Current Electricity

NCERT Examples

Date __/__/__ Ch: 3

Example 3.1

Estimate the - - - - - - - - - - - - drift motion.

Solution :-

Given -

$A = 1 \times 10^{-7} m^2$

$I = 1.5 A$

No of atoms = no of electrons

Atomic mass of copper = 63.5 u

Density of copper = $9 \times 10^3 Kg/m^3$

$V_d = ?$

$I = neAV_d$

$$V_d = \frac{I}{neA}$$

For n

We Know

No of atom in 63.5g = 6×10^{23}

No of atom in 1 g = $\frac{6 \times 10^{23}}{63.5}$

" " " $9 \times 10^6 g$ = $\frac{6 \times 10^{23}}{63.5} \times 9 \times 10^6$

$$n = \frac{6 \times 9}{63.5} \times 10^{29}$$

$$= \frac{\cancel{5400}^{\,1080}}{\cancel{63.5}_{\,127}} \times 10^{28}$$

8.5
127) 1080
1016
640
635
5

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

$$V_d = \frac{I}{neA} = \frac{1.5}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-7}}$$

$$V_d = \frac{1.50 \times 10^{-28+19+7}}{8.5 \times 1.6}$$

$$V_d = \frac{\overset{30}{\cancel{150}} \times 10^{-2}}{\underset{17}{\cancel{85}} \times 16} = \frac{30 \times 10^{-2}}{16 \times 17} = \frac{30 \times 10^{-2}}{272}$$

$$V_d = \frac{300 \times 10^{-3}}{272}$$

$$272 \overline{)\,300\,}(1.1$$
$$\underline{272}$$
$$280$$

$$V_d = 1.1 \times 10^{-3}\ m/s$$

$$V_d = 1.1\ mm\ s^{-1}$$ Ans

(b)

$$\frac{V_{drift}}{V_{thermal}} = ?$$

For $V_{thermal}$

$$\frac{1}{\cancel{2}} m v^2 = \frac{3}{\cancel{2}} K_B T$$

$$v^2 = \frac{3 K_B T}{m}$$

For m

Mass of 6×10^{23} atoms $= 63.5\ g$

so mass of one atom $= \frac{63.5}{6 \times 10^{23}}\ g$

$$= \frac{63.5 \times 10^{-3}}{6 \times 10^{23}}\ kg$$

$$v^2 = \frac{3 K_B T}{m} = \frac{1.38 \times 10^{-23} \times 300 \times 6 \times 10^{23}}{63.5 \times 10^{-3}}$$

$$= \frac{1.38 \times 300 \times 6 \times 10^{3}}{63.5} \quad [T = 27°C + 273 = 300\ K]$$

$$= \frac{138 \times 18 \times 10^5}{635}$$

$$v^2 = \frac{138 \times 18 \times 10^4}{635}$$

$$v^2 = \frac{2484 \times 10^4}{635}$$

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

$R_t = R_0 (1 + \alpha \Delta T)$

or $R_t - R_0 = R_0 \alpha \Delta T$

or $R_2 - R_1 = R_1 \alpha \Delta T$

$$\Delta T = \frac{R_2 - R_1}{R_1 \alpha}$$

$$= \frac{85.8 - 75.3}{75.3 \times 1.70 \times 10^{-4}}$$

$$= \frac{10.5 \times 10^4}{75.3 \times 1.70}$$

$$\Delta T = \frac{105 \times 10^4}{1280.1}$$

$$= \frac{1050 \times 10^2}{128}$$

$$\Delta T = 8.2 \times 10^2$$

or $T_2 - T_1 = 820$

$T_2 = 820 + T_1$

$T_2 = 820 + 27$

$= 847°C$ Ans

Thus the steady temperature of the nicrome element $= 847°C$

Example - 3.4

~~The resistance - - - - - - - of the bath.~~

Solution :→

~~Given →~~

~~Ice point $T_1 = 0°C$~~

~~Steam point $T_2 = 100°C$~~

$R_0 = 5\ \Omega$

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Example 3.4

The resistance of - - - - - - - - - of the bath.

