.



15. A resistance of 2 Ω is connected across one gap of a meter-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2 Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is

(1) 3 Ω (2) 4 Ω (3) 5 Ω (4) 6 Ω

Sol. Answer (1)

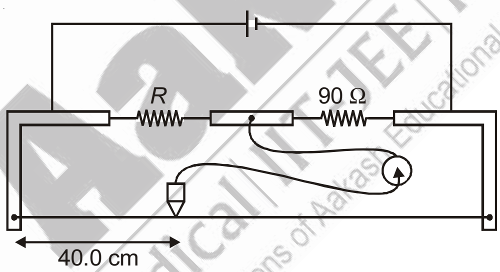
In first situation, the balancing length is at a distance '*x*' from left end and 100 – *x* from other end. In second case, balancing length is at a distance 100 – *x* from left end. ∴ shift is (100 – x) – *x* = 20 cm

x = 40 cm, 100 – x = 60 cm

$\frac{R}{2} = \frac{60}{40}$ (by Wheatstone bridge principle)

or $R = 3\ \Omega$

16. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the metre bridge is 1 mm. The unknown resistance is



(1) 60 ± 0.15 Ω (2) 135 ± 0.56 Ω

(3) 60 ± 0.25 Ω (4) 135 ± 0.23 Ω

Sol. Answer (3)

$\frac{R_1}{x} = \frac{R_2}{(100-x)}$ (Balanced Wheatstone)

For R,

$$\frac{R}{40} = \frac{90}{60} \Rightarrow R = \frac{90 \times 40}{60}$$

$$\frac{R}{90} = \frac{x}{100-x}$$

For ΔR,

$$\ln R = \ln x - \ln(100-x)$$

$$\frac{\Delta R}{R} = \frac{\Delta x}{x} - \frac{\Delta(100 - x)}{(100 - x)}$$

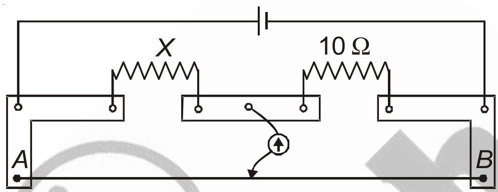
$$\frac{\Delta R}{R} = \frac{\Delta x}{x} + \frac{\Delta x}{(100 - x)}$$

$$\Delta R = \left(\frac{0.1}{40} + \frac{0.1}{60}\right) 60$$

$\Delta R = 0.25\ \Omega$

$\Rightarrow$ $R = 60 \pm 0.25\ \Omega$

17. A meter bridge is set-up as shown, to determine an unknown resistance X using a standard 10 ohm resistor. The galvanometer shows null point when tapping key is at 52 cm mark. The end corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of X is



(1) 10.2 ohm (2) 10.6 ohm

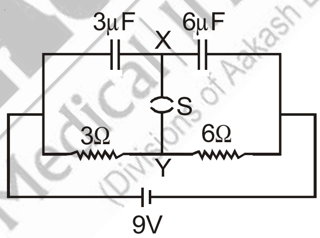
(3) 10.8 ohm (4) 11.1 ohm

Sol. Answer (2)

$$\frac{X}{53} = \frac{10}{50}$$

$\Rightarrow$ $X = 10.6\ \Omega$

18. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is

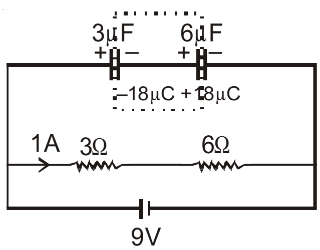


(1) 0 (2) 54 μC

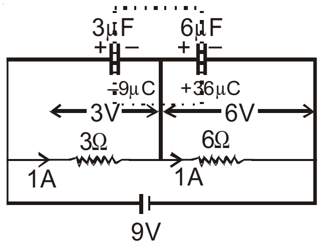
(3) 27 μC (4) 81 μC

Sol. Answer (3)

The circuit before closing switch is shown



The circuit after closing the switch is shown

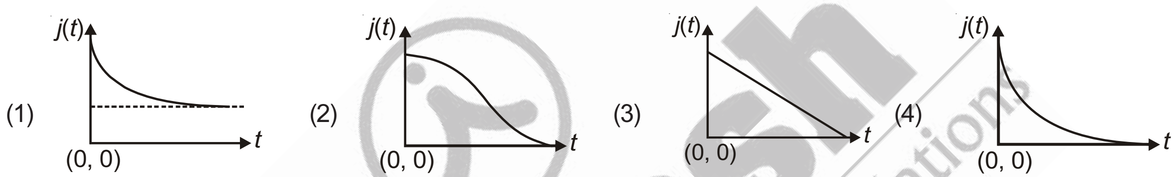


Initially, the charge in dotted region is zero

Finally, the charge in dotted region is +27 μC (=36 – 9)

$\therefore$ 27μC charge flows from *Y* to *X*.

19. An infinite line charge of uniform electric charge density λ lies along the axis of an electrically conducting infinite cylindrical shell of radius *R*. At time $t = 0$, the space inside the cylinder is filled with a material of permittivity ε and electrical conductivity σ. The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density $j(t)$ at any point in the material?



Sol. Answer (4)

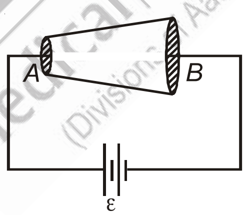
It is an RC discharging circuit.

SECTION - B

Objective Type Questions (More than one options are correct)

[Electric Current in Conductors]

1. Figure shows a conical conducting wire connected to a source of emf. Let E, v_d, i represent the electric field, drift velocity and current at a cross-section of the wire. As one moves from end *A* to end *B* of the wire,



(1) *E* increases (2) *E* decreases (3) v_d decreases (4) *i* remains same

Sol. Answer (2, 3, 4)

Since there is no source or sink of charge inside, so current (*i*) remains constant at each cross-section.

Current density, $j = \dfrac{i}{A}$ decreases as one moves from *A* to *B*.

$\because \; v_d = \dfrac{j}{ne}$; $\quad \therefore \; v_d$ also decreases

$j = \sigma E$

$\therefore$ *E* also decreases.

2. There are two concentric metallic spherical shells of radii a and b ($a < b$). The shells are being maintained at a constant potential difference V. The medium between the shells is filled with a material of resistivity ρ. Select the correct alternatives. At a distance r ($a < r < b$) from the centre of the shells

(1) Electric field is $\dfrac{Vab}{r^2(b-a)}$

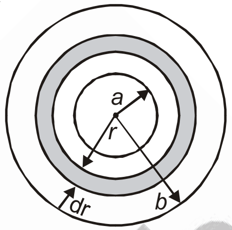
(2) Current density is $\dfrac{Vab}{\rho r^2(b-a)}$

(3) Electric field is $\dfrac{V}{(b-a)}$

(4) Current density is $\dfrac{V}{\rho(b-a)}$

Sol. Answer (1, 2)

Resistance of element, $dR = \rho.\dfrac{dr}{4\pi r^2}$



Integrating,

$$R = \frac{\rho}{4\pi}\int_a^b \frac{dr}{r^2} = \frac{\rho}{4\pi}\left[\frac{1}{a}-\frac{1}{b}\right] = \frac{\rho(b-a)}{4\pi\ ab}$$

$$\therefore \quad i = \frac{V}{R} = \frac{4\pi V\,ab}{\rho(b-a)}$$

$$\therefore \quad j = \frac{i}{A} = \frac{4\pi Vab}{\rho(b-a)}\cdot\frac{1}{4\pi r^2} = \frac{Vab}{\rho r^2(b-a)}$$

$$\because \quad \rho j = E$$

$$\therefore \quad E = \frac{Vab}{r^2(b-a)}$$

3. A long conductor of circular cross-section of area S is made of material whose resistivity depends on radial distance from axis as $\rho = \dfrac{\alpha}{r^2}$ where α is a positive constant. The conductor carries current I.

