



# POSTAL BOOK PACKAGE 2024

## ELECTRICAL ENGINEERING

.....

### CONVENTIONAL Practice Sets

#### CONTENTS

#### ELECTRIC CIRCUITS

---

1. Basics, Circuit Elements, Nodal & Mesh Analysis .....	2
2. Circuit Theorems .....	25
3. Capacitors and Inductors .....	60
4. Transient Response of DC and AC Networks (First Order RL & RC Circuits, Second Order RLC Circuits) .....	68
5. Sinusoidal Steady State Analysis, AC Power Analysis .....	108
6. Magnetically Coupled Circuits .....	125
7. Frequency Response and Resonance .....	141
8. Two Port Networks .....	157
9. Network Topology, Miscellaneous .....	191

# 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,

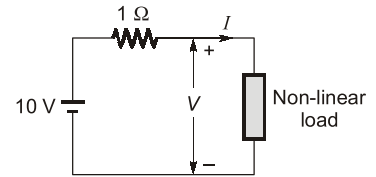
$$V + I = 10 \quad \dots(i)$$

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

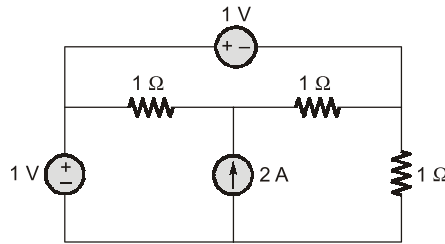
On solving equation (i) and equation (ii)

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,

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

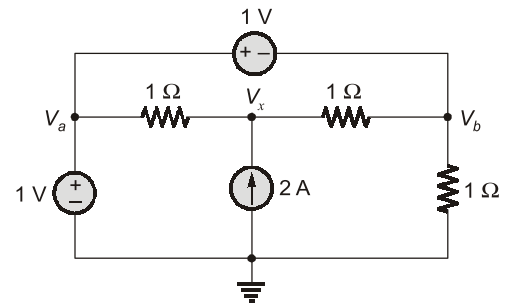
Also,  $V_a - V_b = 1\text{ V}$

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

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  $= 600\text{ W}$

$$I = I_1 + I_2$$

$$I_1 = I_2$$

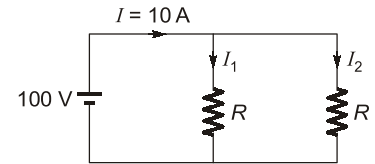
$$I_1 = I_2 = \frac{10 \text{ A}}{2} = 5 \text{ A}$$

$$P = I_1^2 R$$

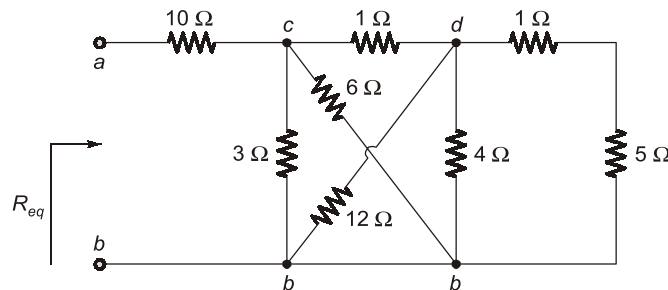
$$R = \frac{P}{I_1^2} = \frac{600}{(5)^2} = 24 \Omega$$

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

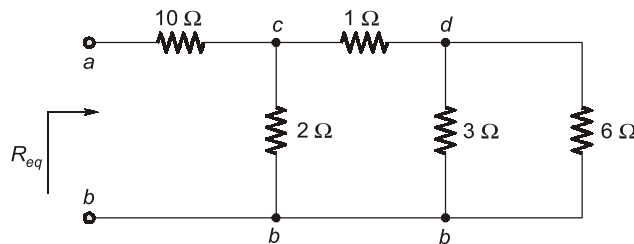
$$= \frac{3 \times 6}{3 + 6} = 2 \Omega$$

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

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,

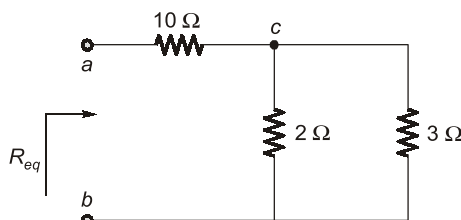
$$1 \Omega + 5 \Omega = 6 \Omega$$



Further  $3 \Omega$  and  $6 \Omega$  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.

