Current Electricity

NCERT Exercise

3.1) Here $\mathcal{E} = 12V$, $r = 0.4\,\Omega$

The current drawn from the battery will be maximum when the external resistance in the circuit is zero

$R = 0$

$$I_{max} = \frac{\mathcal{E}}{r} = \frac{12}{0.4}$$

$$= 30A$$

3.2)

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

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

$$R = \frac{\mathcal{E}}{I} - r = \frac{10}{0.5} - 3$$

$$= 17\,\Omega$$

Terminal voltage,

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

$$= 8.5V$$

3.3) i) $R = R_1 + R_2 + R_3 = 6\,\Omega$

ii) $I = \frac{\mathcal{E}}{R} = \frac{12}{6} = 2A$

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

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

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

3.4) i) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

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

$= \frac{19}{20}$

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

ii) $I_1 = \frac{\varepsilon}{R_1} = \frac{20}{2} = 10 A$,

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

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

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

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

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

$= \frac{117 - 100}{100 \times 1.70 \times 10^{-4}}$ $= 1000$

$t_2 = 1000 + t_1$
$= 1000 + 27$
$= 1027°C$

3.6) $l = 15 m$

$A = 6 \times 10^{-7} m^2$

$R = 5 \Omega$

$$\rho = \frac{RA}{l} = \frac{5 \times 6 \times 10^{-7}}{15}$$

$$= 2 \times 10^{-7} \Omega m$$

3.7) $R_1 = 2.1 \Omega$

$t_1 = 27.5°C$ R_2

$R_2 = 2.7 \Omega$

$t_2 = 100°C$

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

$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = \frac{0.6}{21 \times 72.5}$$

$$= 0.00394 °C^{-1}$$

3.8) $V = 230 V$

$I_1 = 32 A$

$I_2 = 2.8 A$

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

Resistance at room temperature

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

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

$$\therefore t_2 - t_1 = \frac{R_2 - R_1}{R_1 \alpha} = \frac{82.143 - 71.875}{71.875 \times 1.70 \times 10^{-4}}$$

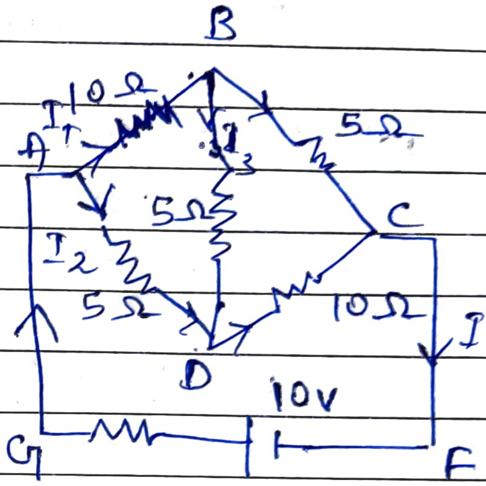
$= \frac{10.268 \times 10^4}{71.875 \times 1.7} = 840.35^\circ C$

$t_2 = 840.35 + 27$

$= 867.35^\circ C$

3.9) For loop ABDA

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



For loop BCDB

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

For loop ADCFGA

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

$10 I_1 - 5 I_2 + 5 I_3 = 0$ —— (1)

$5 I_1 - 10 I_2 - 20 I_3 = 0$ —— (2)

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

solving equation (1), (2) and (3)

$I_1 = \frac{4}{17}$ A

$I_2 = \frac{6}{17}$ A

$I_3 = -\frac{2}{17}$ A

$I_{AB} = I_1 = \frac{4}{17}$ A

$I_{BC} = I_1 - I_3 = \frac{6}{17}$ A

$I_{DC} = I_2 + I_3 = \frac{4}{17}$ A

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$I_{AD} = I_2 = \frac{6}{17} A$

$I_{BD} = I_3 = -\frac{2}{17} A$

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

3.10) $l = 35.9 cm$
$R = X = 7$
$S = Y = 12.5 \Omega$

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

$\therefore 125 = \frac{100 - 39.5}{39.5} \times R$

$R = \frac{12.5 \times 39.5}{60.5} = 8.16 \Omega$

Connection are made by thick copper strips to ~~~~ minimise the resistance OR connection where are not account for in the above formula.

