Exercises

3.1 Emf, $E = 12V$.
Internal resistance of the battery, $r = 0.4\Omega$
Max current drawn from the battery $= I$

According to Ohm's law.
$E = Ir$
$I = \frac{E}{r}$

$= \frac{12}{0.4} = 30A$.

Current drawn from the battery $= 30A$.

3.2 Emf of the battery, $E = 10V$
Internal resistance of the battery $= 3\Omega$
Current in the circuit $= 0.5A$
Resistance of the resistor $= R$
The relation for current using Ohm's law is,
$I = \frac{E}{R+r}$

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

$R + 3 = \frac{10}{0.5} \Rightarrow 20\Omega = R + 3$

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

Terminal ~~voltage~~ voltage of the resistor is
17Ω an

Terminal voltage of the resistor = V
According to Ohm's Law.

$V = IR$
$= 0.5 \times 17$
$= 8.5V$

Terefore, the resistance of the resistor is 17 Ω and the terminal voltage is 8.5 V.

3.3 a) Three resistor of resistance 1Ω, 2Ω, 3Ω are combined in series. Total resistance of the combination is given by the ~~g~~ algebric sum of individual resistances.

Total resistance = $1+2+3 = 6Ω$

b) Current flowing through the circuit = I
Emf of the battery, $E = 12V$
Total resistance of the circuit, $R = 6Ω$.
The relation for current using Ohm's Law is.

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

$= \frac{12}{6} = 2A$.

Potential drop across 1Ω resistor = V_1
From Ohm's law, the value of V_1 :-
$V_1 = 2 \times 1 = 2V$ — (i)

Potential drop across 2 Ω resistor = V_2
Again from Ohm's law, the value of V_2:-
$V_2 = 2 \times 2 = 4V$ ------(ii)

Potential drop across 3 Ω resistor = V_3
Again from Ohm's law. the value of V_3:-
$V_3 = 3 \times 2 = 6V$ ------(iii)

∴ The potential drop across 1 Ω, 3 Ω, 2 Ω resistors are, 2 V, 6 V and 4 V respectively.

3·4a) There are three resistors of resistance.
$R = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 5\Omega$

Total resistance (R) is given by.

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

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

$$= \frac{10+5+4}{20} = \frac{19}{20}$$

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

∴ Total resistance of the combination is $\frac{20}{19}\ \Omega$.

b) Emf of the battery, $V = 20V$

Current (I_1) flowing through resistor R_1:-

$$I_1 = \frac{V}{R_1} = \frac{20}{2} = 10\ A.$$

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Current (I_2) flowing through resistor (R_2) :-

$$I_2 = \frac{V}{R_2} = \frac{20}{4} = 5A.$$

Current (I_3) flowing through resistor (R_3) :-

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

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

$\therefore$ Current through each resistor is 10A, 5A and 4A respectively. and total current = 19A.

3.5 Room Temp, $T = 27°C$
Resistance of the heating element at T, $R = 100\Omega$
Let, T_1 is the increased temperature of the filament.
Resistance of the heating element at T_1, $R_1 = 117\Omega$

Temp. co-efficient of the material of the filament.

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

α is given by the relation :-

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

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

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

$T_1 - 27 = 1000$

$T_1 = 1027°C$

$\therefore$ At 1027°C, the resistance of the element is 117 Ω

3.6 Length of the wire, $l = 15 m$
Area of cross-section of the wire, $a = 6.0 \times 10^{-7} m^2$
Resistance of the material of the wire, $R = 5.0 \Omega$
Resistivity of the material of the wire $= \rho$
Resistance is related with resistivity as:-

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

$$\rho = \frac{Ra}{l}$$

$$= \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7} \ \Omega m$$

$\therefore$ Resistivity of the material is $2 \times 10^{-7} \Omega m$.