(1) The field intensity E will be same at all points of the cross section of given conductor

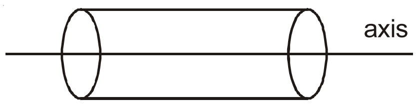
(2) E would be $\dfrac{2\pi\alpha I}{S^2}$

(3) The resistance of a unit length of conductor would be $\dfrac{2\pi\alpha}{S^2}$

(4) None of these

Sol. Answer (1, 2, 3)

$$I = \int jdS = \int_0^R \frac{E}{\rho}.2\pi r dr = E\int_0^R \frac{2\pi r^3}{\alpha}dr$$



$$I = E\frac{2\pi}{\alpha}.\frac{R^4}{4}$$

$$I = \frac{\pi E}{2\alpha}\cdot R^4$$

$$\pi R^2 = S$$

$$R^2 = \frac{S}{\pi}$$

$$I = \frac{\pi E}{2\alpha}\times\frac{S^2}{\pi^2}$$

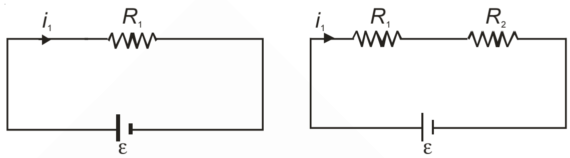
$$\boxed{E = \frac{2\pi\alpha I}{S^2}}$$

$$R_U = \frac{E}{I} = \frac{2\pi\alpha}{S^2}$$

4. A resistance R_1 is connected to a source of constant voltage. On connecting a resistance R_2 in series with R_1

(1) The total thermal power dissipated increases
(2) Thermal power dissipated by R_1 decreases
(3) Thermal power dissipated by R_1 increases
(4) Total power dissipated decreases

Sol. Answer (2, 4)



$$i_1 = \frac{\varepsilon}{R_1}$$

$$i_2 = \frac{\varepsilon}{R_1 + R_2}$$

$\Rightarrow$ $i_2 < i_1$

Thermal power generated in $R_1 = i^2 R_1$

$\therefore$ $i_1^2 R_1 > i_2^2 R_1$

$\Rightarrow$ Thermal power generated in R_1 decreases.

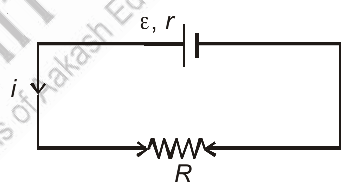
Total thermal power generated in two cases,

$$\frac{\varepsilon^2}{R_1} > \frac{\varepsilon^2}{R_1 + R_2} \quad \Rightarrow \text{decreases.}$$

5. A cell supplies a current of 2 A to an external resistance of 2 Ω and a current of 1 ampere to another external resistance of 4.5 Ω connected across the cell separately. Select the correct alternative(s).

(1) Emf of the cell is 5 V
(2) Emf of the cell is 4.25 V
(3) Internal resistance of the cell is 0.5 Ω
(4) Internal resistance of the cell is 3.25 Ω

Sol. Answer (1, 3)



$$i = \frac{\varepsilon}{R + r}$$

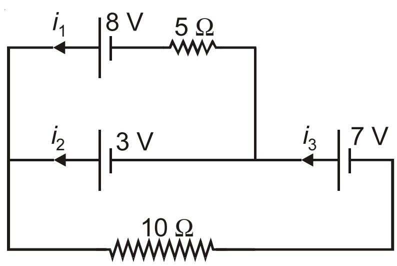
$$\Rightarrow \quad 2 = \frac{\varepsilon}{2 + r} \qquad \ldots(1)$$

$$\text{and } 1 = \frac{\varepsilon}{4.5 + r} \qquad \ldots(2)$$

Solving (1) and (2) , we get

ε = 5 V, r = 0.5 Ω.

6. Consider the circuit shown. Which of the following values is/are correct?



(1) i_3 = 1 A
(2) i_1 = 1 A
(3) i_2 = 0
(4) i_3 = 2 A

Sol. Answer (1, 2, 3)

Kirchhoff's loop theorem implies,

$+7 + 3 - 10\,i_3 = 0$

$\Rightarrow\ i_3 = 1\text{A}$

$-10\,i_3 + 7 - 5i_1 + 8 = 0$

$\Rightarrow\ 5i_1 = 5$

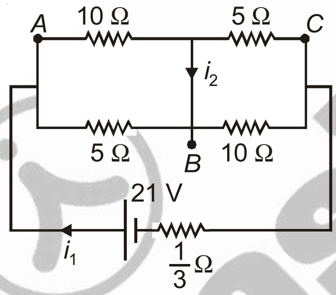
$\Rightarrow\ i_1 = 1\text{A}.$

From Kirchhoff's Junction Rule,

$i_3 = i_1 + i_2$

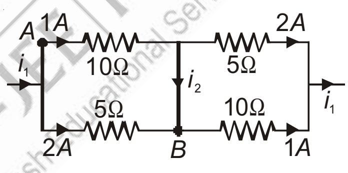
$\Rightarrow\ i_2 = 0$

7. Consider the following arrangement of resistors. The currents in various branches are shown. Select the correct alternative(s).



(1) $i_1 = 3$ A (2) $i_1 = \frac{63}{47}$ A (3) $i_2 = -1$ A (4) $V_A - V_B = 10$ V

Sol. Answer (1, 3, 4)



Equivalent resistance of circuit = $\frac{10\times5}{10+5}\times2+\frac{1}{3}=7\,\Omega$

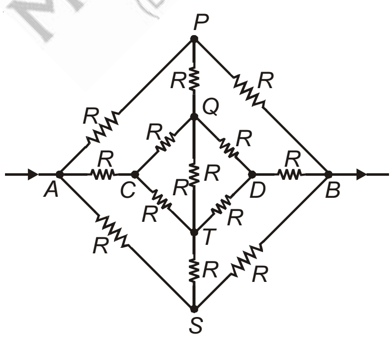
$\therefore\ i_1=\frac{21}{7}=3\text{ A}$

Current distribution is shown in the diagram.

$\therefore\ i_2 = 1 - 2 = -1$ A

$V_A - V_B = 1\text{ A} \times 10\ \Omega = 10$ V

8. A current enters from *A* and leaves at *B* through the network shown. Select the correct alternative(s).



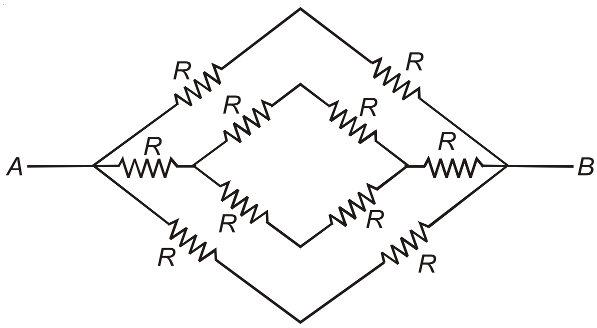
(1) $R_{AB}=\frac{3R}{4}$ (2) $R_{AB}=\frac{5R}{6}$

(3) Points *P*, *Q*, *T* and *S* are at same potential (4) Points *C* and *D* are at same potential

Sol. Answer (1, 3)

From symmetry, points P, Q, T and S are at same potentials.

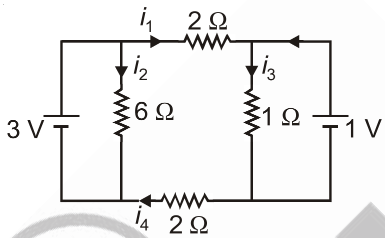
$\therefore$ Equivalent circuit is



This is a series and parallel combination of resistors.

