UNIT 1

Define following :

1. **Active and passive elements**
2. **Linear circuits and non-linear circuits**
3. **Unilateral and bilateral elements**
4. **Passive and active network.**

i. Active and passive elements :

1. The elements which supply energy to the network are known as active elements.
2. The voltage sources like batteries, DC generator, AC generator and current sources like photoelectric cells, metadyne generators fall under the category of active elements.
3. The components which dissipate or store energy are known as passive components. Resistors, inductors and capacitors fall under the category of passive elements.

ii. Linear circuits and non-linear circuits :

1. Resistive elements for which the volt-ampere characteristic is a straight line are called linear, and the electric circuits containing only linear resistances are called linear circuits.
2. Resistive elements for which the volt-ampere characteristic is other than a straight line are termed as non-linear, and so the electric circuits containing them are called non-linear circuits.

iii. Unilateral and bilateral elements :

1. An electric circuit, whose characteristics or properties are same in either direction is called the bilateral circuit. Example : The distribution or transmission line can be made to perform its function equally well in either direction.
2. An electric circuit whose characteristics or properties change with the direction of its operation (e.g. a diode rectifier), is called the unilateral circuit.

iv. Passive network and active network :

1. A network is said to be passive if it contains no source of emf in it.
2. When a network contains one or more sources of emf and/or current, it is said to be active.

Que 1.3. **Draw V-I characteristics of voltage and current sources.**

Answer

1. V-I characteristics of voltage sources :

The volt-ampere characteristic is depicted in Fig. 1.3.1. Dotted line is for an ideal voltage source. Within a permissible range of a current a practical DC voltage source maintains the terminal voltage within a narrow range of its nominal range.

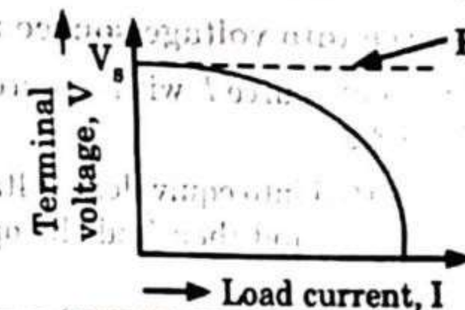


Fig. 1.3.1. For a practical voltage source.

2. V-I Characteristics of current source :

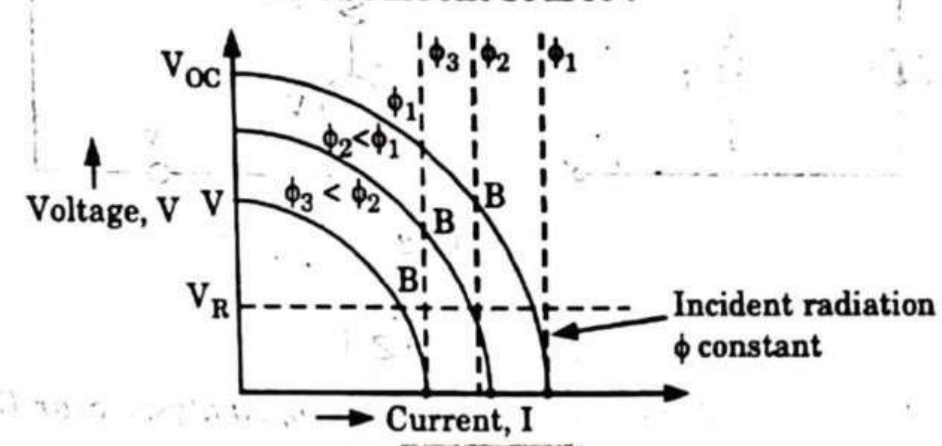


Fig. 1.3.2.

V-I characteristic of a practical current source is compared with that of ideal current source (dotted vertical lines). The limit V_R upto which a current source maintains the current is drawn by horizontal dotted line. Beyond this value of output voltage the current falls.

Que 1.4. **Explain source transformation principle in circuit.**

Answer

A. Conversion of voltage source into current source :

1. Let us consider a practical voltage source V_s with a source or internal resistance R_s as shown in Fig. 1.4.1.
2. The voltage source can be converted into equivalent current source by short circuiting the terminal xy and then find the current through xy short circuit path.

$$I_s = \frac{V_s}{R_s}$$

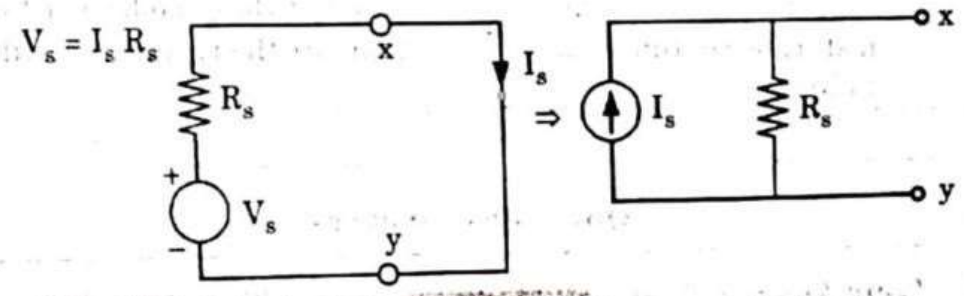


Fig. 1.4.1.

B. Conversion of current source into voltage source :

1. Let us consider a practical current source I_s with a source or internal resistance R_s as shown in Fig. 1.4.2.
2. This current source can be converted into equivalent voltage source by open circuited the terminal voltage and then find the open circuited voltage.

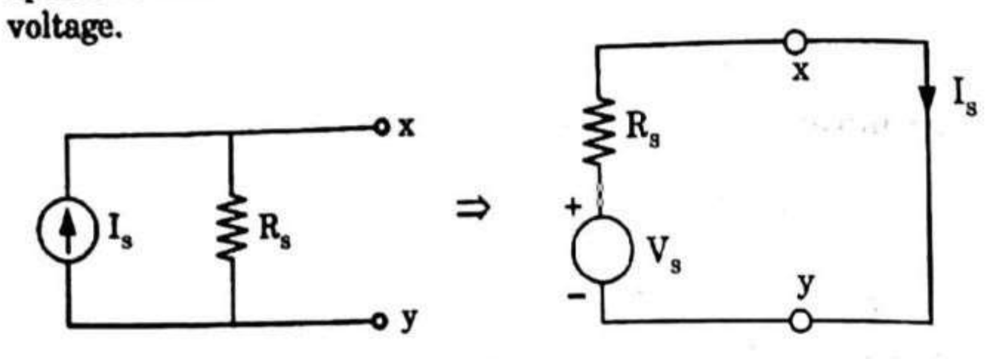


Fig. 1.4.2.

PART-2

Kirchhoff's Law, Loop and Nodal Method of Analysis, Star-Delta Transformation.

CONCEPT OUTLINE : PART-2

- **Kirchhoff's voltage law (KVL) :** This law states that the algebraic sum of voltage around any closed path is zero

$$\sum_{n=1}^{N} V_n = 0$$

where, V_n is the voltage in n^{th} element of a closed loop having n element.

- **Kirchhoff's current law (KCL) :** This law states that the algebraic sum of current entering the node is equal to zero.

i.e., $$\sum_{n=1}^{N} i_n = 0$$

where, i_n is the current in n^{th} branch.

- **Nodal analysis :** In this analysis independent nodes are considered and voltages are assumed at these nodes w.r.t one node called datum node. The equations are then framed according to KCL.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.5. **State and explain Kirchhoff's law. What are the limitations and applications of Kirchhoff's law in circuit theory? Explain.**

AKTU 2016-17(Sem-1), Marks 07

Answer

A. Kirchhoff's law : Refer Concept Outline : Part-2, Page 1–5D, Unit-1.

B. Limitations of Kirchhoff's law :

1. If more number of variables are present, then using these methods can be quite time consuming due to more number of equations.
2. KVL and KCL are not applied to distributed networks. Because in that case capacitance, inductance have their own internal resistances and are distributed over the long network line.

C. Applications of Kirchhoff's law :

1. The current distribution in various branches of the circuit is made with directions of their flow complying with first law of Kirchhoff (KCL).
2. Kirchhoff's second law (KVL) is applied to each mesh (one by one) separately and algebraic equations are obtained by equating the algebraic sum of emfs acting in each mesh equal to the algebraic sum of respective drop in same mesh.

Que 1.6. **Use source transformation method to compute the current through 6 Ω resistor of Fig. 1.6.1.**

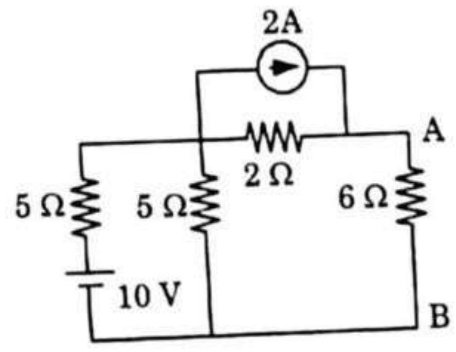


Fig. 1.6.1.

AKTU 2014-15(Sem-2), Marks 10

Answer

1. Changing the current source of 2 A to voltage source and voltage source of 10 V to current source.
2. Changing the voltage source of 10 V to current source,

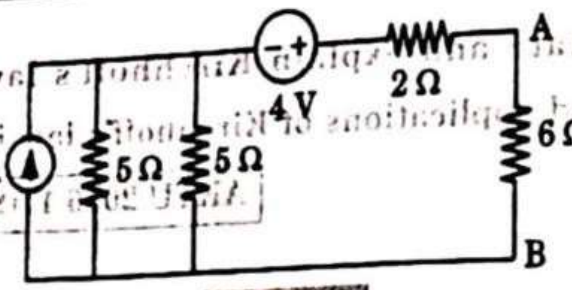


Fig. 1.6.2.

3. **Using parallel combination of resistors,**

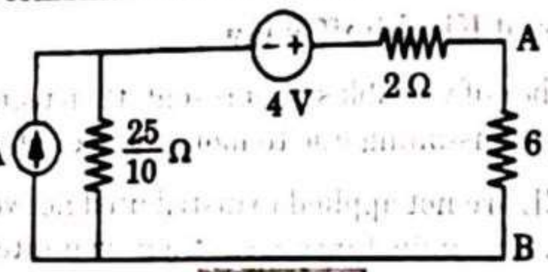


Fig. 1.6.3.

4. **Changing current source of 2 A to voltage source,**

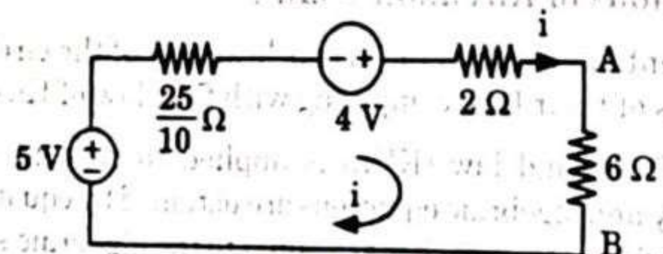


Fig. 1.6.4.

5. **Applying mesh law,** $5 - 2.5i + 4 - 2i - 6i = 0$

$$9 - 10.5\,i = 0$$

$$\therefore \quad i = \frac{9}{10.5} = 0.857\ \text{A}$$

Que 1.7. **Determine current in 4 ohm resistor by using mesh analysis in the circuit shown in Fig. 1.7.1 below.**

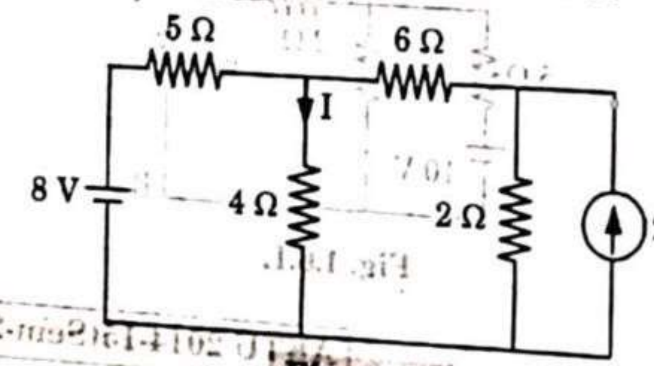


Fig. 1.7.1.

