Chapter-3

3.1. Here, $E = 12V$, $r = 0.4\Omega$

The current drawn from the battery will be maximum when the external resistance in the circuit is zero i.e $R = 0$.

$\therefore I_{max} = \frac{E}{r} = \frac{12}{0.4} = 30A$.

3.2. $E = 10V$, $r = 3\Omega$, $I = 0.5A$

As, $I = \frac{E}{R+r}$.

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

$\Rightarrow R = \frac{E}{I} - r$.

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

$\Rightarrow R = 17\Omega$.

So, Terminal voltage, $V = IR$

$= 0.5 \times 17 = 8.5V$.

3.3. i) $R_s = R_1 + R_2 + R_3 = (1 + 2 + 3)\Omega = 6\Omega$.

ii) Current in the circuit, $I = \frac{E}{R} = \frac{12}{6} = 2A$.

$\therefore$ Potential drops across different ~~resistance~~ resistors are

$V_1 = IR_1 = 2 \times 1 = 2V$.

$V_2 = IR_2 = 2 \times 2 = 4V$

$V_3 = IR_3 = 2 \times 3 = 6V$

3.4. i) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20}$

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

ii) Currents drawn through different resistors are

$I = \frac{E}{R_1} = \frac{20}{2} = 10A$, $I_2 = \frac{E}{R_2} = \frac{20}{4} = 5A$

$I_3 = \frac{E}{R_3} = \frac{20}{5} = 4A$.

Total current drawn from the battery,

$I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19A$.

3.5, Here, $R_1 = 100\,\Omega$, $R_2 = 117\,\Omega$, $t_1 = 27°c$.
$\alpha = 1.70 \times 10^{-4}\,°C^{-1}$

As, $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

$\therefore t_2 - t_1 = \frac{R_2 - R_1}{R_1 \alpha} = \frac{117 - 100}{100 \times 1.70 \times 10^{-4}} = 1000$

$\Rightarrow t_2 = 1000 + t_1 = 1000 + 27 = 1027°c$

3.6, Here $l = 15\,m$, $A = 6.0 \times 10^{-7}\,m^2$, $R = 5\,\Omega$

Resistivity, $\rho = \frac{RA}{l} = \frac{5.0 \times 6.0 \times 10^{-7}}{15}$

$= 2.0 \times 10^{-7}\,\Omega\,m$.

3.7, Here, $R_1 = 2.1\,\Omega$, $t_1 = 27.5°C$, $R_2 = 2.7\,\Omega$, $t_2 = 100°C$.
Temperature coefficient of resistivity of silver,

$\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

$= \frac{2.7 \times 2.1}{2.1(100 - 27.5)} = \frac{0.6}{2.1 \times 72.5} = 0.00394°c^{-1}$

3.8. Here, $V = 230\ V$, $I_1 = 3.2 A$

$I_2 = 2.8 A$, $\alpha = 1.70 \times 10^{-4}\ °C^{-1}$

Resistance at room temperature,

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

Resistance at steady temperature,

$$R_2 = \frac{V}{I_2} = \frac{230}{2.8} = 82.143\ \Omega$$

Now, $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

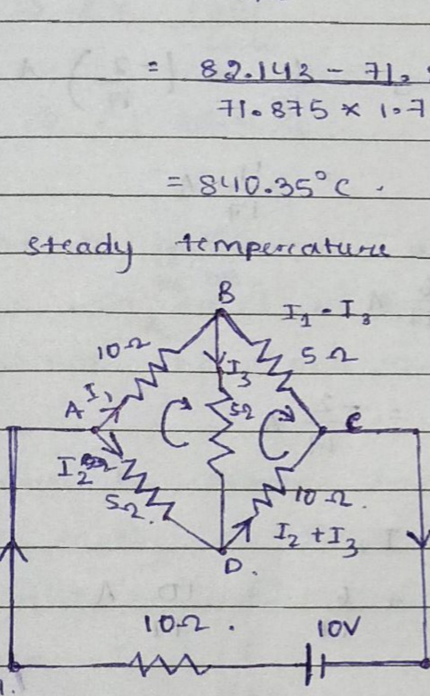
$$\therefore t_2 - t_1 = \frac{R_2 - R_1}{R_1 \alpha}$$

$$= \frac{82.143 - 71.875}{71.875 \times 1.7}$$

$$= 840.35°C.$$

So, steady temperature of element, $t_2 = 840.35 + 27 = 867.35°C$.

