K L Deemed to be University
Department of Electronics and Communication Engineering – KLVZA
2025-26 _ Odd Sem

BASIC ELECTRICAL AND ELECTRONIC CIRCUITS

Syllabus

Course Code: 25EC1101 **L-T-P-S : 3-0-2-0**

CO-1: AC & DC Fundamentals: **DC Fundamentals:** Basic circuit elements and sources, Series and Parallel connection of circuit elements, Star-Delta transformation, Ohm's Law, Kirchhoff's Laws. **AC fundamentals:** Peak Value, Time period, Frequency, RMS & Average values, Form factor, peak factor and power factor.
CO-2: Circuit Analysis Techniques: Mesh analysis, Nodal analysis, Thevenin's Theorem, Norton's Theorem, Maximum power transfer theorem, Superposition theorem

KONERU LAKSHMAIAH EDUCATION FOUNDATION
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B.Tech - Odd Sem : Semester in Exam-I
Academic Year:2025-2026

25EC1101 – BASIC ELECTRICAL AND ELCTRONIC CIRCUITS

Set No:

Model Question Paper

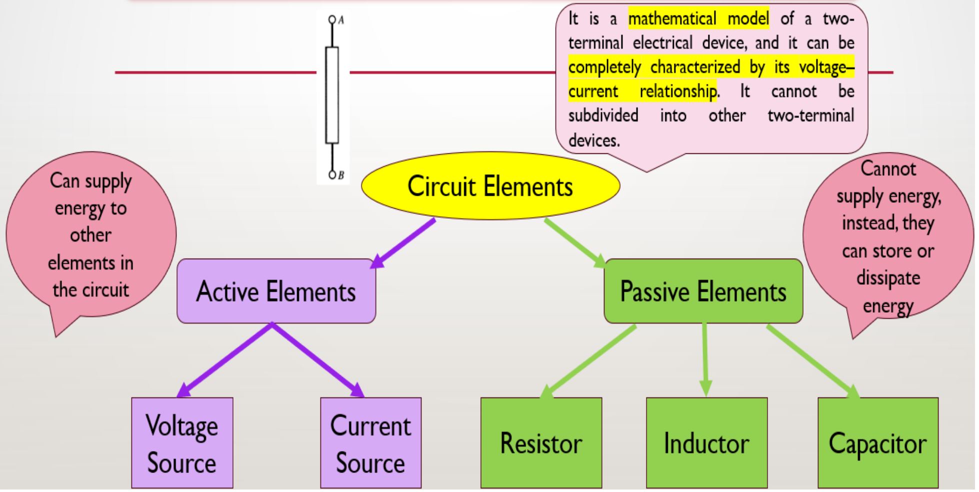
Time: 90 Mins	Max. Marks: 50

S.NO	Answer All Questions	Choice	Options	Marks	CO	CO BTL	COI BTL
1.	**ANSWER ALL QUESTIONS (6 X 2 = 12 M)**			**12Marks**			
1.A.				2Marks	CO1		
1.B.				2Marks	CO1		
1.C.				2Marks	CO1		
1.D.				2Marks	CO2		
1.E.				2Marks	CO2		
1.F.				2Marks	CO2		
2.	**ANSWER ALL QUESTIONS (4 X 4 = 16 M)**			**16Marks**			
2.A.				4Marks	CO1		
2.B.				4Marks	CO1		
2.C.				4Marks	CO2		
2.D.				4Marks	CO2		
3.	**ANSWER ALL QUESTIONS (5 + 6 = 11 M)**	**choice Q-4**		**11Marks**	**CO1**		
3.A.				5Marks	CO1		
3.B.				6Marks	CO1		
4.	**ANSWER ALL QUESTIONS (5 + 6 = 11 M)**			**11Marks**	**CO1**		
4.A.				5Marks	CO1		
4.B.				6Marks	CO1		
5.	**ANSWER ALL QUESTIONS (5 + 6 = 11 M)**	**choice Q-6**		**11Marks**	**CO2**		
5.A.				5Marks	CO2		
5.B.				6Marks	CO2		
6.	**ANSWER ALL QUESTIONS (5 + 6 = 11 M)**			**11Marks**	**CO2**		
6.A.				5Marks	CO2		
6.B.				6Marks	CO2		

CO1 Terminal Important Questions (2 Marks/4 Marks/5 Marks/6 Marks)

1. Define the following
   i) Voltage ii) Current iii) Power iv) Energy
2. Differentiate between active and passive elements.
3. Give the V–I relation in a resistor, capacitor, and inductor.
4. State Ohm's law.
5. Differentiate between ideal and practical sources.
6. Describe in detail about dependent sources.
7. Define Node, Branch, Path, and Loop with the help of a simple circuit.
8. State Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL).
9. Describe the Star – Delta Transformation in electrical circuits.
10. Explain about Star to Delta Conversion.
11. Explain about Delta to Star Conversion.
12. Describe different parameters of sinusoidal ac signal
13. List out the differences between ac and dc circuits.
14. Define average value, RMS value, form factor and peak factor with expression(mathematical formula) of an ac signal.