Solution:-

Given that :-

Ice point $T_1 = 0°C$

steam point $T_2 = 100°C$

Resistance at ice point. $R_0 = 5\,\Omega$

Resistance at steam point $R_{100} = 5.23\,\Omega$

Resistance at hot bath $R_t = 5.795\,\Omega$

Let the temperature of hot bath $= t°C = ?$

We have

$$R_2 - R_1 = R_1 \alpha (T_2 - T_1) \text{ ——— (i)}$$

here

$$R_{100} - R_0 = R_0 \alpha (100 - 0)$$

or $$R_{100} - R_0 = R_0 \alpha \times 100 \text{ ——— (ii)}$$

also $$R_t - R_0 = R_0 \alpha (t - 0)$$

or $$R_t - R_0 = R_0 \alpha t \text{ ——— (iii)}$$

Divide eq^n (iii) by (ii), we get

$$\frac{R_t - R_0}{R_{100} - R_0} = \frac{\cancel{R_0 \alpha} t}{\cancel{R_0 \alpha} \times 100}$$

or $$t = \frac{R_t - R_0}{R_{100} - R_0} \times 100$$

$$= \frac{5.795 - 5}{5.23 - 5} \times 100$$

$$= \frac{0.795}{0.23} \times 100$$

$$= \frac{79.3}{23} \times 10^2$$

$$= 3.456 \times 10^2$$

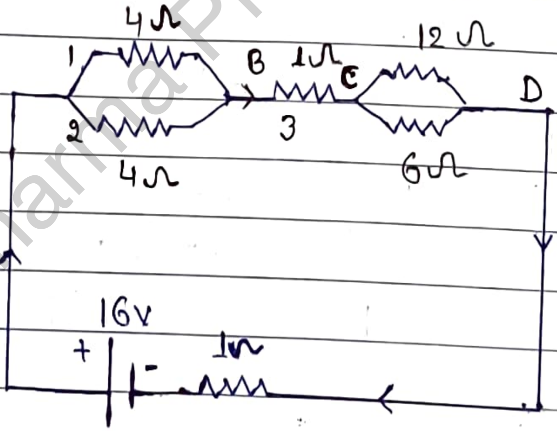
$$t = 345.6°C$$

Thus the temperature of the bath is 345.65 °C Ans

Example 3.5 (Not in new syllabus)
A Network - - - - - - - the voltage drop.

Solution:-

Given:



Let the resistances are given as

$R_1 = R_2 = 4\Omega$, $R_3 = 1\Omega$
$R_4 = 12\Omega$ and $R_5 = 6\Omega$
and the internal resistance of the battery $r = 1\Omega$

emf of the battery $= 16V$

From fig.
R_1 and R_2 are in parallel. Therefore.

$$R_{12} = \frac{R_1 R_2}{R_1 + R_2} = \frac{4\times4}{4+4} = \frac{16}{8} = 2\Omega$$

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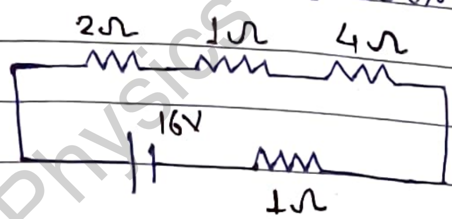
$R_{12} = 2\Omega$

R_4 and R_5 are also in $\parallel$. Therefore

$$R_{45} = \frac{R_4 R_5}{R_4 + R_5} = \frac{12 \times 6}{12+6} = \frac{\cancel{72}^{4}}{\cancel{18}} = 4$$