3.9.



For loop ABDA,

$$10I_1 + 5I_3 - 5I_2 = 0 \quad —(1)$$

For loop BCDB,

$$5(I_1 - I_3) - 10(I_2 + I_3) - 5I_3 = 0$$

$$\Rightarrow 5I_1 - 10I_2 - 20I_3 = 0 \quad —(2)$$

For loop ADCFGA,

$$5I_2 + 10(I_2 + I_3) + 10(I_1 + I_2) = 10$$

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$\Rightarrow 10I_1 + 25I_2 + 10I_3 = 10$ ——— (3).

By solving the equations (1), (2) and (3), we get

$I_1 = \frac{4}{17}$ A , $I_2 = \frac{6}{17}$ A and $I_3 = \frac{-2}{17}$ A.

Accordingly the current in different branches are,

$\Rightarrow$ current in branch (AB) $= I_1 = \frac{4}{17}$ A.

$\Rightarrow$ current in branch (BC) $= I_1 - I_3 = \frac{4}{17} - \left(\frac{-2}{17}\right)$ A

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

$\Rightarrow$ current in branch (DC) $= I_2 + I_3 = \frac{6}{17} + \left(\frac{-2}{17}\right)$ A.

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

$\Rightarrow$ current in branch (AD) $= I_2 = \frac{6}{17}$ A.

$\Rightarrow$ current in branch (BD) $= I_3 = \frac{-2}{17}$ A.

and total current, $I = I_1 + I_2$

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

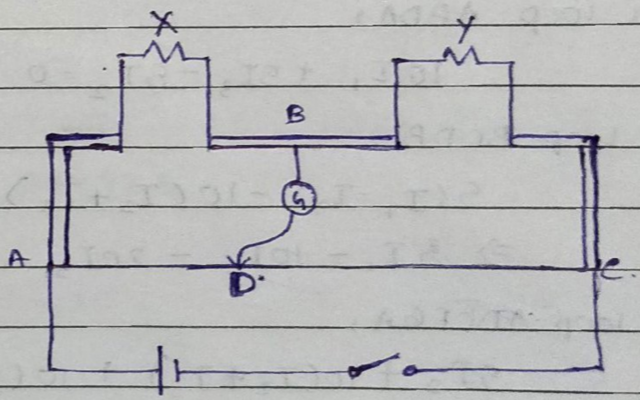
3.10, Here, $l = 39.5$ cm , $R = X = ?$, $S = Y = 12.5\ \Omega$.

As $S = \frac{100 - l}{l} \times R$.

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

$\Rightarrow R = \frac{12.5 \times 39.5}{60.5}$

$= 8.16\ \Omega$.



The connections between resistors in a wheatstone or meter bridge are made to thick copper strips in order to minimise the resistances.

ii) When X and Y are interchanged

$R = Y = 12.5\,\Omega$, $S = X = 8.16\,\Omega$, $l = ?$

$\Rightarrow S = \frac{100 - l}{l} \times R$

$\Rightarrow 8.16 = \frac{100 - l}{l} \times 12.5$

$\Rightarrow 8.16\,l = 1250 - 12.5\,l$

$\Rightarrow l = \frac{1250}{20.66}$

$\Rightarrow l = 60.5\,\Omega$.

iii) When the galvanometer and cell are interchanged then there will be no effect to balancing length. No, the galvanometer will not show any current.

3.11) When the storage battery of 8.0 volt is charged with a dc supply of 120 V, then the net emf of the circuit will be $E = 120 - 8 = 112\,V$.

then $I = \frac{E}{R + r} = \frac{112}{15.5 + 0.5} = 7\,A$.

∴ The terminal voltage of the battery during charging

$V = E + Ir = 8.0 + 7 \times 0.5 = 11.5\,V$.

The purpose of having a series resistor in the charging circuit is that it limits the current drawn from the external source.

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3.12) Here, $E_1 = 1.25\,V$, $l_1 = 35\,cm$, $l_2 = 63\,cm$, $E_2 = ?$

Now, $\frac{E_2}{E_1} = \frac{l_2}{l_1}$

$\Rightarrow E_2 = \frac{l_2}{l_1} \times E_1$

$= \frac{63 \times 1.25}{35}$

$= 2.25\,V$.

3.13) Here, $n = 8.5 \times 10^{28}\,m^{-3}$, $l = 3\,m$.