Electric Circuit Elements



BASIC ELECTRICAL QUANTITIES

- **Voltage:** Voltage, also known as electric potential difference, measures energy per unit charge. Voltage is measured in volts (V).

$$v = \frac{\text{energy}}{\text{charge}} = \frac{dw(\text{Joules})}{dq(\text{coulombs})}\ (V)$$

- **Current:** Electric current is the flow of electric charge in a conductor per unit time such as a wire. It is the rate of flow of electric charge through a circuit. The unit of measurement for electric current is the ampere (A).

$$i = \frac{\text{charge}}{\text{time}} = \frac{dq(\text{coulombs})}{dt(\text{seconds})}\ (A)$$

- **Power:** Power in an electrical context is the rate at which energy is transferred or converted per unit time. It is the product of voltage and current and is measured in watts (W)

$$P = \frac{\text{energy}}{\text{time}} = \frac{dw(\text{Joules})}{dt(\text{seconds})}(W)$$

We can also write $P = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt} = v \times i(W)$

- **Energy:** The electrical Energy (W) is given by product of power and time.

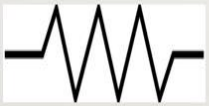
$W = P \times t$ (or) $W = \int_0^t p\,dt$

Resistor

- **Definition:** Resistor is a two-terminal electronic component that limits the flow of electric current. It dissipates electrical energy as heat.

  It can be a fixed value or a variable resistor.

- **Unit:** The value of resistor is called resistance. It is denoted by R and the unit of resistance is Ohms (Ω).
- **Symbol:**



Fixed Resistor

Variable Resistor

V & I relationship of a Resistor

$V = IR$

$I = \frac{V}{R}$

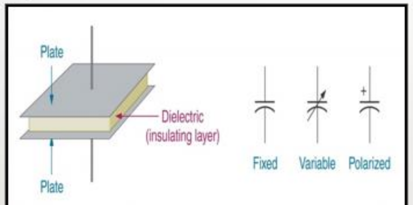
$R = \frac{V}{I}\ (\Omega)$

Conductance $G = \frac{1}{R}$

Units of Conductance is mho or Siemens

Capacitor

- **Definition:** A capacitor is an electronic component that stores electrical energy in an electric field.
- **Unit:** The value of capacitor is called capacitance. It is denoted by C and the unit of capacitance is farads.
- **Symbol:**



(a) Capacitor construction (b) Common capacitor symbols

Capacity is directly proportional to charge and inversely proportional to voltage

$C = \frac{Q}{V}$ or $Q = CV$ $E_{stored} = ½CV^2$

where

C = the capacity (or capacitance) of the component, in coulombs per volt, or Farads

Q = the total charge stored by the component

V= the voltage across the capacitor

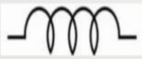
V & I relationship of a Capacitor

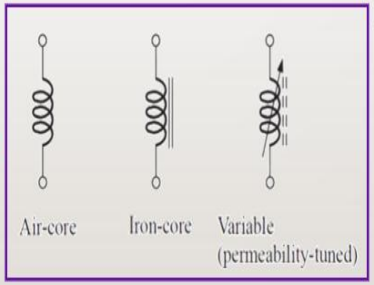
$$i = C\frac{dv}{dt}$$

C-Capacitor (Farads)

Inductor

- **Definition:** An inductor is essentially a coil of wire with an iron core. They store energy in magnetic field. An inductor is an electromagnet.
- **Unit:** The value of inductor is called inductance. It is denoted by L and the unit of resistance is henry (H).
- **Symbol:**





Energy Stored in an Inductor

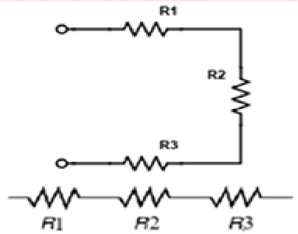
$E_{stored} = \frac{1}{2}LI^2$

V & I relationship of an Inductor

$$v = L\frac{di}{dt}$$

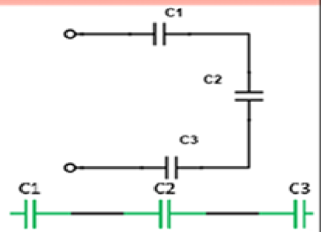
L-Inductance (Henry)

Resistors in Series



$$R = R1 + R2 + R3$$

Capacitor in Series

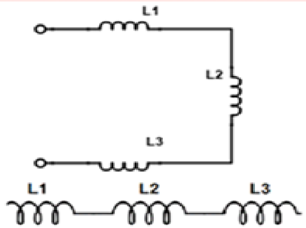


$$\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}$$

For the special case of two capacitors are in series,

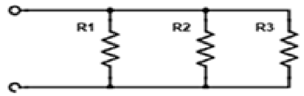
$$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$$

Inductors in Series



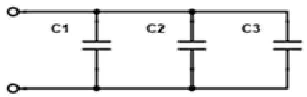
$$L = L1 + L2 + L3$$

Resistors in Parallel



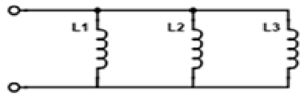
$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

Capacitors in Parallel



$$C = C1 + C2 + C3$$

Inductors in Parallel

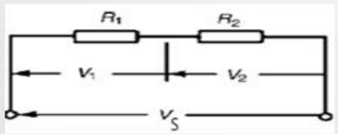


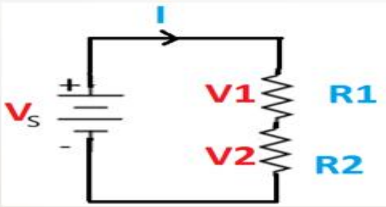
$$\frac{1}{L} = \frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3}$$

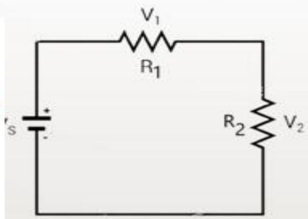
Voltage Division Rule (VDR)

Resisters connected in **series** have the same current passing through them, but supply voltage is divided on individual resistors using the voltage divider rule.

