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ELECTRONICS ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

NETWORK THEORY

1 CHAPTER

Basics, Circuit Elements, Nodal & Mesh Analysis

Q.1 A 10 V battery with an internal resistance of 1 Ω is connected across a non-linear load whose V-I characteristics is given by $7I = V^2 + 2$ V. Find the current delivered by the battery.

Solution:

Using KVL,

$$V + I = 10 \qquad ...(i)$$

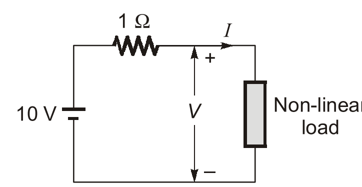
Given,

$$7I = V^2 + 2\text{ V} \qquad ...(ii)$$

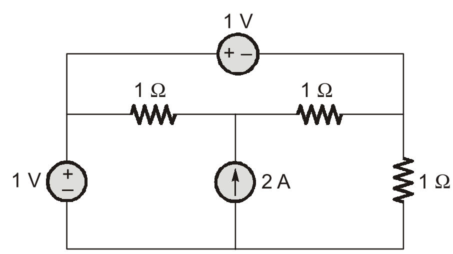
On solving equation (i) and equation (ii)

we get, $V = 5$ Volts

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



Q.2 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,

$$\frac{V_x - V_a}{1} + \frac{V_x - V_b}{1} = 2$$

$$\Rightarrow \quad 2V_x - (V_a + V_b) = 2$$

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

Also, $V_a - V_b = 1$ V

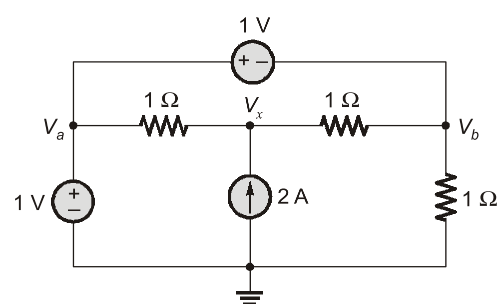
$$V_a = 1\text{ V}$$

Thus, $V_b = 0$ V

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

$\therefore$ Power delivered by current source $= V_x \cdot I$ $\quad$ [$I = 2$ A (given)]

$= (1.5) \times 2 = 3$ Watts



Q.3 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?

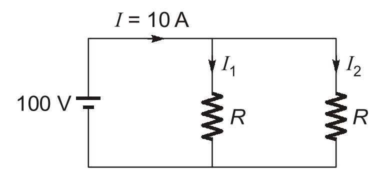
Solution:

Given, Power dissipated in one coil $= 600$ W

$$I = I_1 + I_2$$

$$I_1 = I_2$$

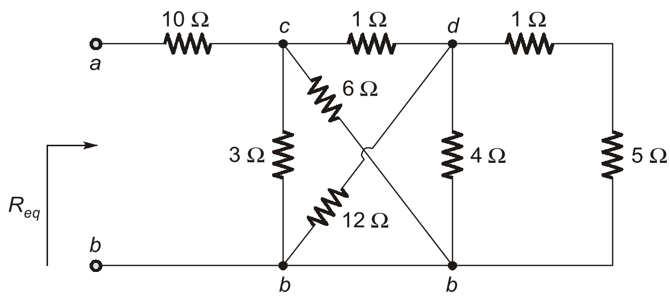
$$I_1 = I_2 = \frac{10\text{ A}}{2} = 5\text{ A}$$



Power dissipated, $P = I_1^2 R$

Hence, resistance of coil, $R = \frac{P}{I_1^2} = \frac{600}{(5)^2} = 24\ \Omega$

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



Solution:

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

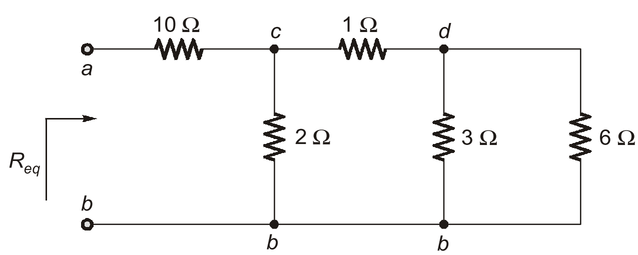
$$= \frac{3 \times 6}{3+6} = 2\ \Omega$$

Similarly, 12 Ω and 4 Ω 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 Ω and 5 Ω resistors are in series, hence combined resistance,

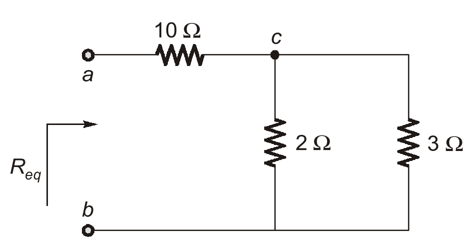
$$1\ \Omega + 5\ \Omega = 6\ \Omega$$



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

This 2 Ω in series with 1 Ω.

