Chapter - 3
Current Electricity

1. According to ohm's law,

$E = IR$

Rearranging, we get,

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

$\Rightarrow I = \frac{12}{0.4} = 30A$

Therefore, the maximum current drawn from the given battery is 30A.

2. ~~According to ohm's law,~~

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

$\Rightarrow R+r = \frac{E}{I} = \frac{10}{0.5} = 20\ \Omega$

$\Rightarrow R = 20 - 3 = 17\ \Omega$

According to ohm's law,

$V = IR$

$\Rightarrow V = 0.5 \times 17$

$\Rightarrow V = 8.5\ V$

Therefore, the resistance of the resistor is $17\ \Omega$ and the terminal voltage is 8.5V.

3. (a) As the combination is series

$\Rightarrow$ Total resistance $= 1\Omega + 2\Omega + 3\Omega$

$= 6\ \Omega$

(b) $I = \frac{E}{R}$

$\Rightarrow I = \frac{12}{6} = 2A$

$\Rightarrow V_1 = 2 \times 1 = 2V$

$V_2 = 2 \times 2 = 4V$

$V_3 = 2 \times 3 = 6V$

4(a) As the combination is parallel

$\Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\Rightarrow \frac{1}{R} = \frac{10+5+4}{20}$

$\Rightarrow R = \frac{20}{19}$

(b) $I_1 = \frac{V}{R_1}$

$\Rightarrow I_1 = \frac{20}{2} = 10A$

$I_2 = \frac{V}{R_2}$

$\Rightarrow I_2 = \frac{20}{4} = 5A$

$I_3 = \frac{V}{R_1}$

$\Rightarrow I_3 = \frac{20}{5} = 4A$

$\Rightarrow I = I_1 + I_2 + I_3 = 19A$

$\Rightarrow$ Total current is 19A

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5. $\alpha = \dfrac{R_1 - R}{R(T_1 - T)}$

$T_1 - T = \dfrac{R_1 - R}{R\alpha}$

$\Rightarrow T_1 - 27 = \dfrac{117 - 100}{100(1.7 \times 10^{-4})}$

$\Rightarrow T_1 - 27 = 1000$

$\Rightarrow T_1 = 1027°C$

Therefore, the resistance of the element is 117 Ω at T_1 is 1027°C

6. $R = \rho \dfrac{L}{A}$

$\Rightarrow \rho = \dfrac{R \times A}{L} = \dfrac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}$

Therefore, the resistivity of the material is calculated to be 2×10^{-7}

7. $\alpha = \dfrac{R_2 - R_1}{R_1(T_2 - T_1)}$

$\alpha = \dfrac{2.7 - 2.1}{2.1(100 - 27.5)}$

$= 0.0039°C^{-1}$

Therefore, the temperature coefficient of resistivity of silver is $0.0039°C^{-1}$

8. $R_1 = \frac{V}{I}$

$\Rightarrow R_1 = \frac{230}{3.2} = 71.87\ \Omega$

$R_2 = \frac{230}{2.8} = 82.14\ \Omega$

$\Rightarrow \alpha = \frac{R_2 - R_1}{R_1 (T_2 - T_1)}$

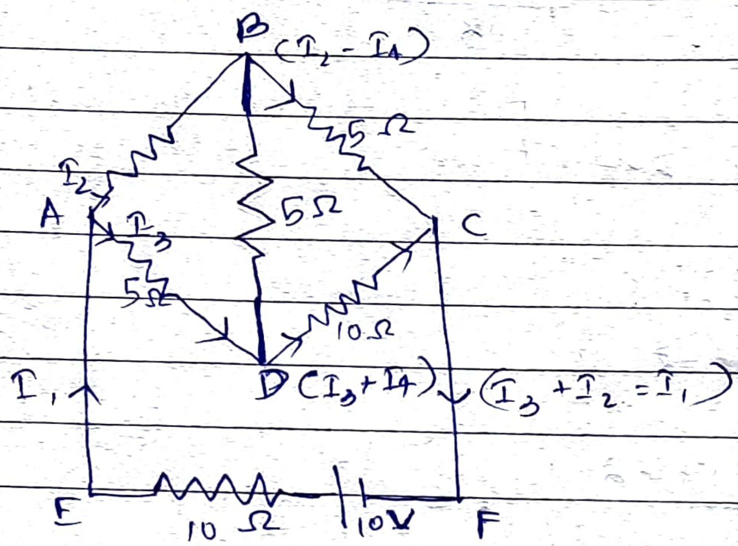
$\Rightarrow T_2 - 27 = \frac{82.14 - 71.87}{71.87 \times (1.7 \times 10^{-4})}$