The voltage division rule (VDR) **does not apply to parallel circuits,** because the voltage remains the same across all parallel components.







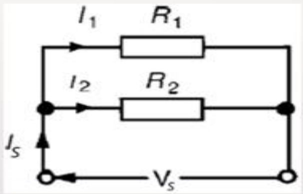
$$V_1 = \frac{R_1}{R_1 + R_2}V_S$$

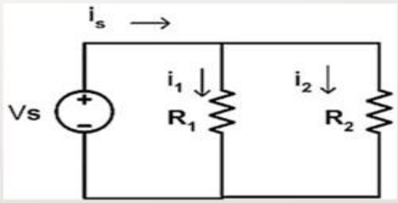
$$V_2 = \frac{R_2}{R_1 + R_2}V_S$$

Current Division Rule (CDR)

Resisters connected in **parallel** have the same voltage, but the supply current is divided on individual resistors (splitting of current between the branches of the divider) using the current divider rule.

The current division rule (CDR) **does not apply to series circuits,** because the current remains the same across all series components.

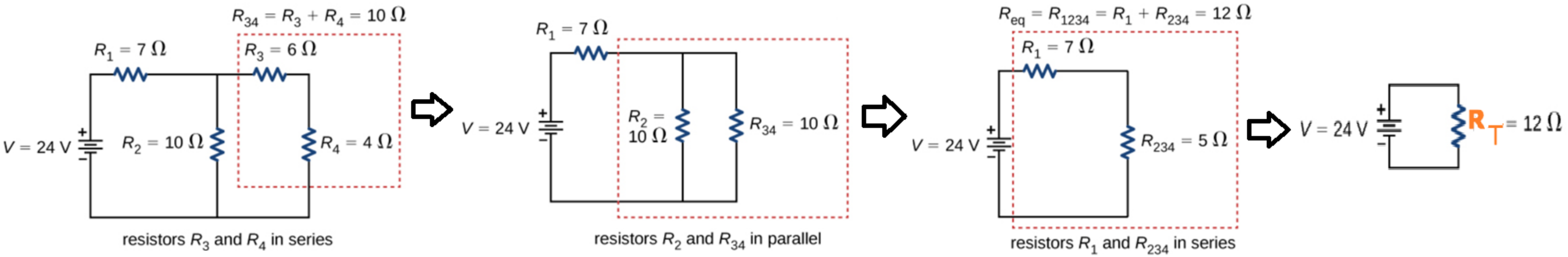




$$i_1 = \frac{R_2}{R_1 + R_2}i_s$$

$$i_2 = \frac{R_1}{R_1 + R_2}i_s$$

How to find total resistance (R_T) in series and parallel connections?



$$\boxed{R_T = (4+6\ ||10)+7}$$

Example: What is the voltage across the 10 Ω resistor in Fig. 1.21.

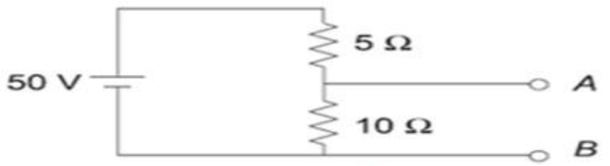


Fig. 1.21

$$\text{Voltage across } 10\ \Omega = V_{10} = 50 \times \frac{10}{10+5} = \frac{500}{15} = 33.3\ \text{V}$$

Example : Find the voltage between A and B in a voltage divider network shown in Fig.

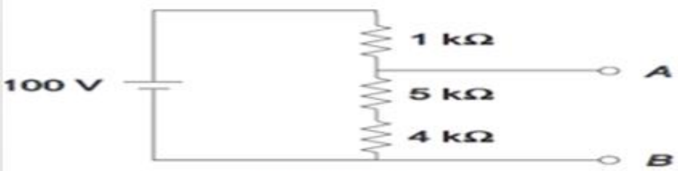
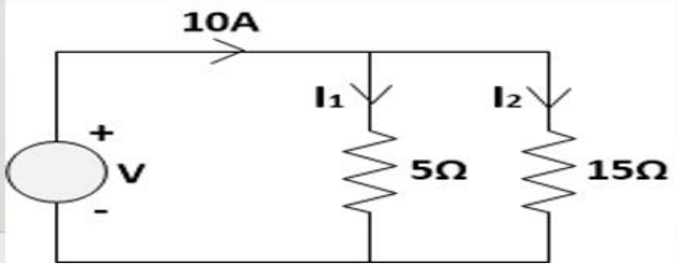


Fig. 1.22

$$\text{Voltage across } 9\ \text{k}\Omega = V_9 = V_{AB} = 100 \times \frac{9}{10} = 90\ \text{V}$$