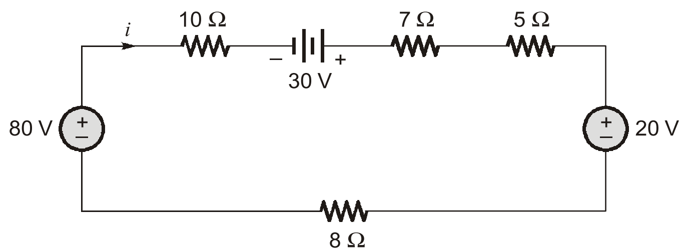
Given equivalent as (2 + 1) Ω = 3 Ω as shown below.



Now 2 Ω and 3 Ω parallel's combination in series with 10 Ω resistance.

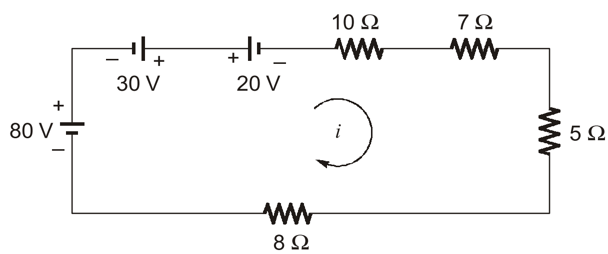
Hence, $$R_{ab} = R_{eq} = 10\,\Omega + (2\,\Omega \,||\, 3\,\Omega)$$
$$= 10 + \frac{2 \times 3}{2+3} = 11.2\,\Omega$$

Q.5 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.

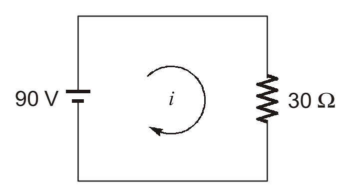
All the resistance, combined in series as,

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

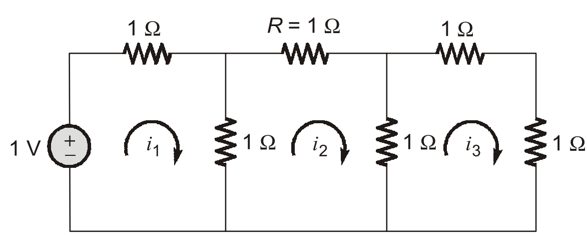
Simply applying kVL, $-90 + 30i = 0$

Hence, $i = 3$ A

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



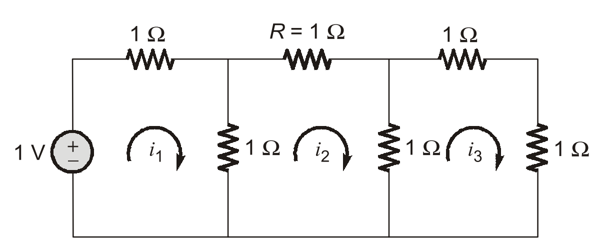
Q.6 Find the power dissipated in the resistor R in the ladder network shown in the figure below.



Solution:

Using KVL in loop,

$$1 = 2i_1 - i_2 \quad \text{...(1)}$$
$$0 = 3i_2 - i_1 - i_3 \quad \text{...(2)}$$
$$0 = 3i_3 - i_2 \quad \text{...(3)}$$



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

By solving the equations, we get,

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

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

Q.7 The following mesh equations pertain to a network:

$$8I_1 - 5I_2 - I_3 = 110$$
$$-5I_1 + 10I_2 + 0 = 0$$
$$-I_1 + 0 + 7I_3 = 115$$

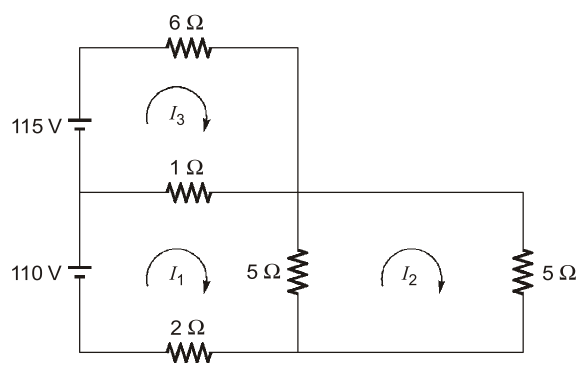
Draw network showing each element.

