Electric Current

(1.1) $\mathcal{E} = 12V$
$r = 0.4\,\Omega$
$\therefore$ For maximum current, $R = 0$;
$\Rightarrow I_{max} = \dfrac{\mathcal{E}}{r+R} = \dfrac{12}{0.4+0} = \dfrac{12}{0.4} = 30\,A$

(1.2) $\mathcal{E} = 10V$ $\qquad r = 3\,\Omega$
$I = 0.5A$ $\qquad R = ?$

$\therefore I = \dfrac{\mathcal{E}}{r+R} \Rightarrow 0.5 = \dfrac{10}{3+R}$

$\Rightarrow 10 = 1.5 + 0.5R \Rightarrow 8.5 = 0.5R$
$\Rightarrow R = \dfrac{8.5}{0.5} = 17\,\Omega$

(3.3) $R_1 = 1\,\Omega$ $\qquad R_3 = 3\,\Omega$
$R_2 = 2\,\Omega$

(a) $\therefore R_{eq} = R_1 + R_2 + R_3 = 1+2+3 = 6\,\Omega$

(b) $\dfrac{\mathcal{E}}{r+R} = I \Rightarrow I = \dfrac{12}{6} = 2A$

$V_1 = IR_1 = 2\times1 = 2V$
$V_2 = IR_2 = 2\times2 = 4V$
$V_3 = IR_3 = 2\times3 = 6V$

(3.4) $R_1 = 2\,\Omega$ $\qquad R_3 = 5\,\Omega$
$R_2 = 4\,\Omega$

(a) $\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} \Rightarrow \frac{1}{R_{eq}} = \frac{10+4+5}{20}$

$\Rightarrow R_{eq} = \frac{20}{19}$

(b) $\frac{\varepsilon}{r+R} = I \Rightarrow I = \frac{20}{20/19} \Rightarrow I = 19$

$\Rightarrow V_{net} = IR = 19 \times \frac{20}{19} = \underline{\underline{20V}}$

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

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

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

(3.5) $T_1 = 27^\circ$ $\qquad T_2 = ?$

$R_1 = 100$ $\qquad R_2 = 117$

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

$\Rightarrow \alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \Rightarrow 1.70 \times 10^{-4} = \frac{(117 - 100)}{100\,(T_2 - 27)}$

$\Rightarrow \frac{1.70 \times 10^{-2}}{100} = \frac{17}{T_2 - 27}$

$\Rightarrow T_2 - 27 = 100 \Rightarrow T_2 = 1027^\circ C$

(3.6) $A = 6 \times 10^{-7}$ $\qquad l = 15m$

$R = 5\Omega$

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

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3.7 $R_1 = 2.1$ $R_2 = 2.7$

$T_1 = 27.5$ $T_2 = 100$

$\therefore \alpha = \dfrac{(R_2 - R_1)}{R_1 (T_2 - T_1)} = \dfrac{(2.7 - 2.1)}{2.1(100 - 27.5)}$

$= \dfrac{\cancel{0.6}^{2}}{\cancel{2.1}_{7} \times 72.5} = 0.0039\ ^\circ C^{-1}$

(3.8) $\alpha = 1.7 \times 10^{-4}$

$R_1 = \dfrac{230}{3.2} = 71.87$ $R_2 = \dfrac{230}{2.8} = 82.14$

$T_1 = 27^\circ C$ $T_2 = ?$

$\alpha = \dfrac{R_2 - R_1}{R_1 (T_2 - T_1)} \Rightarrow 1.7 \times 10^{-4} = \dfrac{(82.14 - 71.87)}{71.87 (T_2 - 27)}$

$\Rightarrow T_2 - 27 = 840$

$\Rightarrow T_2 = 867$

(3.9) $\frac{10}{5} \neq \frac{5}{10}$. The bridge is not balanced, hence current will flow through the path BD

Across ABDA

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

Across BCBB

$\Rightarrow 5(I_1 - I_g) - 10(I_2 + I_g) - 5I_g = 0 \Rightarrow 5_1 - 20I_g - 10I_2 = 0$

Across ADCA

$\Rightarrow 5I_2 + 10(I_g + I_2) + 10(I_1 + I_2) = 10$

$\Rightarrow 10I_1 + 25I_2 + 10I_g = 10$

$-10I_1 + 5I_2 = 5I_g \Rightarrow I_g = -2I_1 + I_2$

$\Rightarrow 5I_1 - 20I_g - 10I_2 = 0$

$\Rightarrow I_1 - 4(-2I_1 + I_2) - 2I_2 = 0$

$\Rightarrow 9I_1 - 6I_2 = 0 \Rightarrow 3I_1 - 2I_2 = 0$ — (i)

