CHAPTER 3

CURRENT ELECTRICITY

CLASS 12TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS

3.1: **The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0.4Ω, what is the maximum current that can be drawn from the battery?**

SOLUTION:

Given – emf (E) = 12 V, Internal resistance (R) = 0.4Ω.

Need to find – Maximum current (I).

According to Ohm's Law,

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

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

Therefore, the maximum current drawn from the battery is 30 A.

3.2: **A battery of emf 10 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5 A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?**

SOLUTION:

Given – emf (E) = 10 V, Internal resistance (r) = 3Ω, Current (I) = 0.5 A.

Need to find – Resistance of the resistor (R) and terminal voltage (V) of the battery when circuit is closed.

According to Ohm's Law,

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

$$0.5A = \frac{10V}{(R + 3)\Omega}$$

$$(R + 3) = 20\Omega$$

$$R = 17\Omega$$

Terminal voltage of the resistor (V) = IR

$V = (0.5A)(17\Omega) = 8.5\ V$

Therefore, the resistance of the resistor is 17Ω and the terminal voltage is 8.5 V.

3.3: At room temperature (27.0 °C) the resistance of a heating element is 100Ω. What is the temperature of the element if the resistance is found to be 117Ω, given that the temperature coefficient of the material of the resistor is 1.70×10^{-4} °C^{-1}.

SOLUTION:

Given – Room temperature (T) = 27.0 °C, Resistance at room temp (R) = 100Ω,

New resistance (R') = 117Ω, Temperature coefficient (α) = 1.70×10^{-4} °C^{-1}

Need to find – Temperature (T'), at which resistance changes to R'.

Temperature coefficient of the material of the filament is given by,

$$\alpha = \frac{(R'-R)}{R(T'-T)}$$

$$(T'-T) = \frac{(R'-R)}{R\alpha}$$

$$T'-27 = \frac{117-100}{100(1.7\times10^{-4})}$$

$$T'-27 = 1000$$

$$T' = 1027^{\circ}C$$

Therefore, the resistance of the element is 117Ω at 1027 C.

3.4: A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 . What is the resistivity of the material at the

temperature of the experiment?

SOLUTION:

Given – Length of wire (l) = 15 m, Cross-section area (A) = 6.0×10^{-7} m^2, Resistance (R) = 5.0Ω.
Need to find – Resistivity (ρ) of the material.
Resistivity, as determined by the resistance formula, is:

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

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

$$= \frac{5\times6\times10^{-7}}{15} = 2\times10^{-7}\,\Omega\text{m}$$

Therefore, the resistivity of the material is 2×10^{-7}Ωm.

3.5: A silver wire has a resistance of 2.1Ω at 27.5 °C, and a resistance of 2.7Ω at 100 °C. Determine the temperature coefficient of resistivity of silver.

SOLUTION:

Given – Resistance (R_1) = 2.1Ω at temperature (T_1) = 27.5 °C

Resistance (R_2) = 2.7Ω at temperature (T_2) = 100 °C

Need to find – Temperature coefficient (α).

Temperature coefficient of the material of the filament is given by,

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

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

Therefore, the temperature coefficient of silver is 0.0039°C^{-1}.

3.6: A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27.0 °C? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is 1.70 × 10^{-4} °C^{-1}.

SOLUTION:

Given – Supply voltage (V) = 230 V, Initial current (I) = 3.2 A, Settled current (I') = 2.8 A, Room temperature (T_1) = 27.0 °C, Temperature coefficient (α) = 1.70 × 10^{-4} °C^{-1}.

Need to find – Steady temperature (T_2) of the heating element.

Initial resistance (R_1) is given by,

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

$$= \frac{230}{3.2} = 71.87\Omega$$

Similarly, Resistance at the steady state (R_2) is given by,

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

With the formula of temperature coefficient we get,

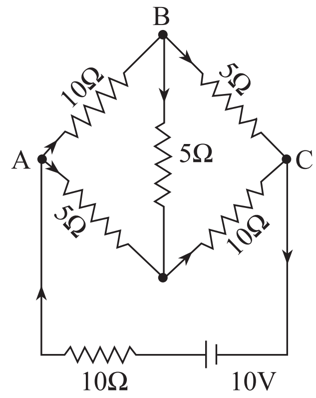
$$\alpha = \frac{(R_2 - R_1)}{R_1\left(T_2 - T_1\right)}$$

$$(T_2 - 27^\circ C) = \frac{(82.14 - 71.87)}{(71.87 \times 1.7 \times 10^{-4})} = 840.5$$

$$T_2 = (840.5 + 27) = 867.5^\circ C$$

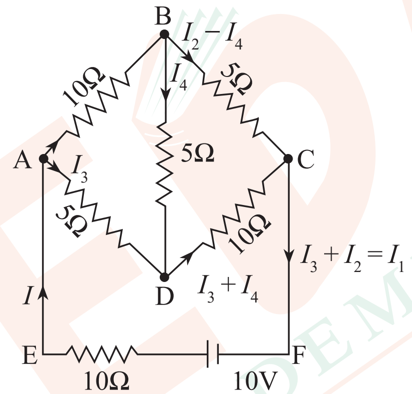
Therefore, the steady temperature of the heating element is 867.5°C.

3.7: **Determine the current in each branch of the network shown in Fig.:**



SOLUTION:

Current flowing through various branches of the network is shown in figure.



