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CH - Current Electricity

Exercises

Q1) Emf = 12 V

$R = 0.4\ \Omega$

$\therefore$ The maximum current drawn from the

Maximum current = I

$E = Ir$

$I = E/r = \frac{12}{0.04} \times \frac{12 \times 100}{0.04 \times 100} = \frac{1200}{4} = \boxed{30\ A}$

Q2) Emf = 10 V

$R = 3\ \Omega$

$I = 0.5\ A$

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

$R+r = \frac{E}{I} = \frac{10}{0.5} = 20\ \Omega$

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

$\Rightarrow V = IR$

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

$\therefore$ The ~~the~~ resistance of the resistor is $17\ \Omega$ and terminal voltage of the battery when the circuit is closed is 8.5 V.

Q3) (a) Total resistance $= 1+2+3 = 6\,\Omega$.

(b) Current $= I$.
Emf $= 12V$.
Total Resistance $= 6\,\Omega$.

$I = E/R = 12/6 = \boxed{2A}$.

Potential drop across $1\,\Omega$ resistor $= V_1$.

$V_1 = 2 \times 1 = 2V$

Potential drop across $2\,\Omega$ resistor $= V_2$

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

Potential drop across $3\,\Omega$ resistor $=$

$V_3 = 2 \times 3 = 6V$

$\therefore$ The potential drop across $1\,\Omega$, $2\,\Omega$ and $3\,\Omega$ resistors are 2V, 4V and 6V respectively.

Q4) (a) Total resistance of the combination =

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{10+5+4}{20}$$

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

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

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(6) Emf = 20V

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

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

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

$I = I_1 + I_2 + I_3 = 10 + 5 + 4 = \boxed{19A}$

∴ The current through each resistor is 10A, 5A and 4A and total current is 19A.

Q5) $T = 27°C$
$R = 100\,\Omega$
$R_1 = 117\,\Omega$

Temperature of the element $= \alpha = \frac{R_1 - R}{R(T_1 - T)}$

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

$\Rightarrow T_1 - 27 = \frac{117 - 100}{100(17 \times 10^{-4})} = \frac{17}{100(1.7 \times 10^{-4})}$

$\Rightarrow T_1 - 27 = 1000$

$\Rightarrow T_1 = 1000 + 27 = \boxed{1027°C}$

∴ At 1027°C, the resistance of the element is 117 Ω.

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Q6) $L = 15 m$.

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

$R = 5 \Omega$.

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

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

Q7) $T_1 = 27.5°C$.

$R_1 = 2.1 \Omega$.

$T_2 = 100°C$

$R_2 = 2.7 \Omega$.

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

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

∴ The temperature coefficient of resistivity of silver is 0.0039°C.

Q8) $V = 230 V$

$I_1 = 3.2 A$

$R_1 = V / I$.

$R_1 = 230/3.2 = 71.87 \Omega$.

$I_2 = 2.8 A$

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

The temperature coefficient of nichrome averaged over temp. range involved is 1.70×10^{-4} °C.

$T_1 = 27°C$.

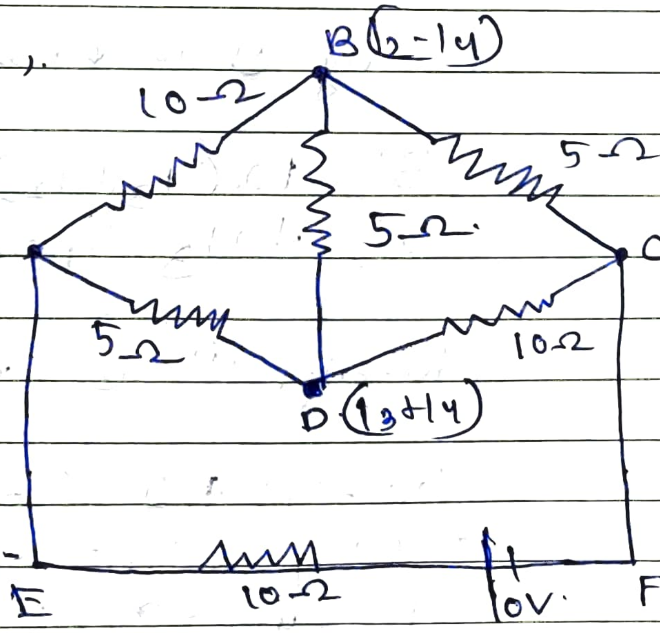
$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

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

$$T_2 = 840.5 + 27 = 867.5°C.$$

∴ The steady temperature of the heating element is 367·5 °C.

