# Ch-3- Current Electricity

## Exercises

**Q.1**

$\mathcal{E} = 12V$

$r = 0.4\Omega$

$\mathcal{E} = Ir$

$\Rightarrow 12 = I\,0.4$

$\Rightarrow I = \frac{12}{0.4} = \frac{\cancel{12}^{3} \times 10}{\cancel{4}_{1}} = 30A$

**Q.2**

$\mathcal{E} = 10V$

$r = 3\Omega$

$I = 0.5A$

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

$\Rightarrow 0.5 = \frac{10}{R+3}$

$\Rightarrow 0.5(R+3) = 10$

$\Rightarrow 0.5R + \frac{\cancel{5}^{1}}{\cancel{10}_{2}} \times 3 = 10$

$\Rightarrow 0.5R = 10 - \frac{3}{2}$

$\Rightarrow 0.5R = \frac{20-3}{2} = \frac{17}{2}$

$\Rightarrow R = \frac{17}{\cancel{2}_{1}} \times \frac{\cancel{10}^{\cancel{2}\,1}}{\cancel{5}_{1}} = 17\Omega$

3.3 a)


Total resistance $= 1\Omega + 2\Omega + 3\Omega$
$= 6\Omega$

b) $\mathcal{E} = 12V$
$R = 6\Omega$

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

$\Rightarrow I = \frac{\cancel{12}^{2}}{\cancel{6}_{1}} = 2A$

Potential drop across $1\Omega$ resistor $= V_1 = 2 \times 1 = 2V$

Potential drop across $2\Omega$ resistor $= V_2 = 2 \times 2 = 4V$

Potential drop across $3\Omega$ resistor $= V_3 = 2 \times 3 = 6V$

3.4. a) $R_1 = 2\Omega$
$R_2 = 4\Omega$
$R_3 = 5\Omega$

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

$\Rightarrow \frac{1}{R_p} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5}$

$\Rightarrow \frac{1}{R_p} = \frac{2+1}{4} + \frac{1}{5}$

$\Rightarrow \frac{1}{R_p} = \frac{15+4}{20}$

$\Rightarrow \frac{1}{R_p} = \frac{19}{20}\,\Omega$

$\Rightarrow R_p = \frac{20}{19}\,\Omega$

6) $\mathcal{E} = 20V$

$R = \frac{20}{19}\,\Omega$

$~~I = \frac{\mathcal{E}}{R} = \frac{20}{\frac{20}{19}} = \frac{20 \times 19}{20} = 19A~~$

Current through $2\Omega$ resistor $(I_1) = \frac{V}{R_1}$

$= \frac{\cancel{20}^{10}}{\cancel{2}_1} = 10A$

Current through $4\Omega$ resistor $(I_2) = \frac{V}{R_2}$

$= \frac{\cancel{20}\,5}{\cancel{4}_1} = 5A$

Current through $5\Omega$ resistor $(I_3) = \frac{V}{R_3} = \frac{\cancel{20}\,4}{\cancel{5}_1} = 4A$

Total Current $= I_1 + I_2 + I_3$

$= 10A + 5A + 4A$

$= 19A.$

3.5 $T = 27°C$

$R = 100\,\Omega$

$R_1 = 117\,\Omega$

$\alpha = 1.7 \times 10^{-4}\,°C^{-1}$

$\Rightarrow \alpha = \frac{R_1 - R}{R(T_1 - T)}$

$\Rightarrow T_1 - T = \frac{R_1 - R}{R\alpha}$

$~~R_1 = R[1 + \alpha(T_1 - T)]~~$

$~~117 = 100[1 + 1.7 \times 10^{-4}(T_1 - 27)]~~$

$~~\frac{117}{100} = 100 + 1.7 \times 10^{-2}(T_1 - 27)~~$

$\longrightarrow$

$$\Rightarrow T_1 - 27 = \frac{117-100}{100(1.7\times10^{-4})}$$

$$\Rightarrow T_1 - 27 = \frac{17}{\frac{17}{1\cancel{0}}\times\cancel{100}\times\frac{1}{10^{\cancel{4}\,3}}}$$