$10I_1 + 25I_2 + 10I_g = 10$

$\Rightarrow 2I_1 + 5I_2 + 2I_g = 2$

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

$\Rightarrow -2I_1 + 7I_2 = 2$ — (ii)

$-2I_1 + 7I_2 = 2 \Rightarrow -6I_1 + 21I_2 = 6$

$3I_1 - 2I_2 = 0 \qquad 6I_1 - 4I_2 = 0$

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

$3I_1 - 2I_2 = 0 \Rightarrow 3I = 2I_2$

$\Rightarrow 3I_1 = \frac{2 \times 6}{17} \Rightarrow I_1 = \frac{4}{17}$

$I_g = -2I_1 + I_2 = \frac{-2\times4}{17} + \frac{6}{17} = \left(\frac{-2}{17}\right) A$

In branch $AB = \left(\frac{4}{17}\right)$

" " $BC = \frac{4}{17} - \left(\frac{-2}{17}\right) = \left(\frac{6}{17}\right)$

" " $DD = \left(\frac{-2}{17}\right)$

" " $AD = \left(\frac{6}{17}\right)$

" " $BD = \left(\frac{6-2}{17}\right) = \left(\frac{4}{17}\right)$

(3.10)

(a) $l_1 = 39.5$ cm

$X = ?$ $\qquad Y = 12.5$

∴ for balance condition

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

$\Rightarrow X = \frac{60.5}{39.5} \times 12.5 = 8.16\,\Omega$

Thick copper strip are taken here to minimize the resistance.

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(d) If x & y are interchanged, balance point will be l_2

$$\frac{y}{x} = \frac{l_2}{100 - l_2}$$

$$\Rightarrow \frac{y}{x} \quad \frac{12.5}{8.16} = \frac{l_2}{100 - L_2} \Rightarrow l_2 = 60.5$$

(e) If galvanometre & ~~batterie~~ cell are interchanged, the galvanometre will show no deflection, hence no current will flow through it.

8

(3.11) $\varepsilon = 8V$ $\quad$ $V = 120V$

$R = 15.5$ $\quad$ $r = 0.5$

$$V_{net} = V - \varepsilon = 120 - 8 = 112V$$

$$\therefore I = \frac{V_{net}}{R + r} = \frac{112}{15.5 + 0.5} = \frac{112}{16} = 7A$$

Voltage across $R = 7 \times 15.5 = 108.5$

$\therefore$ Terminal voltage = Total voltage − Voltage drop
$= 120 - 108.5$
$= 11.5V$

(3.12) $E_1 = 1.25V$ $\quad$ $l = 35$

$E_2 = ?$ $\quad$ $l_2' = 63$

$$\therefore \frac{E_1}{E_2} = \frac{l_1}{l_2} \Rightarrow \frac{1.25}{E_2} = \frac{35}{63} \Rightarrow E_2 = \frac{1.25 \times \cancel{63}^{9}}{\cancel{35}_{5}}$$

$$= 2.25V$$

(3.13) $n = 8.5 \times 10^{28}$ $\quad A = 2 \times 10^{-6}$

$I = 3A$

$\therefore \cancel{V_d =} \cancel{Ine} \; I = neAV_d \Rightarrow V_d = \frac{I}{neA}$

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

$\therefore$ total time take $= \frac{\text{drift velocity}}{\text{length}}$

$= \frac{\cancel{3}}{\frac{\cancel{3}}{8.5 \times 1.6 \times 2 \times 10^{3}}} = \cancel{3}\ 8.5 \times 1.6 \times 2 \times 10^{3}$

$= 27 \times 10^{3} = 2.7 \times 10^{4} s$

(3.14) $\sigma = 10^{-9} C/m^2$ $\quad I = 1800A$

$r = 6.37 \times 10^{6}$

$\therefore A = 4\pi r^2$

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

$= 5.09 \times 10^{14}$

$q = \sigma A$

$= 10^{-9} \times 5 \times 10^{14} = 5 \times 10^{5}$

$I = \frac{q}{t} = \frac{5 \times 10^{5}}{1800} = 282.77 s$

3.15 (a) No of secondary cells $(n) = 6$
Emf of each cell $= 2.0$
$r = 0.015$ $\qquad R = 8.5$

$\therefore I = \frac{n\varepsilon}{nr+R} \quad \frac{6 \times 2}{6 \times 0.015 + 8.5} = \frac{12}{8.59} = 1.39$

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

(b) For maximum current ; $I_{max} = \frac{\varepsilon}{r}$

$\Rightarrow I_{max} = \frac{1.9}{380} = \frac{19}{3800} = \frac{0.01}{2} = 0.005\,A$

The cell can't be used to drive a motor as it requires very large amount of current.