ii) when X and Y are interchanged

$R = Y = 12.5 \Omega$
$S = X = 8.16$
$S = \frac{100 - l}{l} \times R$

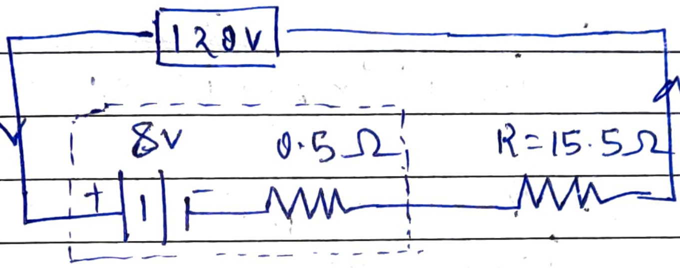
$\Rightarrow 8.16 = \frac{100 - l}{l} \times 125$

$\Rightarrow 8.16 l = 1250 - 12.5 l$

$l = \frac{1250}{20.66} = 60.5 cm$ from end A

iii) When the galvanometer and cell are interchanged at the balance point, the conditions of the balanced bridge are still satisfied and so again the galvanometer will not show any current.

3.11) $\mathcal{E} = 120 - 8 = 112V$



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

The terminal voltage of the battery during charging

$$V = \mathcal{E} + Ir = 8 + 7 \times 0.5$$
$$= 11.5V$$

The series resistor limits the current drawn from the external source. In its absence the current will be dangerously high.

3.12) $\mathcal{E}_1 = 1.25\ V,\ l_1 = 35\ cm$

$l_2 = 63\ cm$

$$\mathcal{E}_2 = \frac{l_2}{l_1} \times \mathcal{E}_1 = \frac{63 \times 1.25}{35} = 2.25V$$

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

$l = 3\ m$

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

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

$I = 3\ A$

Drift speed, $v_d = \frac{I}{enA}$

$= \frac{3}{1.6 \times 10^{-19} \times 8.5 \times 10^{28} \times 2 \times 10^{-6}}\ ms^{-1}$

$= \frac{3}{16 \times 85 \times 2 \times 10}\ ms^{-1}$

$= 1.1 \times 10^{-4}\ ms^{-1}$

Required time,

$t = \frac{l}{v_d} = \frac{3}{1.1 \times 10^{-4}} s = 27.3 \times 10^{4} s$

$= 7.57 h$

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

Radius of Earth, $R = 6.37 \times 10^{6} m$

Current, $I = 1800 A$

Total charge, q = surface area $\times \sigma$

$= 4\pi R^2 \sigma$

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

$= 509.65 \times 10^{3} C$

Required time, $t = \frac{q}{I}$

$= \frac{509.65 \times 10^{3}}{1800} = 283.135$

$= 283 s.$

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3.15) a) $\mathcal{E} = 2V$

$r = 0.015\,\Omega$

$R = 8.5\,\Omega$

$n = 6$

$$I = \frac{n\mathcal{E}}{R+nr} = \frac{6\times 2}{8.5+6\times 0.015} = \frac{12}{8.59}\ A$$

$$= 1.4\ A$$

Terminal voltage

$$V = IR = 1.4 \times 8.5 = 11.9\ V$$

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

$r = 380\,\Omega$

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

This secondary cell cannot drive the starting motor of a car because that requires a large current of about 100 A for a few second.

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

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

3.16) Mass = volume × density

$= Ald$

$$= \frac{\rho l}{R} \cdot ld = \frac{\rho d l^2}{R}$$

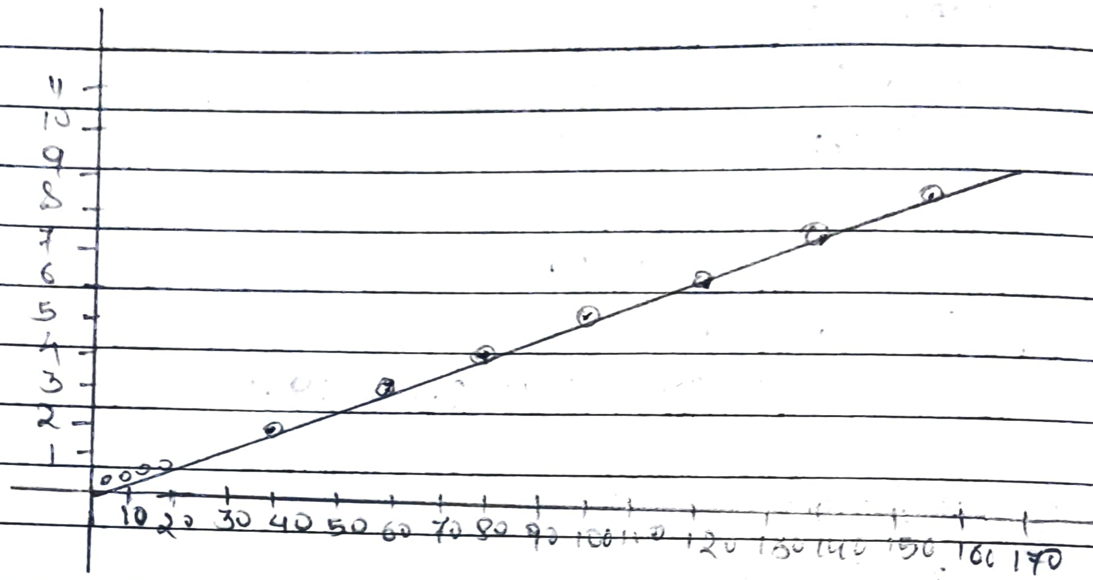
As the two wire are of equal length and have the same resistance their mass ratio will be

