



# POSTAL BOOK PACKAGE 2024

## ELECTRICAL ENGINEERING

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### CONVENTIONAL Practice Sets

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#### ELECTRIC CIRCUITS

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# 1

CHAPTER

## Electric Circuits

# Basics, Circuit Elements, Nodal & Mesh Analysis

**Q1** A 10 V battery with an internal resistance of  $1\ \Omega$  is connected across a non-linear load whose  $V$ - $I$  characteristics is given by  $7I = V^2 + 2\text{ V}$ . Find the current delivered by the battery.

**Solution:**

Using KVL,

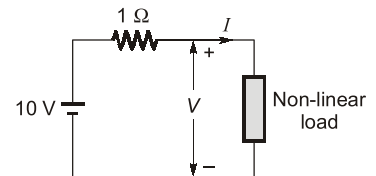
$$V + I = 10 \quad \dots(i)$$

Given,  $7I = V^2 + 2\text{ V} \quad \dots(ii)$

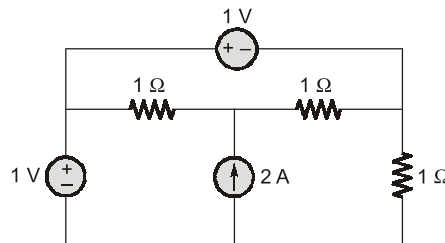
On solving equation (i) and equation (ii)

we get,  $V = 5\text{ Volts}$

$$I = 5\text{ A}$$



**Q2** Find the power delivered by the current source in the figure shown below.



**Solution:**

Consider node voltages  $V_a$ ,  $V_b$ ,  $V_x$  as shown below.

Applying nodal analysis,

$$\begin{aligned} \Rightarrow \quad \frac{V_x - V_a}{1} + \frac{V_x - V_b}{1} &= 2 \\ \Rightarrow \quad 2V_x - (V_a + V_b) &= 2 \end{aligned}$$

$$\Rightarrow \quad V_x = \frac{2 + (V_a + V_b)}{2} \quad \dots(i)$$

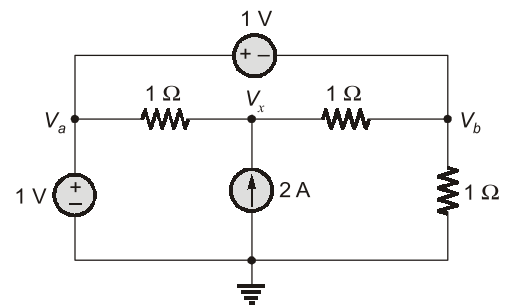
Also,  $V_a - V_b = 1\text{ V}$

$$V_a = 1\text{ V}$$

Thus,  $V_b = 0\text{ V}$

Solving further,  $V_x = \frac{2 + (1 + 0)}{2} = 1.5\text{ V}$

$\therefore$  Power delivered by current source  $= V_x \cdot I \quad [I = 2\text{ A (given)}]$   
 $= (1.5) \times 2 = 3\text{ Watts}$



**Q3** Two identical coils connected in parallel across 100 V dc supply, take 10 A current from the supply. Power dissipated in one coil is 600 W. What is the resistance of each coil?

**Solution:**

Given, Power dissipated in one coil  $= 600\text{ W}$

$$I = I_1 + I_2$$

$$I_1 = I_2$$

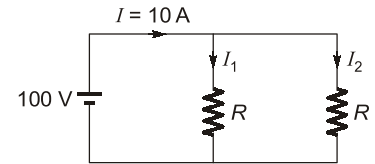
$$I_1 = I_2 = \frac{10 \text{ A}}{2} = 5 \text{ A}$$

$$P = I_1^2 R$$

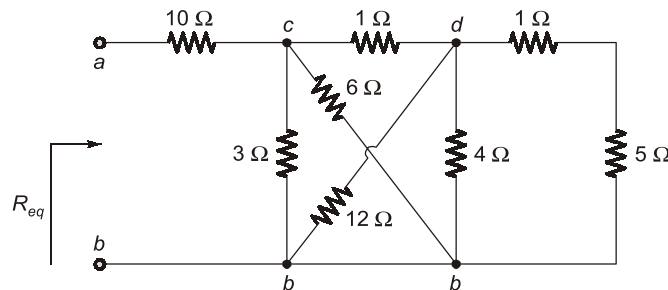
$$R = \frac{P}{I_1^2} = \frac{600}{(5)^2} = 24 \Omega$$