$\therefore \quad R_{AB} = \dfrac{3R}{4}$

9. In the circuit shown, current in different branches are marked. Select the correct alternative(s).



(1) $i_1 = \dfrac{1}{2}$ A (2) $i_4 = \dfrac{1}{2}$ A

(3) $i_2 = \dfrac{1}{2}$ A (4) $i_3 = 1$ A

Sol. Answer (1, 2, 3, 4)

$i_3 \times 1 = 1 \Rightarrow i_3 = 1$ A

$i_2 \times 6 = 3 \Rightarrow i_2 = \dfrac{1}{2}$ A

$+3 - 2 \times i_1 - 1 \times i_3 - 2 \times i_4 = 0$

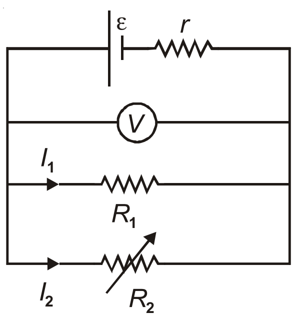
$\Rightarrow 2i_1 + 2i_4 = 2$

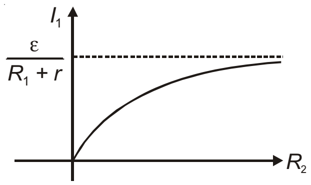
$\Rightarrow i_1 + i_4 = 1$ …(1)

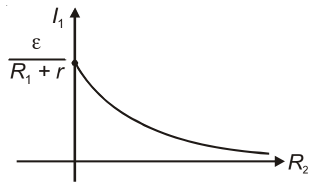
Also, $i_1 = i_4$ … (2)

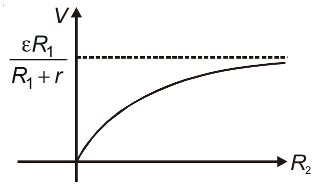
$\therefore \quad i_1 = i_4 = \dfrac{1}{2}$ A.

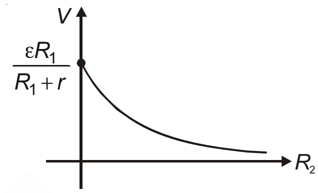
10. In the circuit shown, R_2 is varied from zero to infinity, keeping other values constant. Which of the following graphs is/are correct?



(1) 

(2) 

(3) 

(4) 

Sol. Answer (1, 3)

At $R_2 = 0$

No current passes through R_1, all current passes through R_2.

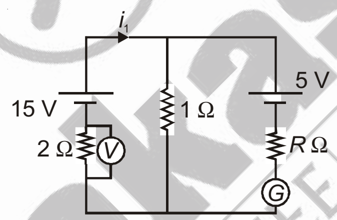
$\Rightarrow$ $V = i_2 R_2 = 0$

At $R_2 = \infty$, all current passes through R_1 and $I_1 = \dfrac{\varepsilon}{R_1 + r}$

$\Rightarrow$ $V = I_1 R_1 = \dfrac{\varepsilon R_1}{R_1 + r}$

Therefore, graphs are as shown in options (1) and (3).

11. In the circuit shown, reading of galvanometer is zero. Select the correct alternative(s).



(1) Reading of ideal voltmeter is 10 V
(2) i_1 = 5 A
(3) R must be zero
(4) R can have any value

Sol. Answer (1, 2, 4)

$i_1 = \dfrac{15}{2+1} = 5$ A (Since no current flows through galvanometer)

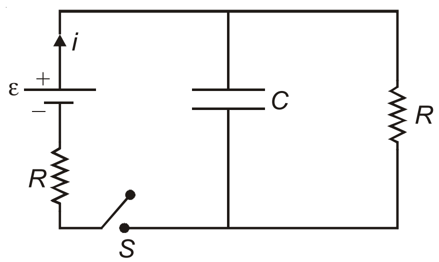
Voltmeter reading = i_1 × 2 = 5 × 2 = 10 V

Potential drop across 1 Ω resistor = 1 × 5 = 5 V

This is equal to emf of second cell. Hence no current passes through galvanometer irrespective of the value of R.

[RC Circuit]

12. In the circuit shown, the switch is closed at t = 0. Select the correct alternatives.



(1) At t = 0, i = $\frac{\varepsilon}{R}$

(2) At t = 0, i = $\frac{\varepsilon}{2R}$

(3) At steady state, charge on the capacitor is $\frac{\varepsilon C}{2}$

(4) The current at any instant is given by $i = \frac{\varepsilon}{2R}(1 + e^{-2t/RC})$

Sol. Answer (1, 3, 4)

At t = 0, all current passes through capacitor (Since capacitor acts as short circuit)

$\therefore \quad i = \frac{\varepsilon}{R}$

In steady state, no current passes through capacitor, (it behaves as open circuit)

$\therefore \quad i = \frac{\varepsilon}{2R} = i_0$

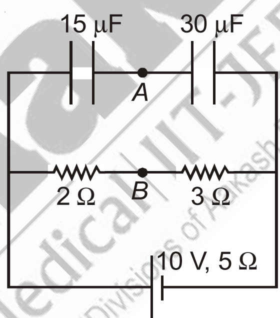
At steady state, voltage across capacitor = $iR = \frac{\varepsilon}{2}$

$\therefore$ Charge on capacitor = $\frac{\varepsilon}{2}C$

Time constant of circuit = $\frac{RC}{2}$

$\therefore$ Instantaneous current = $i_0 e^{-\frac{2t}{RC}} = \frac{\varepsilon}{R} e^{\frac{-2t}{RC}}$

13. The figure shows two capacitors connected in parallel with two resistance and a battery of emf 10 V, internal resistance 5 Ω. At steady state,



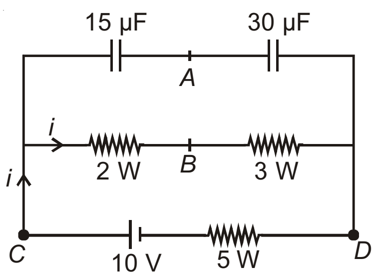
(1) $V_A - V_B = -\frac{4}{3}$ V

(2) $V_A - V_B = +\frac{4}{3}$ V

(3) Energy stored in 15 μF capacitor is $\frac{15}{18} \times 10^{-4}$ J

(4) Energy stored in 30 μF capacitor is $\frac{75}{18} \times 10^{-5}$ J

Sol. Answer (1, 3, 4)



In steady state, $i = \frac{10\text{ V}}{(2+3+5)\ \Omega} = 1$ A

V_1 = P.D. across 2 Ω resistor = 1 × 2 = 2 V

V_2 = P.D. across 15 μF capacitor = $\frac{30}{15+30} \times 5 = \frac{2}{3} \times 5 = \frac{10}{3}$ V

$\therefore \quad V_A - V_B = V_1 - V_2 = 2 - \frac{10}{3} = -\frac{4}{3}$ V

Energy stored in 15 μF capacitor = $\frac{1}{2}CV^2 = \frac{1}{2}\times 15\times\left(\frac{10}{3}\right)^2\times 10^{-6} = \frac{15}{18}\times 10^{-4}$ J

Energy stored in 30 μF capacitor = $\frac{1}{2}\times 30\times 10^{-6}\times\left(5-\frac{10}{3}\right)^2 = \frac{1}{2}\times 30\times 10^{-6}\times\frac{25}{9} = \frac{75}{18}\times 10^{-5}$ J

14. Two identical metallic balls of radius a are placed in a homogeneous poorly conducting medium with resistivity ρ. Distance between them is much larger than their size. If initially (t = 0) they have charge q_0 and $-q_0$ respectively. Choose the correct option among the followings :

(1) The resistance of medium between balls under above consideration would be $\frac{\rho}{2\pi a}$

(2) $q(t) = q_0 e^{-\frac{\rho\varepsilon_0}{t}}$ where q is charge on the charged ball

(3) $q(t) = q_0 e^{-\frac{t}{\rho\varepsilon_0}}$ where q is charge on positive charged ball

(4) None of these

Sol. Answer (1, 3)

At time t, charges on balls are $+q$, $-q$. since the balls are at large distance from one another, electric field near the surface of each ball is practically determined by the charge of nearest sphere and its charge can be distributed uniformly on the surface. Surrounding the positively charged ball by a concentric sphere adjoining directly the balls surface, we write the expression for current through this sphere.