3.7. Temp. $T_1 = 27.5°C$
Resistance of silver wire at T_1, $R_1 = 2.1 \Omega$
Temp. $T_2 = 100°C$
Resistance of silver wire at T_2, $R_2 = 2.7 \Omega$
Temp co-efficient of silver $= \alpha$

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

$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039 \ °C^{-1}$$

$\therefore$ The temp. co-efficient of silver is $0.0039 \ °C^{-1}$

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3.8 Supply voltage $V = 230V$
Initial current drawn, $I_1 = 3.2A$.
Initial resistance $= R_1$

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

$$= \frac{230}{3.2} = 71.87\ \Omega.$$

Steady state value of the current, $I_2 = 2.8A$

Resistance at the steady state $= R_2$, which is given as:-

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

Temp. co-efficient of nichrome, $\alpha = 1.70 \times 10^{-4}\ °C^{-1}$
Initial temp. of nichrome, $T_1 = 27.0°C$
Steady state temp. reached by nichrome $= T_2$

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

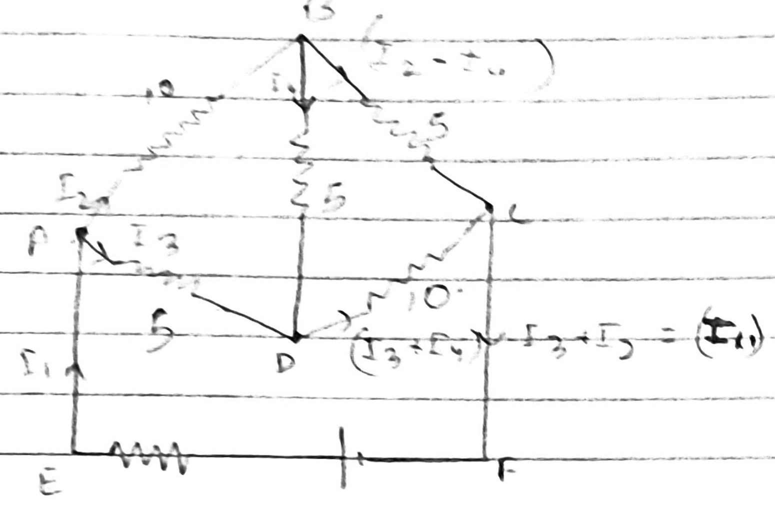
$$T_2 - 27°C = \frac{82.14 - 71.87}{71.87 \times 1.7 \times 10^{-4}} = 8.$$

$$T_2 - \cancel{8}27 = 840.5$$

$$T_2 = 840.5 + 27 = 867.5°C$$

∴ Rs The steady temp. of the heating element is 867.5°C.

3.9



I_1 = current flowing through the outer circuit.
I_2 = Current flowing through branch AB
I_3 = Current flowing through branch AD
$I_2 - I_4$ = Current flowing through branch BC
$I_3 + I_4$ = Current flowing through branch DC
I_4 = ~~so~~ current flowing through branch BD

For closed circuit ABDA, potential is zero

$$10 I_2 + 5 I_4 - 5 I_3 = 0$$
$$2 I_2 + I_4 - I_3 = 0$$
$$I_3 = 2 I_2 + I_4 \quad \text{—} \quad (1)$$

For closed ~~cir~~ circuit ABCFEA, potential is zero ?

$$5(I_2 - I_4) - 10(I_3 + I_4) - 5 I_4 = 0$$
$$5 I_2 - 5 I_4 - 10 I_3 - 10 I_4 - 5 I_4 = 0$$
$$5 I_2 - 10 I_3 - 20 I_4 = 0$$
$$I_2 = 2 I_3 + 4 I_4 \quad \text{—} \quad (2)$$

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Four closed circuit BCDD, potential is zero,

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

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

$\boxed{\cancel{10I_2 + 5I_4 - 5I_3 = 0} \quad \cancel{I_3 = 2I_2 + I_4}}$

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

$I_2 = 2I_3 - 4I_4$ — (2)

Four the closed circuit ABCFEA, potential is zero,

$-10 + 10(I_2) + 10(I_2) + 5(I_2 - I_4) = 0$

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

$3I_2 + 2I_1 - I_4 = 2$ — (3)

from eqⁿ (1) & (2), we obtain

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

$I_3 = 4I_3 + 8I_4 + I_4$

$-3I_3 = 9I_4$

$3I_4 = I_3$ — (4).