Q.09). In closed circuit ABDA,



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

In closed circuit BCDB,

$$5(I_2 - I_4) - 10(I_3 + I_4) - 5I_4 = 0$$
$$5I_2 - 5I_4 - 10I_3 - 10I_4 - 5I_4 = 0$$
$$5I_2 - 10I_2 - 20I_4 = 0$$
$$I_2 = 2I_3 - 4I_4$$

In closed circuit ABCFEA.

$$-10 + 10(I_1) + 10(I_2) + 5(I_2 - I_4) = 0$$

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

$3I_2 + 2I_1 - I_4 = 2$ -- ③

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

$I_3 = 4I_3 + 8I_4 + I_4$

$-3I_3 = 9I_4$

$-3I_4 = +I_3$ - ④

Putting ④ in equation ①,

$\cancel{I_3} = 2I_2 + I_4$

$-4I_4 = 2I_2$

$I_2 = -2I_4$ - ⑤

$I_1 = I_3 + I_2$ - ⑥

Putting ⑥ in equation ①,

$3I_2 + 2(I_3 + I_2) - I_4 = 2$

$5I_2 + 2I_3 - I_4 = 2$ - ⑦

Putting ④, ⑤ in equation 7,

$5(-2I_4) + 2 - (3I_4) - I_4 = 2$

$-10I_4 - 6I_4 - I_4 = 2$

$17I_4 = -2$

$I_4 = \boxed{-2/17\ A}$

Equation ④ reduced to

$I_3 = -3(I_4)$

$I_3 = -3(-2/17) = 6/17$ A.

$I_2 = -2(I_4)$

$I_2 = -2(-2/17) = 4/17$ A

$I_2 - I_4 = 4/17 - 2/17 = 6/17$ A.

$I_3 + I_4 = 6/17 + 2/17 = 4/17$ A

$I_1 = I_3 + I_2$

$I_1 = 6/17 + 4/17 = \boxed{10/17 \text{ A}}$

In breanch AB = $\boxed{4/17 \text{ A}}$.

In branch BC = $\boxed{6/17 \text{ A}}$

In branch CD = $\boxed{-4/17 \text{ A}}$

In branch AD = $\boxed{6/17 \text{ A}}$

In breanch BD = $\boxed{-2/17 \text{ A}}$

Total currend = $4/17 + 6/17 + -4/17 + 6/17 - 2/17 = \boxed{10/17 \text{ A}}$

Q10) (A) Let L_1 be the balance point.

$L_1 = 39.5\,cm$

$S = 12.5\,\Omega$

$$\frac{R}{S} = \frac{100 - L_1}{L_1}$$

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

(b) If R and S are interchanged.

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

(c) If the galvanometer and the cell are interchanged, the position of the balance point remains unchanged. So, the galvanometer will show no current.

Q11) $E = 8\,V$

$r = 0.5\,\Omega$

$V = 120\,V$

$R = 15.5\,\Omega$

$V' = V - E$

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

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

$$I = \frac{112}{15.5 + 0.5} = 112/16$$

$I = 7\,A$

$I \times R = 7 \times 15.5 = \boxed{108.5\,V}$

DC supply voltage = Terminal voltage + voltage drop

$\therefore$ Terminal voltage = $120 - 108.5 = \boxed{11.5\,V}$

→ A series resistor, when connected in a charging circuit, limits the current drawn from the external source.

Q12) Emf of the cell = 1·25 V

$I_1 = 35\ cm$

$I_2 = 63\ cm$

$$\frac{E_1}{E_2} = \frac{I_1}{I_2}.$$

$E_2 = E_1 \times I_2 / I_1.$

$E_2 = 1{\cdot}25 \times 63/35 = \boxed{2{\cdot}25\ V}$

Q13). $n = 8{\cdot}5 \times 10^{28}\ m^{-3}$

Length of the copper wire.

$l = 3\ m$

Let the area of cross - section of the wire be
$A = 2 \times 10^{-6}\ m^2$

$I = 3\ A$

$I = nAeV_d$

$e = 1{\cdot}6 \times 10^{-19} C.$

V_d = Length of wire / time taken to cover.

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$$t = \frac{n \times A \times e \times t}{I}$$

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

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

Q14). $\sigma = 10^{-19}\ cm^{-2}$
$v = 400\ kV$
$I = 1800\ V$
$r = 6.37 \times 10^{6}\ m$
$A = 4\pi r^2$
$= 4 \times 3.14 \times (6.37 \times 10^{6})^2 = 5.09 \times 10^{14}\ m^2$

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

Time taken to neutralize the earth's surface:
$T = q/I = t = \frac{5.09 \times 10^{5}}{1800} = \boxed{283 s}$

Q15). ⓐ Emf of the secondary cells, $\varepsilon = 2.0V$.
$n = 6$
$E = n\varepsilon = 6 \times 2 = 12V$
Internal resistance, $r = 0.015\ \Omega$

$R = 8.5\ \Omega$

$R_{total} = nr + R = 6 \times 0.015 + 8.5 = 8.59\ \Omega$

$I = E / R_{total} = 12 / 8.59 = 1.4A$

$V = IR = 1.4 \times 8.5 = \boxed{11.9V}$

(b) Emf of secondary cell, $\varepsilon = 1.9V$.
$r = 380\Omega$.

$I = \varepsilon / r = \frac{1.9}{380} = 0.005A$

The current required to start a motore is 100 Amp. The current produced is 0.005A. So, the starting motore of the care cannot be started with this current.