AKTU 2017-18(Sem-1), Marks 07

Answer

1. Converting 2 A current source with a parallel resistance of 2 Ω into an equivalent voltage source of 4 V in series with a 2 Ω resistance :

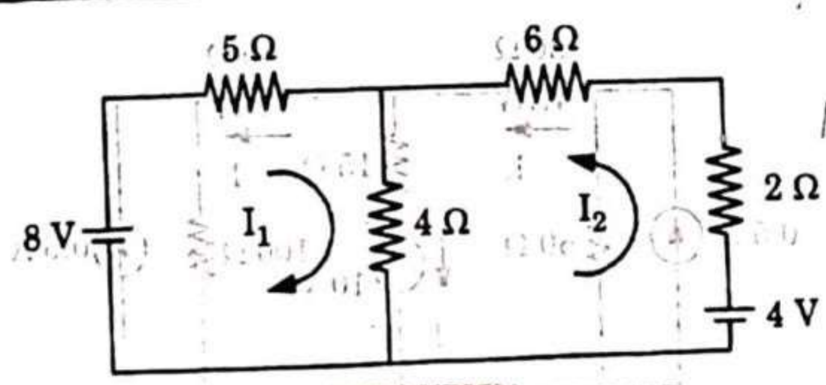


Fig. 1.7.2.

2. Applying Kirchhoff's voltage law to mesh I and II, we have

From mesh I :

$$8 - 5I_1 - 4\,(I_1 + I_2) = 0$$

$$9I_1 + 4I_2 = 8 \qquad \text{...(1.7.1)}$$

From mesh II :

$$4 - 8I_2 - 4\,(I_2 + I_1) = 0$$

$$12I_2 + 4\,I_1 = 4$$

$$I_1 + 3I_2 = 1 \qquad \text{...(1.7.2)}$$

3. Solving eq. (1.7.1) and (1.7.2), we get

$$I_2 = 0.04\ \text{A}$$

$$I_1 = 0.87\ \text{A}$$

4. Current across 4 Ω resistor,

$$I = I_1 + I_2$$

$$= 0.87 + 0.04 = 0.91\ \text{A}$$

Que 1.8. **Find current in 2 ohm resistance in the following Fig. 1.8.1 using loop analysis method.**

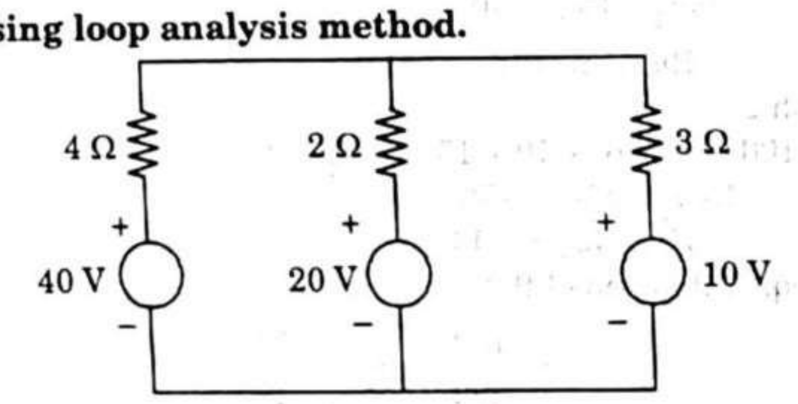


Fig. 1.8.1.

AKTU 2015-16(Sem-2), Marks 10

Answer

The procedure is same as Q. 1.7, Page 1–7D, Unit-1.

(Ans. Current in 2 Ω resistor = 0.77 A)

Que 1.9. **Using mesh analysis, find the currents I_1, I_2 and I_3 in the following circuit of Fig. 1.9.1.**

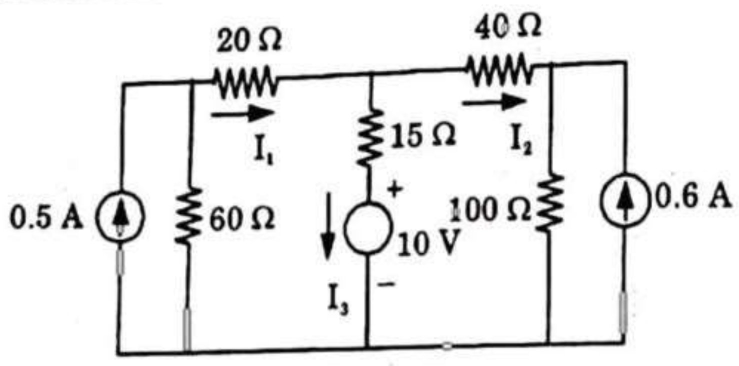


Fig. 1.9.1.

AKTU 2016-17(Sem-1), Marks 07

Answer

1. The equivalent circuit is

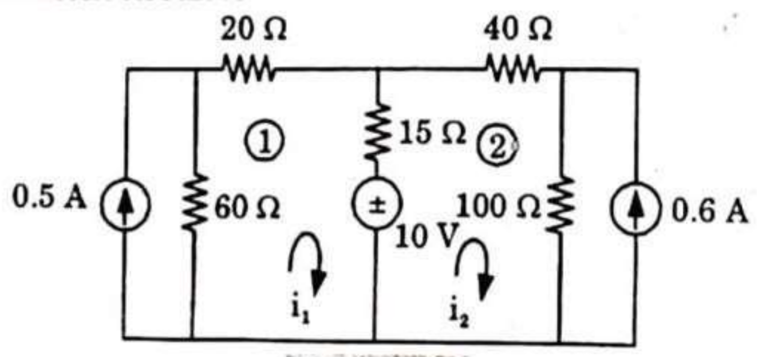


Fig. 1.9.2.

2. In mesh 1

$$20i_1 + 15(i_1 - i_2) - 10 + 60(i_1 - 0.5) = 0$$

$$95i_1 - 15i_2 = 40$$

$$19i_1 - 3i_2 = 8 \quad \text{...(1.9.1)}$$

3. In mesh 2

$$40i_2 + 100(i_2 + 0.6) + 10 + 15(i_2 - i_1) = 0$$

$$155i_2 - 15i_1 = -70$$

$$31i_2 - 3i_1 = -14 \quad \text{...(1.9.2)}$$

4. From eq. (1.9.1) and (1.9.2),

$$i_1 = \frac{103}{290}\text{ A}, i_2 = -\frac{121}{290}\text{ A}$$

5. Now, the current flowing through 20 Ω is I_1, hence

$$I_1 = i_1 = \frac{103}{290} = 0.355\text{ A}$$

6. Current flowing through 40 Ω is I_2, hence

$$I_2 = i_2 = -\frac{121}{290} = -0.4127\text{ A}$$

and current flowing through 15 Ω is I_3

$$I_3 = (i_1 - i_2) = \left(\frac{103-(-121)}{290}\right) = \frac{224}{290} = 0.772\text{ A}$$

Que 1.10. **Find current in each branch by using nodal analysis. Also calculate total power loss.**

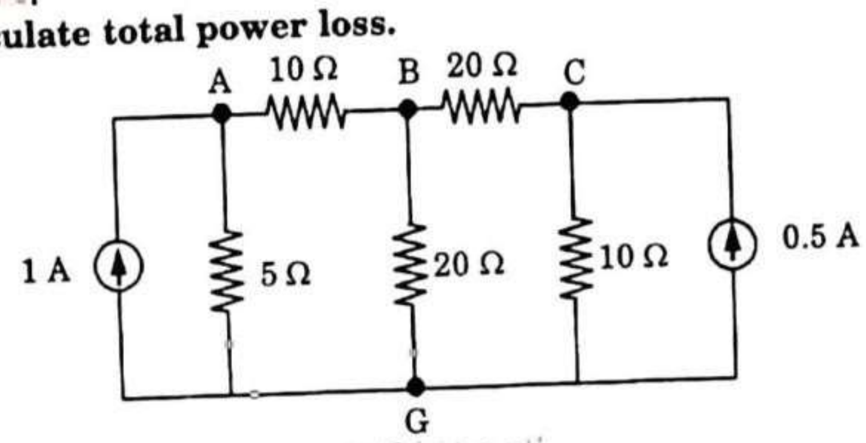


Fig. 1.10.1.

AKTU 2013-14(Sem-1), Marks 05

Answer

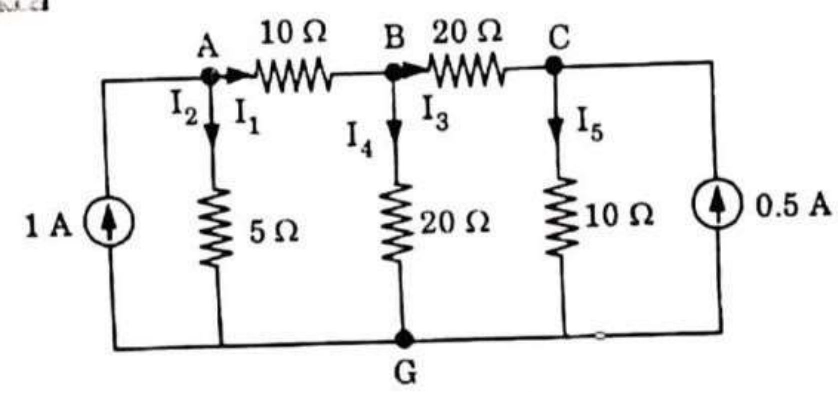


Fig. 1.10.2.

1. At node A, $\quad 1 = I_1 + I_2$

$$1 = \frac{V_A - V_B}{10} + \frac{V_A}{5}$$

$$3V_A - V_B = 10 \quad \text{...(1.10.1)}$$

2. At node B, $\quad I_1 = I_3 + I_4$

$$\frac{V_A - V_B}{10} = \frac{V_B - V_C}{20} + \frac{V_B}{20}$$

$$2V_A - 4V_B + V_C = 0 \quad \text{...(1.10.2)}$$

3. At node C, $\quad I_3 + 0.5 = I_5$

$$\frac{V_B - V_C}{20} + 0.5 = \frac{V_C}{10}$$

$$V_B - 3V_C = -10 \quad \text{...(1.10.3)}$$

4. Solving eq. (1.10.1), (1.10.2) and (1.10.3), we get

$$V_A = 4.44;\ V_B = 3.33;\ V_C = 4.44$$

5. Value of currents are :

$$I_2 = \frac{V_A}{5} = \frac{4.44}{5} = 0.888 \text{ A}$$

$$I_1 = \frac{V_A - V_B}{10} = 0.111 \text{ A}$$

$$I_3 = \frac{V_B - V_C}{20} = -0.055 \text{ A}$$

$$I_4 = \frac{V_B}{20} = 0.1665 \text{ A}$$

$$I_5 = \frac{V_C}{10} = 0.444 \text{ A}$$

6. Total power loss $= (0.111)^2 \times 10 + (0.888)^2 \times 5 + (-0.055)^2 \times 20 + (0.1665)^2 \times 20 + (0.444)^2 \times 10 = 6.65 \text{ W}$

Que 1.11. **Using Nodal analysis find the current through 1 Ω resistance shown in Fig. 1.11.1.**

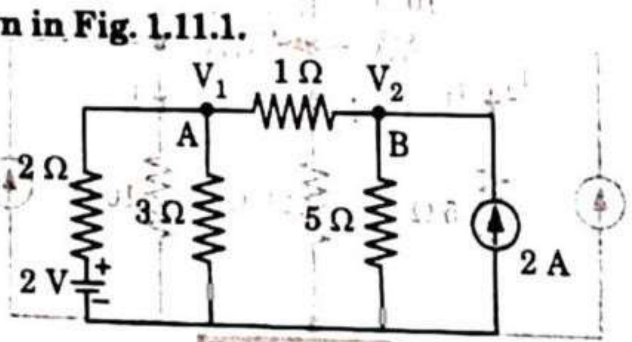


Fig. 1.11.1.

AKTU 2016-17(Sem-2), Marks 07

Answer

The procedure is same as Q. 1.10, Page 1–10D, Unit-1.