$I = 4\pi a^2 J$

where J = current density

$J = \frac{E}{\rho}$ and $E = \frac{q}{4\pi\varepsilon_0 a^2}$

$I = \frac{q}{\varepsilon_0\rho}$

Let us now find the P.D. between balls

$\Delta V \approx \frac{2q}{4\pi\varepsilon_0 a}$

$C = \frac{q}{\Delta V} = \frac{q.4\pi\varepsilon_0 a}{2q} = 2\pi\varepsilon_0 a$

$R = \frac{\Delta V}{I} = \frac{\rho}{2\pi a}$

$T = RC = 2\pi\varepsilon_0 a\times\frac{\rho}{2\pi a} = \rho\varepsilon_0$

$q(t) = q_0 e^{-\frac{t}{\rho\varepsilon_0}}$

$\tau = RC = 2\pi\varepsilon_0 a\times\frac{\rho}{2\pi a} = \rho\varepsilon_0$

$q(t) = q_0 e^{-\frac{t}{\rho\varepsilon_0}}$

15. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K?

(1) 4 if wires are in parallel
(2) 2 if wires are in series
(3) 1 if wires are in series
(4) 0.5 if wires are in parallel

Sol. Answer (2, 4)

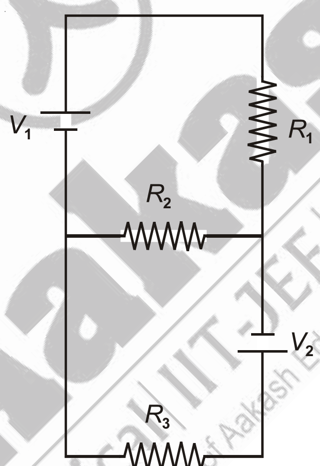
$$t = \frac{H}{P} = \frac{HR}{V^2}$$

$\Rightarrow \quad t \propto R.$ $\qquad R = \rho l / A, R' = \dfrac{\rho l}{4A}$ (as $d' = 2d$)

When wires are in series, $R_1 = R' + R' = 2R' = \dfrac{R}{2} \Rightarrow t' = \dfrac{t}{2} = 2\text{ min}$

When wires are in parallel, $R_2 = \dfrac{R'}{2} = \dfrac{R}{8} \Rightarrow t' = \dfrac{t}{8} = 0.5\text{ min}$

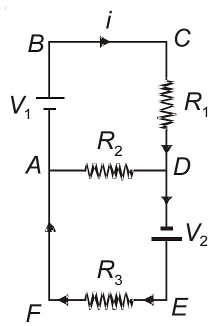
16. Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if



(1) $V_1 = V_2$ and $R_1 = R_2 = R_3$
(2) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
(3) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$
(4) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

Sol. Answer (1, 2, 4)

Using KVL, in *ABCDEFA,* we get



$$-iR_1 + V_2 - iR_3 + V_1 = 0 \Rightarrow \quad i = \frac{V_1 + V_2}{R_1 + R_3}$$

Using KVL in *ABCDA,* $0 + V_1 - iR_1 = 0 \Rightarrow i = \dfrac{V_1}{R_1}$

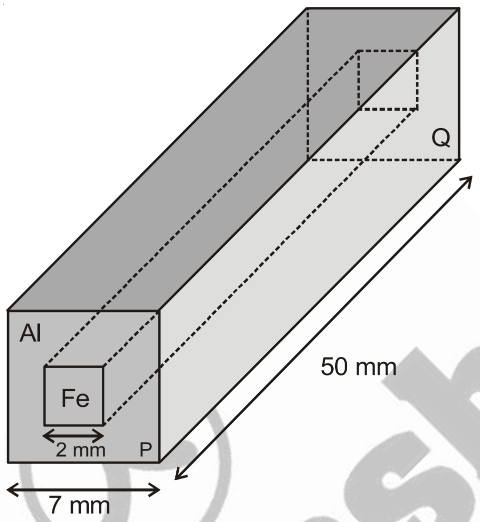
$$\Rightarrow \quad \frac{V_1}{R_1} = \frac{V_1 + V_2}{R_1 + R_3}$$

$$\Rightarrow \quad V_1R_1 + V_1R_3 = V_1R_1 + V_2R_1$$

$\Rightarrow \dfrac{V_1}{R_1} = \dfrac{V_2}{V_3}$

Now possible answers are (1), (2), (4).

17. In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are $2.7 \times 10^{-8}\ \Omega$ m and $1.0 \times 10^{-7}\ \Omega$ m, respectively. The electrical resistance between the two faces P and Q of the composite bar is



(1) $\dfrac{2475}{64}\ \mu\Omega$ (2) $\dfrac{1875}{64}\ \mu\Omega$ (3) $\dfrac{1875}{49}\ \mu\Omega$ (4) $\dfrac{2475}{132}\ \mu\Omega$

Sol. Answer (2)

$R_{Al} = \dfrac{2.7\times10^{-8}\times50\times10^{-3}}{45\times10^{-6}} = \dfrac{2.7\times50}{45}\times10^{-5} = \dfrac{27\times50}{45}\times10^{-6} = 30 \times 10^{-6}\Omega = 30\ \mu\Omega$

$R_{Fe} = \dfrac{10^{-7}\times50\times10^{-3}}{4\times10^{-6}} = \dfrac{5000}{4}\times10^{-6} = 1250\ \mu\Omega \quad R = \dfrac{R_1R_2}{R_1+R_2} = \dfrac{1250\times30}{1280}\ \mu\Omega = \dfrac{1875}{64}\ \mu\Omega$

18. Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_C < R/2$, which of the following statement(s) about any one of the galvanometers is(are) true?

(1) The maximum voltage range is obtained when all the components are connected in series

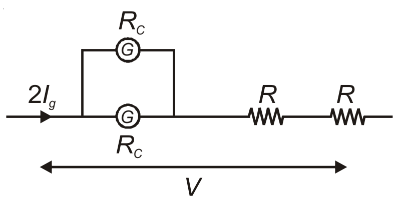
(2) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer

(3) The maximum current range is obtained when all the components are connected in parallel

(4) The maximum current range is obtained when the two galvanometers are connected in series and the combination is connected in parallel with both the resistors

Sol. Answer (2, 3)

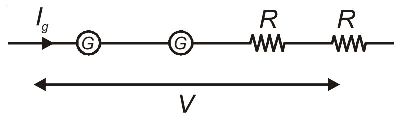
Range for voltmeter



(1) $V_1 = 2I_g\left(2R + \dfrac{R_c}{2}\right)$

(2) $V_2 = I_g(2R + 2R_c) = 2I_g(R + R_c)$

Now, $V_1 - V_2 = 2I_g\left(2R + \frac{R_c}{2} - R - R_c\right)$



$\Rightarrow V_1 - V_2 = 2I_g\left(R - \frac{R_c}{2}\right) > 0 \quad \Rightarrow V_1 > V_2$

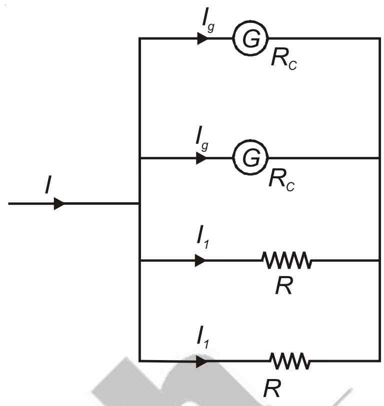
Hence maximum range will be obtained in Case-1