$$\Rightarrow T_1 - 27 = 1000$$

$$\Rightarrow T_1 = 1000 + 27$$

$$T_1 = 1027^\circ C$$

**3.6** $A = 6.0\times10^{-7}\,m^2$

$l = 15m$

$R = 5.0\,\Omega$

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

$$\Rightarrow 5 = \frac{\rho \cdot 15}{6\times10^{-7}}$$

$$\Rightarrow 5\times6\times10^{-7} = 15\rho$$

$$\Rightarrow \rho = \frac{\cancel{5}\times\cancel{6}\times10^{-7}}{\cancel{15}\,\cancel{3}}$$

$$= 2\times10^{-7}\,\Omega m$$

**3.7** $R_1 = 2.1\,\Omega$

$T_1 = 27.5^\circ C$

$R_2 = 2.7\,\Omega$

$T_2 = 100^\circ C$

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} = \frac{2.7-2.1}{2.1(100-27.5)} = \frac{0.6}{210 - 57.75}$$

$$= 0.0039^\circ C^{-1}$$

3.8

$V = 230\,V$

$I_1 = 3.2\,A$

$I_2 = 2.8\,A$

$\alpha = 1.7 \times 10^{-4}\,°C^{-1}$

$T_1 = 27.0°C$

$$R_1 = \frac{V}{I_1} = \frac{230}{3.2} = 71.87\,\Omega$$

$$R_2 = \frac{V}{I_2} = \frac{230}{2.8} = 82.14\,\Omega$$

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

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

$$\Rightarrow 1.7 \times 10^{-4} = \frac{10.27}{\cancel{71.87\,T_2} \; 71.87(T_2 - 27)}$$

$$\begin{array}{r} 82.14 \\ -71.87 \\ \hline 10.27 \end{array}$$

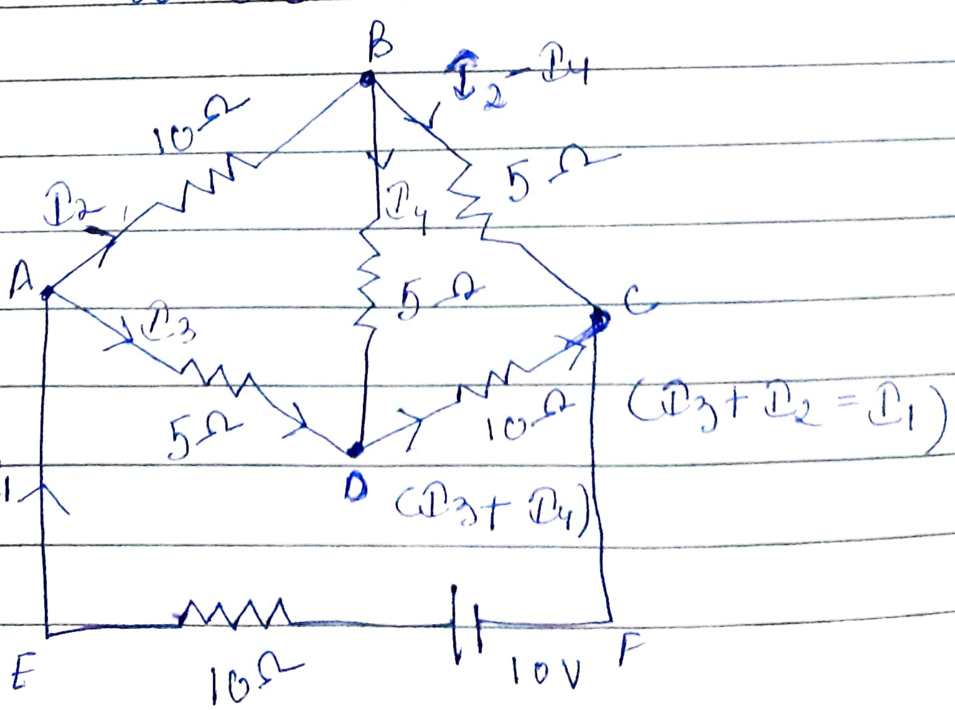
$$\Rightarrow T_2 - 27 = \frac{10.27}{71.87 \times 1.7 \times 10^{-4}}$$

$$\Rightarrow T_2 - 27 = 840.5$$

$$\Rightarrow T_2 = 840.5 + 27$$

$$= 867.5°C.$$

3.9



For ABDA, $10I_2 + 5I_4 - 5(I_3) = 0$

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

$\Rightarrow 5(2I_2 + I_4 - I_3) = 0$

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

$\Rightarrow I_3 = 2I_2 + I_4$ —— (I)