(**Ans.** Current through 1 Ω resistor = 1.22 A)

Que 1.12. **Using nodal analysis, find current through 8 Ω resistor.**

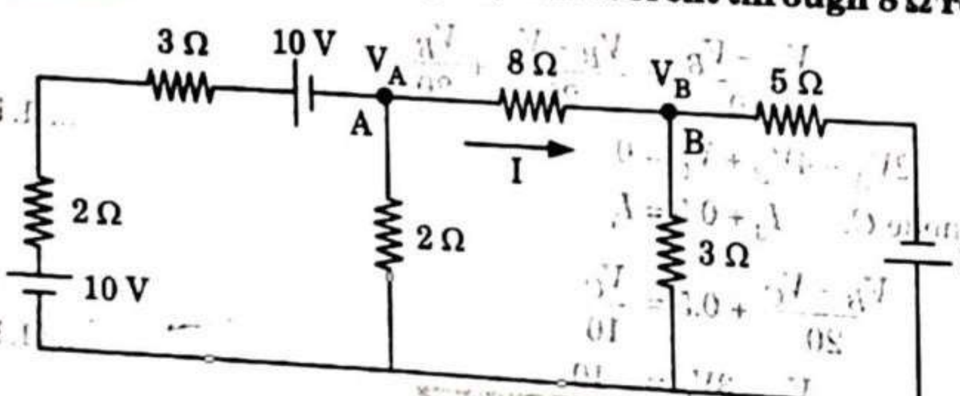


Fig. 1.12.1.

AKTU 2017-18(Sem-2), Marks 07

Answer

1. At node A, $\frac{V_A + 10 - 10}{5} + \frac{V_A - 0}{2} + \frac{V_A - V_B}{8} = 0$

$$8V_A + 20V_A + 5V_A - 5V_B = 0$$

$$33\,V_A = 5V_B$$

$$\therefore \quad V_A = \frac{5V_B}{33} \quad \text{...(1.12.1)}$$

2. At node B, $\frac{V_B - V_A}{8} + \frac{V_B - 0}{3} + \frac{V_B + 25}{5} = 0$

$$15V_B - 15V_A + 40V_B + 24V_B + 600 = 0$$

$$79V_B - 15V_A = -600 \quad \text{...(1.12.2)}$$

3. Putting value of V_A in eq. (1.12.2), we get

$$79V_B - \frac{75}{33}V_B = -600$$

$$\therefore \quad V_B = -7.82 \text{ V}$$

4. Putting value of V_B in eq. (1.12.1),

$$V_A = \frac{5}{33} \times -7.82 = -1.18 \text{ V}$$

5. Current through 8 Ω resistor

$$I = \frac{V_A - V_B}{8} = \frac{-1.18 + 7.82}{8} = 0.83 \text{ A}$$

Que 1.13. **Deduce delta connected system from star connected system.**

AKTU 2013-14(Sem-1), Marks 05

OR

Derive an expression of star to delta transformation and vice-versa.

AKTU 2013-14(Sem-2), Marks 10

OR

Derive the delta to star transformation.

AKTU 2014-15(Sem-2), Marks 05

OR

Derive the relation for star to delta and delta to star transformation.

AKTU 2017-18(Sem-1), Marks 07

Answer

A. Delta to star transformation :

1. Three resistances connected as shown in Fig. 1.13.1(*a*), are said to be delta connected.

2. Three resistances connected together at a common point O, as shown in Fig. 1.13.1(*b*) are said to be star (Y) connected.
3. The replacement of delta or mesh by equivalent star system is known as delta to star transformation.
4. The two systems will be equivalent or identical if the resistance measured between any pair of lines is same in both of the systems, when the third line is open.

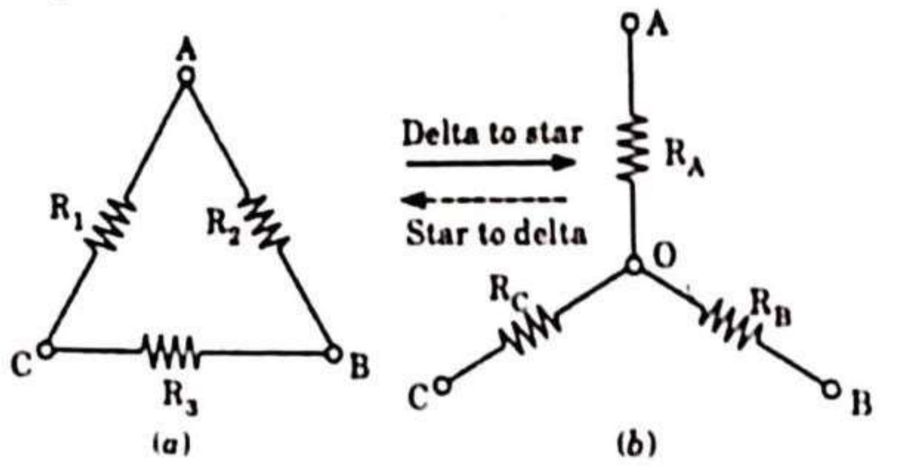


Fig. 1.13.1. Delta to star transformation.

5. Hence resistances between terminals B and C,

$$R_{BC} = R_3 \parallel (R_1 + R_2)$$

$$= \frac{R_3(R_1 + R_2)}{R_1 + R_2 + R_3} \text{ in delta system}$$

and $\quad R_{BC} = R_B + R_C$ in star system

6. Since the two systems are identical, resistances measured between terminals B and C in both of the systems must be equal.

So
$$R_B + R_C = \frac{R_3(R_1 + R_2)}{R_1 + R_2 + R_3} \quad ...(1.13.1)$$

7. Similarly resistances between terminals C and A being equal in the two systems

$$R_C + R_A = \frac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3} \quad ...(1.13.2)$$

Similarly resistance between terminals A and B

$$R_A + R_B = \frac{R_2(R_1 + R_3)}{R_1 + R_2 + R_3} \quad ...(1.13.3)$$

8. Adding eq. (1.13.1), (1.13.2) and (1.13.3), we get

$$2(R_A + R_B + R_C) = \frac{2(R_1R_3 + R_2R_3 + R_1R_2)}{R_1 + R_2 + R_3}$$

$$R_A + R_B + R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1 + R_2 + R_3} \quad ...(1.13.4)$$

9. Subtracting eqs. (1.13.1), (1.13.2), (1.13.3) from (1.13.4) respectively, we have

$$R_A = \frac{R_1R_2}{R_1 + R_2 + R_3} \quad ...(1.13.5)$$

$$R_B = \frac{R_2R_3}{R_1 + R_2 + R_3} \quad ...(1.13.6)$$

$$R_C = \frac{R_3R_1}{R_1 + R_2 + R_3} \quad ...(1.13.7)$$

B. Start to delta transformation :

1. Consider $Y - \Delta$ connections as shown in Fig. 1.13.2.

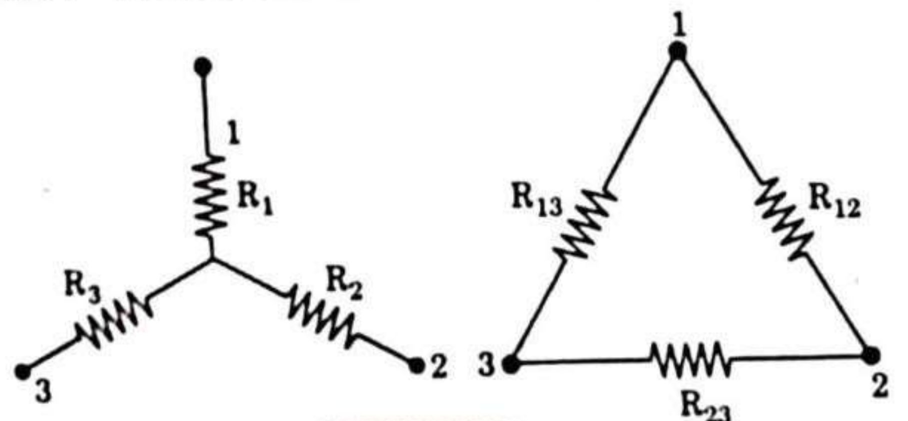


Fig. 1.13.2.

2. Resistance between terminals (1) and (2) in Y-connection is

$$R_{1-2}Y = R_1 + R_2 \quad ...(1.13.8)$$

3. Resistance between terminal 1 and 2 in Δ-connection is

$$R_{1-2}\Delta = R_{12} \parallel (R_{13} + R_{23}) = \frac{R_{12}(R_{13} + R_{23})}{R_{12} + R_{13} + R_{23}} \quad ...(1.13.9)$$

4. If the Y-connection drawn in Fig. 1.13.2 is equivalent to the Δ-connection, eq. (1.13.8) and (1.13.9) must be equal.

$$\therefore \quad R_1 + R_2 = \frac{R_{12}(R_{13} + R_{23})}{R_{12} + R_{13} + R_{23}} \quad ...(1.13.10)$$

5. Similarly, $\quad R_1 + R_3 = \frac{R_{13}(R_{12} + R_{23})}{R_{13} + R_{12} + R_{23}} \quad ...(1.13.11)$

and $\quad R_2 + R_3 = \frac{R_{23}(R_{13} + R_{12})}{R_{12} + R_{23} + R_{13}} \quad ...(1.13.12)$

6. Solving eqs. (1.13.10), (1.13.11) and (1.13.12)

$$R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3}$$

$$R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1}$$

$$R_{13} = R_1 + R_3 + \frac{R_1R_3}{R_2}$$

Que 1.14. Using star-delta transformation, find the current in the branch bc of the circuit. Consider all the values of resistance are in ohms.

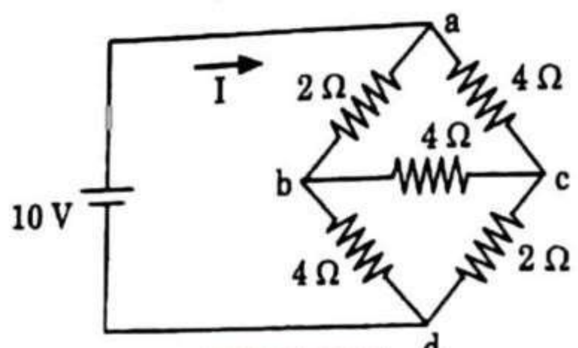


Fig. 1.14.1.

AKTU 2014-15(Sem-1), Marks 10

Answer

1. Applying delta to star transformation, we get Fig. 1.14.2.

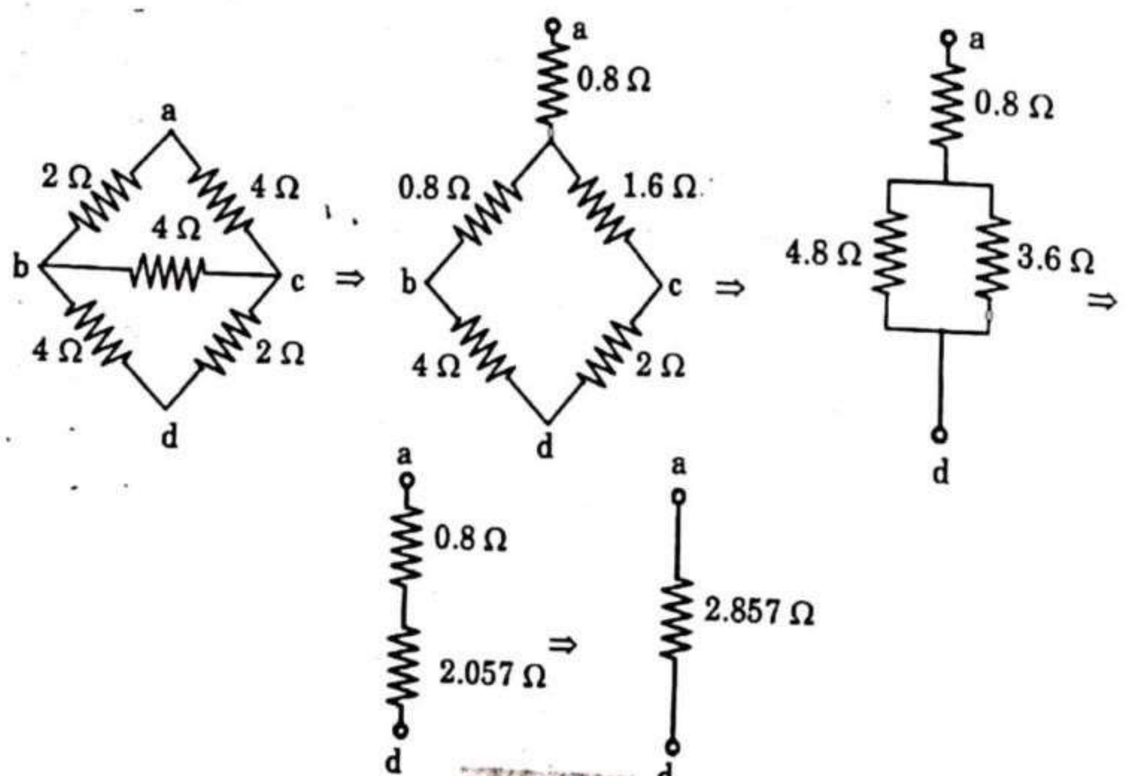


Fig. 1.14.2.