$\Rightarrow T_2 - 27 = 840.5$

$\Rightarrow T_2 = 840.5 + 27 = 867.5^\circ C$

Hence, the steady temperature of the heating element is $867.5^\circ C$

9.



Let us take ABDA into consideration,

$10 I_2 + 5 I_4 - 5 I_3 = 0$

$\Rightarrow 2 I_2 + I_4 - I_3 = 0$

$\Rightarrow I_3 = 2 I_2 + I_4$ —— (1)

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Let us take ABCFEA into consideration,

$\Rightarrow -10 + 10(I_1) + 10(I_2) + 5(I_2 - I_4) = 0$

$\Rightarrow 10 = 15 I_2 + 10 I_1 - 5 I_4$

$\Rightarrow 3I_2 + 2I_2 - I_4 = 2$ ——— (3)

Let us take BCDB into consideration,

$\Rightarrow 5(I_2 - I_4) - 10(I_3 + I_4) - 5 I_4 = 0$

$\Rightarrow 5 I_2 - 5 I_4 - 10 I_3 - 10 I_4 - 5 I_4 = 0$

$\Rightarrow 5 I_2 - 10 I_3 - 20 I_4 = 0$

$\Rightarrow I_2 = 2 I_3 - 4 I_4$ ——— (2)

~~Let us~~ From equn (1) and (2),

$\Rightarrow I_3 = 2(2I_3 + 4 I_4) + I_4$

$\Rightarrow I_3 = 4 I_3 + 8 I_4 + I_4$

$\Rightarrow -3 I_3 = 9 I_4$

$\Rightarrow -3 I_4 = + I_3$ ——— (4)

Putting equation (4) in equation ~~(2), we~~ (1), we have:

$I_3 = 2I_2 + I_4$

$\Rightarrow -4 I_4 = 2 I_2$

$\Rightarrow I_2 = -2 I_4$ ——— (5)

From the above equation, we infer that:

$I_1 = I_3 + I_2$ ——— (6)

Putting equation (4) in equation (1), we get.

$\Rightarrow 3 I_2 + 2(I_3 + I_2) - I_4 = 2$

$\Rightarrow 5 I_2 + 2 I_3 - I_4 = 2$ ——— (7)

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Putting equations (4) and (5) in equation (7), we get

$\Rightarrow 5(-2I_4) + 2(-3I_4) - I_4 = 2$

$\Rightarrow -10I_4 - 6I_4 - I_4 = 2$

$\Rightarrow 17I_4 = -2$

$\Rightarrow I_4 = \frac{-2}{17}$ A

Equation (4) reduces to

$I_3 = -3(I_4)$

$\Rightarrow I_3 = -3\left(\frac{-2}{17}\right) = \frac{6}{17}$ A

$\Rightarrow I_2 = -2(I_4)$

$\Rightarrow I_2 = -2\left(\frac{-2}{17}\right) = \frac{4}{17}$ A

$\Rightarrow I_2 - I_4 = \frac{4}{17} - \frac{-2}{17} = \frac{6}{17}$ A

$\Rightarrow I_3 + I_4 = \frac{6}{17} - \frac{-2}{17} = \frac{4}{17}$ A

$\Rightarrow I_1 = I_3 + I_2$

$\Rightarrow I_1 = \frac{6}{17} + \frac{4}{17} = \frac{10}{17}$ A

Therefore, current in each branch are:

$AB = \frac{4}{17}$ A

$BD = \frac{-2}{17}$ A

$BC = \frac{6}{17}$ A

Total current $= \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17}$

$= \frac{10}{17}$ A

$CD = \frac{-4}{17}$ A

$AD = \frac{6}{17}$ A

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10. (a) Let L_1 be the balance point from end A.
Given,
$L_1 = 39.5$ cm
$S = 12.5\ \Omega$

$\Rightarrow \frac{R}{S} = \frac{100 - L_1}{L_1}$

$\Rightarrow R = \frac{100 - 39.5}{39.5} \times 12.5 = 8.2\ \Omega$

Thus, calculated resistance of the resistor $R = 8.2\ \Omega$

(b) If R and S are interchanged, then the lengths will also be interchanged.
Hence, the new length will be:
$l = 100 - 39.5 = 60.5$ cm

(c) If the galvanometer and the cell are interchanged, the position of the balance point remains unchanged. Therefore, the galvanometer will show no current.

11. $I = \frac{V'}{R + r}$

$\Rightarrow I = \frac{112}{15.5 + 5}$

$\Rightarrow I = \frac{112}{16}$

$\Rightarrow I = 7A$

voltage $= I \times R = 7 \times 15.5$
$= 108.5$ V

Terminal voltage of battery $= 120 - 108.5 = 11.5$ V

12. $\frac{E_1}{E_2} = \frac{I_1}{I_2}$

$\Rightarrow E_2 = E_1 \times \frac{I_2}{I_1}$

$\Rightarrow E_2 = 1.25 \times \frac{63}{35} = 2.25\ V$

13. $I = \frac{nAel}{t}$

$\Rightarrow t = \frac{n \times A \times e \times l}{I}$

$\Rightarrow t = \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$

$\Rightarrow t = 2.7 \times 10^4$ sec

14. surface area of the earth

$= 4\pi r^2$

$= 4 \times 3.14 \times (6.37 \times 10^6)^2 = 5.09 \times 10^{14}\ m^2$

charge on earth surface =

$q = \sigma A$

$= 10^{-9} \times 5.09 \times 10^{14}$

$= 5.09 \times 10^5$ C

Time taken to neutralize the earth's surface

$= t = \frac{q}{I}$

$= \frac{5.09 \times 10^5}{1800}$

$= 283$ s

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15 (a) Total EMF $= n\varepsilon = 6 \times 2 = 12V$

Total resistance in circuit $R_{total} = nr + R$

$= 6 . 0.015 + 8.5$

$= 8.59 \Omega$

Current drawn from supply $= \frac{E}{R_{total}} = \frac{12}{8.59} = 1.4 A$

Terminal velocity $V = IR$

$= 1.4 \times 8.5$

$= 11.9 V$

(b) Maximum current drawn from the cell, $I = \frac{\varepsilon}{r}$

$= \frac{1.9}{380}$

$= 0.005 A$

16. $R_1 = \rho_1 \frac{l_1}{A_1}$ —— (1)

$R_2 = \rho_2 \frac{l_2}{A_2}$ —— (2)

It is given that $R_1 = R_2$ and $l_1 = l_2$

$\Rightarrow \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$

$\Rightarrow \frac{A_1}{A_2} = \frac{\rho_1}{\rho_2}$

$= \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}}$

$= 1.52$

Mass of aluminium, m_1

$= A_1 l_1 \times d_1$

Mass of copper, m_2

$= A_2 l_2 \times d_2$

$\Rightarrow \frac{m_1}{m_2} = \frac{(A_1 l_1 \times d_1)}{(A_2 l_2 \times d_2)}$

Since $l_1 = l_2$

$\Rightarrow \frac{m_1}{m_2} = \frac{A_1 d_1}{A_2 d_2}$

$\Rightarrow \frac{m_1}{m_2} = \frac{(1.52)}{(2.7/8.9)}$

$= 1.52 \times 0.303$

$\Rightarrow \frac{m_1}{m_2} = 0.46$

The mass ratio of aluminium to copper is 0.46. Since aluminium is lighter, it is preferred for long suspensions of cables.