Range for ammeter

(1) $I_g R_c = I_1 R$

$I = 2(I_g + I_1)$

$\Rightarrow I = 2\left(I_g + I_g\frac{R_c}{R}\right)$

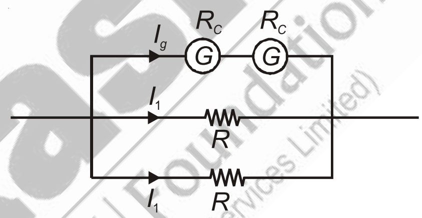


$\Rightarrow I = 2I_g\left(\frac{R + R_c}{R}\right)$

(2) $I_g(2R_c) = I_1 R$

Range $I = 2I_1 + I_g$

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



$\Rightarrow I = I_g\left(\frac{R + 4R_c}{R}\right)$

Now, $2I_g\left(1 + \frac{R_c}{R}\right) - I_g\left(1 + \frac{4R_c}{R}\right) = I_g\left[1 - \frac{2R_c}{R}\right] > 0$

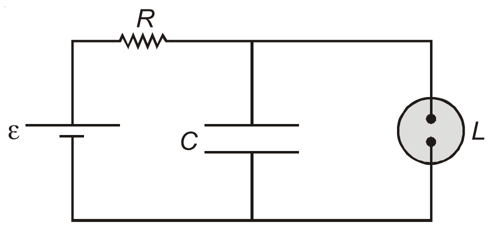
As $R_C < \frac{R}{2}$

SECTION - C

Linked Comprehension Type Questions

Comprehension-I

Figure shows the circuit of a flashing lamp, used at construction sites. The fluorescent lamp L, having negligible capacitance, is connected in parallel across the capacitor C of an RC circuit. There is a current through the lamp only when the potential difference across it reaches the breakdown voltage V_L. In this event, the capacitor discharges completely through the lamp and lamp flashes momentarily.



1. Consider an instant, when the capacitor has just discharged through the flash light. Taking this instant as $t = 0$, the time after which the lamp flashes momentarily is given by

(1) $T_0 = RC\ln\left(\dfrac{\varepsilon}{\varepsilon - V_L}\right)$ (2) $T_0 = RC\left[1 - \ln\left(\dfrac{\varepsilon}{V_L}\right)\right]$

(3) $T_0 = RC\ln\left(\dfrac{\varepsilon}{V_L}\right)$ (4) $T_0 = RC\ln\left(\dfrac{\varepsilon - V_L}{\varepsilon}\right)$

Sol. Answer (1)

The lamp flashes briefly when potential drop across the lamp becomes equal to breakdown voltage V_L, then,

$$V_L = \varepsilon\left(1 - e^{\frac{-t}{RC}}\right)$$

$$\Rightarrow \quad e^{\frac{-t}{RC}} = 1 - \frac{V_L}{\varepsilon} \quad \Rightarrow \quad -\frac{t}{RC} = \ln\left(1 - \frac{V_L}{\varepsilon}\right) \quad \Rightarrow \quad t = RC\ln\frac{\varepsilon}{\varepsilon - V_L}$$

2. The number of flashes per second produced by the arrangement is (neglecting the time of flashing or discharging of capacitor)

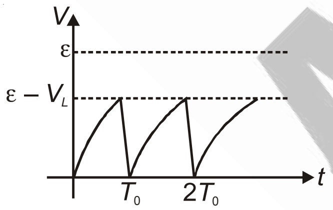
(1) $\dfrac{1}{RC\ln\left(\dfrac{\varepsilon}{\varepsilon - V_L}\right)}$ (2) $\dfrac{1}{RC\ln\left(\dfrac{\varepsilon}{V_L}\right)}$ (3) $\dfrac{1}{RC\ln\left(\dfrac{\varepsilon - V_L}{\varepsilon}\right)}$ (4) $\dfrac{1}{RC\left[1 - \ln\left(\dfrac{\varepsilon}{V_L}\right)\right]}$

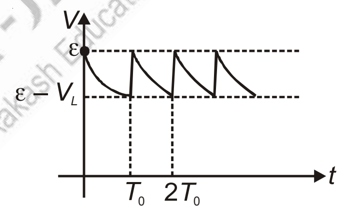
Sol. Answer (1)

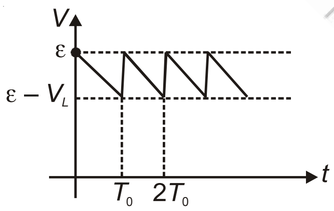
Time taken for one flash, $t = RC\ln\dfrac{\varepsilon}{\varepsilon - V_L}$

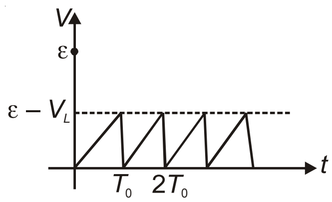
$\therefore$ No. of flashes per second = $\dfrac{1}{t} = \dfrac{1}{RC\ln\left(\dfrac{\varepsilon}{\varepsilon - V_L}\right)}$

3. Which of the following graphs represents the variation of potential drop across the resistor?

(1)


(2)


(3)


(4)


Sol. Answer (2)

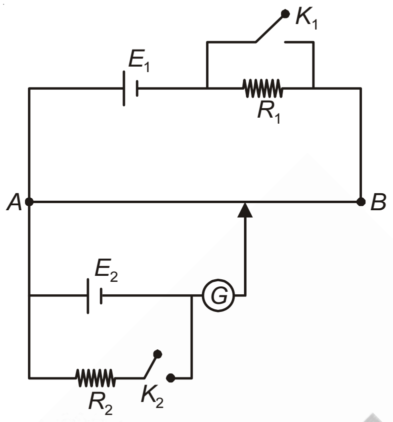
Voltage across resistor,

$$V_R = \varepsilon - V_C = \varepsilon - \varepsilon\left(1 - e^{\frac{-t}{RC}}\right) = \varepsilon\, e^{\frac{-t}{RC}}$$

and minimum value of V_R is = $\varepsilon - V_L$

Comprehension-II

Figure shows the circuit of a potentiometer. The length of the potentiometer wire *AB* is 50 cm. The emf of the battery E_1 is 4 volt, having negligible internal resistance. Values of resistances R_1 and R_2 are 15 ohm and 5 ohm respectively. When both the keys are open, the null point is obtained at a distance of 31.25 cm from end *A* but when both the keys are closed, the balance length reduces to 5 cm only. R_{AB} = 10 Ω.



1. The emf of the cell E_2 is

(1) 1 volt (2) 2 volt (3) 3 volt (4) 4 volt

Sol. Answer (1)

$$\text{Potential gradient} = \frac{V_{AB}}{L} = \frac{I \times R}{L} = \frac{4}{(15+10)} \times \frac{10}{50} = \frac{40}{25 \times 50}\,\frac{\text{volt}}{\text{cm}}$$

$$\Rightarrow E_2 = Kl = \frac{40}{25 \times 50} \times 31.25 = 1\,\text{volt}$$

2. The internal resistance of cell E_2 is

(1) 4.5 Ω (2) 5.5 Ω (3) 6.5 Ω (4) 7.5 Ω

Sol. Answer (4)

When both keys are closed then R_1 is short circuited to

$$\frac{E_2}{R_2 + r} \times R_2 = Kl = \frac{4 \times 10}{10 \times 50} \times 5 \quad \Rightarrow \frac{5 \times 1}{5 + r} = \frac{4}{50} \times 5 \Rightarrow r = 7.5\,\Omega$$

3. The balance length when key K_2 is open and K_1 is closed is given by

(1) 10.5 cm (2) 11.5 cm (3) 12.5 cm (4) 13.5 cm

Sol. Answer (3)

When K_2 is open and K_1 is closed. In this case R_1 is short circuited and emf E_2 is balanced against potentiometer.

$$E_2 = \left[\frac{4}{10} \times \frac{10}{50}\right] \times l \Rightarrow l = \frac{10 \times 50}{4 \times 10} = 12.5\,\text{cm}$$

4. The balance length when key K_1 is open and K_2 is closed, is given by

(1) 10.5 cm (2) 11.5 cm (3) 12.5 cm (4) 13.5 cm

Sol. Answer (3)

When K_1 is open and K_2 is closed. In this case R_1 is included in the potentiometer, circuit and terminal potential difference of E_2 is balanced by the potentiometer.

$$\frac{E_2 R_2}{R_2 + r} = \frac{4}{25} \times \frac{10}{50} \times l$$

$$\frac{1 \times 5}{5 + 7.5} = \frac{4}{125} \times l$$

l = 12.5 cm

5. Which of the following can be a possible way to connect the batteries in the potentiometer setup above?

(1) Positive terminal of E_1 and positive terminal of E_2 connected to point A

(2) Negative terminal of E_1 and negative terminal of E_2 connected to A

(3) Positive terminal of E_1 and negative terminal of E_2 connected to A

(4) Positive terminal of E_2 and negative terminal of E_1 connected to A

Sol. Answer (1, 2)

As in potentiometer arrangement we equate potential differences thus batteries has to be joined with same polarities.