2. So
$$R_{eq} = 2.857\ \Omega$$
$$I = \frac{10}{2.857} = 3.5\text{ A}$$

3. Taking bc branch open,

Current in section $abd = 3.5 \times \dfrac{6}{6+6} = 1.75$ A

Current in section $acd = 3.5 \times \dfrac{6}{6+6} = 1.75$ A

4. Voltage,
$$V_{bd} = 4 \times 1.75 = 7\text{ V}$$
$$V_{cd} = 2 \times 1.75 = 3.5\text{ V}$$

5. Current in branch bc $I_{bc} = \dfrac{7 - 3.5}{4} = 0.875$ A

Que 1.15. Determine the effective resistance between terminals A-B in the network of Fig. 1.15.1.

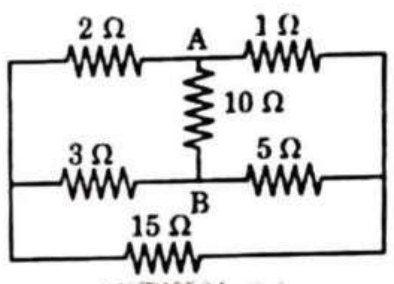


Fig. 1.15.1.

AKTU 2014-15(Sem-2), Marks 10

Answer

1. Converting delta to star,
$$R_1 = \frac{5 \times 3}{5+3+15} = \frac{15}{23}\ \Omega$$
$$R_2 = \frac{15 \times 3}{5+3+15} = \frac{45}{23}\ \Omega$$
$$R_3 = \frac{15 \times 5}{5+3+15} = \frac{75}{23}\ \Omega$$

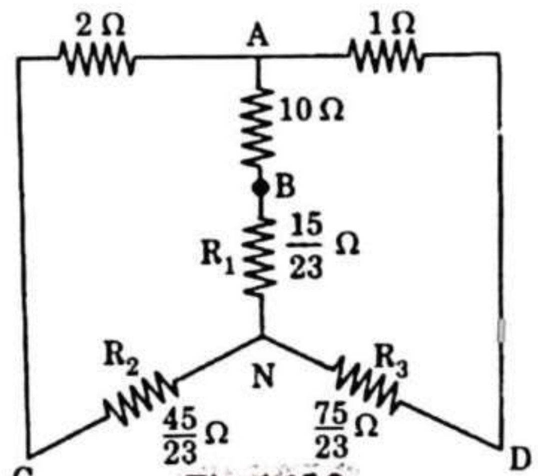


Fig. 1.15.2.

2. Solving series circuit,

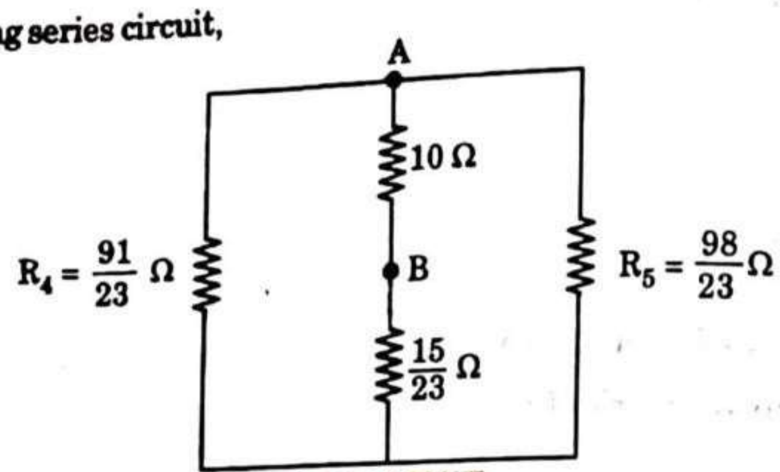


Fig. 1.15.3.

as
$$R_4 = 2 + \frac{45}{23} = \frac{91}{23}\ \Omega$$
$$R_5 = 1 + \frac{75}{23} = \frac{98}{23}\ \Omega$$

3. Solving circuit,

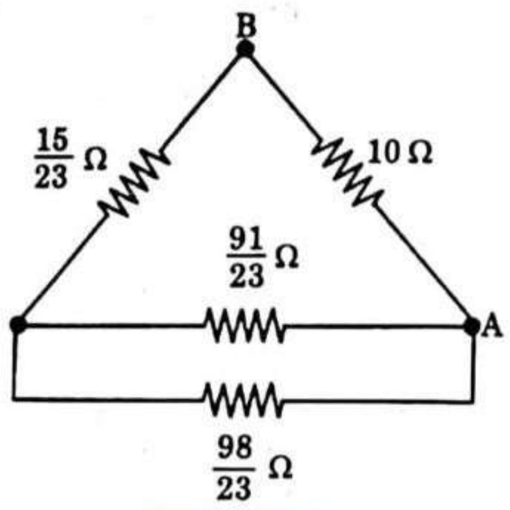


Fig. 1.15.4.

4. Solving parallel circuit,

as
$$R_6 = \frac{\frac{91}{23} \times \frac{98}{23}}{\frac{91}{23} + \frac{98}{23}} = 2.05\ \Omega$$

5. Equivalent resistance across AB is

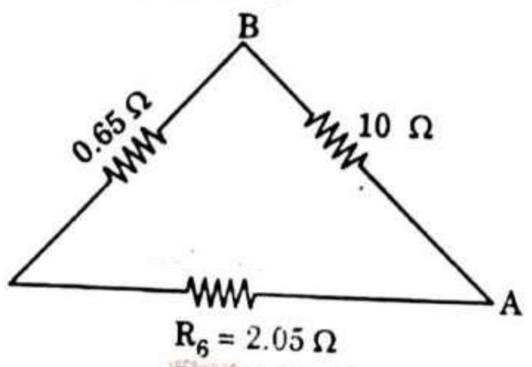


Fig. 1.15.5.

$$R_{AB} = \frac{10(0.65 + 2.05)}{10 + 0.65 + 2.05} = 2.12\ \Omega$$

PART-3

Superposition Theorem, Thevenin's Theorem, Norton's, Theorem.

CONCEPT OUTLINE : PART-3

There are four theorems to solve DC networks :
1. Superposition theorem
2. Thevenin's theorem
3. Norton's Theorem

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.16. **Explain superposition theorem.**

Answer

A. Statement :

If a number of voltage or current sources are acting simultaneously in a linear network, the resultant current in any branch is the algebraic sum of the current that would be produced in it, when each source acts alone replacing all other independent sources by their internal resistances.

B. Explanation :

1. In Fig. 1.16.1(a), to apply superposition theorem, let us first take the source V_1 alone at first replacing V_2 by short circuit [Fig. 1.16.1(b)].

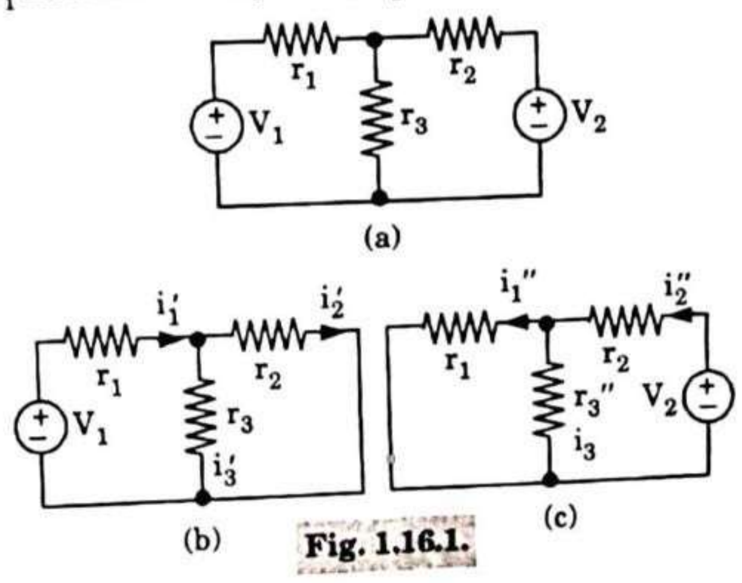


Fig. 1.16.1.

2. Here,
$$i_1' = \frac{V_1}{\frac{r_2 r_3}{r_2 + r_3} + r_1}$$
$$i_2' = i_1'\frac{r_3}{r_2 + r_3} \text{ and } i_3' = i_1' - i_2'$$
3. Next, replacing V_1 by short circuit. Let the circuit be energized by V_2 only [Fig. 1.16.1(c)]

Here,
$$i_2'' = \frac{V_2}{\frac{r_1 r_3}{r_1 + r_3} + r_2} \text{ and } i_1'' = i_2''\frac{r_3}{r_1 + r_3}$$
Also,
$$i_3'' = i_2'' - i_1''$$
4. As per superposition theorem,
$$i_3 = i_3' + i_3''$$
$$i_2 = i_2' - i_2''$$
$$i_1 = i_1' - i_1''$$

Que 1.17. **Discuss Thevenin's theorem.**

Answer

A. Statement :

Any two terminal bilateral linear DC circuit can be replaced by an equivalent circuit consisting of a voltage source and a series resistor.

B. Explanation :

1. Let us consider a simple DC circuit as shown in Fig. 1.17.1(*a*). We are to find I_L by Thevenin's theorem.
2. In order to find the equivalent voltage source, r_L is removed [Fig. 1.17.1(*b*)] and V_{oc} is calculated
$$V_{oc} = I r_3 = \frac{V_S}{r_1 + r_3} r_3$$
3. Now, to find the internal resistance of the network (Thevenin's resistance or equipment resistance) in series with V_{oc}, the voltage source is removed by a short circuit as shown in Fig. 1.17.1(c)
$$R_{TH} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$
4. As per Thevenin's theorem, the equivalent circuit is shown in Fig. 1.17.1(*d*).
$$I_L = \frac{V_{oc}}{R_{TH} + r_L}$$

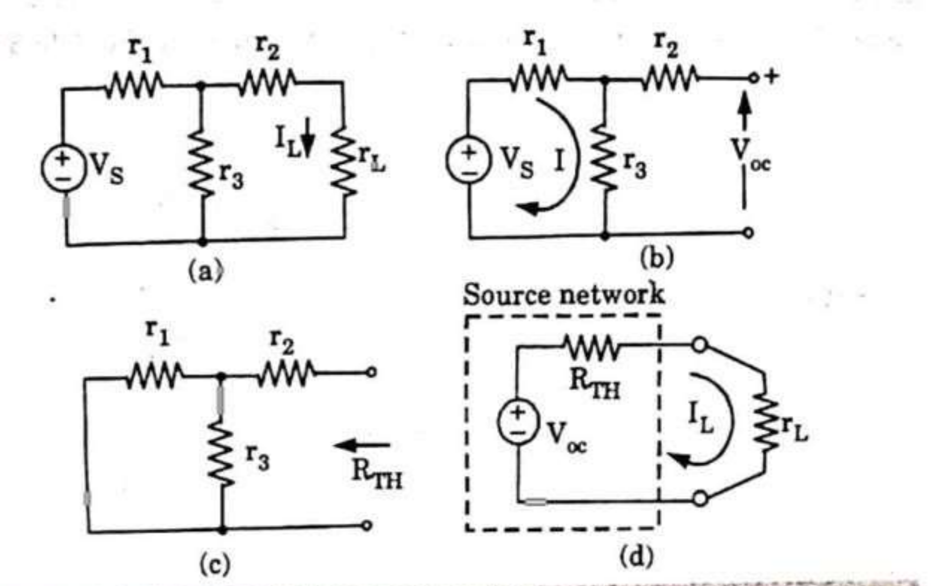


Fig. 1.17.1. (a) A simple DC circuit, (b) Finding of V_{oc} (c) Finding of R_{TH} (d) Finding of I_L, forming Thevenin's equivalent circuit.