For BCDB,

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

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

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

$\Rightarrow 5(I_2 - 2I_3 - 4I_4) = 0$

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

For ABCFEA,

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

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

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

$\Rightarrow 5(3I_2 + 2I_1 - I_4) = 10$

$\Rightarrow 3I_2 + 2I_1 - I_4 = \frac{\cancel{10}\,2}{\cancel{5}\,1} = 2$

$\Rightarrow 3I_2 + 2I_1 - I_4 = 2$ —— (III)

From eq (I), (II), ~~(III)~~, we get :-

$I_3 = 2I_2 + I_4$

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

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

$\Rightarrow -3I_3 = 9I_4$

$\Rightarrow I_3 = \frac{\cancel{9}\,3\,I_4}{-\cancel{3}\,1} = -3I_4$

$\Rightarrow I_3 = -3I_4$ —— (IV)

Putting eq (IV) in (I), we get :-

$$I_3 = 2I_2 + I_4$$
$$\Rightarrow -3I_4 = 2I_2 + I_4$$
$$\Rightarrow -2I_2 = I_4 + 3I_4$$
$$\Rightarrow -2I_2 = 4I_4$$
$$\Rightarrow I_2 = \frac{\cancel{4}^{2} I_4}{\cancel{-2}_{1}} = -2I_4$$
$$\Rightarrow I_2 = -2I_4 \text{ ——— (V)}$$

$$I_1 = I_3 + I_2 \text{ ——— (VI)}$$

Putting eq VI in eq III, we get :-

$$\cancel{\Rightarrow I_3 = 2I_2 + I_4} \quad 3I_2 + 2I_1 - I_4 = 2$$
$$\Rightarrow 3I_2 + 2(I_3 + I_2) - I_4 = 2$$
$$\Rightarrow 3I_2 + 2I_3 + 2I_2 - I_4 = 2$$
$$\Rightarrow 5I_2 + 2I_3 - I_4 = 2 \text{ ——— (VII)}$$

Putting eq (IV) and (V) in eq (VII), we get :-

$$5I_2 + 2I_3 - I_4 = 2$$
$$\Rightarrow 5(-2I_4) + 2(-3I_4) - I_4 = 2$$
$$\Rightarrow -10I_4 - 6I_4 - I_4 = 2$$
$$\Rightarrow -17I_4 = 2$$
$$\Rightarrow I_4 = \frac{-2}{17}$$

In eq (IV); $I_3 = -3I_4 = -3 \times \frac{-2}{17} = \frac{6}{17}$ A

In eq (V); $I_2 = -2I_4 = -2 \times \frac{-2}{17} = \frac{4}{17}$ A

$I_1 = I_3 + I_2$

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

$I_2 - I_4 = \frac{4}{17} - \left(-\frac{2}{17}\right) = \frac{4}{17} + \frac{2}{17} = \frac{6}{17}\,A$

$I_3 + I_4 = \frac{6}{17} + \left(-\frac{2}{17}\right) = \frac{6}{17} - \frac{2}{17} = \frac{4}{17}\,A$

I in branch AB $= \frac{4}{17}\,A$

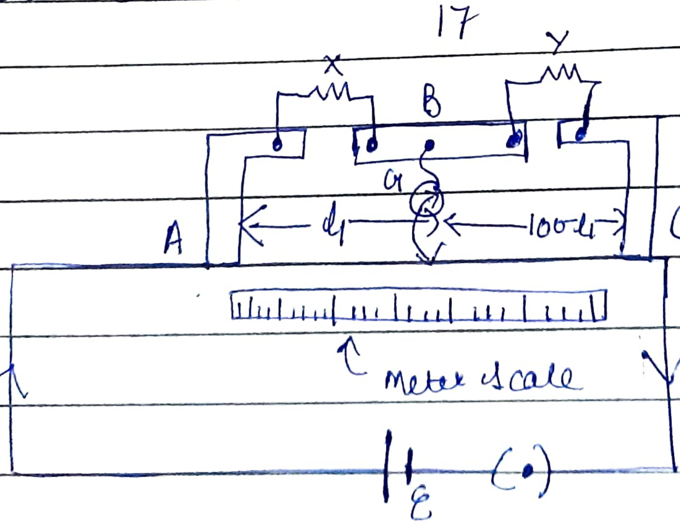
I in branch BC $= \frac{6}{17}\,A$

I in branch CD $= -\frac{4}{17}\,A$

I in branch AD $= \frac{6}{17}\,A$

I in branch BD $= -\frac{2}{17}\,A$

3.10




$100.0 - 39.5 = 0.5$

$l_1 = 39.5\,cm$

R of Y $= 12.5\,\Omega$

$\frac{X}{Y} = \frac{100 - l_1}{l_1} \Rightarrow X = \frac{100 - 39.5}{39.5} \times 12.5 = \frac{60.5}{39.5} \times 12.5 \Rightarrow$