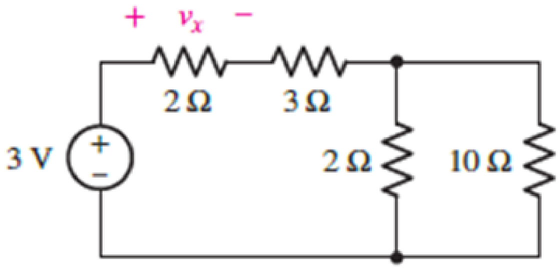
Example: Calculate the current flowing in the resistors?



$$I_1 = 10 \times \frac{15}{5+15} = \frac{150}{20} = 7.5\ \text{A}$$

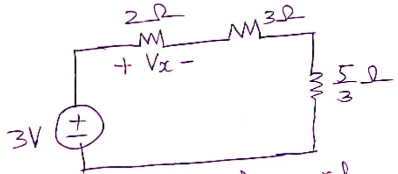
$$I_2 = 10 \times \frac{5}{5+15} = \frac{50}{20} = 2.5\ \text{A}$$

Example: **Employ the voltage division rule to calculate the voltage labelled v_x in the circuit of Fig.**



Sol

$$2\,\Omega \,||\, 10\,\Omega = \frac{2\times 10}{2+10} = \frac{20}{12} = \frac{5}{3}\,\Omega$$



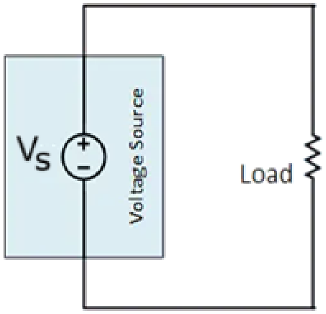
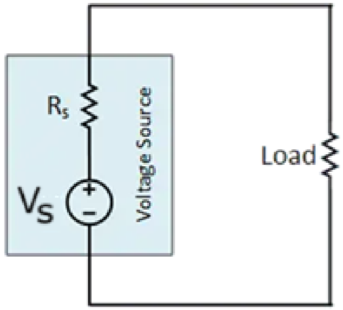
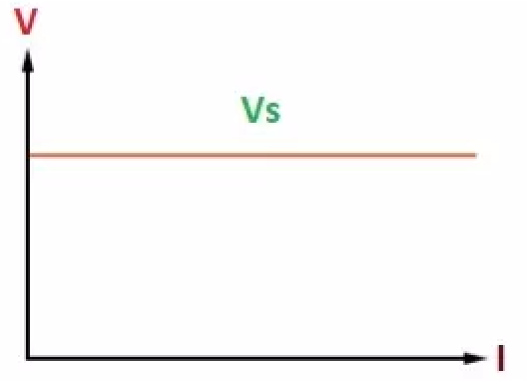
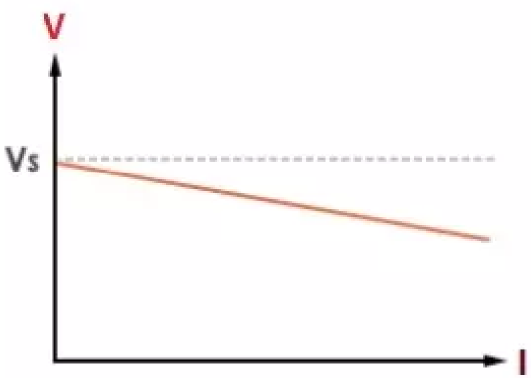
By apply voltage division rule,

$$V_x = \frac{3\times 2}{\left(2+3+\frac{5}{3}\right)}$$

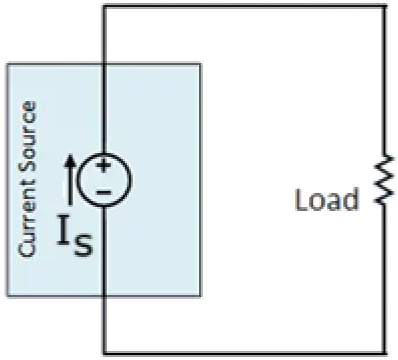
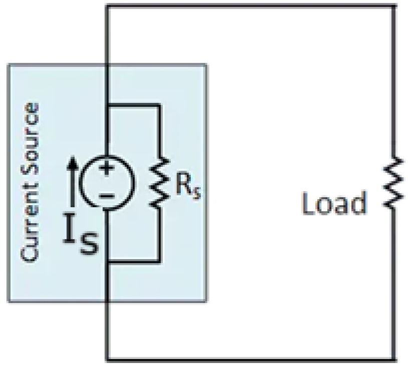
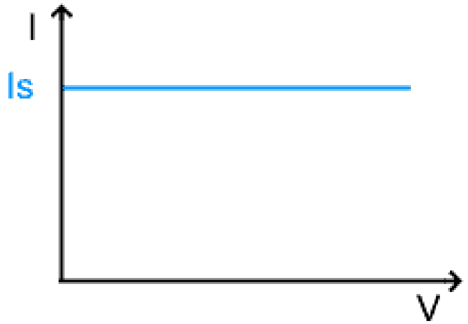
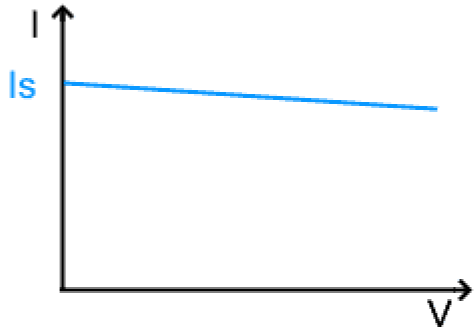
$$= \frac{6}{\frac{20}{3}}$$

$$= \frac{9}{10}\,V$$

List out difference between ideal and real(practical) voltage sources.