Q6) $\rho_{Al} = 2.63 \times 10^{-8} \Omega m$
$d_1 = 2.7$.
Resistance of aluminium wire $= R_1$.
Area $= A_1$.
$\rho_{Cu} = 1.72 \times 10^{-8} \Omega m$

$d_2 = 8.9$.

Let l_2 be the length of copper wire and m_2 be its mass.
Resistance of the copper wire $= R_2$.
Area $= A_2$.

$R_1 = \rho_1 \frac{l_1}{A_1}$ —(1)

$R_2 = \rho_2 \frac{l_2}{A_2}$ —(2)

$R_1 = R_2$

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

$l_1 = l_2$

$\therefore \frac{P_1}{A_1} = \frac{P_2}{A_2}$.

$\frac{A_1}{A_2} = \frac{P_1}{P_2}$.

$\frac{A_1}{A_2} = \frac{P_1}{P_2} = \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}} = 2.63/1.72$

$m_1 =$ volume $\times$ density

$= A_1 l_1 \times d_1 = A_1 l_2 d_1$ - (3)

$m_2 =$ Volume $\times$ density

$= A_2 l_2 \times d_2 = A_2 l_2 d_2$ - (4)

Dividing equation (3) by equation (4),

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

$l_1 = l_2$,

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

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

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

∴ The mass ratio of aluminium to copper is 0.46

Q17) Ohm's law is valid to high accuracy. This means that the resistivity of the alloy manganin is nearly independent of temperature.

Q18) (a) Current is given to be steady. Therefore it is constant. The current density, electric field, drift speed depends on the area of cross-section inversely.

(b) No, examples of non-ohmic elements are vacuum diode, semiconductor diode, etc.

(c) Because the maximum current drawn from a source = E/r.

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

Q19) (a) Greater (d) 10^{22}

(b) lower

(c) nearly independent of

Q20) (a) Total no. of resistors = n

Resistance of each resistor = R

(i) The minimum effective resistance is got when the resistors are connected in series. $R_1 = \boxed{nR}$

(ii) $nR / R/n = \boxed{n^2}$

(b) The resistance given are $1\,\Omega, 2\,\Omega, 3\,\Omega$

(i) $11/3\,\Omega$

Effective resistance $= \frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2}\right] = 3/2$

$R' = 2/3\,\Omega$

These resistors are connected in series with $3\,\Omega$.

Effective resistance $= R = R' + 3 = (2/3) + 3 = \boxed{11/3\,\Omega}$

(ii) $11/5\,\Omega$

Resistance $= \frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{3}\right] = \boxed{\frac{5}{6}\,\Omega}$

$R' = \boxed{6/5\,\Omega}$

(iii) $6\,\Omega$

$R = 1\,\Omega + 2\,\Omega + 3\,\Omega = \boxed{6\,\Omega}$

(iv) (6/11) Ω.

$$\frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2} + \frac{1}{3}\right] = \frac{11}{6}\,\Omega$$

$$R' = \frac{6}{11}\,\Omega.$$

(c) (a) Effective resistance $= \frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{4}\right] = \frac{3}{4}\,\Omega.$

$$R' = \boxed{\frac{4}{3}\,\Omega}.$$

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

(b) Effective resistance $= R+R+R+R+R = \boxed{5R}$

Q21) Let the effective resistance of the infinite network be x.

$$= R + XR/(X+R)] + R$$

$$R' = 2R + [XR/X+R]$$

$$R' = X.$$

$$\Rightarrow 2R + [XR/(X+R)] = X.$$

$\therefore x + \sqrt{3} = 2.732\,\Omega.$

$E = 12\,V,\ r = 0.5\,\Omega$

$$R = 1\,\Omega$$

$$= 2\times1 + [X\times1/X+1] = X.$$

$$I = E/(X+r) = \frac{12}{(2.732+0.5)} = \boxed{3.713\,A}.$$

$$X^2 - 2X - 2 = 0.$$

$$X = \frac{(-2) \pm \sqrt{(-2)^2 - 4\times1\times(-2)}}{2}$$

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

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Q22) (a) Constant emf of the standard cell $E_1 = 1.02$ V

The balance point on the wire $l_1 = 67.3$.

Balance point $l = 82.3$ cm.

$(E_1 / l_1) = (\varepsilon / l)$.

$$\varepsilon = (l \times E_1 / l_1) = \frac{82.3 \times 1.02}{67.3} = \boxed{1.247 V}$$

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

(c) No.

(d) No, if ε is greater than the emf of the driver cell of the potentiometer, there will be no balance point on the wire AB.

(e) The circuit will not be suitable, because the balance point will be very close to the end A and the percentage of error in the measurement will be very large.

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Q23) $\varepsilon = 1.5\,V$ cell.

Balance point of the cell in open circuit $= l = 76.3\,cm$

$R = 9.5\,\Omega$.

$l_1 = 64.8\,cm$

Internal resistance $= R\left[\frac{l}{l_1} - 1\right] r$

$$= 9.5\left[\frac{76.3}{64.8} - 1\right] = \boxed{1.69\,\Omega}.$$