Or $R_{45} = 4\Omega$

Now R_{12}, R_3 and R_{45} are in series. Therefore



$R_{12345} = 2+1+4$
$= 7\Omega$

Now the $r = 1\Omega$ is also is series.
so

$$Req = R_{12345} + r$$
$$= 7 + 1$$
$$Req = 8\Omega \text{ Ans}$$

(b) The total current I in the circuit

$$I = \frac{E}{R+r} = \frac{E}{Req} = \frac{16}{8} = 2$$

Or $I = 2A$

Let the current through 4Ω and 4Ω is I_1 and I_2, As 4Ω are in parallel, we have

$$I_1 R_1 = I_2 R_2$$

Or $$\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{4}{4} = 1$$

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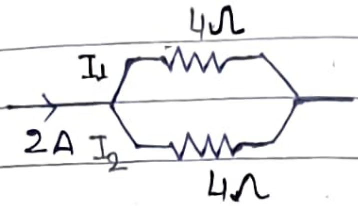


or $I_1 = I_2$

also we have

$$I_1 + I_2 = 2A$$

Hence $I_1 = I_2 = 1A$

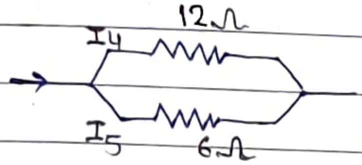
Now current through 1Ω, between BC

$$I_3 = 2A$$

Now consider that the current is I_4 in 12Ω resistor and I_5 through 6Ω resistor. These resistors are in parallel. Therefore

$$I_4 R_4 = I_5 R_5$$

or $$\frac{I_4}{I_5} = \frac{R_5}{R_4} = \frac{6}{12} = \frac{1}{2}$$



or $I_5 = 2I_4$

also we have

$$I_4 + I_5 = 2A$$

or, $I_4 + 2I_4 = 2A$

or, $3I_4 = 2A$

$$I_4 = \frac{2}{3}A$$

and $I_5 = 2I_4$

$$= 2 \times \frac{2}{3}A$$

or $$I_5 = \frac{4}{3}A$$

Hence

→ Current through 4Ω and 4Ω = 1 A

→ Current through 1Ω = 2 A

→ Current through 12Ω = $\frac{2}{3}$ A

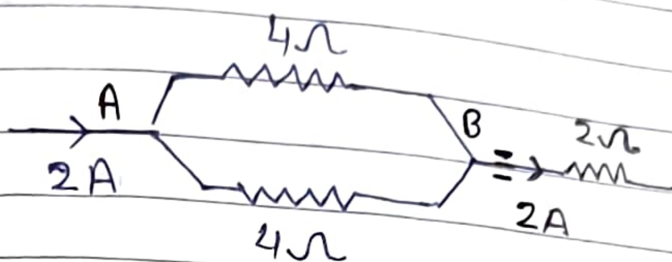
→ Current through 6Ω = $\frac{4}{3}$ A

Ans

Current through $6\Omega = \frac{4}{3}$ A

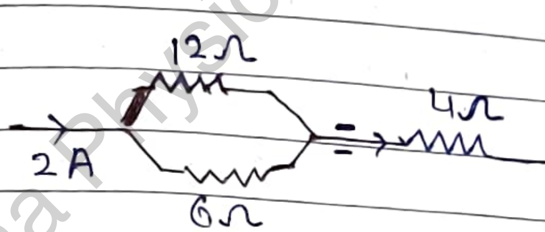
(c) <u>Voltage drops</u>

$\rightarrow V_{AB} = IR$
$= 2 \times 2$
$= 4V$



$\rightarrow V_{BC} = 2 \times 1$ [By $V = IR$]
$= 2V$

$\rightarrow V_{CD} = 2 \times 4$
$= 8V$



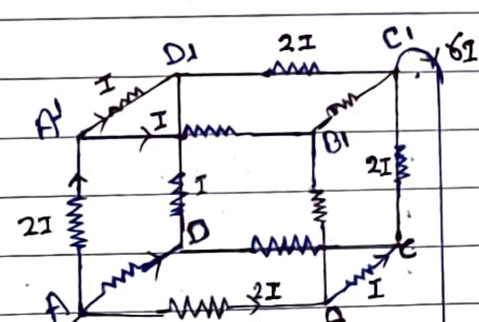
$\Rightarrow$ Hence $\left.\begin{array}{l} V_{AB} = 4V \\ V_{BC} = 2V \\ V_{CD} = 8V \end{array}\right\}$ Ans

* $V_{AD} = V_{AB} + V_{BC} + V_{CD} = 4 + 2 + 8 = 14V$
but EMF = 16V. The loss of 2V is by the internal resistance of 1Ω.