Que 1.18. **Explain Norton's theorem.**

Answer

A. Statement : Any linear circuit containing several energy sources and resistances can be replaced by a single constant current generator in parallel with a single resistor.

B. Explanation :

1. In order to find the current through r_L, (Fig. 1.18.1), replace r_L by short circuit [Fig. 1.18.2].

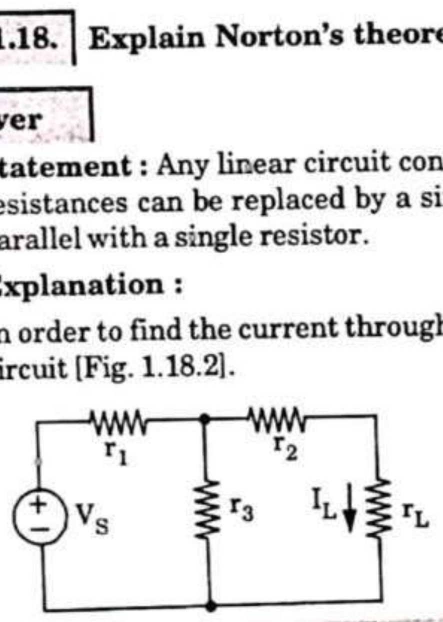


Fig. 1.18.1. A simple DC network.

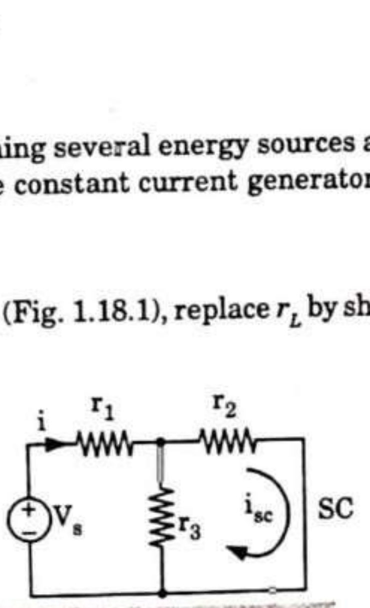


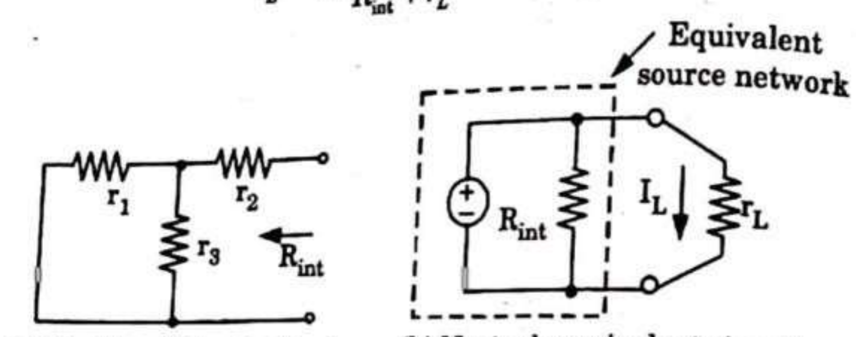
Fig. 1.18.2. Finding of i_{sc}

$$i = \frac{V_S}{r_1 + \frac{r_2 r_3}{r_2 + r_3}} \text{ and } i_{sc} = i\frac{r_3}{r_3 + r_2}$$

2. Now, the short circuit is removed and the independent source is deactivated [Fig. 1.18.3(*a*)].
$$R_{int} = r_2 + \frac{r_1 r_3}{r_1 + r_3}.$$

3. As per Norton's theorem, the equivalent circuit is drawn in Fig. 1.18.3(b).

$$I_L = i_{sc}\,\frac{R_{int}}{R_{int} + r_L}$$



(a) Finding of R_{TH} (or R_{int}). (b) Norton's equivalent circuit.

Fig. 1.18.3.

Que 1.19. **Find V and I in the given circuit by using superposition theorem.**

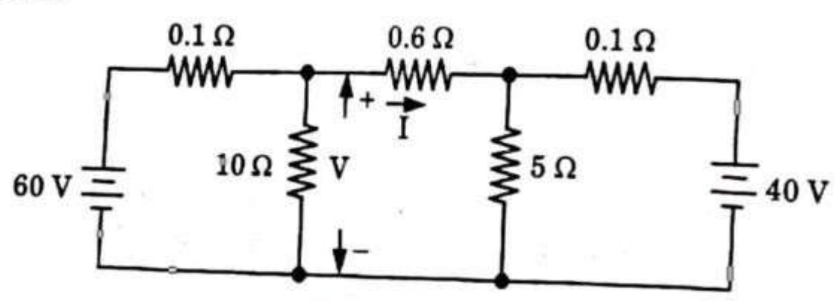


Fig. 1.19.1.

AKTU 2014-15(Sem-1), Marks 10

Answer

Step I : Activating 60 V and deactivating 40 V source

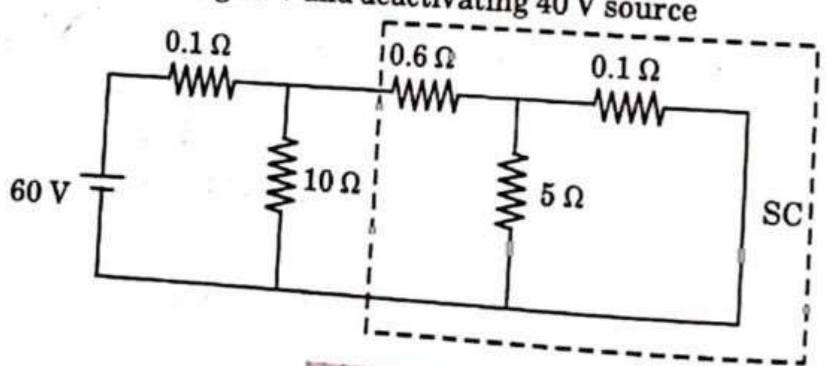


Fig. 1.19.2.

1. $R_{eq}' = (0.1\ \Omega \parallel 5\ \Omega) + 0.6\ \Omega$

$$= \frac{0.1 \times 5}{0.1 + 5} + 0.6$$

$$R_{eq}' = 0.698\ \Omega$$

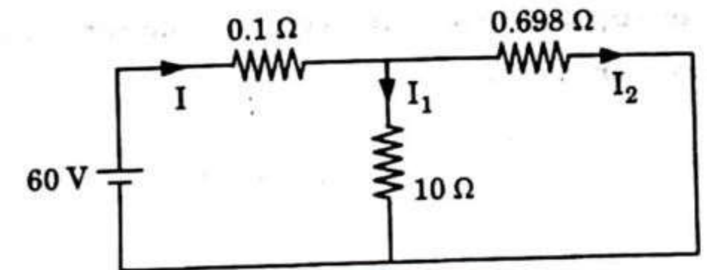


Fig. 1.19.3.

2. $R_{eq} = (0.698\ \Omega \parallel 10\ \Omega) + 0.1\ \Omega$

$$= \frac{0.698 \times 10}{0.698 + 10} + 0.1 = 0.752\ \Omega$$

$$R_{eq} = 0.752$$

3. $I = \dfrac{V}{R_{eq}} = \dfrac{60}{0.752} = 79.7347\ \text{A}$

4. $I_1 = 79.78 \times \dfrac{0.698}{0.698 + 10} = 5.20\ \text{A}$

5. $I_2 = 79.73 \times \dfrac{10}{(0.6 + 10)} = 75.73\ \text{A}$

Step II : Activating 40 V and deactivating 60 V source

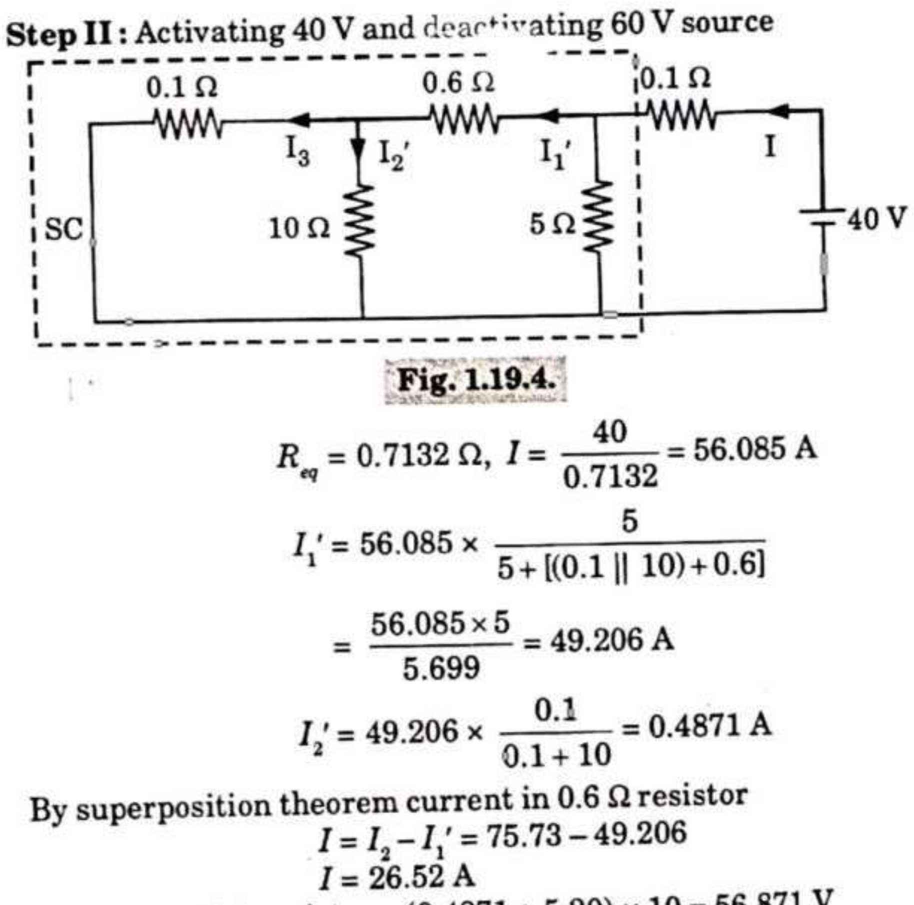


Fig. 1.19.4.

1. $R_{eq} = 0.7132\ \Omega,\ I = \dfrac{40}{0.7132} = 56.085\ \text{A}$

2. $I_1' = 56.085 \times \dfrac{5}{5 + [(0.1 \parallel 10) + 0.6]}$

$$= \frac{56.085 \times 5}{5.699} = 49.206\ \text{A}$$

3. $I_2' = 49.206 \times \dfrac{0.1}{0.1 + 10} = 0.4871\ \text{A}$

4. By superposition theorem current in 0.6 Ω resistor

$$I = I_2 - I_1' = 75.73 - 49.206$$

$$I = 26.52\ \text{A}$$

5. Voltage in 10 Ω resistor = (0.4871 + 5.20) × 10 = 56.871 V

Que 1.20. Use superposition theorem to compute the current through 1 Ω resistor of Fig. 1.20.1.

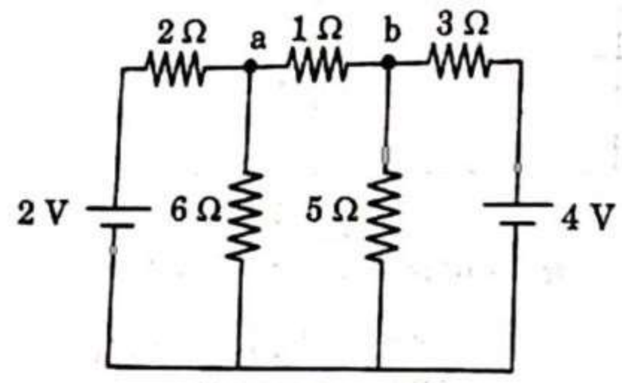


Fig. 2.20.1.