3.16) $\rho_{Al} = 2.63 \times 10^{-8}\,\Omega m$ $\qquad \rho_{Cu} = 1.72 \times 10^{-8}\,\Omega m$
$(Al)_d = 2.7$ $\qquad (Cu)_d = 8.9$

$R_1 = \frac{\rho l_1}{A_1}$ $\qquad R_2 = \frac{\rho l_2}{A_2}$

$R_1 = R_2 \Rightarrow \frac{\rho_1 l_1}{A_1} = \frac{\rho_2 l_2}{A_2}$

$\Rightarrow \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2} \Rightarrow \frac{A_1}{A_2} = \frac{\rho_1}{\rho_2} = \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}}$

$\Rightarrow \frac{A_1}{A_2} = \frac{2.63}{1.72}$

$m_1 = $ Volume $\times$ density $= A_1 l_1 \times d_1 = A_1 l_2 d_2$
$m_2 = A_2 l_2 d_2$

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

$\Rightarrow \frac{m_1}{m_2} = \frac{A_1 d_1}{A_2 d_2} = \frac{2.63}{1.72} \times \frac{2.7}{8.9} = 0.46$

$\therefore m_1 \geq < m_2$

$\therefore$ Al is lighter than Cu. Thus aluminium is prefe--rred over copper.

3.18

(a) When a steady current flow in a metallic conductor of non-uniform cross section; I = constant. Current density, electric field, & drift speed are inv proportional to the area of cross-section. Thus they are not constant.

(b) No; ohm's law is not applicable for all conducting material. Vacuum diode semi-conductor is non-ohmic cond--uctor, Ohm's law is not valid for it.

(c) Acc to Ohm's law $\Rightarrow V = IR \Rightarrow V \propto I$

R is internal resistance $\Rightarrow I = \frac{V}{R}$

If V is low, R should be very low, so that I will be high.

(d) In order to prevent the current from exceeding the safety limit, a high tension must be applied to have a very large internal resistance. If the int resistance is small, then the current drawn can exceed the saftey limit in case of short circuit.

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(a) $(R_{eq})max = nR$

$(R_{eq})min = \frac{R}{n}$

ratio of max. to min. $= \frac{nR}{R/n} = n^2$

(b) (i) $R = \frac{2\times1}{2+1} + 3 = \frac{2}{3} + 3 = \frac{2+9}{3} = \frac{11}{3}$

2Ω & 1Ω in ||el & 3Ω in series.

(ii) $R = \frac{2\times3}{2+3} + 1 = \frac{6}{5} + 1 = \frac{11}{5}$

2Ω & 3Ω are in ||el & 1Ω in series.

(iii) $R_{eq} = 1+2+3 = 6\Omega$

∴ 1Ω, 2Ω, 3Ω are in series.

(iv) $\frac{1}{R_{eq}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} \Rightarrow \frac{6+3+2}{6} = \frac{11}{6} \Rightarrow R_{eq} = \frac{6}{11}$

∴ 1, 2, 3Ω are in ||el

(c) (i) $R_{eq} = \frac{(1+1)(2+2)}{(1+1+2+2)} \Rightarrow$ ~~$R_{eq} =$~~

$\Rightarrow R_{eq} = \frac{2\times\cancel{4}^{2}}{\cancel{6}3} = \frac{4}{3}$ (For 1 set)

For 4 set $R_{eq} = \frac{4\times4}{3} = \frac{16}{3}$ Ω

(iv) All the resistors are in series.

$\therefore R_{eq} = 5 \times R = 5R$

(3.21) $R_1 = 1\,\Omega$

$R_{eq} = R'$

Network is infinite. Thus eq^n will be

$\Rightarrow R' = 2 + \frac{R'}{(R'+1)}$

$\Rightarrow (R')^2 - 2R' - 2 = 0 \Rightarrow R' = \frac{2 \pm \sqrt{4+8}}{2} = \frac{2 \pm \sqrt{12}}{2}$

$\Rightarrow R = 1 + \sqrt{3} = 1 + 1.73 = 2.73$

$\mathcal{E} = 12V$ $\qquad r = 0.5$

$\therefore I = \frac{\mathcal{E}}{R+r} = \frac{12}{2.73+0.5} = \frac{12}{3.23} = 3.72\,A$

(3.22) $R = 10\,\Omega$ $\qquad X = ?$

$l_1 = 58.3$ $\qquad l_2 = 68.5$

$E_1 = IR$ $\qquad E_2 = IX$

$\therefore \frac{E_1}{E_2} = \frac{l_1}{l_2} \Rightarrow \frac{10}{X} = \frac{58.3}{68.5} \Rightarrow X = \frac{68.5 \times 10}{58.3}$

$\Rightarrow X = 11.749\,\Omega$

If we failed to find the ~~poter~~ balance point with the given cell of emf $\mathcal{E}$. Then the potential of R & X must be reduced by putting a resistance in series in it.