Ideal voltage sources	Real(Practical) voltage sources
Ideal voltage sources (V_S) are perfect models used for theoretical analysis. 	Real voltage sources (V_S) have limitations due to internal resistance (R_S), leading to voltage drops and power losses in practical applications. 
Maintains a constant voltage regardless of load current. 	Provides voltage that decreases with increasing load due to internal resistance. 
Internal Resistance (R_S) is zero. causing no voltage drop.	Small but nonzero ($R_S > 0$) causing voltage drop.
Voltage remains constant under any load condition.	Voltage drops as current increases.
No internal power loss.	Some power is lost due to internal resistance ($P = I^2 R_S$).

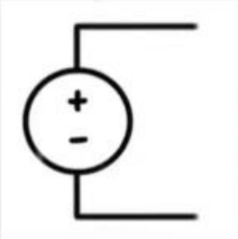
List out difference between ideal and real(practical) current sources.

Ideal current sources	**Real(Practical) current sources**
The ideal current source (I_S) provides the same current to any load resistance and doesn't change its current by changing a load resistance. 	The real current source (I_S) is connected in parallel with the internal resistance (R_S), and the current flowing through it depends on the load. 
Maintains a constant current regardless of load current. 	Provides current that decreases with increasing load due to internal resistance. 
Source resistance (R_S) is infinite.	Source resistance (R_S) is high.
Current remains constant under any load condition.	Current drops as voltage increases.
No internal power loss.	Some power is lost due to internal resistance ($P = I^2 R_s$).

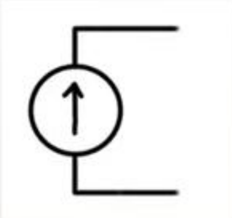
Energy Sources

Independent Source

The source which does not depend on any other quantity like voltage and current) in the circuit.



Voltage Source



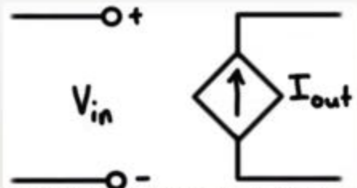
Current Source

Dependent Source

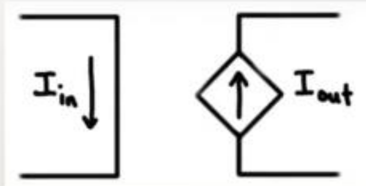
A **Dependent Source** (also called a **Controlled Source**) is an **ideal circuit element** whose output (voltage or current) depends on another voltage or current in the same circuit.

- A dependent voltage source is represented by a diamond symbol with a positive (+) and a negative (-) sign inside.
- A dependent current source is represented by a diamond symbol with an arrow inside. The direction of arrow indicates the direction of current.

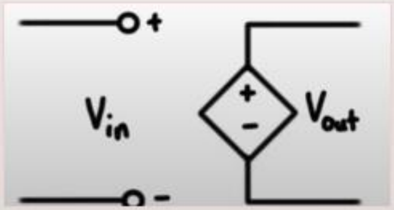
Voltage Controlled Current Source (VCCS)



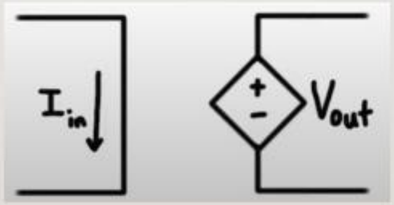
Current Controlled Current Source (CCCS)



Voltage Controlled Voltage Source (VCVS)



Current Controlled Voltage Source (CCVS)