AKTU 2014-15(Sem-2), Marks 05

Answer

The procedure is same as Q. 1.19, Page 1–21D, Unit-1.

[**Ans.** Current through 1 Ω resistor = 0.22A from b to a].

Que 1.21. Find current in 6 Ω using Thevenin's theorem.

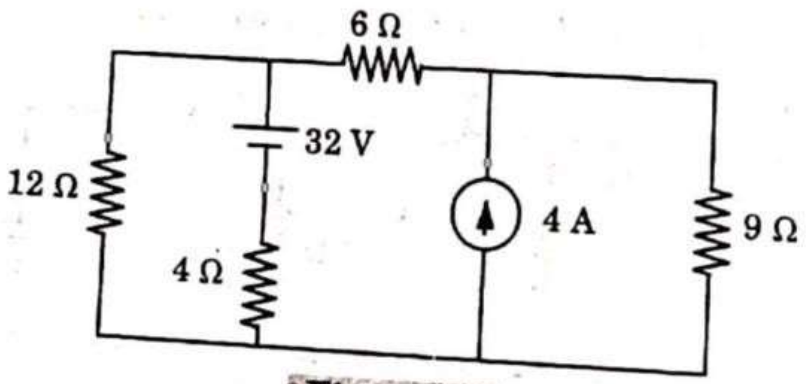


Fig. 1.21.1.

AKTU 2013-14(Sem-1), Marks 05

Answer

1. Calculation of V_{TH} :

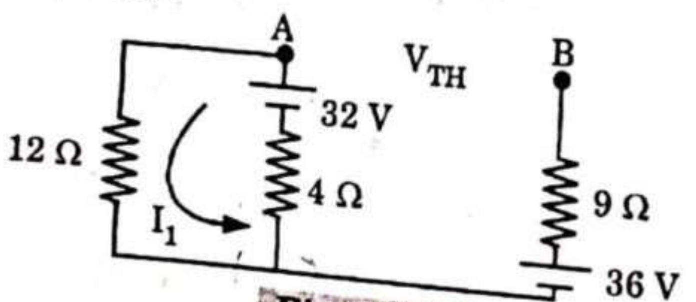


Fig. 1.21.2.

$$V_{TH} = 36 - \frac{32}{16} \times 12 = 12 \text{ V}$$

2. Calculation of R_{TH} :

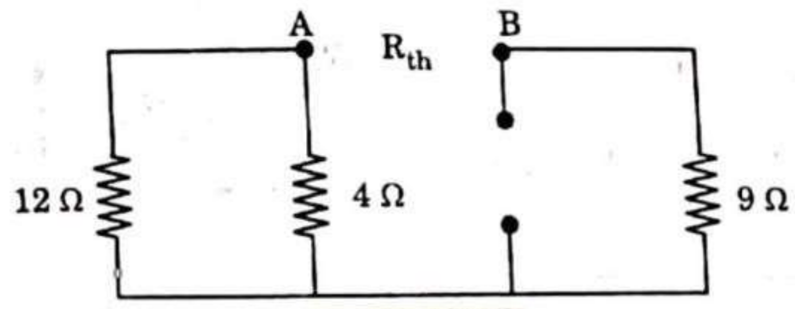


Fig. 1.21.3.

$$R_{TH} = \frac{12 \times 4}{12 + 4} + 9 = 3 + 9 = 12 \ \Omega$$

3. Thevenin's equivalent circuit :

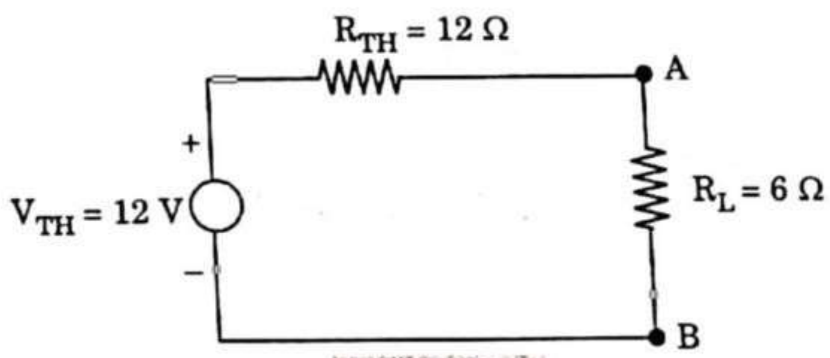


Fig. 1.21.4.

$$I = \frac{V_{TH}}{R_{TH} + R_L} = \frac{12}{12 + 6} = 0.67 \text{ A}$$

Que 1.22. Deduce Thevenin's equivalent between the terminals a and b from the given circuit.

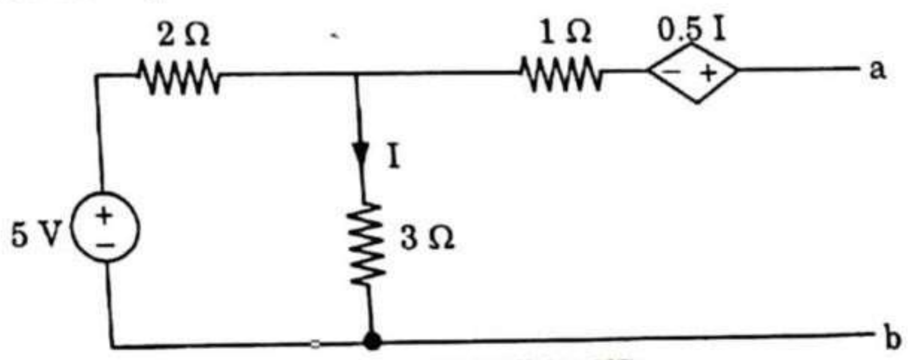


Fig. 1.22.1.

AKTU 2014-15(Sem-1), Marks 10

Answer

1. $$I = \frac{5}{3 + 2} = 1 \text{ A}$$

2. Given network is

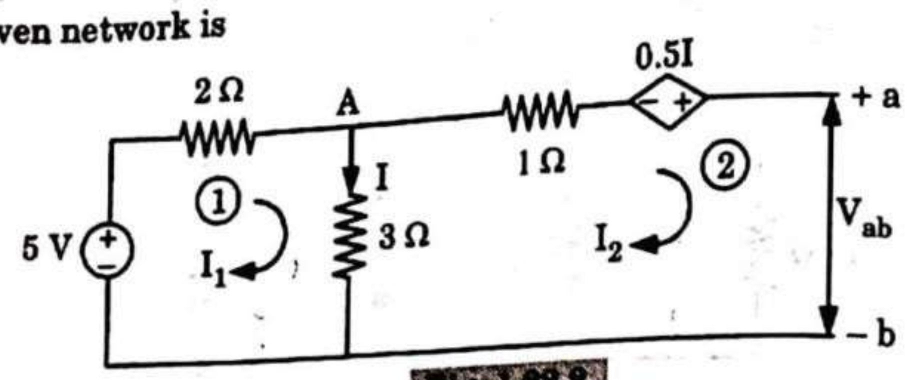


Fig. 1.22.2.

3. **Finding for V_{ab} :** (Open circuit voltage)

$$I = I_1 - I_2$$

Using KVL in loop (1)

$$-5 + 2I_1 + 3(I_1 - I_2) = 0$$

or, $5I_1 - 3I_2 = 5$ ...(1.22.1)

and, $4I_2 - 3I_1 = 0.5(I_1 - I_2) - V_{ab}$

or, $4.5I_2 - 3.5I_1 = -V_{ab}$ ...(1.22.2)

Since, $a - b$ terminal is kept opened.

Hence, $I_2 = 0$ (no current will flow in loop (2))

Putting $5I_1 = 5$

$\therefore$ $I_1 = 1\text{ A} = I$

$\because$ $-3.5 \times 1 = -V_{ab}$

$\therefore$ $V_{ab} = 3.5\text{ V}$

4. **Calculation for short circuit current, *i.e.*, I_{sc} :**

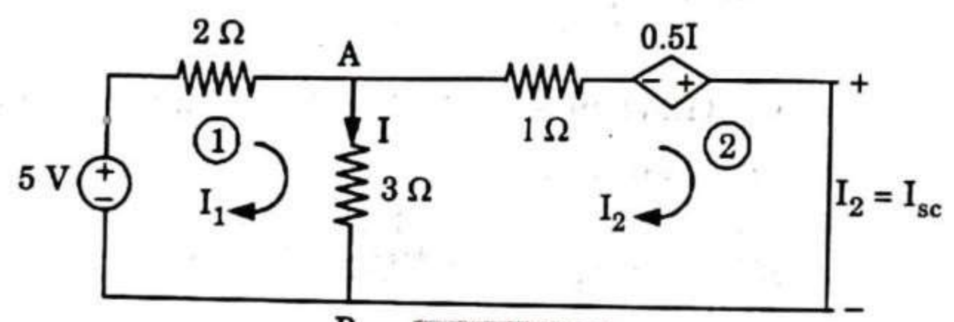


Fig. 1.22.3.

$$I = I_1 - I_2 = I_1 - I_{sc}$$

Using KVL in loop (1)

$$-5 + 5I_1 - 3I_2 = 0$$

$\therefore$ $5I_1 - 3I_2 = 5$ ...(1.22.3)

Again in loop (2) :

$$4I_2 - 3I_1 = 0.5\,(I_1 - I_2)$$

or, $4.5I_2 - 3.5I_1 = 0$

$\therefore$ $3.5I_1 - 4.5I_2 = 0$ ...(1.22.4)

Solving eq. (1.22.3) and (1.22.4)

$$I_1 = 1.88\text{ A}$$

$$I_2 = 1.46\text{ A} = I_{sc}$$

5. **Calculation for V_{TH} :**

$$V_{ab} = V_{TH} = 3.5\text{ V}$$

6. **Calculation for R_{TH} :**

$$R_{TH} = \frac{V_{ab}}{I_{sc}} = \frac{3.5}{1.46} = 2.4\ \Omega$$

7. Thus, Thevenin's equivalent circuit is :

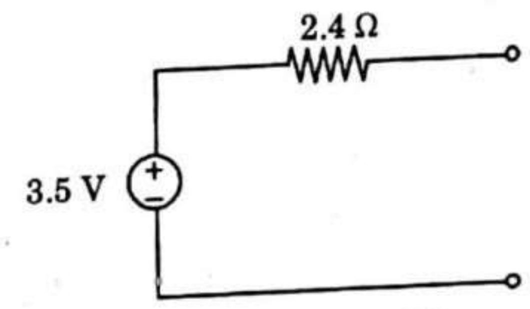


Fig. 1.22.4.

Que 1.23. **State Norton's Theorem. Find current across 15 Ω by using Norton's Theorem.**

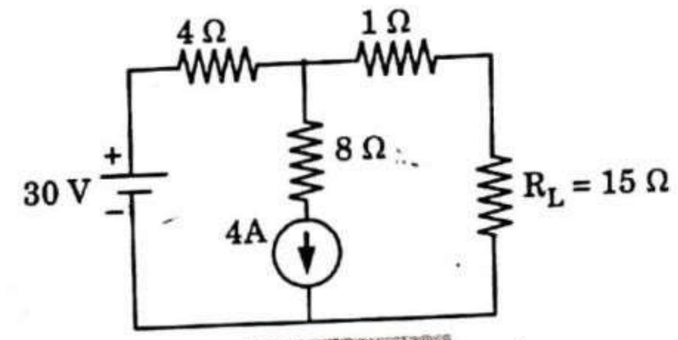


Fig. 1.23.1.