Power dissipated,

Hence, resistance of coil,



**Q.4** Calculate equivalent resistance  $R_{eq}$  in the circuit shown.



**Solution:**

3  $\Omega$  and 6  $\Omega$  resistors in parallel because they are connected to same two nodes c and b. Their combined resistance is

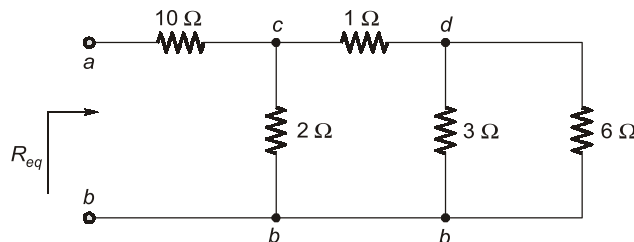
$$= \frac{3 \times 6}{3 + 6} = 2 \Omega$$

Similarly, 12  $\Omega$  and 4  $\Omega$  resistors are in parallel since they are connected to same two nodes d and b.

$$\text{Hence, } 12 \Omega || 4 \Omega = \frac{12 \times 4}{12 + 4} = 3 \Omega$$

Also, 1  $\Omega$  and 5  $\Omega$  resistors are in series, hence combined resistance,

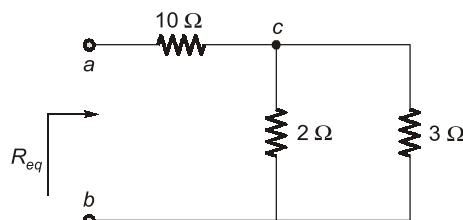
$$1 \Omega + 5 \Omega = 6 \Omega$$



$$\text{Further } 3 \Omega \text{ and } 6 \Omega \text{ in parallel gives equivalent resistance} = \frac{3 \Omega \times 6 \Omega}{(3 + 6) \Omega} = 2 \Omega$$

This 2  $\Omega$  in series with 1  $\Omega$ .

Given equivalent as  $(2 + 1) \Omega = 3 \Omega$  as shown below.

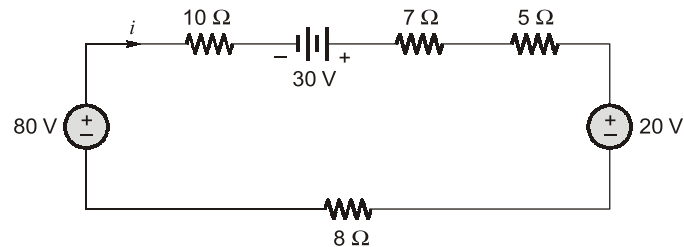


Now 2  $\Omega$  and 3  $\Omega$  parallel's combination in series with 10  $\Omega$  resistance.

Hence,

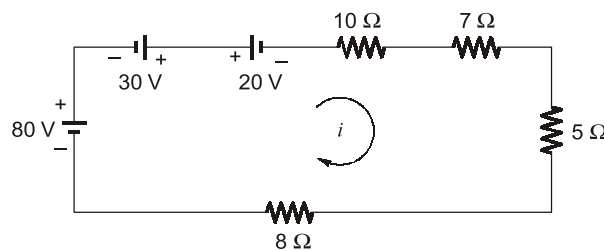
$$\begin{aligned} R_{ab} = R_{eq} &= 10\ \Omega + (2\ \Omega \parallel 3\ \Omega) \\ &= 10 + \frac{2 \times 3}{2 + 3} = 11.2\ \Omega \end{aligned}$$

**Q5** Use resistance and source combinations to determine the current  $i$  in figure shown and power delivered by 80 V source.