Comprehension-III

Consider a simple RC circuit as shown in Figure 1.

Process 1: In the circuit the switch S is closed at t = 0 and the capacitor is fully charged to voltage V_0 (i.e., charging continues for time $T >> RC$). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2: In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time $T >> RC$. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time $T >> RC$. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.

These two processes are depicted in Figure 2.

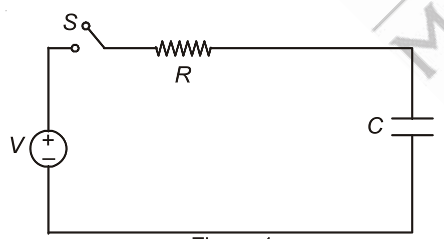


Figure 1

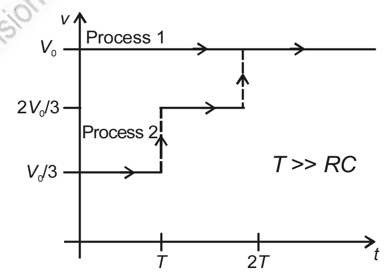


Figure 2

1. In Process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by

(1) $E_C = E_D \ln 2$

(2) $E_C = E_D$

(3) $E_C = 2E_D$

(4) $E_C = \frac{1}{2}E_D$

Sol. Answer (2)

Final charge on capacitor = CV

$W_b = CV^2$

$E_c = \frac{1}{2}CV^2$

$E_D = W_b - \Delta E_c = CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$

$\boxed{E_C = E_D}$

2. In Process 2, total energy dissipated across the resistance E_D is

(1) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

(2) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$

(3) $E_D = 3CV_0^2$

(4) $E_D = \frac{1}{2}CV_0^2$

Sol. Answer (1)

$E_D = W_b - \Delta V$

$= \frac{CV_0}{3}\left[\frac{V_0}{3} + \frac{2V_0}{3} + V_0\right] - \frac{1}{2}CV_0^2 = \frac{CV_0}{3}\left[\frac{V_0 + 2V_0 + 3V_0}{3}\right] - \frac{1}{2}CV_0^2$

$= \frac{CV_0}{3}[2V_0] - \frac{1}{2}CV_0^2$

$= \left(\frac{2}{3} - \frac{1}{2}\right)CV_0^2$

$= \frac{CV_0^2}{6}$

SECTION - D

Matrix-Match Type Questions

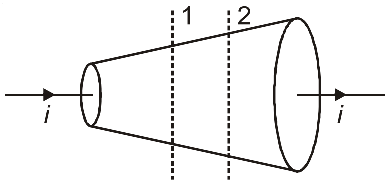
1. Column I lists physical quantities for a uniform current carrying conductor. These quantities depend on quantities given in column II. Match entries in column I to all the quantities in column II on which it depends.

Column I	Column II
(A) Resistivity	(p) Length of conductor
(B) Current through the conductor for a given potential difference across the conductor	(q) Electric field in conductor
(C) Current density in conductor for a given potential difference across the conductor	(r) Temperature of conductor
(D) Thermal power generated per unit volume for given value of potential difference across the conductor	(s) Nature of conductor
	(t) Area of conductor

Sol. Answer A(r, s), B(p, q, r, s, t), C(p, q, r, s), D(p, q, r, s)

Resistance depends upon nature, length area of cross section and temperature.

2. Current i is following through a wire of non-uniform cross-section as shown. Match the following columns.



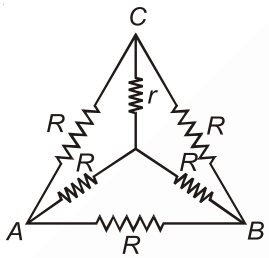
Column-I		Column-II
(A) Current density	(p)	More at section 1 than 2
(B) Electric field	(q)	More at section 2 than 1
(C) Resistance per unit length	(r)	Same at both sections 1 and 2
(D) Potential difference per unit length	(s)	Data insufficient

Sol. Answer A(p), B(p), C(p), D(p)

$$J \propto \frac{1}{A}, E \propto \frac{1}{A}, R \propto \frac{1}{A}, dV \propto \frac{1}{A}$$

3. Column I shows some electrical circuits with point A, B and C marked in the figures. Column II lists value of electrical resistance between any two of these three points. Match incomplete statements given in Column I to the entries in Column II.

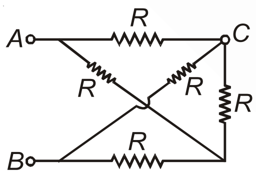
Column I **Column II**

(A) 

Equivalent resistance between

A and B cannot be (r is variable)

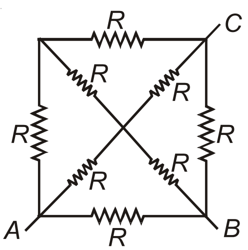
(p) R

(B) 

Equivalent resistance of circuit between

A and B cannot be

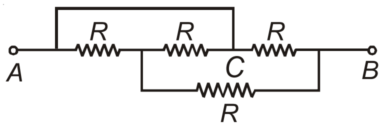
(q) $2R/3$

(C) 

Equivalent resistance of circuit between

A and B cannot be

(r) $5R/3$

(D) 

(s) $3R/5$

Equivalent resistance of circuit between

A and B cannot be

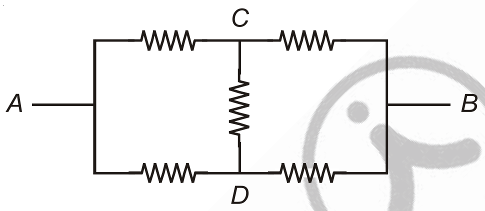
(t) $8R/15$

Sol. Answer A(p, q, r, s, t), B(q, r, s, t), C(p, q, r, s), D(p, q, r, t)

(A) No current will flow in 'r'

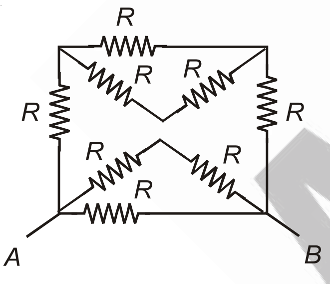
$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{2R} + \frac{1}{2R}$$

$$R_{eq} = \frac{2R}{4} = \frac{R}{2}$$

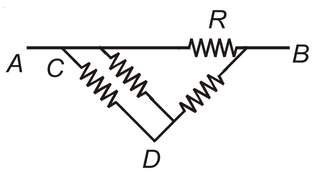
(B) 

$R_{eq} = R$ wheat stone

(C) Due to symmetry

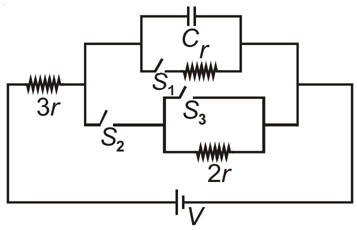


$$\frac{\frac{8R}{3} \times \frac{2R}{3}}{\frac{10R}{3}} = R_{eq} = \frac{8R}{15}$$

(D) 

$$R_{eq} = \frac{\frac{3R}{2} \times R}{\frac{5R}{2}} = \frac{3R}{5}$$

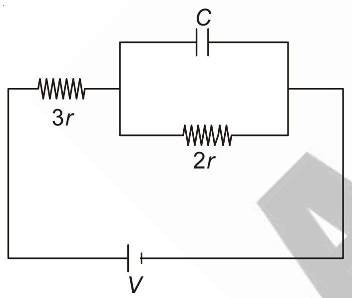
4. Consider the circuit shown in figure. There are three switches S_1, S_2, S_3. Match the columns.