Putting equation (4) in eqⁿ (1),

$I_3 = 2I_4 + I_4$

$-4I_4 = 2I_2$

$I_2 = -2I_4$ — (5)

It is evident from the given figure that,

$I_1 = I_3 + I_2$ — (6)

Putting eqⁿ (6) in (1).

$$3I_2 + 2(I_3 + I_2) - I_4 = 2$$
$$5I_2 + 2I_3 - I_4 = 2 \quad \text{———} \quad (7).$$

Putting eqⁿ (4) & (5) in eqⁿ (7)

$$5(-2I_4) + 2(-3I_4) - I_4 = 2$$
$$-10I_4 - 6I_4 - I_4 = 2$$
$$17I_4 = -2$$
$$I_4 = \frac{-2}{17}\ A.$$

Eqⁿ (4) reduces to

$$I_3 = -3(I_4)$$
$$= -3\left(\frac{-2}{17}\right) = \frac{6}{17}\ A$$

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

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

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

$$I_1 = I_3 + I_2$$
$$= \frac{6}{17} + \frac{4}{17} = \frac{10}{17}\ A.$$

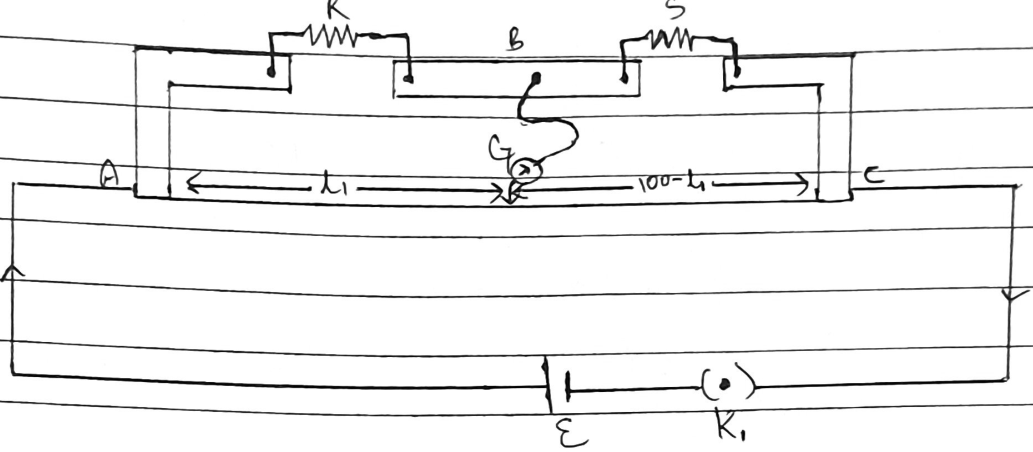
∴ Current in Branch

$AB = \frac{4}{17}\ A$, $CD = \frac{-4}{17}\ A$, $BD = \frac{-2}{17}$

$BC = \frac{6}{17}\ A$, $AD = \frac{6}{17}\ A$.

Total current $= \dfrac{4+6-4+6\cdot 2}{17} = \dfrac{10}{17}$ A.

3.10



a) Balance point from end A, $l_1 = 39.5$ cm
Resistance of the resistor $Y = 12.5\ \Omega$
Condition for the balance is given as,

$$\frac{X}{Y} = \frac{100-l_1}{l_1}$$

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

Therefore, the resistance of resistor X is $8.2\ \Omega$

The connection between resistors in a wheatstone or metre bridge is made of thick copper strips to minimize the resistance, which is not taken into consideration in the bridge formula.

b) If X and Y are interchanged, then l_1 and $100-l_2$ get interchanged.
The balance point of the bridge will be $100-l_1$ from A.

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$100 - l_1 = 100 - 39.5 = 60.5\,cm$

∴ The balance point is 60.5 cm from A.

c) When the galvanometer and cell are interchanged at the balance point of the bridge, the galvanometer will show no deflection. Hence, no current ~~should~~ would flow through the galvanometer.