$A = 2.0 \times 10^{-6}\,m^2$, $e = 1.6 \times 10^{-19}\,C$, $I = 3.0\,A$

Drift speed,

$v_d = \frac{I}{enA}$

$= \frac{3}{1.6 \times 10^{-19} \times 8.5 \times 10^{28} \times 2 \times 10^{-6}}\,m/s$

$= \frac{3}{16 \times 85 \times 2 \times 10}\,m/s$

$= 1.1 \times 10^{-4}\,m/s$.

Required time,

$t = \frac{l}{v_d} = \frac{3}{1.1 \times 10^{-4}} = 2.73 \times 10^4\,s = 7.57$ hour

3.14) Surface charge density, $\sigma = 10^{-9}\,C\,m^{-2}$

Radius of the earth, $R = 6.37 \times 10^6\,m$

Current, $I = 1800\,A$.

Total charge of the globe, q = Surface area $\times \sigma$

$= 4\pi R^2 \sigma$

$= 4 \times 3.14 \times (6.37 \times 10^6)^2 \times 10^{-9}$

$= 509.65 \times 10^3\,C$

And required time, $t = \frac{q}{I} = \frac{509.65 \times 10^3}{1800} = 283.13 \text{ s}$

3.15) a) Here, $E = 2V$, $r = 0.015\ \Omega$, $R = 8.5\ \Omega$, $n = 6$

When the cells are joined in series, the current

$$I = \frac{nE}{R + nr} = \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} = 1.4 \text{ A}$$

Terminal voltage, $V = IR$

$$= 1.4 \times 8.5 = 11.9 \text{ V}$$

b) $E = 1.9$ V, $r = 380\ \Omega$, $R = 0$ (for maximum current)

$$I_{max} = \frac{E}{r} = \frac{1.9}{380} = 0.005 \text{ A}$$

~~3.16) Mass = volume × density = Al d~~

~~$= \frac{\rho l}{R} . ld = \frac{\rho d l^2}{R}$~~ ~~$[\because R = \rho \frac{l}{A}]$~~

~~Ratio of mass = ρ~~

3.16) Given, $\rho_{Al} = 2.63 \times 10^{-8}\ \Omega m$, $\rho_{cu} = 1.72 \times 10^{-8}\ \Omega m$.

relative density of Al = 2.7 and relative density of Cu = 8.9.

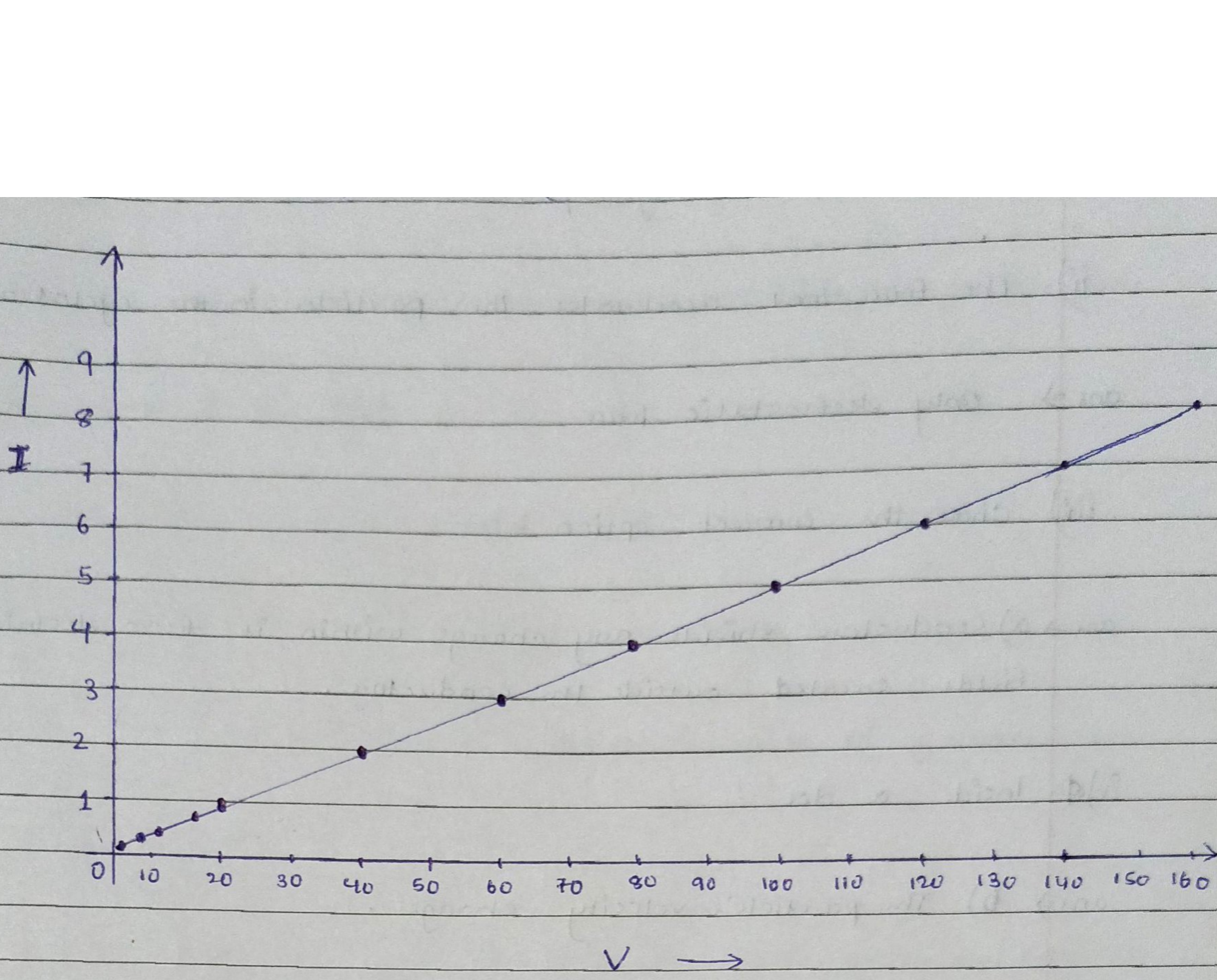
Mass = volume × density = Al d.