$\Rightarrow X = \frac{605}{395} \times \frac{12.5}{10} \times \frac{10}{10} = 8.2\,\Omega$

(b) Balance point of the bridge $= 100 - l_1$

$= 100 - 39.5$

$= 60.5\text{cm}$ from A

(c) When the galvanometer and cell are interchanged at the balance point of the bridge, the galvanometer will show no deflection and therefore no current will pass through the galvanometer.

3.11 $\varepsilon = 8.0V$

$V = 120V$

$r = 0.5\,\Omega$

$R = 15.5\,\Omega$

$V' = V - \varepsilon$

$= 120 - 8 = 112V$

$\begin{array}{r} 15.5 \\ +\ 0.5 \\ \hline 16.0 \end{array}$

$I = \frac{V'}{R + r} = \frac{112}{15.5 + 0.5} = \frac{112}{16} = 7A$

$V = IR = 7 \times 15.5 = 108.5V$

Terminal voltage $= 120 - 108.5 = 11.5\,V$

3.12 $\varepsilon_1 = 1.25V$

$l_1 = 35\text{ cm}$

$l_2 = 63\text{cm}$

$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} \Rightarrow \frac{1.25}{\varepsilon_2} = \frac{35}{63} \Rightarrow \varepsilon_2 = \frac{1.25 \times 63}{35}$

$\phi_0 = 2.25V$

3.13 $n = 8.5 \times 10^{28} m^{-3}$

$l = 3m$

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

$I = 3A$

$\left( \because V_d = \frac{l}{t} \right)$

$\Rightarrow I = neAV_d$

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

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

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

$\Rightarrow t = \frac{85}{10} \times 10^{28} \times \frac{16}{10} \times \frac{1}{10^{19}} \times 2 \times \frac{1}{10^6}$

$= \frac{2720 \times 10^{\cancel{28}}}{10^{\cancel{27}}}$

$= 27200 s$

$= 2.7 \times 10^4 s$

3.14 $\sigma = 10^{-9}$

$I = 1800A$

$r = 6.37 \times 10^6 m$

$A = 4\pi r^2$

$= 4 \times 3.14 \times (6.37 \times 10^6)^2$

$= 4 \times \frac{314}{100} \times \frac{637}{100} \times 10^6 \times \frac{637}{100} \times 10^6$

$= 5.09 \times 10^{14} m^2$

$q = \sigma \times A$

$q = 10^{-19} \times 5.09 \times 10^{14}$

$= \frac{1}{10^{19}} \times \frac{509}{100} \times 10^{14}$

$= 5.09 \times 10^{5}\,C$

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

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

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

$t = 282.77\,s$

3.15 a) $\mathcal{E} = 2.0\,V$

$r = 0.015\,\Omega$

$R = 8.5\,\Omega$

$n = 6$

$I = \frac{n\mathcal{E}}{R + nr}$

$I = \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} = 1.39\,A$

$V = IR = 1.39 \times 8.5 = 11.87\,A$

b) $\mathcal{E} = 1.9\,V$

$r = 380\,\Omega$

$I = \frac{\mathcal{E}}{r} = \frac{1.9}{380} = 0.005\,A$

The cell cannot be used to start a motor as a large →

current is required to start the motor of a car

3.16 $\rho_{Al} = 2.63 \times 10^{-8}\ \Omega m$

$d_{Al} = 2.7$

$\rho_{cu} = 1.72 \times 10^{-8}\ \Omega m$

$d_{cu} = 8.9$

$R_{Al} = \rho_{Al} \dfrac{l_{Al}}{A_{Al}}$

$R_{cu} = \rho_{cu} \dfrac{l_{cu}}{A_{cu}}$

ATQ;

$R_{Al} = R_{cu}$

$\Rightarrow \rho_{Al} \dfrac{l_{Al}}{A_{Al}} = \rho_{cu} \dfrac{l_{cu}}{A_{cu}}$

$\Rightarrow \dfrac{\rho_{Al}}{A_{Al}} = \dfrac{\rho_{cu}}{A_{cu}}$ (As $l_{Al} = l_{cu}$).