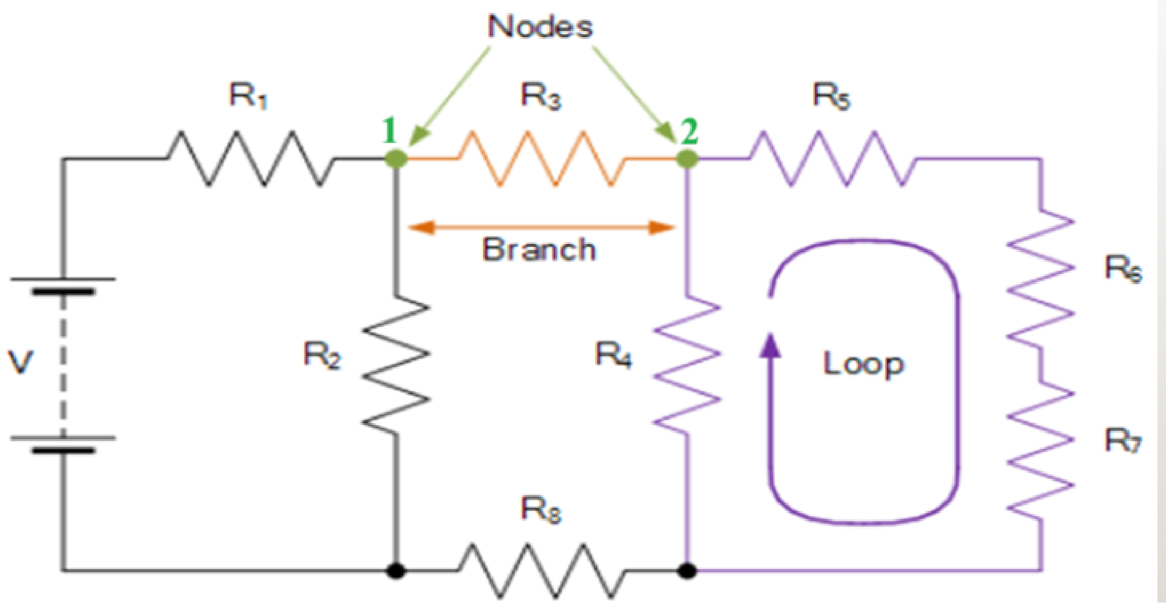


Node, Branch, Loop, Path, Mesh

Node – any point where 2 or more circuit elements are connected together. Each node has one voltage (w.r.t. ground)

Branch – a circuit element (resistor, capacitor, current source, etc.) between two nodes.

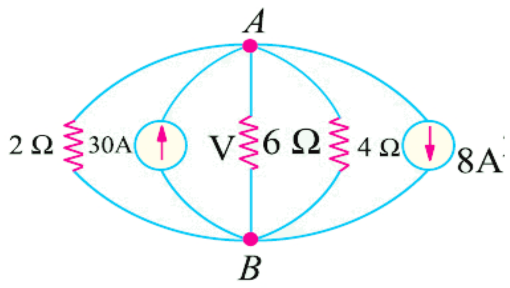
Loop – a collection of branches that form a closed path returning to the same node without going through any other nodes or branches twice.



Path – a sequence of nodes and elements (such as resistors, capacitors, inductors, voltage sources, etc.) in an electrical network where no node is repeated (i.e. each node is visited exactly once).

Mesh – a mesh is a loop in a circuit that contains no other loops within it.

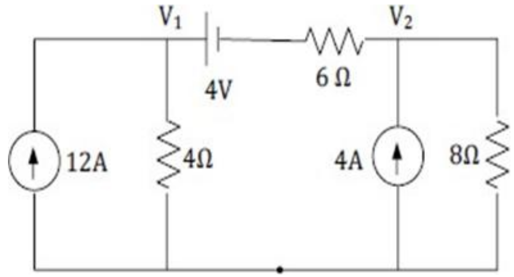
1. Identify the number of Branchesn in the circuit shown below.



Sol

- 2Ω resistor (one branch)
- 30A current source (one branch)
- 6Ω resistor (one branch)
- 4Ω resistor (one branch)
- 8A current source (one branch)

No of branches=5

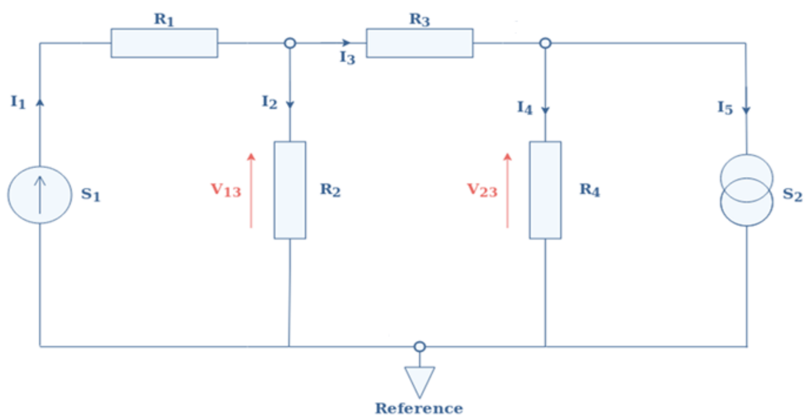


Sol

- 12A current source (one branch)
- 4Ω resistor (one branch)
- 4V voltage source (one branch)
- 6Ω resistor (one branch)
- 4A current source (one branch)
- 8Ω resistor (one branch)

No of branches=6

2. Identify the number of Nodes in the circuit shown in Fig.1 and Fig.2.



Sol

There are 3 distinct nodes in the circuit.

No of nodes=3

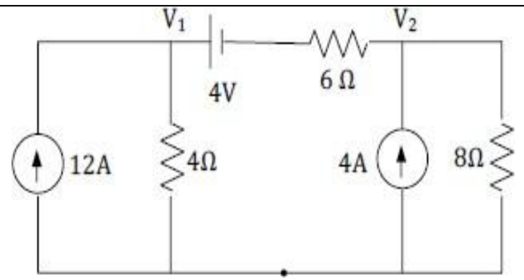
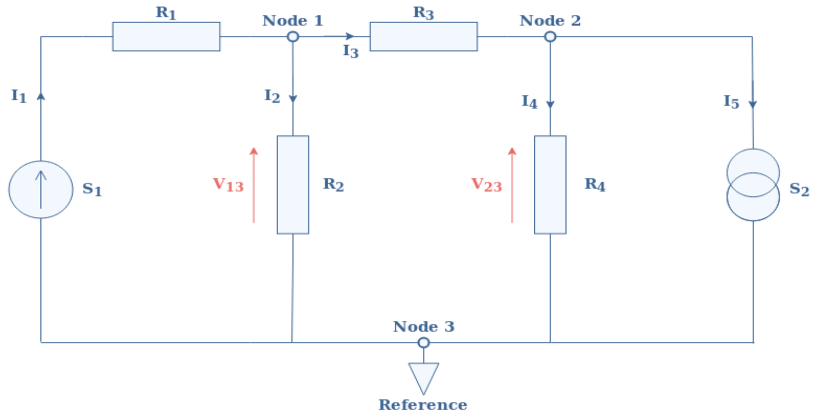