3.11 $\mathcal{E} = 8.0\,V$

$r = 0.5\,\Omega$

$V = 120\,V$

$R = 15.5\,\Omega$

Voltage in the circuit $= V'$

R is connected to the storage battery in series. Hence,

$V' = V - \mathcal{E}$

$V' = 120 - 8 = 112\,V$

Current flowing in the circuit $= I$, so,

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

$= \frac{112}{15.5 + 0.5} = \frac{112}{16} = 7\,A$

Voltage across resistor R $\Rightarrow IR = 7 \times 15.5 = 108.5\,V$

Terminal voltage of battery $= 120 - 108.5 = 11.5\,V$.

A series resistor in a charging circuit limits the current drawn from the external source. The current. The current will be extreamly high in its absence. This is very dangerous.

3.12 $E_1 = 1.25V$

$l_1 = 35cm$

The cell is replaced by another cell of emf E_2.

$l_2 = 63cm$

The balance condition is given by.

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

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

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

∴ Emf of the second cell = 2.25V.

3.13 Number density of free electron in copper conductor, $n = 8.5 \times 10^{28} m^{-3}$

$l = 3.0m$

$A = 200 \times 10^{-6} m^2$

$I = 3.0A$.

Current carried by the wire :-

$I = nAeV_d$

where,

e = Electron charge $= 1.6 \times 10^{-19}C$

V_d = Drift velocity = $\frac{\text{length of the wire } (l)}{\text{Time taken to cover } (t)}$

So

$I = \frac{nAe\,l}{t}$

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

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

$t = 2.7 \times 10^{4}\,s$

$\therefore$ Time taken by an electron to drift from one end of the wire to the other is $2.7 \times 10^{4}\,s$.

3.14. Surface charge density of the earth, $\sigma = 10^{-9}\,C\,m^{-2}$
Current over the entire globe, $I = 1800\,A$
Radius of the earth, $r = 6.37 \times 10^{6}\,m$
Surface area of the earth,

$A = 4\pi r^2$
$= 4\pi (6.37 \times 10^{6})^2$
$= 5.09 \times 10^{14}\,m^2$

Charge on the earth's surface,
$q = \sigma \times A$
$= 10^{-9} \times 5.09 \times 10^{14}$
$= 5.09 \times 10^{5}\,C$

Time taken to neutralize the earth's surface = t,
$I = \frac{q}{t}$

So,

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

$= \frac{5.09 \times 10^5}{1800} = 282.77s$

$\therefore$ Time taken to neutralize the earth's surface $= 282.77s$

2.15 a) Number of secondary cells, $n = 6$
Emf of each secondary cell, $E = 2.00V$
Internal resistance of each ~~cell~~ cell, $r = 0.015\Omega$
Series resistor is connected to the combination of cells.
Resistance of the resistor, $R = 8.5\Omega$

Current drawn from the supply $= I$,

$I = \frac{nE}{R + nr}$

$= \frac{6 \times 2}{8.5 + 6 \times 0.015}$

$= \frac{12}{8.89} = 1.39A$

Terminal voltage, $V = IR = 1.39 \times 8.5 = 11.87A$.

$\therefore$ The current drawn from the supply is 1.39 A and terminal voltage is 11.87A.

b) After a long use, emf of the secondary cell, $\mathcal{E} = 1.9V$

Internal resistance of the cell, $r = 380\Omega$

Max current $= \frac{E}{r} = \frac{1.9}{380} = 0.005A$.

~~Hence, ma~~

$\therefore$ The max current drawn from the cell is 0.005 A. Since a large current is

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required to start the motor of a car, the cell cannot be used to start a motor.