$$= \frac{\rho l}{R} . ld = \frac{\rho d l^2}{R} \quad [\because R = \rho \frac{l}{A}]$$

$$\text{Ratio} = \frac{\rho_{cu} d_{cu}}{\rho_{Al} d_{Al}} = \frac{1.72 \times 10^{-8} \times 8.9}{2.63 \times 10^{-8} \times 2.7} = 2.1558 = 2.2.$$

So, copper wire is 2.2 times heavier than aluminium wire, as aluminium is lighter, it is preferred for long suspension of cables otherwise heavy cable may sag down due to its own weight.

3.17)



The V-I graph is almost a straight line.

∴ Manganin resistor is an ohmic resistor of given ranges of ~~volt~~ voltage and current. As the current increases from 0 to 8 A, the temperature increases but the resistance of manganin does not change. This indicates that the temperature coefficient of resistivity of manganin alloy is negligibly small.

3.18. a) Only current is constant because it is given to be steady. Other quantities like current density, electric field and drift speed vary inversely with area of cross-section.

b) No, Ohm's law is not universally applicable for all conducting elements. Examples of non-ohmic elements are vacuum diode, semiconductor diode, thyristor etc.

c) The maximum current that can be drawn from a voltage supply is $I_{max} = \frac{E}{r}$.

d) If the ~~internal~~ internal resistance is not very large, then the current will exceed the safety limits in case the circuit is short-circuited accidentally.

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

3.20) a) For maximum effective resistance, all the n resistors must be connected in series.

∴ Maximum effective resistance,

$$R_s = nR$$

For minimum effective resistance, all the n resistors must be connected in parallel.

∴ Minimum effective resistance,

$$R_p = \frac{R}{n}.$$

Ratio of the maximum to minimum resistance is

$$\frac{R_s}{R_p} = \frac{nR}{R/n} = \frac{n^2}{1} = n^2 : 1.$$

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

i) Here, Resistors R_1 and R_2 are in parallel combinations, and connected to R_3 in series.

So, $\frac{1}{R_p} = \frac{1}{1} + \frac{1}{2} = \frac{1+2}{2} = \frac{3}{2}$

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

$\therefore R_{equi} = R_p + R_3$

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

$= \frac{11}{3}$

ii) Here, Resistors R_2 and R_3 are in parallel combinations, and connected to R_1 in series.

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

$= \frac{3+2}{6} = \frac{5}{6}$

$\Rightarrow R_p = \frac{6}{5}$.

$\therefore R_{eqv} = R_p + R_1$

$= \frac{6}{5} + 1$

$= \frac{11}{5}$.

iii) Here, R_1, R_2 and R_3 all the resistors are in series.

