Ch-3 - Current elec

Exercises

(3.1) Emf of the battery, $\mathcal{E} = 12V$
Internal resistance, $r = 0.4\Omega$
Maximum current drawn from battery = I
According to Ohm's law,
$\mathcal{E} = Ir$
$I = \mathcal{E}/r = \frac{12}{0.4} = 30A$

Current drawn, 30A.

(3.2) The Emf of battery (10V)
Internal resistance ($r = 3\Omega$)
$I = 0.5A$
Current (I)
$I = \frac{\mathcal{E}}{R+r} = R+r = \frac{\mathcal{E}}{I} = \frac{10}{0.5} = 20\Omega$

Therefore, $R = 20 - 3 = 17\Omega$
Acc. to Ohm's law,
$V = IR$
$V = 0.5 \times 17 = 8.5V$

(3.3) (a) We know that,
$r_1 = 1\Omega$, $r_2 = 2\Omega$, $r_3 = 3\Omega$ are combined in series.
Total resistance (R_T)
$R_T = r_1 + r_2 + r_3 = 6\Omega$

(b) Let current be I.
emf of battery ($\mathcal{E} = 12V$)
Total resistance ($R = 6\Omega$)

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Using Ohm's law :-

$I = E/R = 12/6 = 2A$

Pot. drop across 1Ω (V_1)

$V_1 = 2 \times 1 = \underline{2V}$.

Pot. drop across 2Ω (V_2)

$V_2 = 2 \times 2 = \underline{4V}$.

Pot. drop across 3Ω (V_3)

$V_3 = 3 \times 2 = \underline{6V}$.

(Q.4) (a) Resistors, $r_1 = 2Ω$, $r_2 = 4Ω$, $r_3 = 5Ω$

Total resistance (R_T)

$$\frac{1}{R_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

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

$$= 19/20$$

$R_T = 20/19\ Ω$

(B) Given that emf ($E = 20V$)

let currents be I_1, I_2, I_3

thru, R_1, R_2, R_3

$I_1 = V/R_1 = 20/2 = 10A$

$I_2 = V/R_2 = 20/4 = 5A$

$I_3 = V/R_3 = 20/5 = 4A$

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

(3.5) Given, $T = 27°C$ (room Temp)
$R = 100\Omega$
let temp be increased to T_1
$R_1 = 117\Omega$
Temp coeff. ($\alpha = 1.70 \times 10^{-4}/°C$)

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

=

$$T_1 - T = \frac{R_1 - R}{\alpha} = \frac{117 - 100}{100(1.7 \times 10^{-4})}$$

$T_1 = 1027°C$

Therefore the temp. of resistance element is 1027°C.

(3.6) Given that length of wire, $L = 15m$

Area of cross-section, $a = 6.0 \times 10^{-7} m^2$
Resistance ($R = 5.0\Omega$)

let Resistivity be given as ρ.

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

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

$\rho = 2 \times 10^{-7}$

(3.7) Given Temp $T_1 = 27.5°C$

Resistance R_1 at temp T_1

$R_1 = 2.1\Omega$

Given that temp. ($T_2 = 100°C$)

$R_2 = 2.7\Omega$

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

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

$$\alpha = 0.0039°C^{-1}$$

(3.8) The supply voltage ($V = 230V$)

The initial current ($I_1 = 3.2A$)

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

Current at steady state, $I_2 = 2.8A$

$$R_2 = V/I_2 = \frac{230}{2.8} = 82.14\Omega$$

α of temp range is $1.70 \times 10^{-4} °C^{-1}$

$T_1 = 27.0°C$

Value of steady state reached by nichrome $= T_2$

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

$$T_2 - 27 = \frac{82.14 - 71.87}{71.87(1.7 \times 10^{-4})}$$

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$T_2 - 27 = 840.5$

$T_2 = 840.5 + 27 = 867.5°C$

Steady temp of heating element is $\underline{867.5°C}$

(3.10) (a) let L_1 be the balanced point from end A,

$L_1 = 39.5$ cm

Resistance ($S = 12.5\Omega$)

(condition for balance) $R/S = \frac{100 - L_1}{L_1}$

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

(b) If R and S are interchanged, then the lengths will also interchanged.

∴ The length modifies to

$l = 100 - 39.5 = 60.5$ cm

(c) The galvanometer and the cell are interchanged, the position of the balance point remain unchanged,

Therefore galvanometer shows no current.

(3.11) The Emf ($E = 8.0V$)

The internal resistance ($r = 0.5\Omega$)

DC supply voltage ($V = 120V$)

Effective voltage in circuit $= V_1$

$V_1 = V - E$

$V_1 = 120 - 8 = 112V$

Current flowing in circuit : I

$I = \frac{V}{R+r} = \frac{112}{15.5+15} = \frac{112}{6} = 7A$

Voltage across R,

$I \times R = 7 \times 15.5 = 108.5V$

DC supply voltage = Terminal voltage + voltage across R

Terminal voltage of battery

$= 120 - 180.5 = 11.5V$

(3.12) Emf of the cell, $E_1 = 1.25V$

The balance point of the potentiometer

$I_1 = 35cm$

Emf (E_2) be another cell.