3.16. Resistivity of aluminium $\rho_{Al} = 2.63 \times 10^{-8}\ \Omega m$
Relative density of Al, $d_1 = 2.7$
Let, l_1 be the length of ~~ako~~ Al wire and m_1 its mass.
Resistance of Al wire $= R_1$
Area of Al wire $= A_1$
Resistivity of Cu, $\rho_{Cu} = 1.72 \times 10^{-8}\ \Omega m$
Relative density of Cu, $d_2 = 8.9$
Let, l_2 be the length of Cu wire and m_2 be its mass.
Resistance of the copper wire $= R_2$
Area of Cu wire $= A_2$
The two relations can be written as

$$R_1 = \frac{\rho_1 l_1}{A_1} \quad \text{—— (1)}$$

$$R_2 = \frac{\rho_2 l_2}{A_2} \quad \text{—— (2)}$$

It is given that,

$$R_1 = R_2$$

$$\frac{\rho_1 l_1}{A_1} = \frac{\rho_2 l_2}{A_2}$$

and, $l_1 = l_2$

$$\therefore \quad \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$$

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

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

Mass of Al wire,

$m_1 = V \times d$

$= A_1 l_1 \times d_1$ — (3)

mass of Cu wire,

$m_2 = V \times d$

$= A_2 l_2 d_2$ — (4)

Dividing eq^n (3) ~~& (4)~~ by eq^n (4).

$$\frac{m_1}{m_2} = \frac{A_1 l_1 d_1}{A_2 l_2 d_2}$$

$$\frac{m_1}{m_2} = \frac{A_1 d_1}{A_2 d_2} \quad \{\because l_1 = l_2\}$$

$$\frac{m_1}{m_2} = \frac{2.63}{1.72} \times \frac{2.7}{8.9} = 0.46$$

$\because$ From this ratio we get to know that m_1 is less than m_2. Hence, Al is lighter that copper.

$\therefore$ ~~Aluminimum~~ Aluminium is lighter and preferred for over head power ~~caples~~ cables over copper.

S.17 It can be inferred from the given table that the ratio of voltage with current is a constant, which is equal to 19.7. Hence, manganin is an Ohmic conductor i.e., the alloy obey Ohm's law. According to Ohm's law, the ratio of voltage with current is the resistance of the conductor. Hence, the resistance of manganin is $19.7\ \Omega$.

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

b) No, ohm's law is not universally applicable for all conducting elements. ~~vacuu~~ Vacuum diode semi-conductor is a non-ohmic conductor.

c) According to Ohm's law, the relation for the potential is $V = IR$
Voltage (V) is directly proportional to current (I)
R is the internal resistance of the source
$I = \frac{V}{R}$.

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

d) In order to prohibit the current from exceeding the saftey 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 ~~saftey~~ safety limits in case of a short circuit.

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3.19 a) Alloys of metals usually have greater resistivity than than 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 numbers of resistors = n
Resistance of each resistor = R.

i) When n resistors are connected in series, effective resistance R_1 is the maximum, given by the product nR.

Hence, maximum resistance of the combination, $R_1 = nR$.

ii) When n resistors are connected in parallel, the effective resistance (R_2) is the minimum, given by the ratio $\frac{R}{n}$

Hence ~~minimum~~ minimum resistance of the combination, $R_2 = \frac{R}{n}$

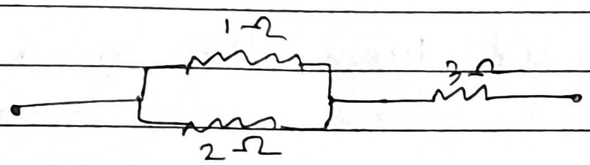
The ratio of the maximum to the minimum resistance is,

$$\frac{R_1}{R_2} = \frac{nR}{\frac{R}{n}} = n^2$$

b) The resistance of the given resistors is,

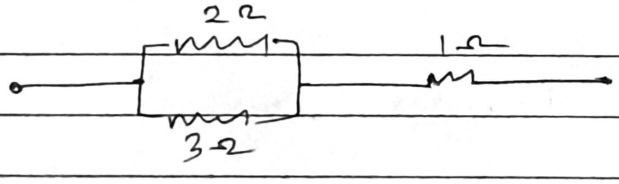
$R_1 = 1\,\Omega$, $R_2 = 2\,\Omega$, $R_3 = 3\,\Omega$

i) $R_{eq} = \frac{11}{3}\,\Omega$



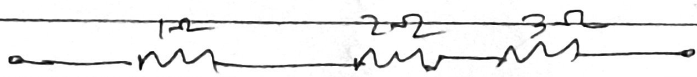
$$R_{eq} = \frac{2\times1}{2+1} + 3 = \frac{2}{3} + 3 = \frac{11}{3}$$