<u>Example 3.6</u> 5

A battery of ------------ of the Cube

Solution



Let a current of magnitude $6I$ enter at A and leave at C'. Here all the resistors are of 1Ω. Therefor we use symmetry for the distribution of current.

By apply Kirchhoff's II rule in loop ABC[illegible]C'E

$$-2I \times I - I \times 1 - 2I \times 1 + 10 = 0$$

$$-5I = -10$$

or $I = 2\,A$

$\therefore$ $6I = 12\,A$

$$R_{eq} = \frac{V}{6I} =$$

$$= \frac{10}{12} = \frac{5}{6}$$

$R_{eq} = \frac{5}{6}\Omega$ Ans

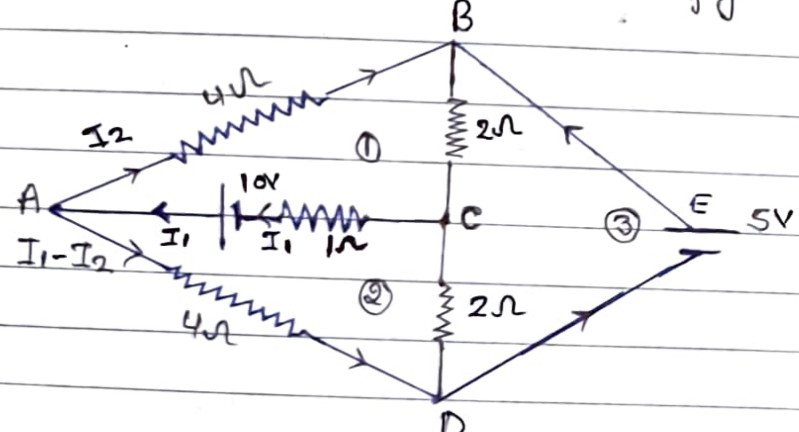
* The current flowing along each edge $= 2I = 2 \times 2 = 4$

$2I = 4\,A$ Ans

Example - 3.7 6

Determine .... Shown in fig.

Solution :→



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Here we have three unknowns I_1, I_2 and I_3. We apply second rule (loop rule) of Kirchhoff to three different loops to find the value of unknow currents.

In loop ①

$$-4I_2 - 2(I_2+I_3) - I_1 + 10 = 0$$

or $I_1 + 4I_2 + 2(I_2+I_3) = 10$

or $I_1 + 6I_2 + 2I_3 = 10$ —— (1)

In Loop ②

$$-4(I_1-I_2) + 2(I_2+I_3-I_1) - I_1 + 10 = 0$$

or $-7I_1 + 6I_2 + 2I_3 = -10$

$7I_1 - 6I_2 - 2I_3 = 10$ —— ②

In loop ③

$$-2(I_2+I_3) - 2(I_2+I_3-I_1) + 5 = 0$$

or $2\times(I_2+I_3) + 2(I_2+I_3-I_1) - 5 = 0$

or $-2I_1 + 4I_2 + 4I_3 = 5$ —— (3)

eqⁿ ① + ② we get

$8I_1 = 20$

or $I_1 = \frac{20}{8}$ or $\boxed{I_1 = \frac{5}{2} A}$

Now ① × 2 − ③

$$\begin{array}{r} 2I_1 + 12I_2 + 4I_3 = 20 \\ -2I_1 + 4I_2 + 4I_3 = 5 \\ + \quad - \quad - \quad\quad - \\ \hline 4I_1 + 8I_2 = 15 \end{array}$$

put $I_1 = \frac{5}{2} \Rightarrow \cancel{4}^2 \times \frac{5}{\cancel{2}} + 8I_2 = 15$