Solution:

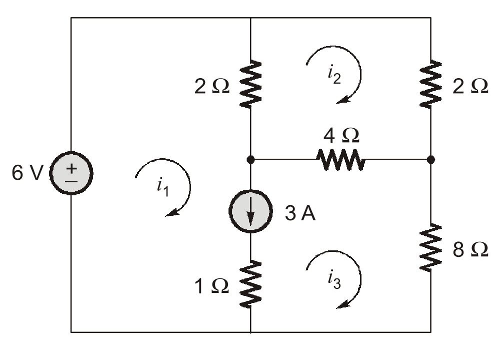
All the mesh equations can be rearrangement as,

$$8I_1 - 5I_2 - I_3 = 110$$
$$\Rightarrow \quad 5(I_1 - I_2) + (I_1 - I_3) + 2I_1 = 110 \qquad \text{...(1)}$$
$$-5I_1 + 10I_2 + 0 = 0$$
$$\Rightarrow \quad 5(I_2 - I_1) + 5I_2 = 0 \qquad \text{...(2)}$$
$$-I_1 + 0 + 7I_3 = 115$$
$$\Rightarrow \quad (I_3 - I_1) + 6I_3 = 115 \qquad \text{...(3)}$$

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



Q.8 Find mesh currents in the circuit,



Solution:

$$i_1 - i_3 = 3 \text{ A} \qquad \text{...(1)}$$

BY KVL for super mesh,

$$2(i_1 - i_2) + 4(i_3 - i_2) + 8i_3 = 6$$
$$2i_1 - 6i_2 + 12i_3 = 6 \qquad \text{...(2)}$$

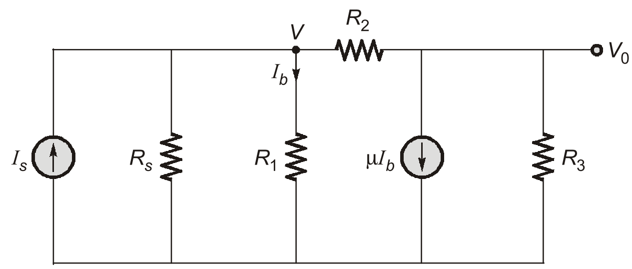
By KVL for second mesh,

$$2i_2 + 4(i_2 - i_3) + 2(i_2 - i_1) = 0$$
$$8i_2 - 4i_3 - 2i_1 = 0 \qquad \text{...(3)}$$

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

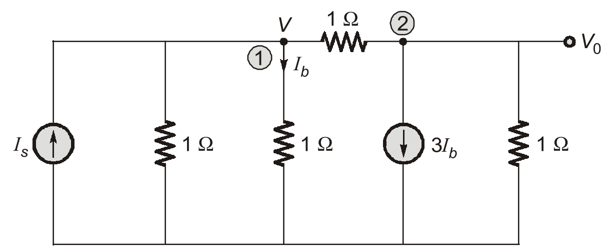
$$i_1 = 3.473 \text{ A}$$
$$i_2 = 1.105 \text{ A}$$
$$i_3 = 0.473 \text{ A}$$

Q.9 For the circuit shown in the figure determine V_0/I_S using nodal analysis.



$R_1 = R_2 = R_3 = R_s = 1\ \Omega$, $\mu = 3$

Solution:



$R_1 = R_2 = R_3 = R_s = 1\ \Omega$, $\mu = 3$

$$V = I_b \quad \text{...(1)}$$

Node (1),

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

$$3V - V_0 = I_s \quad \text{...(2)}$$

Node (2),

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

$$2V_0 - V = -3I_b \quad \text{...(3)}$$

From equation (1), $I_b = V$ put in equation (3)

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

$$2V_0 = -2\ V$$

$\Rightarrow$ $V = -V_0$

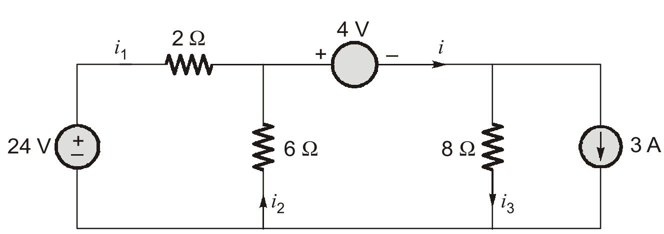
Putting, $V = -V_0$ in equation (2)

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

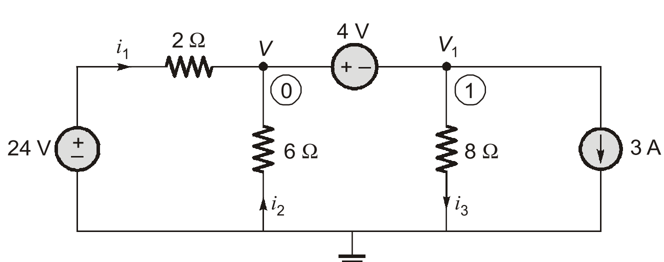
$$-4V_0 = I_s$$

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

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,
$$-i_1 - i_2 + i = 0$$
$$-\left(\frac{24-V}{2}\right)+\left[-\frac{0-V}{6}\right]+i = 0$$
$$\frac{V-24}{2}+\frac{V}{6}+i = 0 \quad ...(1)$$
$$V_1 = V-4$$
KCL at node 1,
$$-i+\frac{V_1}{8}+3 = 0$$
$$i = \left(\frac{V-4}{8}+3\right) \quad ...(2)$$
Combining (1) and (2),
$$\frac{V-24}{2}+\frac{V}{6}+\frac{V-4}{8}+3 = 0$$
Solving,
$$V = 12\text{ V}$$
$$V_1 = 8\text{ V}$$
$$i_1 = \frac{24-12}{2} = 6\text{ A}$$
$$i_2 = -\frac{12}{6} = -2\text{ A}$$
$$i_3 = 1\text{ A}$$

