Chapter-3 Current Electricity

Exercise

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

According to ohm's law,

$$E = Ir$$

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

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

3.2) Given,
$E = 10\,V$
$r = 3\,\Omega$
$I = 0.5\,A$
The relation for current using ohm's law is

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

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

$$= \frac{10}{0.5} = 20\,\Omega$$

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

According to ohm's law,
$$V = IR$$
$$= 0.5 \times 17$$
$$= 8.5\,V$$

Therefore, the resistance of the resistor is $17\,\Omega$ and the terminal voltage is $8.5\,V$.

3.3) (a) Three resistors $1\,\Omega$, $2\,\Omega$ & $3\,\Omega$ are combined in series.

Total resistance,

$$1 + 2 + 3 = 6\,\Omega$$

(b) Current = I

$E = 12\,V$

$R = 6\,\Omega$

The relation for current using ohm's law is,

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

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

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

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

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

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

Total resistance,

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

$$= \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{10+5+4}{20}$$

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

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

(b) $V = 20$

$I_1 = \frac{V}{R_1}$

$= \frac{20}{2} = 10\ A$

$I_2 = \frac{V}{R_2}$

$= \frac{20}{4} = 5\ A$

$I_3 = \frac{V}{R_3}$

$= \frac{20}{5} = 4A$

Total current, $I_1 + I_2 + I_3 = 19\ A$

3.5) $T = 27\ °C$

$R = 100\ \Omega$

Let T_1 is the increased temp.

Resistance after that, $R_1 = 117\ \Omega$

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

α is given by the relation,

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

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

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

$T_1 - 27 = 1000$

$T_1 = 1027\ °C$

3.6) $l = 15 m$

$a = 6.0 \times 10^{-7} m^2$

$R = 5.0 \Omega$

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

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

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

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

3.7) Given,

$T_1 = 27.5 °C$

$R_1 = 2.1 \Omega$

$T_2 = 100 °C$

$R_2 = 2.7 \Omega$

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

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

3.8) Given,

$V = 230 V$

$I_1 = 3.2 A$

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

$$= \frac{230}{3.2}$$

$$= 71.87 \Omega$$

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$I_2 = \cancel{2.8}\ 2.8\,A$

$R_2 = \frac{230}{2.8} = 82.17\ \Omega$

Given, $\alpha = 1.70 \times 10^{-4}\,{}^\circ C^{-1}$
$T_1 = 27.0\ {}^\circ C$

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

$T_2 - 27^\circ C = \frac{82.17 - 71.87}{71.87 \times 1.7 \times 10^{-4}} = 840.5$

$T_2 = 840.5 + 27 = 867.5\ {}^\circ C$

3.9) Let I_1, I_2 & I_3 are the different current of flowing through shown branches.

Now, apply KVL in loop

$10 - I\,10 - I_2 5 - (I_2 + I_3)\,10 = 0$

So, putting in KVL eq^n

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

$\Rightarrow 10 - 10 I_1 - 10 I_2 - 5 I_2 - 10 I_2 - 10 I = 0$
$\Rightarrow 10 - 10 I_1 - 25_2 - 10 I_3 = 0$ — (1)

Now, applying KVL in the loop involving I_1, I_2 & I_3.

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$5I_2 - 10I_1 - 5I_3 = 0$ —— (ii)

Now, the third eqn of KVL

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

On solving eqn 3,

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

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

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

Now, the total current

$I = I_1 + I_2 = \frac{4}{17} + \frac{6}{17} = \frac{10}{17}$

$I = \frac{10}{17}$ A

3.10) (a) Balance point from end A, $l_1 = 39.5$ cm

$Y = 12.5\ \Omega$

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

$X = \frac{100 - 39.5}{39.5} \times 10.5 = 8.2\ \Omega$

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

The connection betn resistors in a Wheatstone or meter bridge is made of thick copper strips to minimize resistance

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

$= 100 - 39.5$

$= 60.5$ cm

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

3.11) $E = 8.0$ V

$r = 0.5\ \Omega$

$V = 120$ V

$R = 15.5\ \Omega$

$V' = V - E$

$V' = 120 - 8 = 112$ V

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

$$= \frac{122}{15.5 + 0.5} = \frac{112}{16} = 7A$$

$IR = 7 \times 15.5 = 108.5$ 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 will be extremely high in its absence. This is very dangerous

3.12) $E_1 = 1.25\ V$
$I_1 = 35\ cm$
$I_2 = 63\ cm$

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

$\Rightarrow E_3 = E_1 \times \frac{l_2}{l_1}$

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

3.13) Given,
$n = 8.5 \times 10^{28}\ m^{-3}$
$l = 3.0\ m$
$A = 2.0 \times 10^{-6}\ m^2$
$I = 3.0 A$