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

$$= 2.2$$

i.e, copper wire is 2.2 time heavier than aluminium wire.

3.17)



Since VI graph is almost a straight line, therefore manganin resistor is an ohmic resistor for given range of voltage and current. As the current increases from 0 to 8A, the temperature increase but the resistance of maganium does not change.

3.18) (a) Only current is constant because it is given to be steady. Other quantities : 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 element. Example of non ohmic element are vaccum diode, semicoductor diode, thyristor, gas discharge tube, electrolytic solution etc.

(c) The maximum current that can be drawn from a voltage supply is given by

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$$I_{max} = \frac{\varepsilon}{r}$$

(d) If the 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 resistor must be connected in series

$$R_s = nR$$

For minimum effective resistance all the n resistor must be connected in parallel. It is given by

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \cdots n \text{ term} = \frac{n}{R}$$

∴ Minimum effect resistance

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

Ratio of the maximum

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

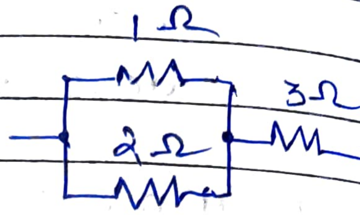
(b) Here $R_1 = 1\Omega$,
$R_2 = 2\Omega$

i) when parallel combination is connected in series with 3Ω resistor

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

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

$$= \frac{11}{3}\,\Omega$$

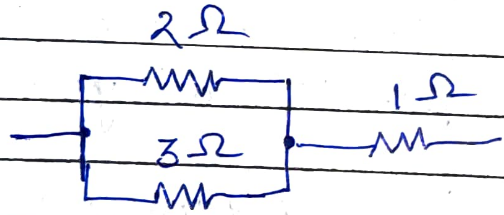


ii) when parallel combination of 2Ω and 3Ω resistor is connected in series with 1Ω resistor

$$R = \frac{R_2 R_3}{R_2 + R_3} + R_1 = \frac{2 \times 3}{2+3} + 1$$

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

$$= \frac{11}{5}\,\Omega$$

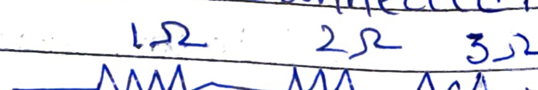


(iii) When the three resistance are connected in series

$$R = R_1 + R_2 + R_3$$

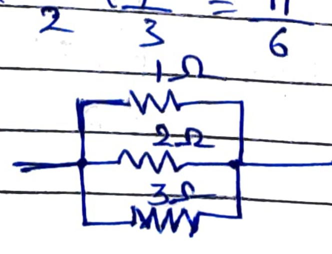
$$= (1+2+3)\,\Omega$$

$$= 6\,\Omega$$

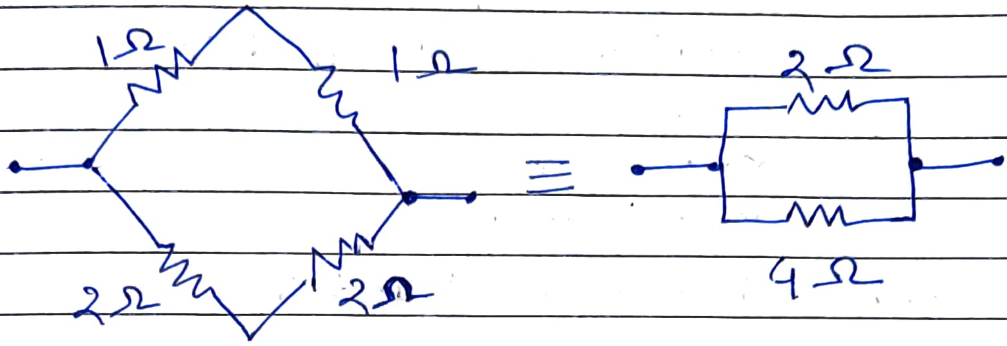


iv) when all the resistances are connected in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{11}{6}$$