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

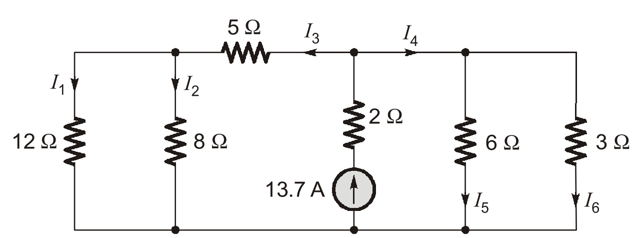
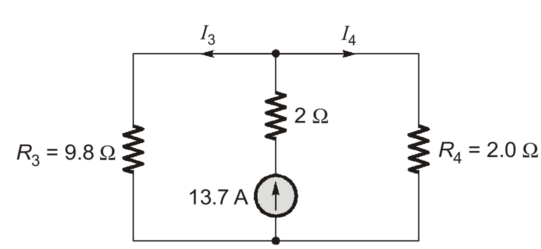


Fig. 1

Solution:

On simplifying the above circuit,

$$R_3 = 5+\frac{(12)(8)}{20} = 9.8\ \Omega$$
$$R_4 = \frac{(6)(3)}{9} = 2\ \Omega$$



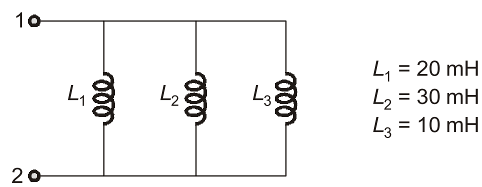
By current division rule,
$$I_3 = \frac{2}{9.8+2}\times 13.7 = 2.32\text{ A}$$
$$I_4 = 13.7-2.32 = 11.38\text{ A}$$
Referring original network (Fig. 1),
$$I_1 = \frac{8}{(12+8)}(2.32) = 0.93\text{ A}$$
$$I_2 = 2.32-0.93 = 1.39\text{ A}$$

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

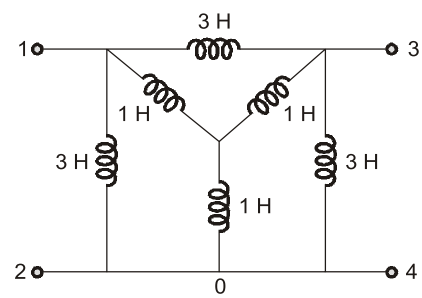
$$I_6 = 11.38 - 3.79 = 7.59 \text{ A}$$

Q.12 Determine equivalent inductance at terminal '1-2' for circuits.

(a)



(b)



Solution:

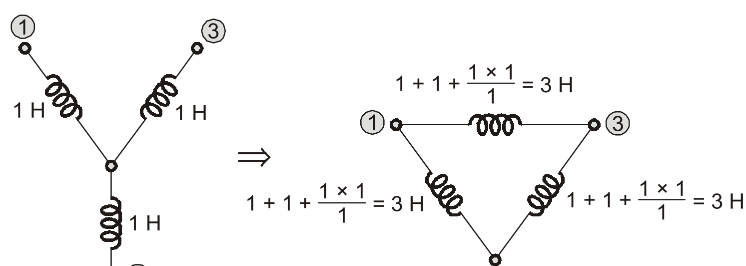
(a) All the inductances are in parallel thus overall equivalent inductance is

$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

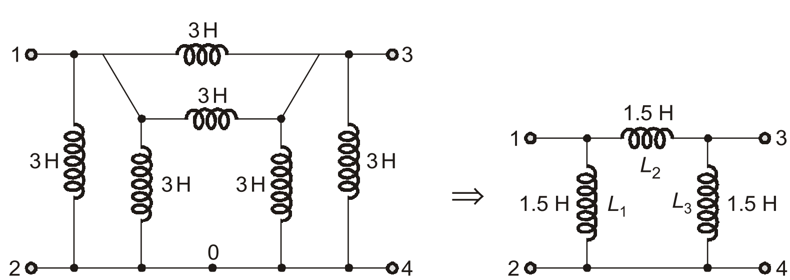
$$\frac{1}{L_{eq}} = \frac{1}{20 \text{ mH}} + \frac{1}{30 \text{ mH}} + \frac{1}{10 \text{ mH}}$$

On solving, $$L_{eq} = \frac{60}{11} \text{ mH} = 5.45 \text{ mH}$$

(b) This problem can be best solved utilising star to delta transformation.
Let us first convert the interconnected inductances to an equivalent delta. This is shown in figure (a)
Hence the equivalent circuit configuration of figure given becomes as shown in figure (b).