$I = nAeVd$
where,
$e = 1.6 \times 10^{-19}\ C$
$Vd = \frac{l}{t}$

$I = neA\frac{l}{t}$

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

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

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

3.14) $\sigma = 10^{-9}$ Cm
$I = 1800$ A
$r = 6.37 \times 10^{6}$ m

Surface area of the earth,

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

Charge on the earth surface,

$$q = \sigma \times A$$
$$= 10^{-9} \times 5.09 \times 10^{14}$$
$$= 5.09 \times 10^{5} \ C$$

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

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

3.15) (a) Given,
$n = 6$
$E = 2.0V$
$r = 0.015 \ \Omega$
$R = 8.5 \ \Omega$

$$I = \frac{nE}{R + nr} = \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} = 13.9A$$

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

Therefore, the current drawn from the supply is 1.39 A and terminal voltage is 11.87 V.

(b) $E = 1.9V$

$R = 380\ \Omega$

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

Since a large current is required to start a motor.

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

$d_1 = 2.7$

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

$d_2 = 8.9$

$R_1 = \rho_1 \frac{l_1}{A_1}$ ---------- (1)

$R_2 = \rho_2 \frac{l_2}{A_2}$ ---------- (2)

It is given that,

$R_1 = R_2$

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

and $l_1 = l_2$

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

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

$= \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}} = \frac{2.63}{1.73}$

Mass of the aluminum wire,

$m_1 = \text{Volume} \times \text{Density}$
$= A_1 l_1 \times d_1 = A_1 l_1 d_1$ ---- (3)

Mass of the copper wire,

$m_2 = \cancel{\text{Volu}}\ \text{Volume} \times \text{Density}$
$= A_2 l_2 \times d_2 = A_2 l_2 d_2$ ------- (4)

Dividing eq^n (3) by eq^n (4), we obtain

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

For, $l_1 = l_2$

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

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

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

If can be inferred from this ratio that 1m is less than 2m. Hence, aluminum is lighter than copper. Since aluminum is ~~lighter~~ lighter, it is ~~preff~~ preferred for overhead power cables over copper.

3.17) It can be inferred from the given the table that ratio of voltage with current is a constant, which is equal to 19.7. Hence, manganin is an ohmic ~~xxxx~~ conductor i.e, the alloy obeys ohm's law. According to Ohm's law, the ratio of voltage with current is the resistance of the conductor. Hence, the resistance of ~~xxxx~~ manganin is 19.7 Ω.

3.18) (a) When a steady current flows in a metallic Conductor of non-uniform cross-section, the ~~current~~ current flowing through the conductor is constant. Current density, electric field and drift speed are inversely 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. ~~xxxxxx~~ Vacuum diode semi-conductor is a non-ohmic conductor. Ohm's law is not valid for it.

(c) According to Ohm's law, the relation for the potential is $V = IR$

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 drawn from the source.

(d). In order to prohibit the current from exceeding the ~~safety~~ 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) Greater

(b) lower

(c) is nearly independent

(d) 10^{22}

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

$(R')^2 - 2R' - 2 = 0$

$R' = \frac{2 \pm \sqrt{4+8}}{2}$

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

Negative value of R' can't be accepted.

$R' = 1 \pm \sqrt{3} = 1 + 1.73 = 2.73\ \Omega$

Given,

$r = 0.5\ \Omega$

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

Supply voltage, $V = 12\,V$

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

3.22) (a) $E_1 = 1.02\,V$

$l_1 = 67.3\,cm$

$l = 82.3\,cm$

$$\frac{E_1}{l_1} = \frac{\varepsilon}{l}$$

$$\varepsilon = \frac{l}{l_1} \times E_1$$

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

(b) The purpose of using the high resistance of 600k Ω is to reduce the current through the galvanometer when the ~~noveme~~ movable contact is far from the balance point.

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

(d) The method would not work if the driver cell of the potentiometer had an emf of 1.0 V. instead of 2.0 V. This is because if the emf of the driver cell of the potentiometer less than the emf of the other cell, then there would be no balance point on the wire.

(e) The circuit would ~~x~~ not work well for determining an 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 error. The given circuit can be modified if a series resistance is connected with the wire AB. The potential drop across AB is slightly greater than the emf measured. The ~~p.e~~ percentage error would be small.

3.23) $R = 9.5\ \Omega$

$l_1 = 76.3$ cm

$l_2 = 64.8$ cm

The relation connecting resistance and emf is,

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

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

$$= 1.68\ \Omega$$