(c)



Resistance R, $\frac{1}{R} = \frac{1}{2} + \frac{1}{4}$

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

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

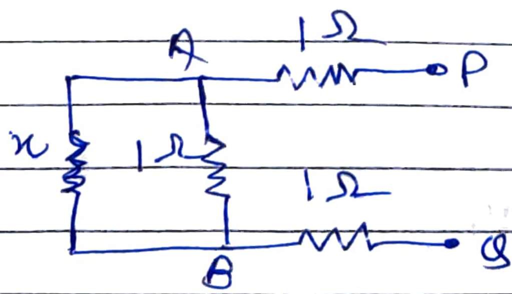
Resistance of the total network

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

(ii) The network is a series combination of 5 resistor, each of resistance R

Equivalent resistance $= 5R$

3.21) Let the equivalent resistance of the infinite network be x. This network consists of infinite units of three resistor 1Ω, 1Ω, 1Ω. The addition of one more such unit across AB will not affect the total ~~res~~ resistance.



Resistance between A and B

= Resistance equivalent to parallel combination of x and 1Ω

$$= \frac{x \times 1}{x \times 1} = \frac{x}{x+1}$$

Resistance between P and Q

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

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

This must be equal to the original resistance x

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

$$x^2 - 2x - 2 = 0$$

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

As the value of resistance cannot be negative,

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

Current, $I = \frac{\text{emf}}{\text{Total resistance}} = \frac{\varepsilon}{x+r} = \frac{12}{2.732 + 0.5}$

$$= 3.713\ A$$

3.22) (a) $\varepsilon_1 = 1.02$

$l_1 = 67.3\text{cm}$

$\varepsilon_2 = \varepsilon = ?$

$l_2 = 82.3\text{cm}$

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \quad \therefore \frac{\varepsilon}{1.02} = \frac{82.3}{67.3}$$

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$\mathcal{E} = \frac{82.3}{67.2} \times 1.02$

$= 1.25\,V$

(b) High resistance of 600kΩ protects the galvanomenter for position for away from the balance point by decreasing current through it.

(c) No, balance point is not affected by resistance because no current flows through the balance point

(d) Yes, the balance point is affected by the internal resistance ~~affects~~ of the driver cell. The internal resistance affects the current though the potentiometer wire, so changes the potential and hence affects the balance point.

(e) No, the arrangement will not work. If $\mathcal{E}$ is greater than the emf of the driver cell of the potentiometer, there will be no balance point on the wire AB

(f) The circuit as it is would be unsitable because the balance point will be very close to the end A and the percentage error in measure-ment will be very large. The circuit is modified by putting a suitable resistor R in series with the wire AB so that potential drop across AB is only sightly greater than the EMF to be measured

3.23) $R = 10\,\Omega$

$l_1 = 58.3$ cm

$l_2 = 68.5$ cm

let ε_1 and ε_2 be the potential drop across R and x respectively and I be the current in potentiometer wire.

$$\text{Then } \frac{\varepsilon_2}{\varepsilon_1} = \frac{Ix}{IR} = \frac{x}{R}$$

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \qquad \therefore \frac{x}{R} = \frac{l_2}{l_1}$$

$$x = \frac{l_2}{l_1} \cdot R$$

$$= \frac{68.5}{58.3} \times 10 = 11.75\,\Omega$$

if there is no balance point, it means potential drop across R or x are greater than the potential drop across the potentiometer wire AB. We should reduce current in the outside circuit suitable by putting a series resistor.

3.24) $l_1 = 76.3$ cm

$l_2 = 64.8$ cm

$R = 9.5\,\Omega$

The formula for the internal ~~or~~ resistance of a cell by potentiometer method is

$$r = R\left(\frac{l_1 - l_2}{l_2}\right) = 9.5\left(\frac{76.3 - 64.8}{64.8}\right)$$

$$= \frac{9.5 \times 11.5}{64.8} = 1.7\,\Omega$$