AKTU 2013-14(Sem-1), Marks 10

Answer

A. **Norton's theorem :** Refer Q. 1.18, Page 1–20D, Unit-1.

B. **Numerical :**

1. Apply KVL in outer loop, [Load terminal is short-circuited]

$$30 - 4I_1 - 1 \times (I_1 - 4) = 0$$

$$30 - 5I_1 + 4 = 0$$

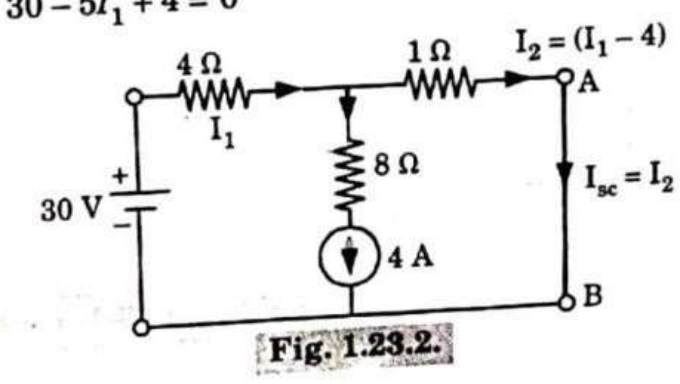


Fig. 1.23.2.

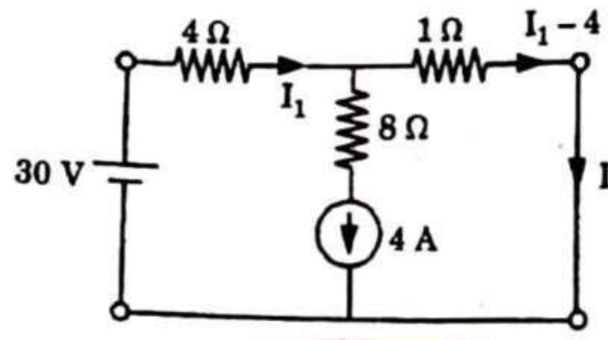


Fig. 1.23.3.

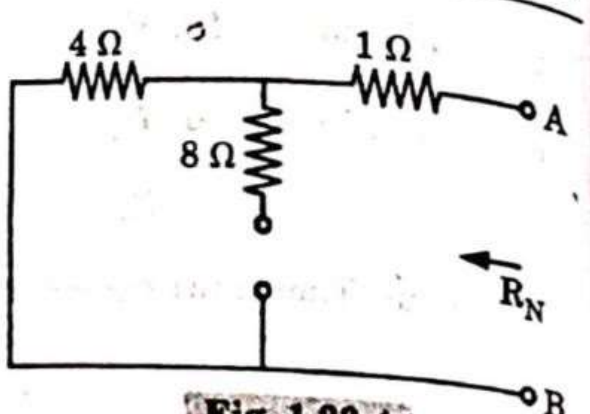


Fig. 1.23.4.

$$I_1 = \frac{34}{5}\ A$$

$$I_2 = I_1 - 4 = \frac{34}{5} - 4 = \frac{14}{5} = 2.8\ A$$

$\because$ $$I_{sc} = I_2 = 2.8\ A$$

2. For Norton's equivalent resistance of the network,

$$R_N = 4 + 1 = 5\ \Omega$$

3. Thus, Norton's equivalent circuit with the load resistor of 15 Ω is as shown in Fig. 1.23.5.

Load current, $$I_L = I_{sc} \times \frac{R_N}{R_N + R_L} = 2.8 \times \frac{5}{5+15} = 0.7\ A$$

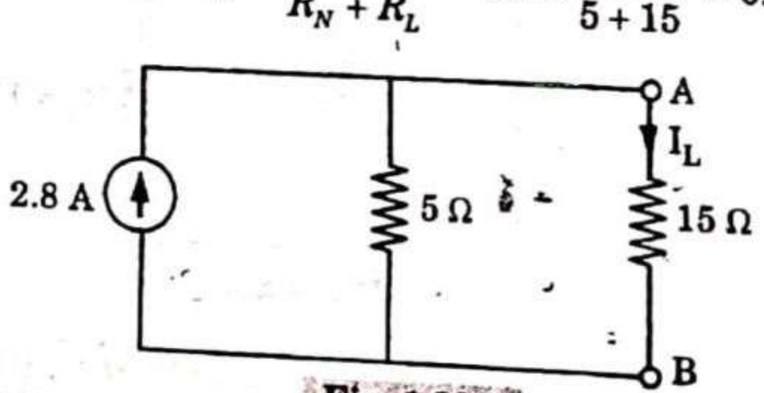


Fig. 1.23.5.

Que 1.24. **State Norton's Theorem. Obtain the Norton's equivalent circuit at terminals AB of the network given in Fig. 1.24.1.**

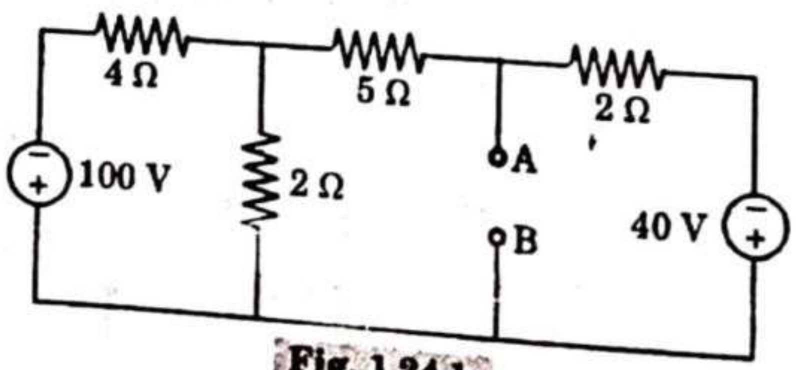


Fig. 1.24.1.

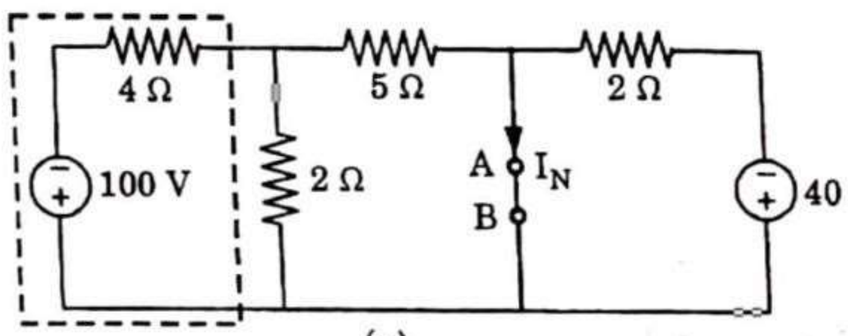
AKTU 2013-14(Sem-2), Marks 10

Answer

A. **Norton's theorem :** Refer Q. 1.18, Page 1–20D, Unit-1.

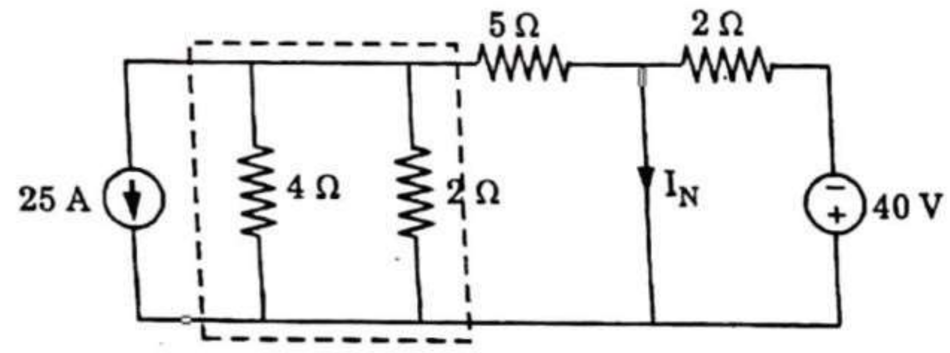
B. **Numerical part :**

1. **Calculation for I_N :** Short circuit A and B



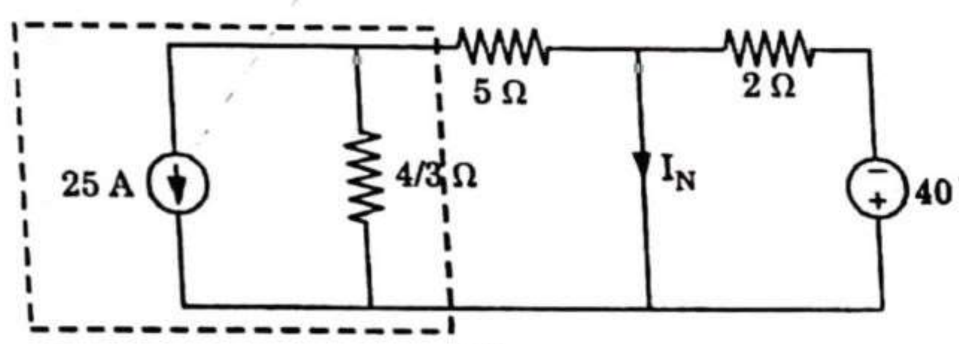
(a)

Changing this voltage source to current source



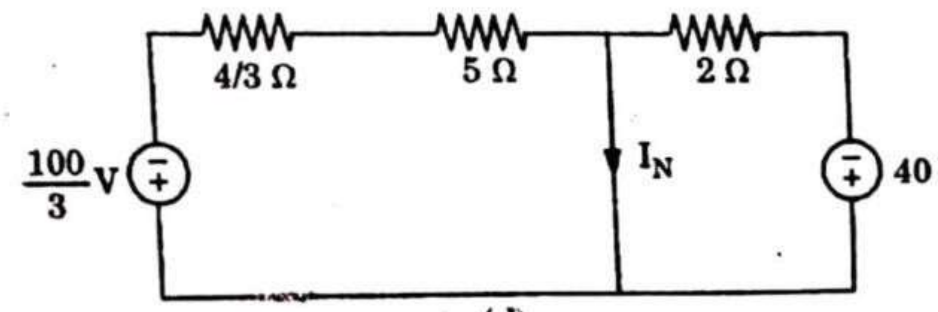
(b)

Solving parallel combination



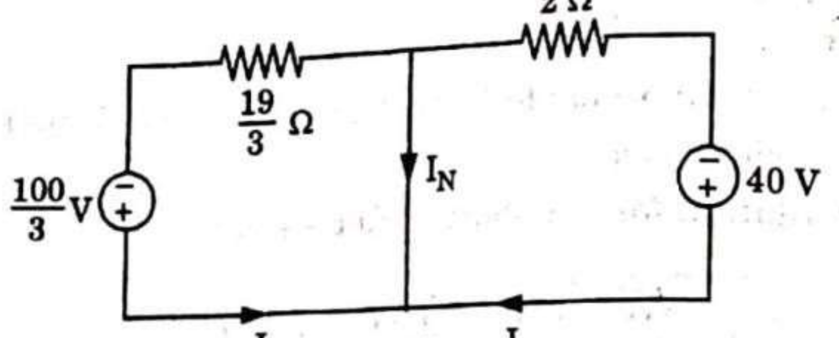
(c)

Again change current source to voltage source,



(d)

Solving series combination

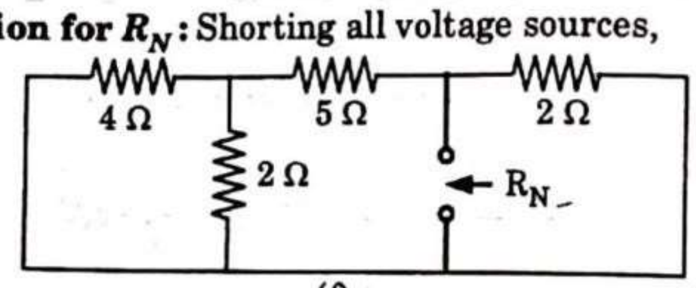


(e)

Now, $I_N = I_1 + I_2$

$$I_N = \frac{\left(\frac{100}{3}\right)}{(19/3)} + \frac{40}{2} = 25.26 \text{ A}$$

2. **Calculation for R_N :** Shorting all voltage sources,

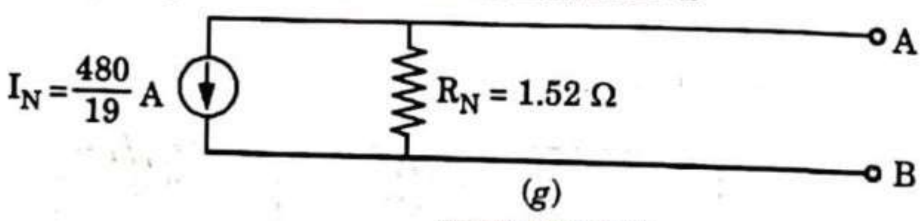


(f)

$$R_N = 2 \parallel (5 + (4 \parallel 2))$$

$$= 2 \parallel \left(5 + \frac{4 \times 2}{4+2}\right) = 1.52\ \Omega$$

So Norton's equivalent circuit at terminal AB is



(g)

Fig. 1.24.2.