ii) $R_{eq} = \frac{11}{5}\,\Omega$



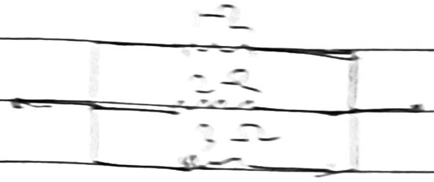
$$R_{eq} = \frac{2\times3}{2+3} + 1 = \frac{6}{5} + 1 = \frac{11}{5}\,\Omega.$$

iii) $R_{eq} = 6\,\Omega$



$$R_{eq} = R_1 + R_2 + R_3 = 1 + 2 + 3 = 6\,\Omega.$$

i) $R_{eq} = \frac{6}{11}\Omega$



$\frac{1}{R_{eq}} = \frac{1}{1}+\frac{1}{2}+\frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6}\Omega$

$R_{eq} = \frac{6}{11}\Omega$.

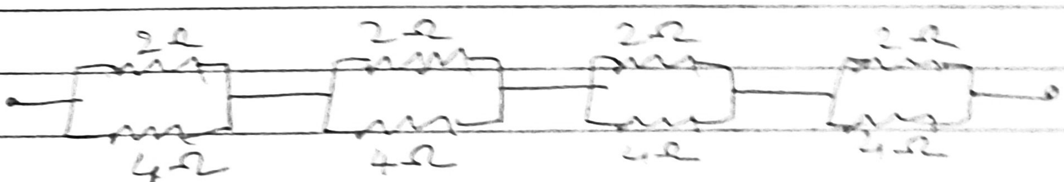
(ii) It can be observed from the given circuit that in the first small loop, two resistors of resistance 1Ω each are connected in series

So, $R_{eq} = 1+1 = 2\Omega$

Also, two resistors of 2Ω each are also connected in series.

So, $R_{eq} = 2+2 = 4\Omega$.

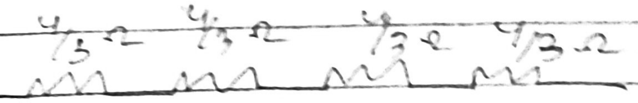
∴ Circuit can be drawn as.



Now, for the 1st loop :-

$R_{eq} = \frac{2\times 4}{2+4} = \frac{8}{6} = \frac{4}{3}\Omega$

Now, the circuit →



Now, $R_{eq} = 4\times\frac{4}{3} = \frac{16}{3}\Omega$

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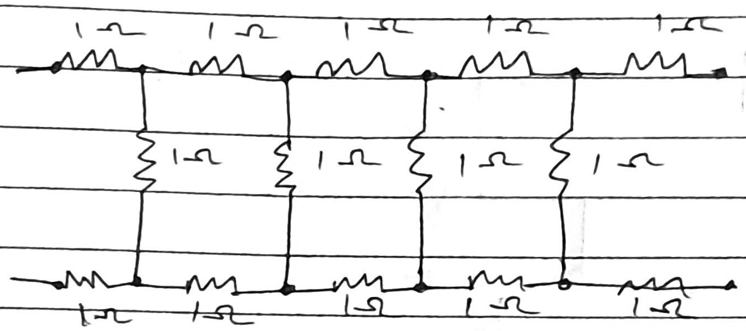
b) In the given circuit all the resistar are connected in series.

so,

$R_{eq} = R + R + R + R + R$

$= 5\Omega$

3.21.