$\Rightarrow \dfrac{A_{Al}}{A_{cu}} = \dfrac{\rho_{cu}}{\rho_{Al}}$

$= \dfrac{2.63 \times \cancel{10^{-8}}\ \cancel{\Omega m}}{1.72 \times \cancel{10^{-8}}\ \cancel{\Omega m}} = \dfrac{2.63}{1.72}$

$m_{Al} =$ volume $\times$ density

$= A_{Al}\, l_{Al} \times d_{Al}$

$m_{cu} =$ Volume $\times$ density

$= A_{cu}\, l_{cu} \times d_{cu}$

$$\frac{m_{Al}}{m_{Cu}} = \frac{A_{Al} l_{Al} d_{Al}}{A_{Cu} l_{Cu} d_{Cu}}$$

$l_1 = l_2$, $\frac{m_{Al}}{m_{Cu}} = \frac{A_{Al} d_{Al}}{A_{Cu} d_{Cu}}$

$$\frac{m_{Al}}{m_{Cu}} = \frac{2.63}{1.72} \times \frac{2.7}{8.9} = 0.46 \qquad \left(\frac{A_{Al}}{A_{Cu}} = \frac{2.63}{1.72}\right)$$

Here $m_{Al}$ is ~~lighter~~ lesser than $m_{Cu}$. So, aluminium is lighter than copper and hence, it is preferred for overhead power cables over copper.

3.17 From the given table, it is observed that the ratio of voltage with current is a constant i.e 19.7. Here, manganin is an ohmic conductor i.e the alloy obeys Ohm's law. According to Ohm's law, the ration of voltage with current is the resistance of the conductor. Hence, the resistance of manganin is 19.7 $\Omega$.

3.18 a) When a steady current flows in a metallic conductor of non-uniform cross-section, the current flowing through a conductor is constant. Current density, electric field, drift speed are inversely proportional to the area of cross section hence they are not constant.

b) No, Ohm's law is not universally ~~accepted~~ applicable for all the conducting elements. Vaccum diode semi-conductor is a non-ohmic conductor. Therefore, Ohm's law is not valid for it.

→

c) According to Ohm's law, $V = IR$ i.e. Voltage V is directly propotional to current I and internal resistance R.

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

If V is low, then R must be very low, so that high current can be drawn from the source.

d) In order to prevent the current from exceeding the safety limit, a high tension supply must have a very large internal resistance. If the internal resistance is not large, then the current drawn can exceed the safety limits in case of a short circuit.

3.19 a) Alloys of metals usually have much greater resistivity than that of their constituent metals.

b) Alloys usually have much lower temperature coefficients of resistance than pure metals.

c) The resistivity of the alloy manganin is nearly independent of increase of temperature.

d) The resistivity of a typical insulator is greater than that of a metal by a factor of the order of $10^{22}$.

3.20 a) Total no. of resistors = n

resistance of each resistor = R

i) When we will combine the n resistors in series, we will obtain $R_1$ resistance as the maximum resistance given by $R_1 = nR$

ii) When we combine the n resistors in parallel, we will obtain $R_2$ resistance as the minimum resistance given by $R_2 = \frac{R}{n}$