$10 + 8I_2 = 15$

$8I_2 = 5 \Rightarrow \boxed{I_2 = \frac{5}{8} A}$

VISTA

$$\boxed{I_2 = \frac{5}{8} A}$$

Now from eq^n 1

$$I_1 + 6I_2 + 2I_3 = 10$$

$$\frac{5}{2} + 6 \times \frac{5}{8} + 2I_3 = 10$$

$$2I_3 = 10 - \frac{5}{2} - \frac{30}{8}$$

$$= \frac{80-20-30}{8}$$

$$2I_3 = \frac{30}{8}$$

$$\boxed{I_3 = \frac{15}{8} A}$$

$I_1 = \frac{5}{2} A$

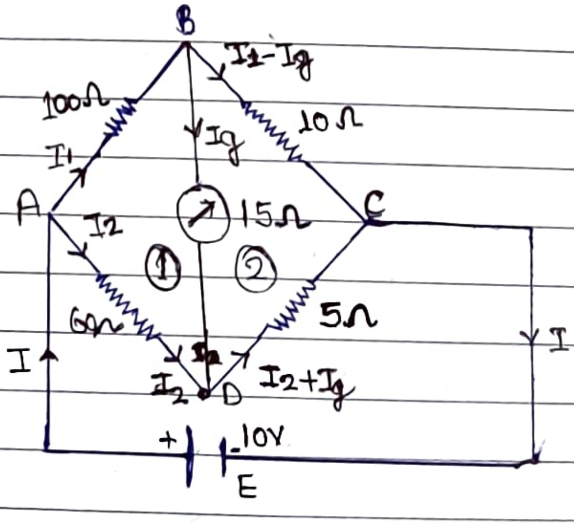
$I_2 = \frac{5}{8} A$ Ans

$I_3 = \frac{15}{8} A$

<u>Example-3.7</u>

The four arms ---------- resistances.

Solution :→



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By KVR $\left[\begin{array}{l}\Sigma V = 0 \\ \Sigma IR = 0\end{array}\right]$

In loop ①

$$100 I_1 + 15 I_g - 60 I_2 = 0$$

$$\text{or} \quad 20 I_1 + 3 I_g - 12 I_2 = 0 \quad \text{——} \; (\mathrm{I})$$

In Loop ②

$$15 I_g + 5 (I_2 + I_g) - 10 (I_1 - I_g) = 0$$

$$15 I_g + 5 I_2 + 5 I_g - 10 I_1 + 10 I_g = 0$$

$$30 I_g + 5 I_2 - 10 I_1 = 0$$

$$6 I_g + I_2 - 2 I_1 = 0 \quad \text{——} \; (\mathrm{II}) \quad \text{OR} \; -2I_1 + 6I_g + I_2 = 0$$

Now in loop ③

$$\Rightarrow \quad 60 I_2 + 5 (I_2 + I_g) - 10 = 0$$

$$\Rightarrow \text{or} \quad 60 I_2 + 5 I_2 + 5 I_g = 10$$

$$\Rightarrow \quad 65 I_2 + 5 I_g = 10$$

$$\text{or} \quad 13 I_2 + I_g = 2 \quad \text{——} \; (\mathrm{III})$$

eqn ① + 10×eqn ②

$$\rightarrow \quad \cancel{20} I_1 + 3 I_g - 12 I_2 = 0 \quad - (\mathrm{I})$$

$$\rightarrow \quad -\cancel{20} I_1 + 60 I_g + 10 I_2 = 0 \quad - (\mathrm{II})$$

$$+ \quad \overline{\quad 63 I_g - 2 I_2 = 0 \quad}$$

$$\Rightarrow \quad I_2 = \frac{63}{2} I_g$$

From eqn ③

$$\Rightarrow \quad 13 I_2 + I_g = 2$$

$$\Rightarrow \quad 13 \times \frac{63}{2} I_g + I_g = 2$$

$$\Rightarrow \quad \frac{819}{2} I_g + I_g = 2 \Rightarrow 409.5 I_g + I_g = 2$$

$$\Rightarrow \quad 410.5 I_g = 2$$

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$\Rightarrow \quad 410.5\, I_g = 2$

$\Rightarrow \quad I_g = \frac{2}{410.5} = 0.00487\, A$

$\Rightarrow$ Or $\boxed{I_g = 4.87\ mA\ \text{Ans}}$