(a)



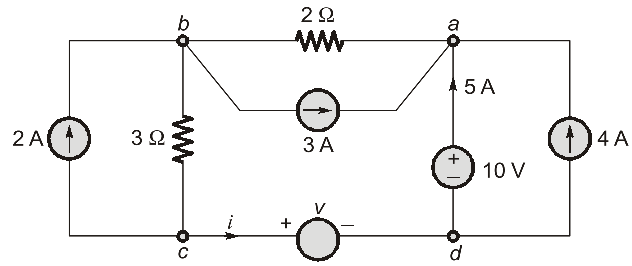
(b)

Redrawing circuits,
Thus the equivalent inductance across 1-2 is given by

$$L_{1-2} = L_1 \,||\, (L_2 + L_3) = 1.5 \,||\, 3 = \frac{1.5 \times 3}{1.5 + 3}.$$

Hence, $$L_{12} = L_{eq} = 1 \text{ H}$$

Q.13 For the circuit shown below, find v, i and the power absorbed by the unknown circuit element.



Solution:

Using nodal analysis at node a, $i_{ab} = 3 + 5 + 4 = 12$ A

$\therefore$ The voltage across the 2 Ω resistor is $12 \times 2 = 24$ V

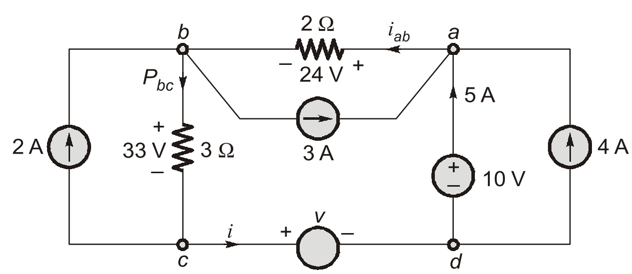
For node b, nodal analysis gives, $i_{bc} = 12 + 2 - 3 = 11$ A

The voltage across 3 Ω resistor is $11 \times 3 = 33$ V

KCL at node c, $i_{bc} = i + 2$

$\Rightarrow$ $i = i_{bc} - 2 = 11 - 2 = 9$ A

Figure with corresponding voltage drops resistances is shown below.



Applying KVL at the loop $abcd$,

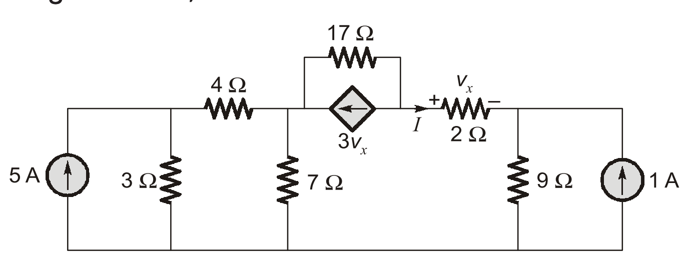
$$-10 + 24 + 33 + v = 0$$

Hence, $v = -47$ V

Power absorbed by unknown element is

$$= v \times i = (-47) \times 9 = -423 \text{ Watts}$$

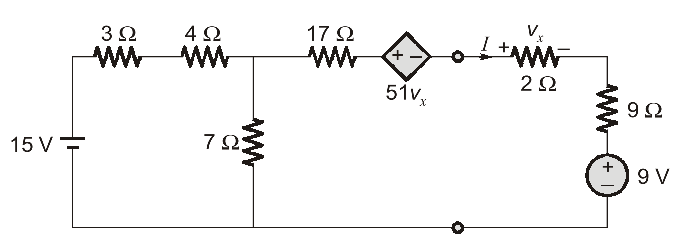
Q.14 In the circuit shown in figure below, find the value of current I.



Solution:

All the current sources are converted into voltage sources and network simplified in the following steps.

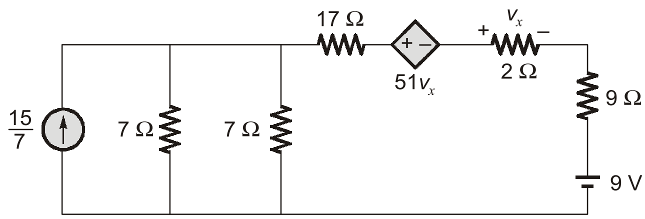
Step-1:



(a)

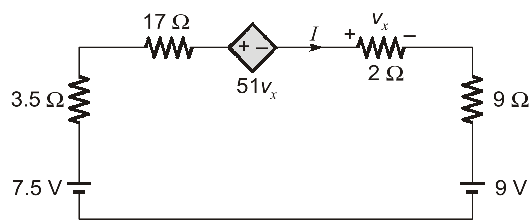
Note: Source transformation is also applicable for dependent sources.