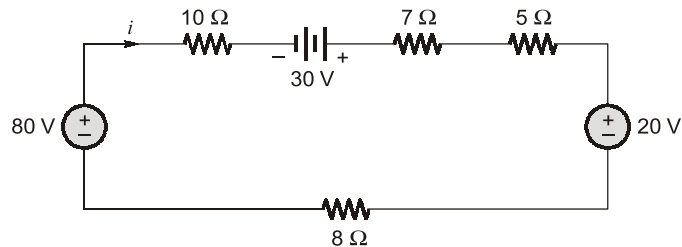


Now  $2 \Omega$  and  $3 \Omega$  parallel's combination in series with  $10 \Omega$  resistance.

Hence,

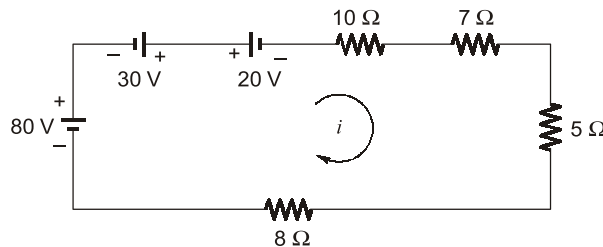
$$\begin{aligned} R_{ab} = R_{eq} &= 10\ \Omega + (2\ \Omega \parallel 3\ \Omega) \\ &= 10 + \frac{2 \times 3}{2 + 3} = 11.2\ \Omega \end{aligned}$$

**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.

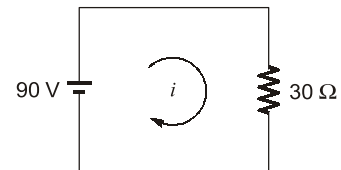
All the resistance, combined in series as,

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

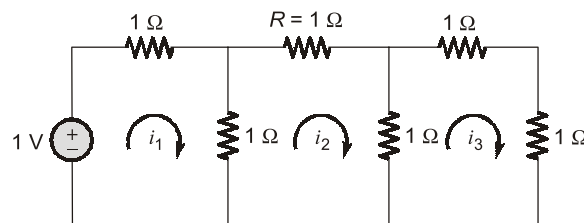
Simply applying KVL,  $-90 + 30i = 0$

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,

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

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

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

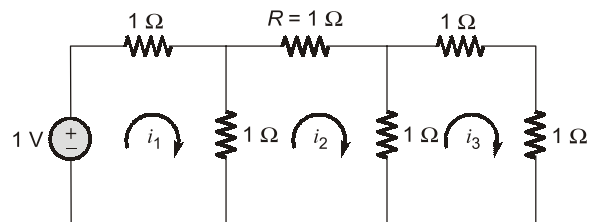
$\therefore$

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

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:**

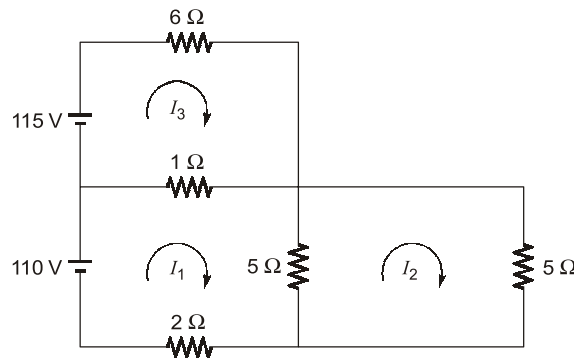
All the mesh equations can be rearrangement as,