**Solution:**

The circuit can be redrawn as,



Further combining the three voltage sources into an equivalent source of 90 V as shown below.

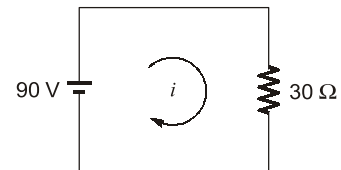
All the resistance, combined in series as,

$$R_{eq} = (10 + 7 + 5 + 8)\ \Omega = 30\ \Omega$$

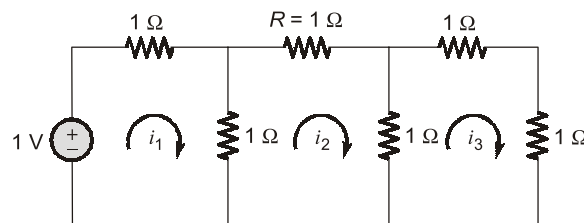
Simply applying KVL,  $-90 + 30i = 0$

Hence,  $i = 3\ \text{A}$

Power delivered by 80 V source =  $80\ \text{V} \times 3\ \text{A} = 240\ \text{W}$



**Q6** Find the power dissipated in the resistor  $R$  in the ladder network shown in the figure below.



**Solution:**

Using KVL in loop,

$$1 = 2i_1 - i_2 \quad \dots(1)$$

$$0 = 3i_2 - i_1 - i_3 \quad \dots(2)$$

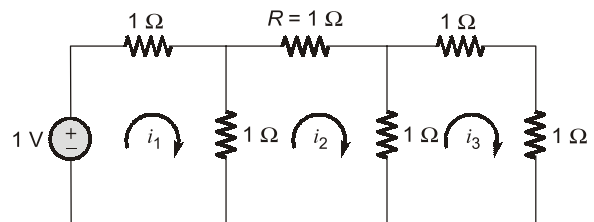
$$0 = 3i_3 - i_2 \quad \dots(3)$$

$$\therefore i_3 = \frac{i_2}{3}$$

By solving the equations, we get,

$$i_2 = \frac{3}{13}\ \text{A}$$

$\therefore$  Power dissipated in the resistor  $R = i^2 R = \frac{9}{169}\ \text{W}$



**Q7** The following mesh equations pertain to a network:

$$\begin{aligned} 8I_1 - 5I_2 - I_3 &= 110 \\ -5I_1 + 10I_2 + 0 &= 0 \\ -I_1 + 0 + 7I_3 &= 115 \end{aligned}$$

Draw network showing each element.

**Solution:**

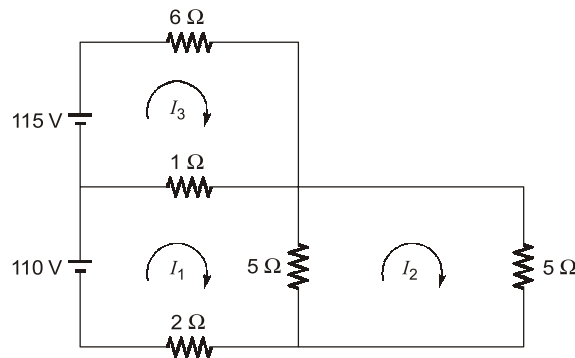
All the mesh equations can be rearrangement as,

$$\Rightarrow \begin{aligned} 8I_1 - 5I_2 - I_3 &= 110 \\ 5(I_1 - I_2) + (I_1 - I_3) + 2I_1 &= 110 \end{aligned} \quad \dots(1)$$