The resistance of each resistor, $R = 1\Omega$
The network is infinite

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

$$(R_{eq})^2 - 2R_{eq} - 2 = 0$$

$$R_{eq} = \frac{2 \pm \sqrt{4+8}}{2}$$

$$= \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$$

Negative value of R_{eq} can not be accepted.

so,

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

Internal resistance of the circuit, $r = 0.5\Omega$

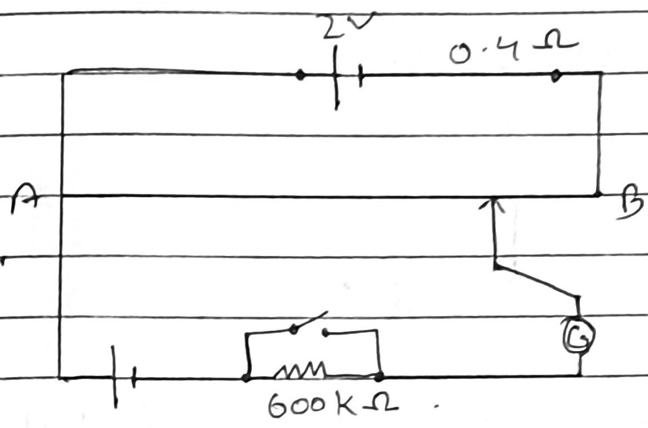
Total resistance $= 2.73 + 0.5 = 3.23\Omega$

Current drawn from the circuit, $I = \frac{V}{R}$

$= \frac{12}{3.23}$

$= 3.72\ A.$

3.22



a) Emf of the cell, $E_1 = 1.02\ V$

$l_1 = 67.3\ cm$

$l_2 = 82.3\ cm$

So,

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

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

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

b) The purpose of using the high resistance of 600 kΩ is to reduce the current through the galvanometer

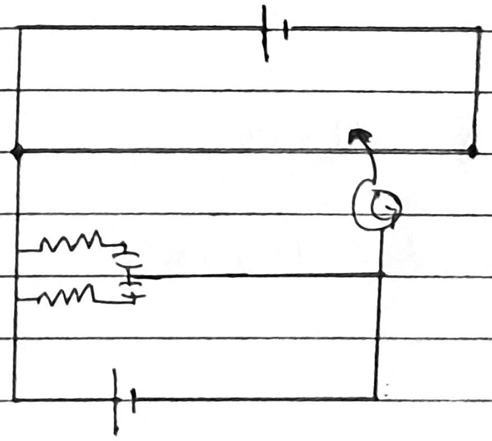
c) The balance point is not affected by the presence of high resistance.

d) The point is not affected by the ~~p~~internal resistance of the driver cell.

e) The method would not work if the driver cell of the potentiometer had an emf of 1.0V instead of 2.0V. This is because if the emf ~~of~~ 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.

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

3.23



$R = 10.0\,\Omega$

$l_1 = 58.3\text{cm}.$

current $= i$

P.D across R, $E_1 = iR$

Resistance of unknown resistor $= x$

$l_2 = 68.5\text{cm}$

PD across X, $E_2 = iX$.

So,

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

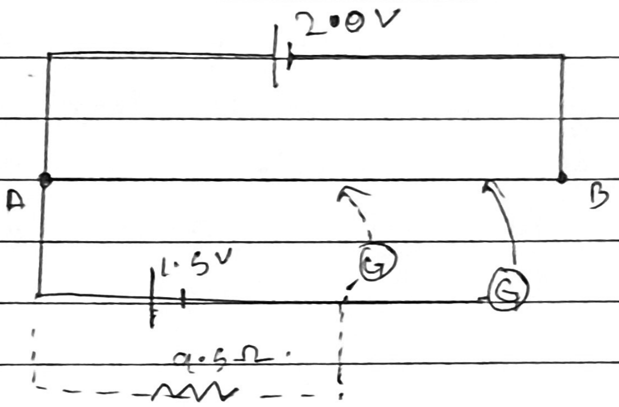
$$\frac{iR}{iX} = \frac{l_1}{l_2}$$

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

$$= \frac{68.5}{58.3} \times 10 = 11.749\ \Omega$$

∴ Value of unknown resistor $X = 11.75\ \Omega$

3.24



Internal resistance of cell = r.

$l_1 = 76.3$ cm

External resistance, $R = 9.5\ \Omega$

$l_2 = 64.8$ cm

Current = I.

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

$$= \frac{76.3 - 64.8}{64.8} \times 9.5 = 1.68\ \Omega$$

∴ Resistance of the cell $= 1.68\ \Omega$