Q 17. Ohm's law is valid to high accuracy. This means that the resistivity of the alloy maganin is nearly independent of temperature.

18 (a) Current is given to be steady. Therefore, it is a constant. The current density, electric field, drift speed depends on the area of cross-section inversely.

(b) No, examples of non-ohmic elements are vacuum diode, semiconductor diode etc.

(c) Because the maximum current drawn from a source = $\frac{\varepsilon}{r}$

(d) If the circuit is shorted (accidentally), the current drawn will exceed safety limits if internal resistance is not large.

19 (a) greater
(b) lower
(c) nearly independent of
(d) 10^{22}

20(a)(i) $\frac{11}{3}\Omega$

$$\frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2}\right] = \frac{3}{2}$$

$$R' = \frac{2}{3}\Omega$$

$$R = R' + 3 = \frac{2}{3} + 3 = \frac{11}{3}$$

(ii) $\frac{11}{5}\Omega$

$$\frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{3}\right] = \frac{5}{6}$$

$$R' = \frac{6}{5}\Omega$$

$$R = R' + 3 = \frac{6}{5} + 1 = \frac{11}{5}\Omega$$

(iii) 6Ω

As resistors are connected with series

$\Rightarrow$ $R = 1\Omega + 2\Omega + 3\Omega = 6\Omega$

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(iv) $\frac{6}{11}\Omega$

$\Rightarrow \frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2} + \frac{1}{3}\right] = \frac{11}{6}\Omega$

$R' = \frac{6}{11}\Omega$

(c) (a) The resistors are connected in parallel

$\Rightarrow \frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{4}\right] = \frac{3}{4}\Omega$

$\Rightarrow R' = \frac{4}{3}\Omega$

All the 4 resistors are connected in series.
Hence the equivalent resistance R each are

$\frac{4}{3} \times 4 = \frac{16}{3}\Omega$

(c) (b) As the resistors are connected in series

$\Rightarrow$ Effective resistance $= R + R + R + R + R$
$= 5R$

21. $R' = R + [xR/(x+R)] + R$

$\Rightarrow R' = 2R + [xR/(x+R)]$

As add 1Ω resistors will not change the resistance

$\Rightarrow R' = x$

$\Rightarrow 2R + [xR/(x+R)] = x$

Since $R = 1\Omega$ we get

$2 \times 1 + [x \times 1/(x+1)] = x$

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

$\Rightarrow x = \frac{(-2) \pm \sqrt{(-2)^2 - 4 \times 1 \times (-2)}}{2}$

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$\Rightarrow$ $x = 1 \pm \sqrt{3}$

As the value of resistance ~~cannot~~ cannot be negative. Therefore, $x = 1 + \sqrt{3} = 2.732\ \Omega$

As $E = 12\ V$; $r = 0.5\ \Omega$

If I is the current drawn;

$\Rightarrow$ $I = \frac{E}{x + r} = \frac{12}{(2.732 + 0.5)} = 3.713\ A$

22 (a) Constant emf $E_1 = 1.02\ V$

The balance point $l_1 = 67.3\ cm$

$\Rightarrow$ Relation between Emf and the balancing point

$= \frac{E_1}{l_1} = \frac{\varepsilon}{l}$

$\Rightarrow$ $\varepsilon = (l \times E_1 / l_1) = \frac{(82.3 \times 1.02)}{67.3}$

$= 1.247\ V$

(b) The purpose of using high resistance of 600 kΩ is to reduce current through the galvanometer when the movable contact is far from the balance point.

(c) No.

(d) No. If ε is greater than the emf of the driven cell of the potentiometer, there will be no balance point on the wire AB.

23. Internal resistance of the cell, r = 1.5 v cell

Balance point of the cell in open circuit,

$l = 76.3 cm$

External resistance, $R = 9.5 \Omega$

New balance point, $l_1 = 64.8 cm$

New expression will be,

$$r = R\left[\frac{l}{l_1} - 1\right]$$

$$r = 9.5\left[\frac{76.3}{64.8} - 1\right]$$

$$= 1.69 \Omega$$