$\therefore R = R_1 + R_2 + R_3$

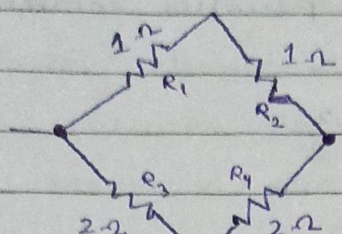
$= 1 + 2 + 3$

$= 6\ \Omega$

iv) Here, R_1, R_2 and R_3 all the resistors are connected in parallel connections.

$$\therefore R = \frac{R_1 + R_2 + R_3}{R_1R_2 + R_2R_3 + R_3R_1} = \frac{1+2+3}{2+6+3} = \frac{6}{11}\ \Omega$$

c) a)



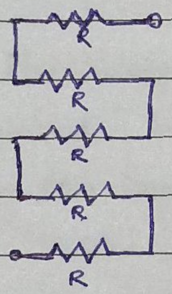
There are 4 units.

Resistance R of one unit, $\frac{1}{R} = \frac{1}{2} + \frac{1}{4} = \frac{2+1}{4} = \frac{3}{4}$.

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

$\therefore$ Resistance of total network (4 units) $= 4 \times \frac{4}{3} = \frac{16}{3}\ \Omega$

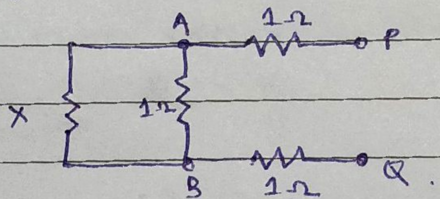
ii)



Here, all the resistors are in series.

$$\Rightarrow R_{eq} = R + R + R + R + R = 5R.$$

3.21) Let the equivalent resistance of the infinite network be X.



Resistance between A and B = Resistance equivalent to parallel combination of X and 1Ω.

$$= \frac{X * 1}{X + 1} = \frac{X}{X+1}.$$

Resistance between P and Q $= \frac{x}{x+1} + 1 + 1$.

$= \frac{x}{x+1} + 2$.

And this is equal to the original resistance x.

$\therefore x = 2 + \frac{x}{1+x}$

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

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

The value of resistance cannot be negative,

$\Rightarrow x = 1 + \sqrt{3} = 2.732\ \Omega$.

Current, $I = \frac{E}{x + r} = \frac{12}{2.732 + 0.5} = 3.713\ A$.

3.22) a) $E_1 = 1.02\ V$, $l_1 = 67.3$ cm, $E_2 = ?$, $l_2 = 82.3$ cm.

$\therefore \frac{E_2}{E_1} = \frac{l_2}{l_1}$

$\Rightarrow \frac{E_2}{1.02} = \frac{82.3}{67.3}$

$\Rightarrow E_2 = \frac{82.3}{67.2} \times 1.02$

$= 1.25 V$.

b) High resistance of 600 kΩ protects the galvanometer for positions far away from the balance point, by decreasing through it.

c) NO, balance point is not affected by high resistance.

d) Yes, the balance point is affected by the internal resistance of the driver cell.

e) NO, the arrangement will not work as if E is greater than the emf of the driver cell of the potentiometer, there will no balance point on the wire AB.

f) The circuit would not work well for determining an extremely small emf. As circuit would be unstable, the balance point would be close to end A. Hence, there would be a large percentage of error.

The given circuit can be modified if a series resistance is connected with wire AB. The potential drop across AB is slightly greater than the emf measured. The percentage error would be small.

2.23) Here, $R = 10\ \Omega$, $l_1 = 58.3$ cm, $X = ?$, $l_2 = 68.5$ cm

then, $\frac{E_2}{E_1} = \frac{IX}{IR} = \frac{X}{R}$

But, $\frac{E_2}{E_1} = \frac{l_2}{l_1}$

$\Rightarrow \frac{X}{R} = \frac{l_2}{l_1}$

$\Rightarrow X = \frac{l_2}{l_1} \cdot R$

$\Rightarrow X = \frac{68.5}{58.3} \times 10$

$= 11.75\ \Omega$.

3.24) Here, $l_1 = 76.3$ cm, $l_2 = 64.8$ cm, $R = 9.5\,\Omega$.

$\therefore r = R\left(\frac{l_1 - l_2}{l_2}\right) = 9.5\left(\frac{76.3 - 64.8}{64.8}\right) = \frac{9.5 \times 11.5}{64.8} = 1.7\,\Omega$.