iii) Ratio of maximum to minimum $= R_1 : R_2$

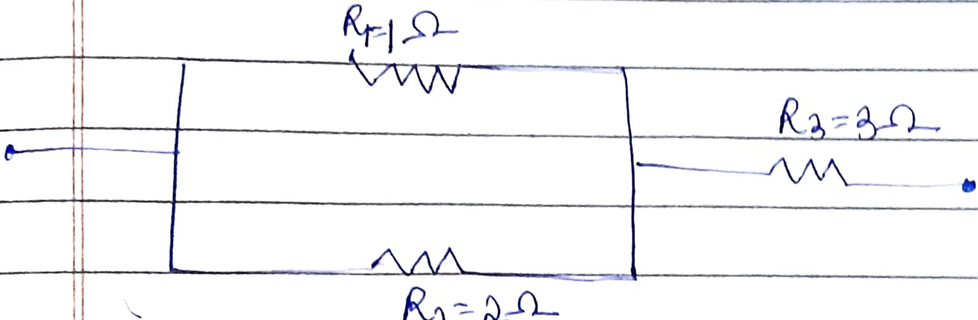
$$= \frac{nR}{\frac{R}{n}}$$

$$R_1 : R_2 = nR \times \frac{n}{R}$$

$$R_1 : R_2 = n^2$$

b) $R_1 = 1\,\Omega$, $R_2 = 2\,\Omega$, $R_3 = 3\,\Omega$

i) Equivalent resistance, $R_e = \frac{11}{3}\,\Omega$




$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1} + \frac{1}{2} = \frac{2+1}{2} = \frac{3}{2}$$

$$R_p = \frac{2}{3}$$

$$R_e = R_p + R_3$$

$$= \frac{2}{3} + 3 = \frac{2+9}{3} = \frac{11}{3}\,\Omega$$

ii) Equivalent resistance, $R_e = \frac{11}{5}\,\Omega$

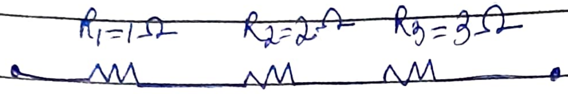
$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = \frac{5}{6}\,\Omega \quad , R_p = \frac{6}{5}$$

$$R_e = R_p + R_1$$

$$R_e = \frac{6}{5} + 1 = \frac{6+5}{5} = \frac{11}{5}\,\Omega$$

$$\cancel{= \frac{5+6}{6} = 11}$$

iii) $R_e = 6\,\Omega$

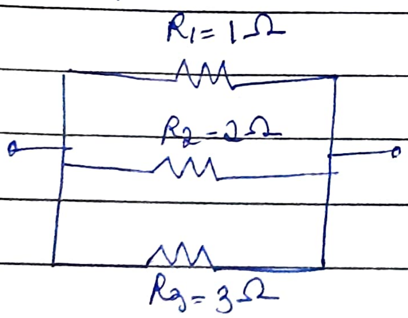



$$R_e = R_1 + R_2 + R_3$$

$$R_e = 1\,\Omega + 2\,\Omega + 3\,\Omega$$

$$R_e = 6\,\Omega$$

iv) $R_e = \frac{6}{11}\,\Omega$



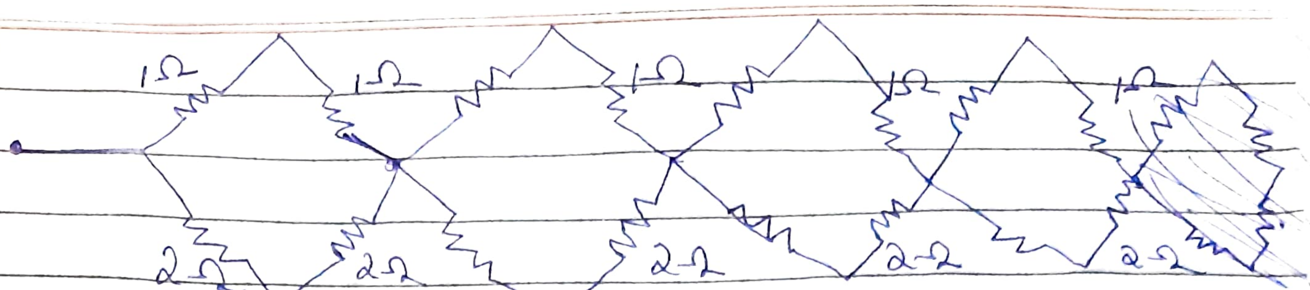

$$\cancel{R_e = \frac{1}{R_p}} = \quad \frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