Current flowing through the outer circuit = I_1

Current flowing through branch AB = I_2

Current flowing through branch AD = I_3

Current flowing through branch BD = I_4

Current flowing through branch BC = $(I_2 - I_4)$

Current flowing through branch CD = $(I_3 + I_4)$

Apply KVL in closed network ABDA,

$$10I_2 + 5I_4 - 5I_3 = 0$$

$$2I_2 + I_4 - I_3 = 0$$

$$I_3 = 2I_2 + I_4 \ldots(i)$$

Apply KVL in closed network BCDB,

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

$$5I_2 + 5I_4 - 10I_3 - 10I_4 - 5I_4 = 0$$

$$5I_2 - 10I_3 - 20I_4 = 0$$

$$I_2 = 2I_3 + 4I_4 \ldots(ii)$$

Apply KVL in closed network ABCFEA,

$$-10+10(I_1)+10(I_2)+5(I_2-I_4)=0$$
$$10=15I_2+10I_1-5I_4$$
$$3I_2+2I_1-I_4=2\ldots(iii)$$

From equation (i) and (ii) we get,

$$I_3=2(2I_3+4I_4)+I_4$$
$$I_3=4I_3+8I_4+I_4$$
$$-3I_3=9I_4$$
$$-3I_4=+I_3\ldots(iv)$$

By putting equation (iv) in equation (i) we get,

$$I_3=2I_2+I_4$$
$$-4I_4=2I_2$$
$$I_2=-2I_4\ldots(v)$$

From figure, ($I_1 = I_2 + I_3$), put this value in equation (i) we get,

$$3I_2+2(I_3+I_2)-I_4=2$$
$$5I_2+2I_3-I_4=2\ldots(vi)$$

Put equation (iv) and (v) in equation (vi) we get,

$$5(-2I_4)+2(-3I_4)-I_4=2$$
$$-10I_4-6I_4-I_4=2$$
$$17I_4=-2$$
$$I_4=\frac{-2}{17}\text{A}$$

From equation (iv),

$$I_3=-3(I_4)$$
$$=-3\left(\frac{-2}{17}\right)=\frac{6}{17}\text{A}$$
$$I_2=-2(I_4)$$
$$=-2\left(\frac{-2}{17}\right)=\frac{4}{17}\text{A}$$
$$I_2-I_4=\frac{4}{17}-\left(\frac{-2}{17}\right)=\frac{6}{17}\text{A}$$
$$I_3+I_4=\frac{6}{17}+\left(\frac{-2}{17}\right)=\frac{4}{17}\text{A}$$
$$I_1=I_3+I_2$$
$$=\frac{6}{17}+\frac{4}{17}=\frac{10}{17}\text{A}$$

Therefore,

Current flowing through branch AB = $I_2 = \frac{4}{17}$ A

Current flowing through branch AD = $I_3 = \frac{6}{17}$ A

Current flowing through branch BD = $I_4 = \frac{-2}{17}$ A

Current flowing through branch BC = $(I_3 - I_4) = \frac{6}{17}$ A

Current flowing through branch CD = $(I_3 + I_4) = \frac{-4}{17}$ A

Total current = $I_1 = (I_2 + I_3) = \left(\frac{4}{17} + \frac{6}{17}\right)\text{A} = \frac{10}{17}$ A

3.8: A storage battery of emf 8.0 V and internal resistance 0.5Ω is being charged by a 120 V dc supply using a series resistor of 15.5Ω. What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?

SOLUTION:

Given – emf (E) = 8.0 V, Internal resistance (r) = 0.5Ω , Supply voltage (V) = 120 V, Series Resistor (R) = 15.5

Need to find – Terminal voltage of the battery (V_R) during charging and the purpose of having series resistor.

Effective voltage in the circuit is given by,

$$V' = (V - E) = (120 - 8)\text{ V} = 112\text{ V}$$

Current flowing in the circuit is given by,

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

$$= \frac{112}{(15.5+0.5)} = \frac{112}{16} = 7\text{A}$$

Voltage across the resistor R is given by,

$$V_R = IR = (7\text{A})(15.5\Omega)$$

$$V_R = 108.5\text{ V}$$

We know that,

Supply voltage (V) = Terminal voltage (V'') + Voltage across resistance R (V_R)

$$V'' = (120) - (108.5) = 11.5\text{ V}$$

A series resistor in a charging circuit restricts the current drawn from the external source. Without it, the current would be excessively high, which is highly dangerous.

3.9: The number density of free electrons in a copper conductor estimated in Example 3.1 is 8.5×10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is 2.0×10^{-6} m^2 and it is carrying a current of 3.0 A.

SOLUTION:

Given – Number density of free electrons (n) = 8.5×10^{28} m^{-3}, length of wire (l) = 3 m,

Area of cross-section (A) = 2.0×10^{-6} m^2, Current (I) = 3 A

Need to find – Time taken (t).

Relation of current in the circuit (I) to drift velocity (v_d) is given by,

$$I = neAv_d \qquad \text{............ (i)}$$

$$\therefore \text{ Drift velocity } (v_d) = \frac{\textit{length of wire } (l)}{\textit{time taken } (t)}$$

Put this value of drift velocity in equation (i) we get,

$$I = neA\left(\frac{l}{t}\right)$$

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

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

$$t = 2.7 \times 10^{4}\,\text{s}$$

Therefore, the time taken by an electron to drift from one end of the wire to the other is $2.7 \times 10^{4}\,\text{s}$.