Column I		Column II
(A) If S_1 and S_3 are opened and S_2 is closed then in steady state, charge on capacitor equals	(p)	$\frac{VC}{4}$
(B) If S_2 and S_3 are opened and S_1 is closed then in steady state, charge on capacitor equals	(q)	$\frac{2CV}{5}$
(C) If S_1 and S_2 are closed and S_3 is opened then in steady state charge on capacitor equals	(r)	$\frac{CV}{3}$
(D) If all the switches are closed then in steady state, charge on capacitor is	(s)	$\frac{2CV}{11}$
	(t)	Zero

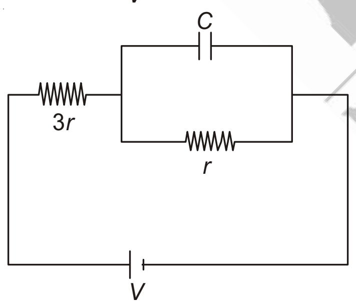
Sol. Answer A(q), B(p), C(s), D(t)

(A)



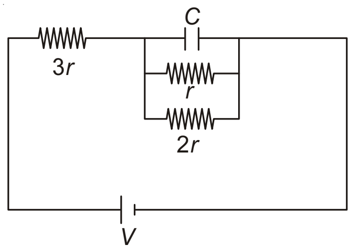
Charge on capacitor in steady state = $\frac{CV^2}{3+2}=\frac{2CV}{5}$

(B)



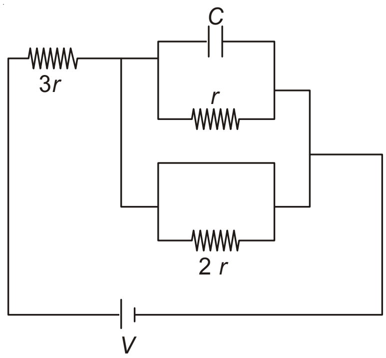
Charge on capacitor in steady state = $\frac{CV}{3+1}=\frac{CV}{4}$

(C)



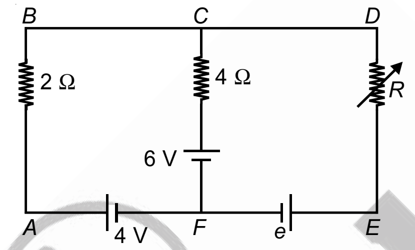
Charge on capacitor in steady state $=\frac{CV\frac{2r}{3}}{3r+\frac{2r}{3}}=\frac{2CV}{11}$

(D)



On closing all the switches capacitor will be shorted and hence charge on it will be Zero.

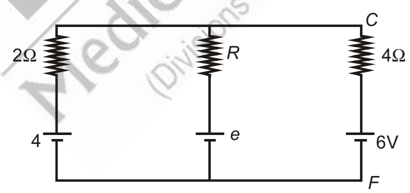
5. Consider the circuit shown 'R' is a variable resistance 'e' is some unknown emf with polarity as shown. Match the following.



Column I		Column II	
(A)	Current passing through 4 Ω resistance can be zero	(p)	Possible if $e = 6$
(B)	Current passing through 4 Ω resistance can be from F to C direction	(q)	Possible if $e > 6$
(C)	Current passing through 2 Ω resistance will be from B to A direction	(r)	Possible if $e < 6$
(D)	Current passing through resistance R will be from E to D direction	(s)	Possible for any value of e
		(t)	Possible for any value of resistance R

Sol. Answer A(p, q, t), B(p, q, r, s, t), C(p, q, r, s, t), D(p, q, r, t)

If equivalent of 4 V battery and e is greater than 6V with polarity same as 6V then current will flow from C to F. If it is less than 6V then current will flow from F to C and if it is equal to 6V then current will be zero.



SECTION - E

Assertion-Reason Type Questions

1. STATEMENT-1 : As we move across a resistor in the direction of current, current decreases.

and

STATEMENT-2 : As we move across a resistor in the direction of current, potential decreases.

Sol. Answer (4)

Current at each cross-section of resistor remains same.

2. STATEMENT-1 : When the plates of a charged capacitor are connected to a resistor, a current starts flowing in the resistor.

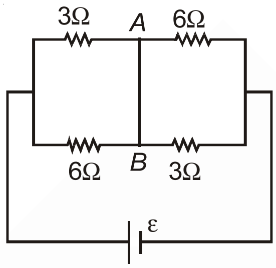
and

STATEMENT-2 : A charged capacitor acts as a battery of steady emf.

Sol. Answer (3)

As the capacitor discharges, the voltage across it decreases. So, it cannot work as a battery of steady emf.

3. Consider the circuit diagram. The connecting wires are assumed to be perfectly conducting.



STATEMENT-1 : The current in branch *AB* is zero.

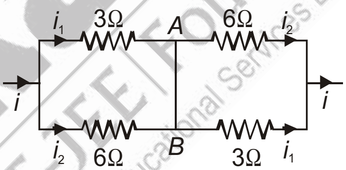
and

STATEMENT-2 : The potential difference between *A* & *B* is zero.

Sol. Answer (4)

Potential difference across *A* and *B* = 0 because they are short circuited.

Current through $AB = i_1 - i_2$



$i_1 = \frac{6}{9}i$

$i_2 = \frac{3}{9}i$

$\therefore \; i_1 - i_2 \neq 0$

4. STATEMENT-1 : As temperature of a conducting wire increases, the slope of V-I graph (V on y-axis and I on x-axis) increases.

and

STATEMENT-2 : For a conductor, the resistance increases with increase in temperature.

Sol. Answer (1)

$\because \; V = IR$

$\Rightarrow$ Slope of *V-I* curve represents *R* and *R* increases with increase in temperature for a conductor.

5. STATEMENT-1 : Fuse wire must have high resistance and low melting point.

and

STATEMENT-2 : Fuse is used for small current flow only.

Sol. Answer (3)

Fuse wire must have high resistance because in series heat produced will be high if *R* is high. The melting point must be low so that wire may melt with increase in temperature.

6. STATEMENT-1 : In a meter bridge, if its wire is replaced by another wire having same length, same material but twice the cross sectional area, then the accuracy of measurement decreases.

and

STATEMENT-2 : Accuracy of meter bridge depends on the length of wire.

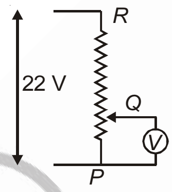
Sol. Answer (4)

Accuracy of meter bridge is independent of the area of cross-section of wire.

SECTION - F

Integer Answer Type Questions

1. A potential difference of 22 V is maintained across a 1200 Ω rheostat *PR*. The voltmeter has a resistance of 600 Ω and *PQ* is one fourth of distance from *P* to *R*. What is the reading (in V) of the voltmeter?

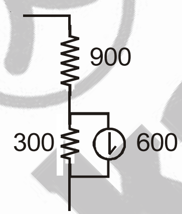


Sol. Answer (4)

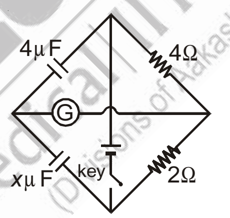
$$R = 900 + \frac{600 \times 300}{900} = 1100$$

$$i = \frac{22}{1000} = \frac{2}{100} = \frac{1}{50}$$

$$V = \frac{1}{50} \times 200 = 4\text{ V}$$



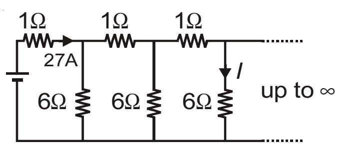
2. Consider the circuit shown with key opened. The key is closed at $t = 0$. Capacitance of one of the shown capacitors is x μF. For what value of x the galvanometer does not show any deflection?