New balance point of potentiometer,

$I_2 = 63cm$

balance condition is given by,

$\frac{E_1}{E_2} = \frac{I_1}{I_2}$, $E_2 = E_1 \times \frac{I_2}{I_1}$

$E_2 = 1.25 \times \frac{63}{35} = 2.25V$

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(3.13) Given that number density of free electron in Cu conductor,

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

Length of copper wire $l = 3 m$

Area of cross-section, $A = 2 \times 10^{-6} m^2$

Equation is given by,

$I = nAeV_d$

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

V_d = Drift velocity $= \frac{l}{t}$

$I = nAe\, l/t$

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

$t = 2.7 \times 10^{4}$ sec

Additional Exercises

(3.19) σ of Earth $= 10^{-9}/m^2$

Potential diff $(V = 400kV)$

$I = 1800A$

$r = 637 \times 10^{6} m$

$A = 4\pi r^2$

$= 4 \times 3.14 \times (6.37 \times 10^{6})^2 = 5.09 \times 10^{14}/m^2$

(charge) $q = \sigma A = 10^{-9} \times 5.09 \times 10^{14}$

$= 5.09 \times 10^{5} C$

Time taken to neutralize

$t = q/I = 283 s$

(3.15) (a) Emf of secondary cell, $\varepsilon = 2.0V$

$n = 6$, $E = n\varepsilon = 6 \times 2 = 12V$

internal resistance ($r = 0.015\Omega$)

Resistance to which the secondary cell are connected

$R = 8.5\Omega$

$R_T = nr + R = 6 \times 0.015 + 8.5$

$= 8.59\Omega$

Current drawn, $I = E/R_T$

$= 12/8.59 = 1.4A$

(b) Emf ($\varepsilon = 1.9V$)

Internal Resistance ($r = 380\Omega$)

Maximum current draw from the cell, $I = \varepsilon/r = \frac{1.9}{380} = 0.005A$

The current req. to start of motor is 100 A. Hence, the current produced is 0.05 A

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(3.17) Ohm's law is valid to high accuracy. This means that the resistivity of the alloy manganin is nearly independent of temperature

(3.18) (a) Current is given to be steady. Therefore, it's a const. The current dens, elec field, drif speed depends on the area of cross-sec inversely.

(b) No, Examples of non-ohmic elements are vacuum diode, semiconductor diode

(c) Maximum current $= \varepsilon / r$

(d) If the circuit is shorted, the current drawn will exceed safety limits if internal resistance is not large.

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

(3.20) no. of resistors $\rightarrow n$
Resistance (R)

the $R_{min} = \frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} \cdots n$

$R_p = R/n$

$R_{max} = nR$

$R_{max} : R_{min} = nR : R/n$

$= n^2$.

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

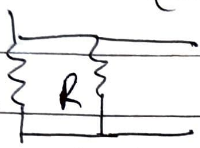
(i) $11/3\ \Omega = \dfrac{1}{\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)} + R_3$

(ii) $11/5\ \Omega = \dfrac{1}{\left(\dfrac{1}{R_2} + \dfrac{1}{R_3}\right)} + R_1$

(iii) $6\Omega = R_1 + R_2 + R_3$

~~(iv) 6/11~~

(3.21)



The equivalent resistance of this net is $R' = R +$ (Eq. resistance when x and R are parallel) $+ R$

$= R + [xR/(x+R)] + R$

$R' = 2R + [xR/(x+R)]$

Since, infinite network,

$R' = x$

$\Rightarrow 2R + [xR/(x+R)] = x$

Since, $R = 1\Omega$,

$2 \times 1 + [x \times 1/(x+1)] = x$

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

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

Current drawn (I)

$= I = \varepsilon/(x+r) = \dfrac{12}{2.732+0.5} = 3.713A$

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3.23) Internal resistance (r = 1.5 V)

Balance point, $l = 76.3$ cm

External resistance, $R = 9.5\,\Omega$

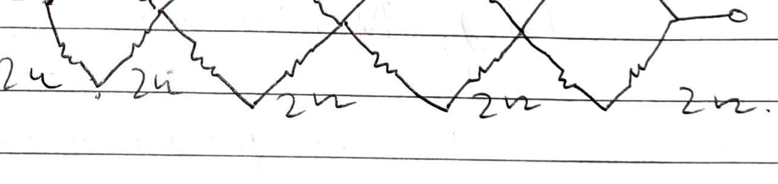
New balance point, $l_1 = 64.8$ cm

$$r = R\left[\frac{l}{l_1} - 1\right] \quad r = 9.5\left[\frac{76.3}{64.8} - 1\right] = 1.69\,\Omega$$

(3.20) (c) (a)

$$\frac{1}{\left(\frac{1}{2\Omega} + \frac{1}{4}\right)} + \frac{1}{\left(\frac{1}{2} + \frac{1}{4}\right)} + \frac{1}{\left(\frac{1}{2} + \frac{1}{4}\right)} + \frac{1}{\left(\frac{1}{2} + \frac{1}{4}\right)}$$

$$= \left(\frac{4}{3} + \frac{4}{3} + \frac{4}{3} + \frac{4}{3}\right) = \left(\frac{16}{3}\,\Omega\right)$$



(b) The resistors are connected in series $= R + R + R + R + R = 5R$

(Q 2) (a) Constant emf $(E_1 = 1.02V)$
The balance point of the wire $(l_1 = 67.3cm)$
The standard cell is then replaced by a cell of unknown emf $\mathcal{E}$ and the balanced point changes to $l = 82.3cm$

$$\mathcal{E}_1 / l_1 = \mathcal{E}/l$$

$$\mathcal{E} = l \times \mathcal{E}_1 / l_1 = \frac{82.3 \times 1.02}{67.3} = 1.247$$

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

(c) No.

(d) No. If $\mathcal{E}$ is greater that the emf of the driver cell of the potentiometer, there will be no balance point on the wire AB.