Que 1.25. **Explain the duality between Thevenin's and Norton's equivalent circuits.**

OR

How Norton's theorem is equivalent to Thevenin's theorem ? Also write the limitations of Thevenin's theorem and find the voltage across load resistance R_L using Thevenin's theorem when load resistance is 2 kΩ.

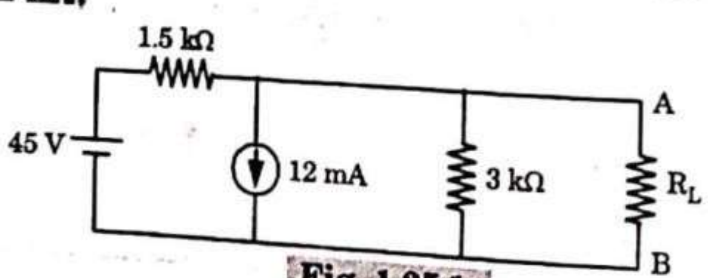


Fig. 1.25.1.

AKTU 2015-16(Sem-1), Marks 10

Answer

A. Duality :

1. Thevenin's and Norton's theorems help in reducing a complex network as seen from two terminals, into a simple circuit so that their response is easily determined.
2. Thevenin and Norton equivalent of N_1 as seen from *ab* are shown in Fig. 1.25.2.

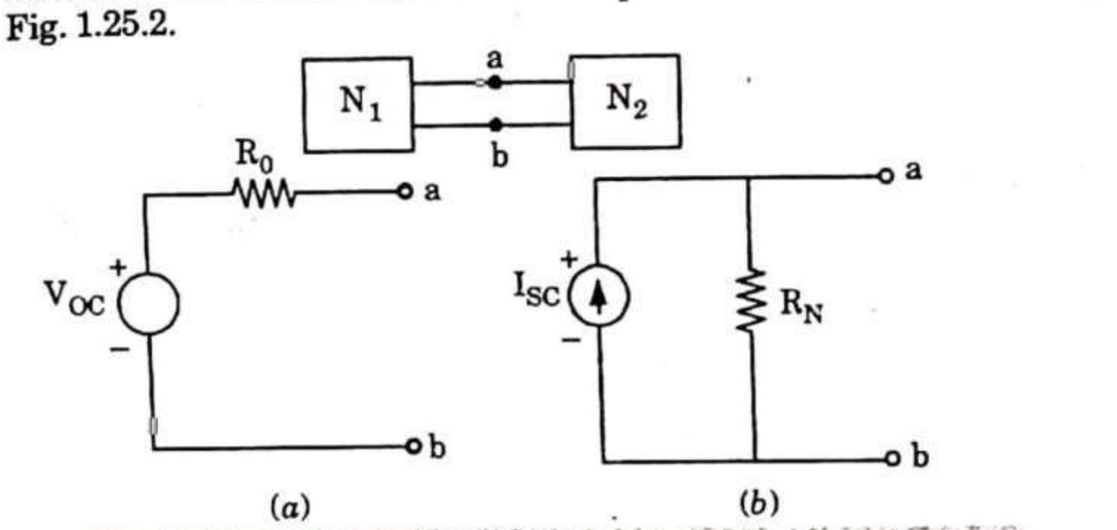


Fig. 1.25.2. (*a*) Thevenin equivalent, (*b*) Norton equivalent.

V_{OC} = Open circuit voltage at *ab* (when N_2 is disconnected)

R_o = Equivalent resistance of N_1 as seen from *ab* with voltage sources short circuited and current sources open circuited.

I_{SC} = Short circuit current flowing from *a* to *b* when terminals *ab* are shorted after disconnecting N_2.

3. We can see that the Norton equivalent follows from the Thevenin equivalent by source conversion and vice versa.
4. For Thevenin equivalent :

$$V_{OC} = V_{TH} = \text{Thevenin voltage}$$
$$R_o = R_{TH} = \text{Thevenin resistance}$$

5. For Norton equivalent :

$$R_o = R_N, \text{ Norton resistance}$$
$$R_N = R_{TH}$$
$$I_{SC} = \frac{V_{OC}}{R_O} = \frac{V_{TH}}{R_{TH}}$$

B. Limitations of Thevenin's theorem :

1. Not applicable to the circuits consisting of non-linear elements.
2. Not applicable to unilateral networks.
3. There should not be magnetic coupling between the load and circuit to be replaced by this theorem.
4. In the load side, there should not be controlled sources, controlled from some other part of the circuit.

C. Numerical :

1. The equivalent resistance of the network with voltage source short-circuited and current source open-circuited with reference to terminals *A* and *B* :

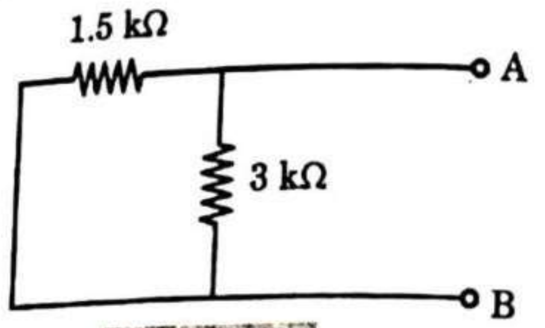


Fig. 1.25.3.

$$R_T = 3 \parallel 1.5 = \frac{3 \times 1.5}{3 + 1.5} = \frac{4.5}{4.5} = 1\ \Omega$$

2. Converting current source of 12 mA connected across 3 kΩ resistance into equivalent voltage source of 36 V in series with resistor of 3 kΩ and removing the 2 kΩ resistor, the circuit is converted as

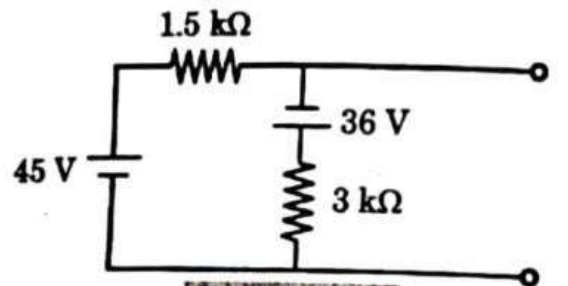


Fig. 1.25.4.

3. The current flowing through the mesh formed by voltage sources and resistors of 1.5 kΩ and 3 kΩ is given as

$$I = \frac{45 + 36}{(1.5 + 3) \times 10^3} = 18\ \text{mA}$$

4. Voltage across terminals A and B,

$$V_{AB} = 45 - 1.5 \times 18 \times 10^{-3} = 44.973\ \text{V}$$

5. Current flowing through resistor of 2 kΩ $= \dfrac{44.973}{1 + 2} = 14.991$ mA

Que 1.26. **Calculate the current in the 6 Ω resistance by using Norton's theorem.**

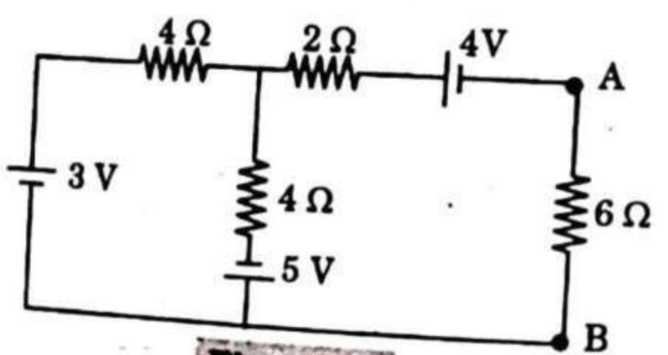


Fig.1.26.1.

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Answer

A. To Find I_{sc} :

1. 6 Ω resistor is short circuited

2. Using KVL in loop (1),

$$-3 + 4I_1 + 4I_1 - 4I_2 - 5 = 0$$

$$8I_1 - 4I_2 = 8 \quad ...(1.26.1)$$

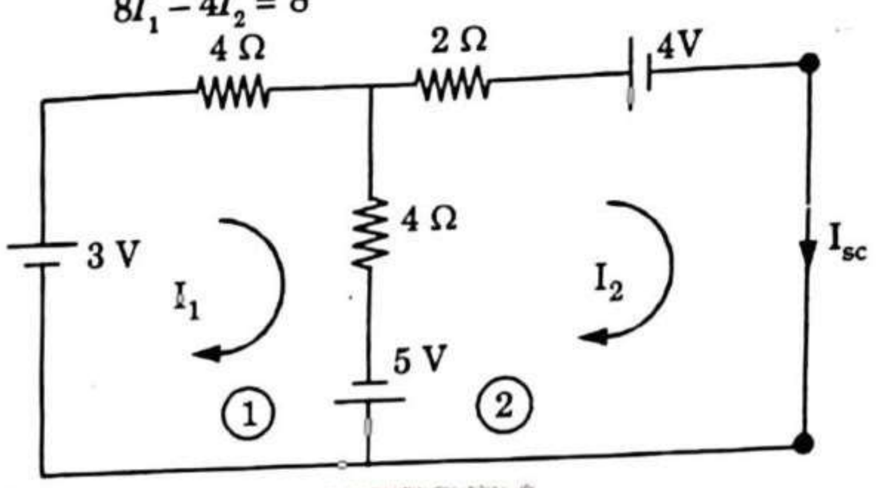

Fig. 1.26.2.

3. Again using KVL in loop (2),

$$5 + 4I_2 + 2I_2 + 4 - 4I_1 = 0$$

$$6I_2 - 4I_1 = -9$$

$$4I_1 - 6I_2 = 9 \quad ...(1.26.2)$$

4. Solving eq. (1.26.1) and (1.26.2), $I_2 = -5/4\ \text{A} = I_{sc}$

B. To Find R_{TH} :

1. Voltage source is short circuited and Load terminal is open circuited
2. $R_{TH} = R_N = 2 + (4 \parallel 4) = 2 + 2 = 4\ \Omega$

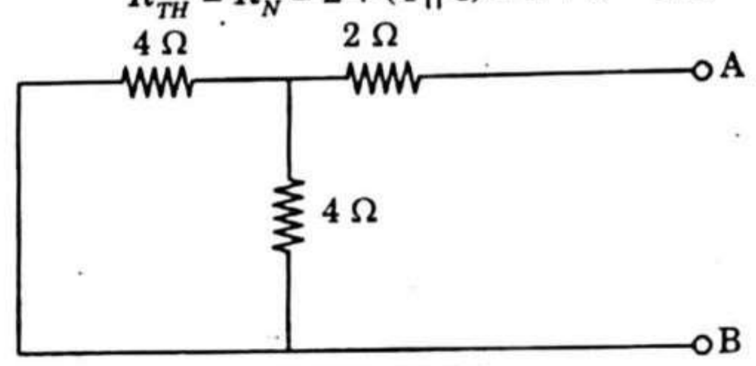

Fig. 1.26.3.

C. Norton's equivalent circuit :

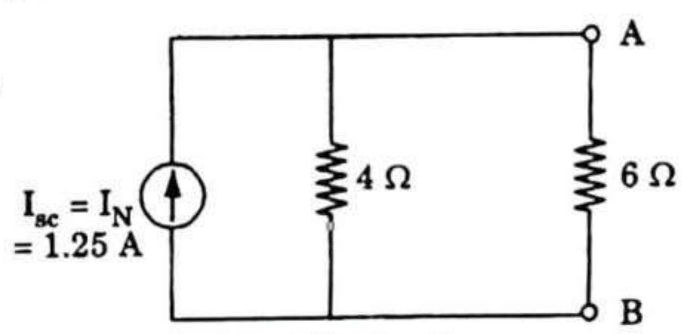

Fig. 1.27.4.

Current through 6 Ω (flowing from A to B)

$$= 1.25 \times \frac{4}{6 + 4} = 0.5\ \text{A}$$

☺☺☺