Sol. Answer (8)

$R_1C_1 = R_2C_2$ for no deflection

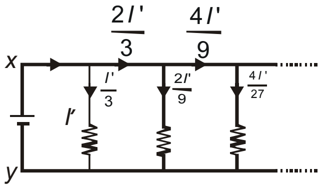
3. Consider the infinite ladder circuit shown. What is the value of current *I* (in A) shown in one of the 6 Ω resistors?



Sol. Answer (4)

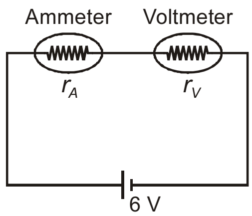
$R_{xy} = 3\ \Omega$

Current distribution is as shown.



4. An ammeter and a voltmeter are connected in series to a battery with an emf = 6 V. When a certain resistance is connected in parallel with the voltmeter, the reading of the latter decreases η = 2 times, whereas the reading of the ammeter increases the same number of times. Find the voltmeter reading (in volts) after the connection of the resistance.

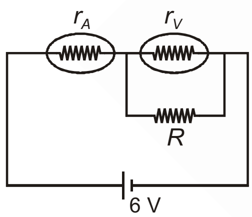
Sol. Answer (2)



Before connecting resistance

$$\text{Voltmeter reading} = \left(\frac{6}{r_A + r_V}\right) r_V$$

$$\text{Ammeter reading} = \frac{6}{r_A + r_V}$$



After connecting resistance

$$\left(\frac{3r_V}{r_A + r_V}\right) = 6 - \frac{6r_A}{r_A + \dfrac{r_V R}{r_V + R}}$$

$$\frac{12}{r_A + r_V} = \frac{6}{r_A + \dfrac{r_V R}{r_V + R}}$$

On solving

$\frac{r_A}{r_V} = \frac{1}{2}$ and voltmeter reading = 2 volt

5. Consider a wire of length ℓ, area of cross-section A and resistivity ρ and resistance $\frac{1}{5}\Omega$. Its length is increased by applying a force on it and its length increases by four times of its original length. Find the new resistance in ohms of the wire.

Sol. Answer (5)

$$A_1\ell_1 = A_2\ell_2$$

$$A_2 = \frac{A}{5}$$

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

$\Rightarrow$ $R_2 = 25R_1$

$R_2 = 5\ \Omega$

6. A current, 32 A, is made to pass through a conductor where the free electrons density is $4 \times 10^{28}\ m^{-3}$ and its area of cross section is $10^{-6}\ m^2$. Find out the value of the drift velocity (in mm/s) of free electrons.

Sol. Answer (5)

$$V_d = \frac{I}{n_e A}$$

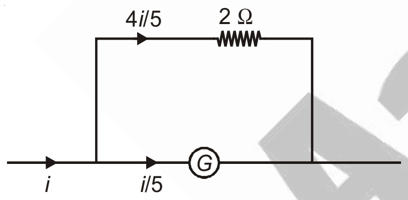
$$\frac{32}{4\times10^{28}\times1.6\times10^{-19}\times10^{-6}} = 5\times10^{-3}\ \text{m/s}$$

7. The deflection in a moving coil galvanometer falls from 50 divisions to 10 divisions when a shunt of 2 Ω is applied. What is the resistance (in ohms) of the galvanometer?

Sol. Answer (8)

Current falls to $\frac{1}{5}$ of the original current due to shunting

$\Rightarrow$



$\Rightarrow$ $\frac{i}{5}\times G = \frac{4i}{5}\times 2$

$G = 8\ \Omega$

8. When two identical batteries of internal resistance 1 Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25\ J_2$, then the value of R in Ω is

Sol. Answer (4)

In case 1, $J_1 = \left(\frac{2\varepsilon}{R+2}\right)^2 R$

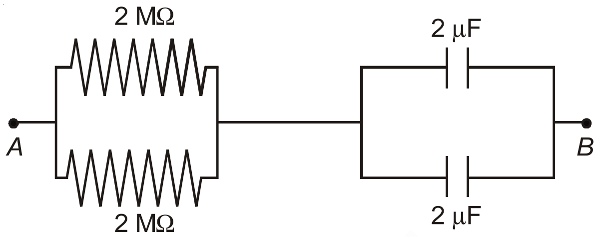
In case 2, $J_2 = \left(\frac{2\varepsilon}{2R+1}\right)^2 R$

$J_1 = 2.25\ J_2$

$\Rightarrow$ $R = 4\ \Omega$

9. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in seconds) does the voltage across them become 4 V?

[Take : ln 5 = 1.6, ln 3 = 1.1]



Sol. Answer (2)

Resistance of circuit = 1 MΩ

Capacitance of circuit = 4 μF

Time constant = RC = 4 s

Voltage across capacitor at time 0 = 0 V

Voltage across capacitor at time ∞ = 10 V

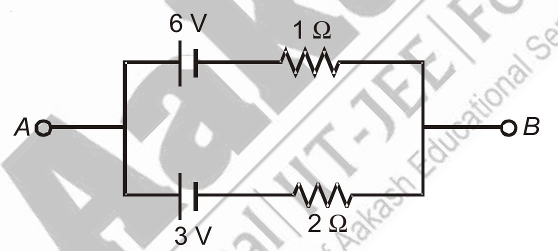
In general

$V = 10(1 - e^{\frac{-t}{4}})$

Putting V = 4 V

We get t = 2 s

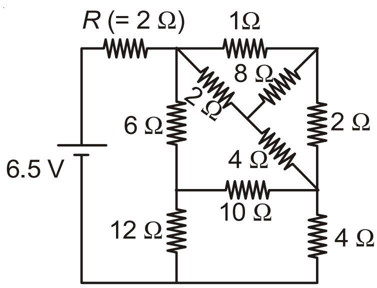
10. Two batteries of different emfs and different internal resistance are connected as shown. The voltage across AB in volts is



Sol. Answer (5)

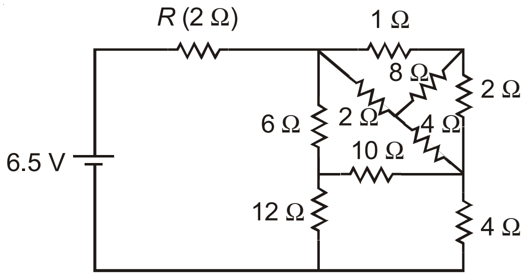
$$V = \frac{\frac{6}{1}+\frac{3}{2}}{\frac{1}{1}+\frac{1}{2}} = \frac{7.5}{\frac{3}{2}} = 5$$

11. In the following circuit, the current through the resistor R (= 2 Ω) is I amperes. The value of I is



Sol. Answer (1)

The circuit is shown below.



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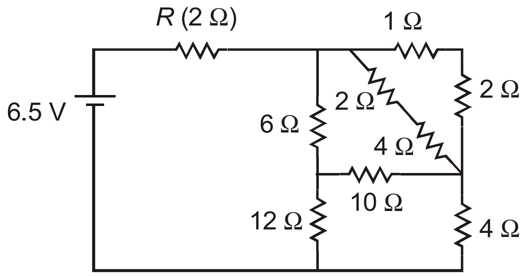

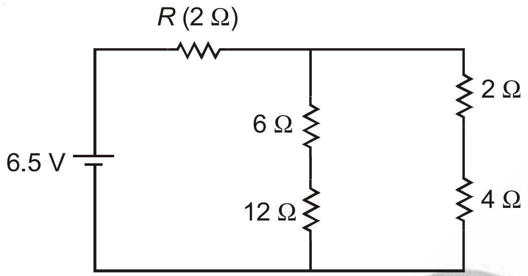

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