Step-2:



(b)

Step-3:



(c)

Step-4:

$$v_x = 2I$$

Applying KVL:

$-7.5 + 3.5I + 17I + 51v_x + 2I + 9I + 9 = 0$

Put $v_x = 2I$

Solving, $I = -11.24 \text{ mA}$

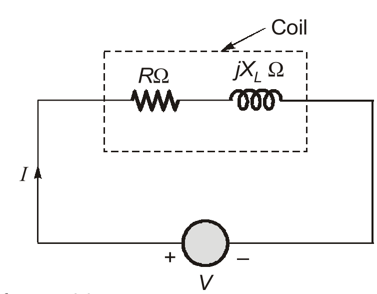
Q.15 An iron choke coil takes 4 A when connected to a 20 V-dc supply and takes 5 A when connected to 65 V, 50 Hz ac supply. Determine:

(*i*) resistance and inductance of the coil

(*ii*) the power factor

Solution:

(*i*) Case-1: When coil is connected to 20 V dc supply.



Current, $I = 4 \text{ A}$

For dc supply, frequency, $f = 0$ Hz

$$I = \frac{V}{R} \Rightarrow R = \frac{V}{I} = \frac{20}{4} = 5\ \Omega$$

Resistance of coil $= 5\ \Omega$

Case-2: When coil is connected to 65 V, 50 Hz ac supply frequency, $f = 50$ Hz

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

So, $$Z = \frac{V}{I} = \frac{65}{5} = 13\ \Omega$$

$$X_L = \sqrt{Z^2 - R^2} = \sqrt{(13)^2 - (5)^2} = 12\ \Omega$$

$$2\pi f L = 12$$

$$L = \frac{12}{2\pi \times 50} = 0.0381974 \text{ or } 38.197 \text{ mH}$$

Inductance of coil, $L = 38.197$ mH

(*ii*) The power factor:

Case-1: If circuit is resistive so power factor will be unity.

$$\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1$$

Case-2: $Z = 13\ \Omega$

Power factor, $$\cos\phi = \frac{R}{Z} = \frac{5}{13} = 0.3846 \quad \text{(lagging)}$$

Q.16 Two conductors, one of copper and the other of iron, are connected in parallel and carry equal currents at 30° C. What proportion of current will pass through each, if the temperature is raised to 90°C? The temperature coefficients of resistance at 0°C are 0.0043/°C and 0.0063/°C for copper and iron respectively.

Solution:

Let resistance of copper and iron are R_1 and R_2 respectively at 30°C.

Now at 90°C, change in temperature,

$$\Delta t = 90° - 30° = 60°C$$

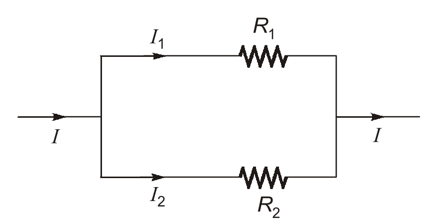
$$R_1' = R_1(1 + \alpha_1 \Delta t) = R_1(1 + 0.0043 \times 60)$$

$$R_1' = 1.258\, R_1 \quad \ldots(i)$$

and $$R_2' = R_2(1 + \alpha_2 \Delta t) = R_2(1 + 0.0063 \times 60)$$

$$= 1.378\, R_2 \quad \ldots(ii)$$

Given currents are equal at 30°C i.e. $I_1 = I_2$



and $$I \propto \frac{1}{R}$$

so, $$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

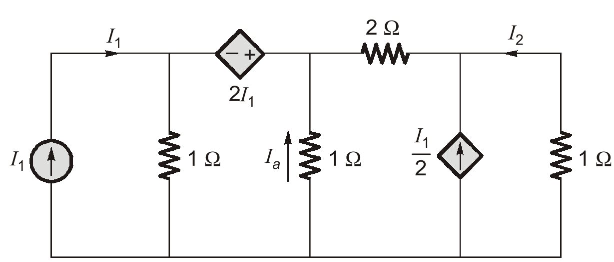
i.e., $$1 = \frac{R_2}{R_1} \Rightarrow R_1 = R_2$$

so, at 90°C, $$\frac{I_1'}{I_2'} = \frac{R_2'}{R_1'} \quad \ldots(iii)$$

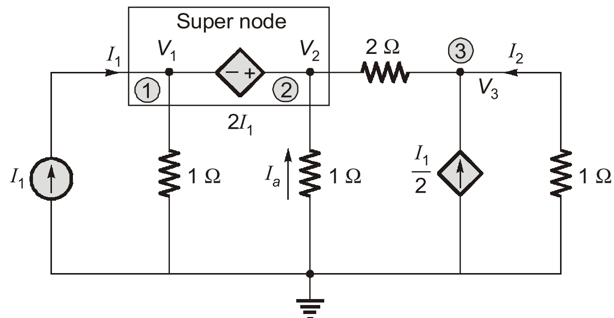
Substituting the value of R_1' and R_2' in equation (*iii*), we get

$$\frac{I_1'}{I_2'} = \frac{1.378}{1.258} = 1.173$$

Q.17 For the network shown below, find the current ratio transfer function given by $\alpha = I_2/I_1$.