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

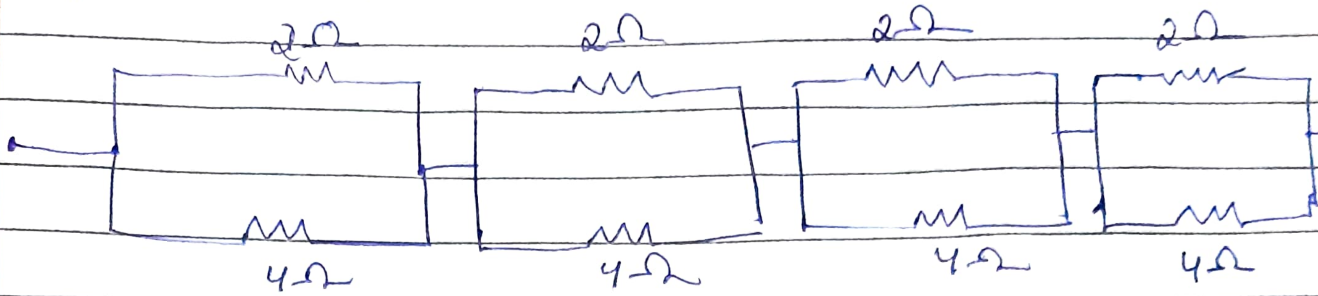
$$\frac{1}{R_e} = \frac{6+3+2}{6} = \frac{11}{6}$$

$$R_e = \frac{6}{11}\,\Omega$$

(c)

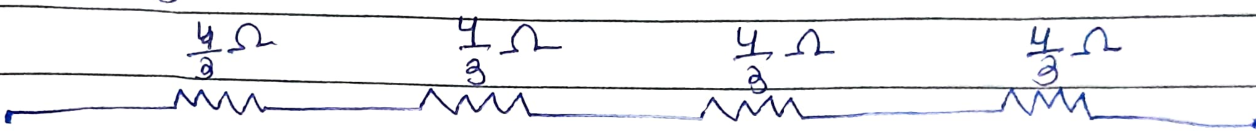



$R_{S_1} = 1+1 = 2\Omega$ $\quad R_{S_2} = 2+2 = 4\Omega$




$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{4} = \frac{2+1}{4} = \frac{3}{4}$$

$$R_p = \frac{4}{3}\Omega$$




$$R_{se} = \frac{4}{3}\Omega + \frac{4}{3}\Omega + \frac{4}{3}\Omega + \frac{4}{3}\Omega$$

$$R_{se} = \frac{4+4+4+4}{3} = \frac{16}{3}$$

$$R_{se} = \frac{16}{3}\Omega$$

Equivalent resistance $= \frac{16}{3}\Omega$

3.24 $R = 10\Omega$

$R_{eq} \Rightarrow$ Equivalent resistance

$$R_{eq} = 2 + \frac{R_{eq}}{(R_{eq}+1)}$$

$$\Rightarrow R_{eq}^2 - 2R_{eq} - 2 = 0$$

$$\Rightarrow R_{eq} = \frac{2 \pm \sqrt{4+8}}{2} = \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$$

$\Rightarrow$

$R_{eq} = (1+\sqrt{3}) = 1+1.73 = 2.73\,\Omega$

$r = 0.5\,\Omega$

$R_1 = R_{eq} + 0.5$

$= 2.73 + 0.5$

$= 3.23\,\Omega$

$V = 12V$

We know,

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

$I = \frac{12}{3.23} = 3.72A$

3.22 a) $\varepsilon_1 = 1.02V$

$l_1 = 67.3\,cm$

$l = 82.3\,cm$

$\Rightarrow \frac{\varepsilon_1}{l_1} = \frac{\varepsilon}{l}$

$\Rightarrow \frac{1.02}{67.3} = \frac{\varepsilon}{82.3}$

$\Rightarrow \varepsilon = \frac{1.02 \times 82.3}{67.3} = 1.247V$

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

c) No, the balance point is not affected by this high resistance.

$\rightarrow$

d) No, the method would not work if the driver cell of the potentiometer had an emf of 1·0 V instead of 2·0 V because if the emf of the driver cell of the potentiometer is less than the emf of the other cell, then there would be no balance point on the wire.

3·23

$l_1 = 76 \cdot 3 \text{ cm}$

$R = 9 \cdot 5 \, \Omega$

$l_2 = 64 \cdot 8 \text{ cm}$

$$\begin{array}{r} 76\cdot 3 \\ -64\cdot 8 \\ \hline 11\cdot 5 \end{array}$$

$$r = \left( \frac{l_1 - l_2}{l_2} \right) R$$

$$r = \frac{76\cdot 3 - 64\cdot 8}{64\cdot 8} \times 9\cdot 5 = 1\cdot 68 \, \Omega$$