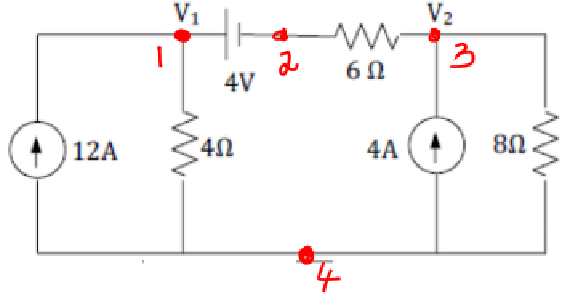
Fig.2.

Sol

There are 4 distinct nodes in the circuit.

No of nodes=4





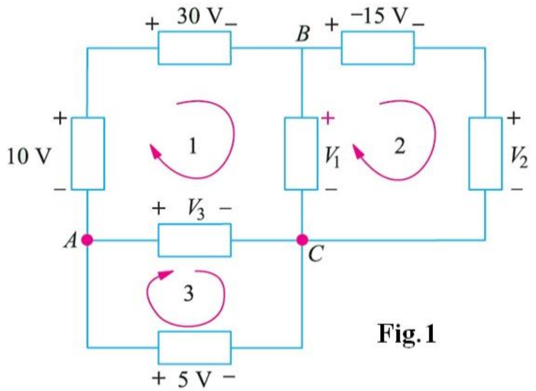


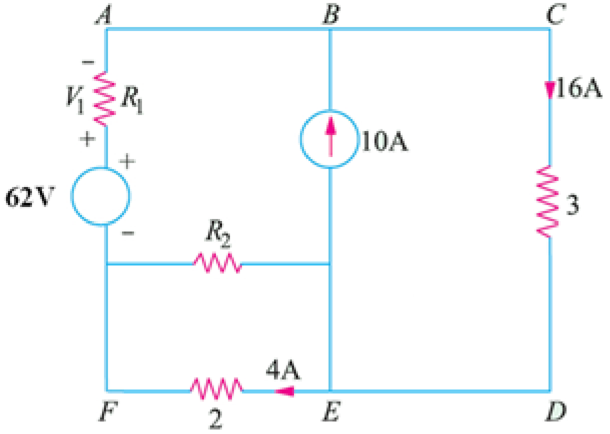
Fig.1

Sol

There are 5 distinct nodes in the circuit.