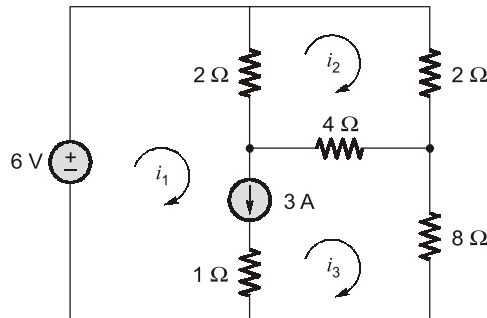
$$\Rightarrow \begin{aligned} -5I_1 + 10I_2 + 0 &= 0 \\ 5(I_2 - I_1) + 5I_2 &= 0 \end{aligned} \quad \dots(2)$$

$$\Rightarrow \begin{aligned} -I_1 + 0 + 7I_3 &= 115 \\ (I_3 - I_1) + 6I_3 &= 115 \end{aligned} \quad \dots(3)$$

On the basis of equation (1), (2) and (3), we can draw the network as,



**Q8** Find mesh currents in the circuit,



**Solution:**

$$i_1 - i_3 = 3 \text{ A} \quad \dots(1)$$

BY KVL for super mesh,

$$\begin{aligned} 2(i_1 - i_2) + 4(i_3 - i_2) + 8i_3 &= 6 \\ 2i_1 - 6i_2 + 12i_3 &= 6 \end{aligned} \quad \dots(2)$$

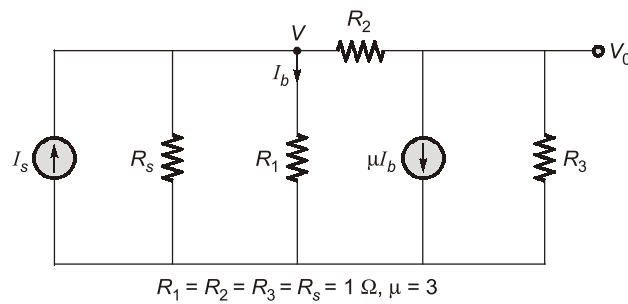
By KVL for second mesh,

$$\begin{aligned} 2i_2 + 4(i_2 - i_3) + 2(i_2 - i_1) &= 0 \\ 8i_2 - 4i_3 - 2i_1 &= 0 \end{aligned} \quad \dots(3)$$

Solving equations (1), (2) and (3), we get

$$\begin{aligned} i_1 &= 3.473 \text{ A} \\ i_2 &= 1.105 \text{ A} \\ i_3 &= 0.473 \text{ A} \end{aligned}$$