Solution:



Consider nodes (1) and (2). These two nodes constitutes a super node.

$$V_2 - V_1 = 2I_1 \qquad ...(1)$$

Super node equation,

$$\frac{V_1}{1} - I_1 + \frac{V_2}{1} + \frac{V_2 - V_3}{2} = 0 \qquad ...(2)$$

$$V_1 + V_2 + 0.5V_2 - 0.5V_3 = I_1$$

$$V_1 + 1.5V_2 - 0.5V_3 = I_1$$

Node (3):

$$\frac{V_3 - V_2}{2} - I_2 - \frac{I_1}{2} = 0 \qquad ...(3)$$

Put, $$\frac{V_3 - V_2}{2} = 0.5I_1 + I_2$$

$$V_1 - I_1 + V_2 - 0.5I_1 - I_2 = 0$$

$$V_1 + V_2 = 1.5I_1 + I_2 \qquad ...(4)$$

From (1) and (4),

$$V_2 = 1.75I_1 + 0.5I_2$$

Also, $$V_3 - V_2 = I_1 + 2I_2$$

$$V_3 = V_2 + I_1 + 2I_2$$

$$V_3 = 2.75I_1 + 2.5I_2 \qquad ...(5)$$

Also, $$I_2 = -V_3$$

From equation (5), $$-I_2 = 2.75I_1 + 2.5I_2$$

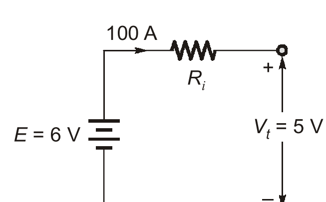
$$-3.5I_2 = 2.75I_1$$

$$\alpha = \frac{I_2}{I_1} = \frac{-2.75}{3.5} = -0.786$$

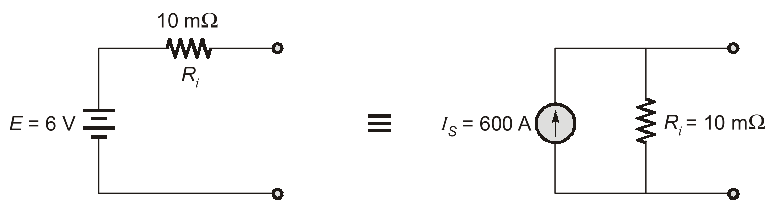
Q.18 A storage battery has a no-load terminal voltage of 6 V. When the current through the battery is 100 A, the terminal voltage drops to 5 V. Show a pictorial representation of the battery as a constant current source.

Solution:

Using given data:

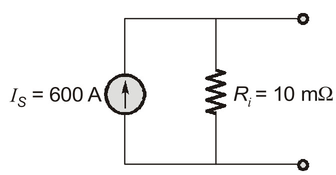


$$E = \text{Open voltage of battery} = 6\text{ V}$$
with a current of 100 A
$$V_t = E - (100)\,R_i$$
$$V_t = 5\text{ V} = 6 - 100\,R_i$$
$$R_i = 10\text{ m}\Omega$$

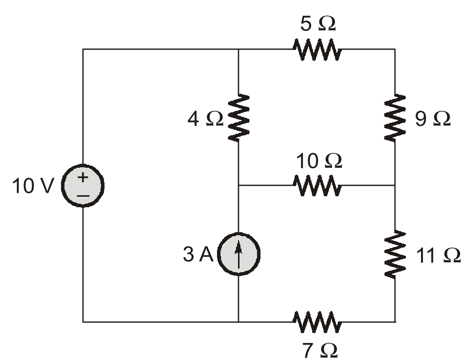


$$I_s = \frac{E}{R_i} = \frac{6}{10\times10^{-3}} = 600\text{ A}$$

Constant current source,



Q.19 Determine the current in various branches of circuit shown below using mesh-analysis.



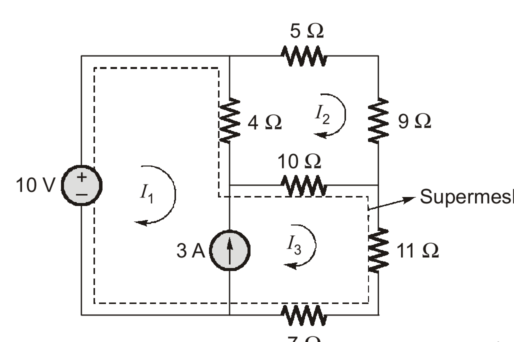
Solution:

Choosing three mesh currents, I_1, I_2, I_3 as shown below in figure.