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

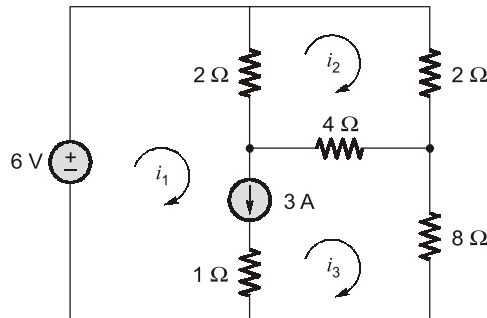
$$\Rightarrow \begin{aligned} -5I_1 + 10I_2 + 0 &= 0 \\ 5(I_2 - I_1) + 5I_2 &= 0 \end{aligned} \quad \dots(2)$$

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

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,

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

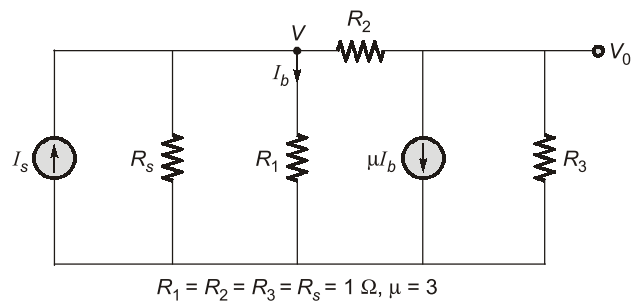
By KVL for second mesh,

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

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

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

**Q9** 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),

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

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

$$2V_0 = -2V$$

$\Rightarrow$

$$V = -V_0$$

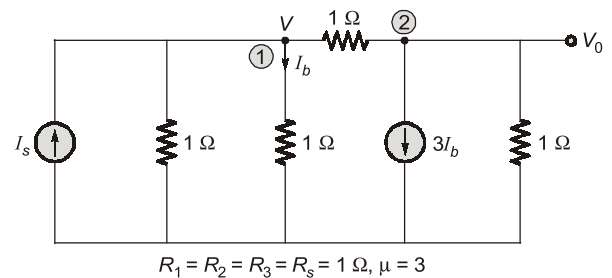
Putting,

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

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

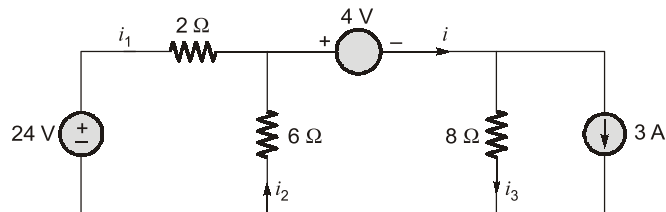
$$-4V_0 = I_s$$

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

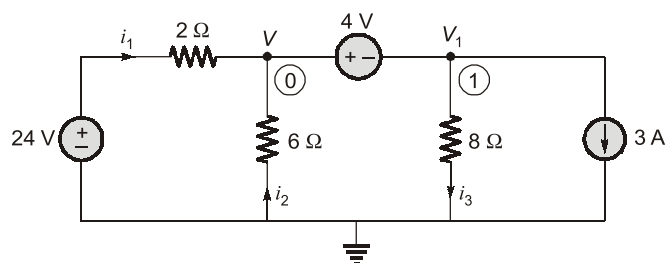


$\dots(3)$

**Q10** 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,

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

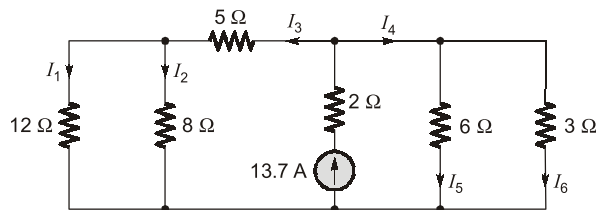
Combining (1) and (2),

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

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),

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

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

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

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