**Q.9** For the circuit shown in the figure determine  $V_0/I_s$  using nodal analysis.



**Solution:**

$$V = I_b \quad \dots(1)$$

Node (1),

$$\frac{V}{1} + \frac{V}{1} + \frac{V - V_0}{1} - I_s = 0$$

$$3V - V_0 = I_s \quad \dots(2)$$

Node (2),

$$\frac{V_0}{1} + \frac{V_0 - V}{1} + 3I_b = 0$$

$$2V_0 - V = -3I_b$$

From equation (1),

$$I_b = V \text{ put in equation (3)}$$

$$2V_0 - V = -3V$$

$$2V_0 = -2V$$

$\Rightarrow$

$$V = -V_0$$

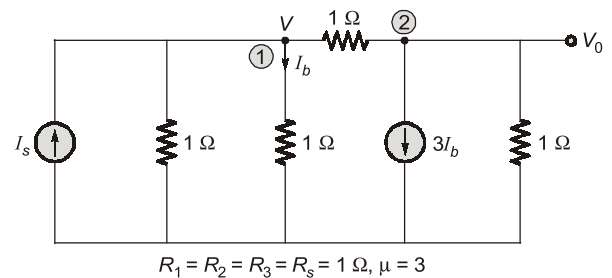
Putting,

$$V = -V_0 \text{ in equation (2)}$$

$$3(-V_0) - V_0 = I_s$$

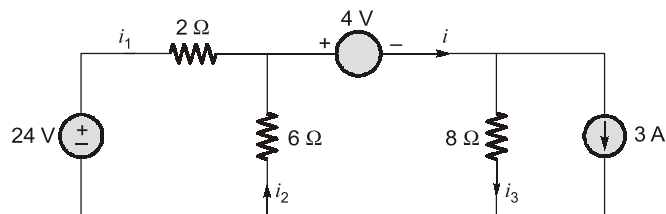
$$-4V_0 = I_s$$

$$\frac{V_0}{I_s} = -\frac{1}{4} = -0.25$$

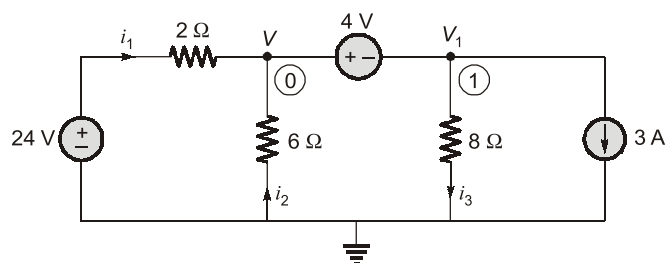


$\dots(3)$

**Q.10** For the circuit shown in figure, determine the currents  $i_1$ ,  $i_2$  and  $i_3$  using nodal analysis.



**Solution:**



By nodal analysis,

$$\begin{aligned} -i_1 - i_2 + i &= 0 \\ -\left(\frac{24-V}{2}\right) + \left[-\frac{0-V}{6}\right] + i &= 0 \\ \frac{V-24}{2} + \frac{V}{6} + i &= 0 \quad \dots(1) \\ V_1 &= V - 4 \end{aligned}$$

KCL at node 1,

$$\begin{aligned} -i + \frac{V_1}{8} + 3 &= 0 \\ i &= \left(\frac{V-4}{8} + 3\right) \quad \dots(2) \end{aligned}$$

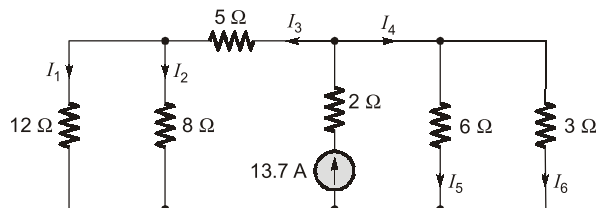
Combining (1) and (2),

$$\frac{V-24}{2} + \frac{V}{6} + \frac{V-4}{8} + 3 = 0$$

Solving,

$$\begin{aligned} V &= 12 \text{ V} \\ V_1 &= 8 \text{ V} \\ i_1 &= \frac{24-12}{2} = 6 \text{ A} \\ i_2 &= -\frac{12}{6} = -2 \text{ A} \\ i_3 &= 1 \text{ A} \end{aligned}$$

**Q.11** Find all branch currents in the network shown in figure below.



**Fig. 1**

**Solution:**

On simplifying the above circuit,

$$R_3 = 5 + \frac{(12)(8)}{20} = 9.8 \Omega$$

$$R_4 = \frac{(6)(3)}{9} = 2 \Omega$$

By current division rule,

$$I_3 = \frac{2}{9.8+2} \times 13.7 = 2.32 \text{ A}$$

$$I_4 = 13.7 - 2.32 = 11.38 \text{ A}$$

Referring original network (Fig. 1),

$$I_1 = \frac{8}{(12+8)} (2.32) = 0.93 \text{ A}$$

$$I_2 = 2.32 - 0.93 = 1.39 \text{ A}$$

$$I_5 = \frac{3}{(6+3)} (11.38) = 3.79 \text{ A}$$

$$I_6 = 11.38 - 3.79 = 7.59 \text{ A}$$