Here a supermesh is created including mesh 1 and 3 as shown by dotted lines.

Equation for supermesh,

$$I_3 - I_1 = 3\text{ A}$$
$$4(I_1 - I_2) + 10\,(I_3 - I_2) + I_3 \times 1 + 7I_3 = 10$$
$$4I_1 - 14I_2 + 18\,(3 + I_1) = 10 \text{ (substitute for } I_3)$$
$$4I_1 - 14I_2 + 54 + 18I_1 = 10$$
$$22I_1 - 14I_2 = -44 \qquad \ldots(1)$$



Equation for mesh 2,

$$14I_2 + 10\,(I_2 - I_3) + 4(I_2 - I_1) = 0$$
$$-4I_1 + 28I_2 - 10(3 + I_1) = 0$$
$$-14I_1 + 28I_2 = 30 \qquad \ldots(2)$$

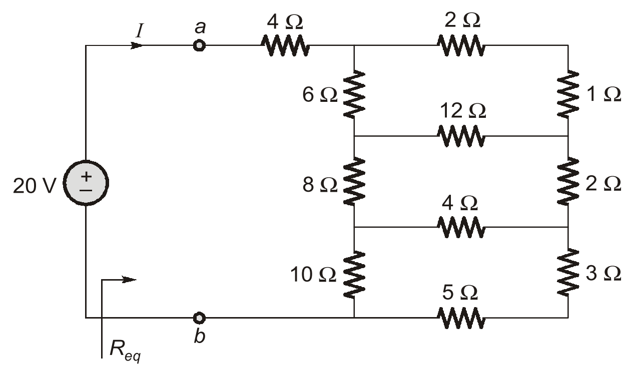
Solving (1) and (2) we get,

$$I_1 = -1.933\text{ A}$$
$$I_2 = 0.1047\text{ A}$$
$$I_3 = 3 + I_1 = 1.067\text{ A}$$

The branch currents are:

$$I_{10\,V} = I_1 = -1.933\text{ A}$$
$$I_{4\,\Omega} = I_1 - I_2 = -2.0377\text{ A}$$
$$I_{5\,\Omega} = I_{9\,\Omega} = I_2 = 0.1047\text{ A}$$
$$I_{10\,\Omega} = I_3 - I_2 = 0.9623\text{ A}$$
$$I_{1\,\Omega} = I_{7\,\Omega} = I_3 = 1.067\text{ A}$$

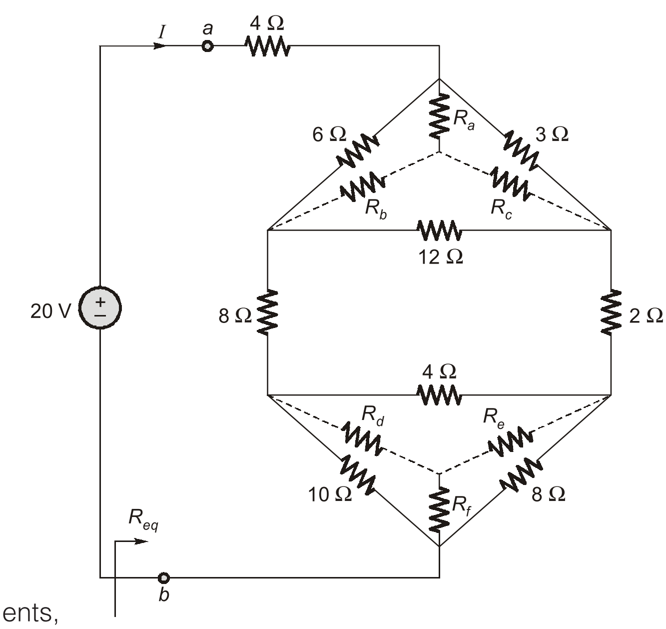
Q.20 Find R_{eq} and current I in the circuit shown below.



Solution:

The given circuit can be equivalently drawn as follows:

Using Y-Δ transformation,



$$R_a = \frac{6\times 3}{6+3+12} = \frac{6}{7}\ \Omega$$

$$R_b = \frac{6\times 12}{21} = \frac{24}{7}\ \Omega$$

$$R_c = \frac{3\times 12}{21} = \frac{12}{7}\ \Omega$$

$$R_d = \frac{4\times 10}{4+10+8}\ \Omega = \frac{4\times 10}{22}\ \Omega = \frac{20}{11}\ \Omega$$

$$R_e = \frac{4\times 8}{22}\ \Omega = \frac{16}{11}\ \Omega$$

$$R_f = \frac{8\times 10}{22}\ \Omega = \frac{40}{11}\ \Omega$$

By replacing delta network portion with star equivalents,