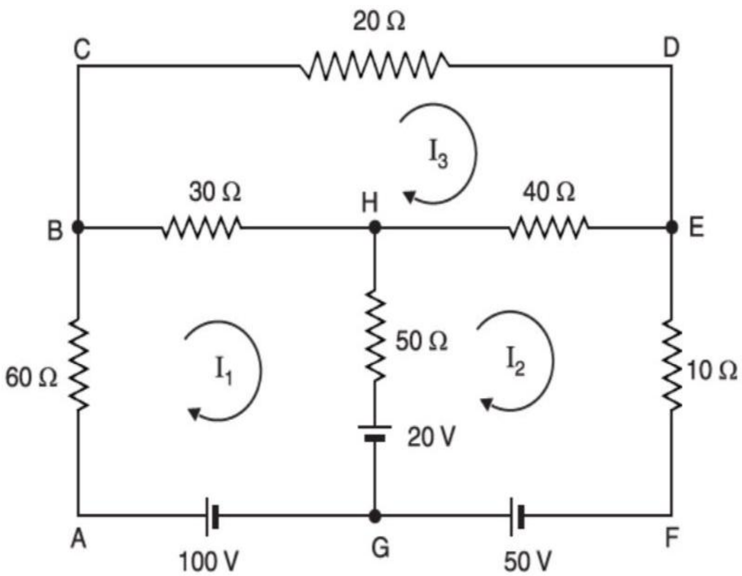
No of nodes=5

3. Identify the number of Meshes in the circuit shown below.



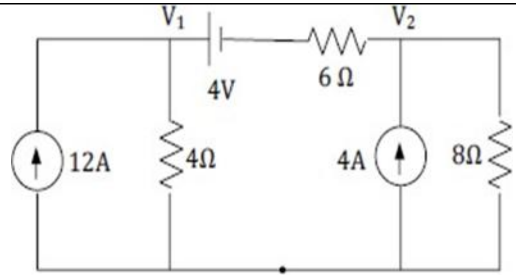
Sol

Number of Meshes=3



Sol

Number of Meshes=3



Sol

Number of Meshes=3

4. Identify the number of loops in the circuit shown in Fig.3.

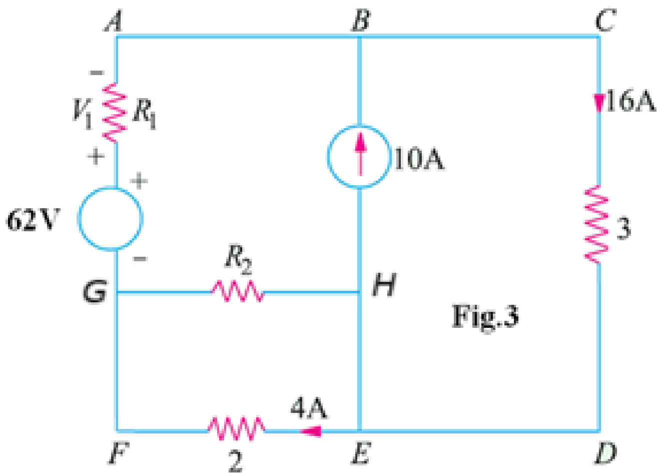
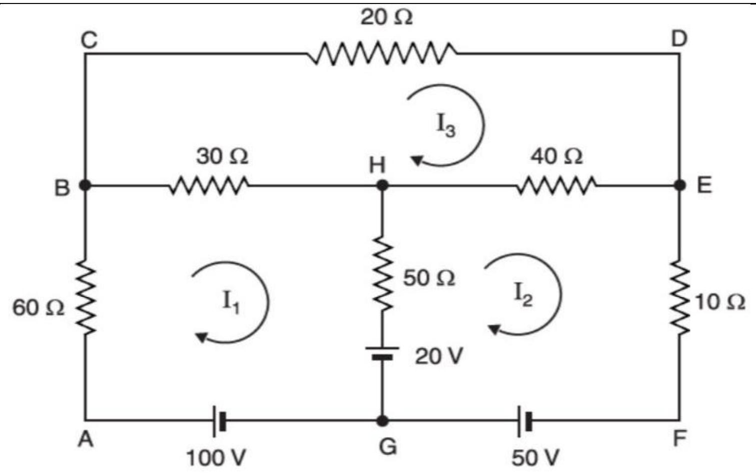


Fig.3

Sol

Number of loops =7 (**A**BCDEFG**A**, **A**BHG**A**, **G**HEF**G**, **B**CDEH**B**, ABHEFGA, **G**HBCDEF**G**, **G**ABCDEH**G**)



Sol

Number of loops =7 (**B**CDEH**B**, **A**BHG**A**, **E**FGH**E**, **A**BHEFG**A**, **A**BCDEFG**A**, **A**BCDEHG**A**, **B**CDEFGH**B**)

Ohm's Law

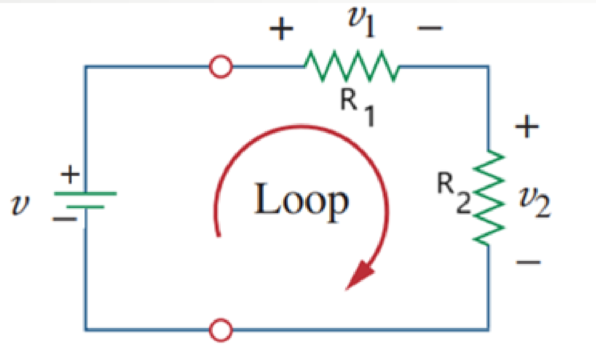
Ohm's Law states that the current flowing through a conductor is directly proportional to the voltage across it and inversely proportional to its resistance, provided the temperature and other physical conditions remain constant. (German physicist, Georg Simon Ohm in 1827)

$$I = \frac{V}{R} \quad (or) \quad V = RI \quad (or) \quad R = \frac{V}{I}$$

$$i = \frac{v}{R} \quad (or) \quad v = Ri \quad (or) \quad R = \frac{v}{i}$$

Kirchoff's Laws

- **Kirchhoff's Voltage Law (KVL)** states that the total voltage around any closed loop in a circuit is zero.
- The algebraic sum of voltages around each loop is zero.
- Σ Voltage Drops - Σ Voltage Rises = 0



According to KVL:

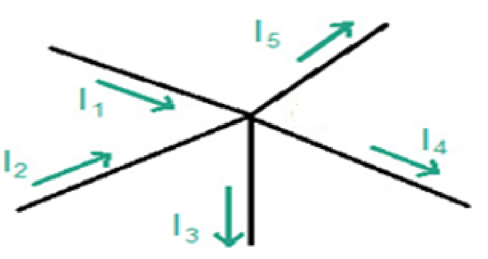
$$\boxed{\sum V = 0}$$

$$-v + v_1 + v_2 = 0$$

Kirchhoff's Current Law (KCL) states that the total current entering a node in an electrical circuit is equal to the total current leaving the node.

The algebraic sum of currents entering and leaving a node is zero.

Σ Currents In - Σ Currents Out = 0



According to KCL:

$$\boxed{\Sigma I = 0}$$

$I_1 + I_2 - I_3 - I_4 - I_5 = 0$

$I_1 + I_2 = I_3 + I_4 + I_5$

Give the V – I relation in a resistor, capacitor, and inductor.

1. Write the V-I relations of a Resistor.

   Voltage V=IR

   Current $I=\frac{V}{R}$

2. Write the V-I relations of an Inductor.

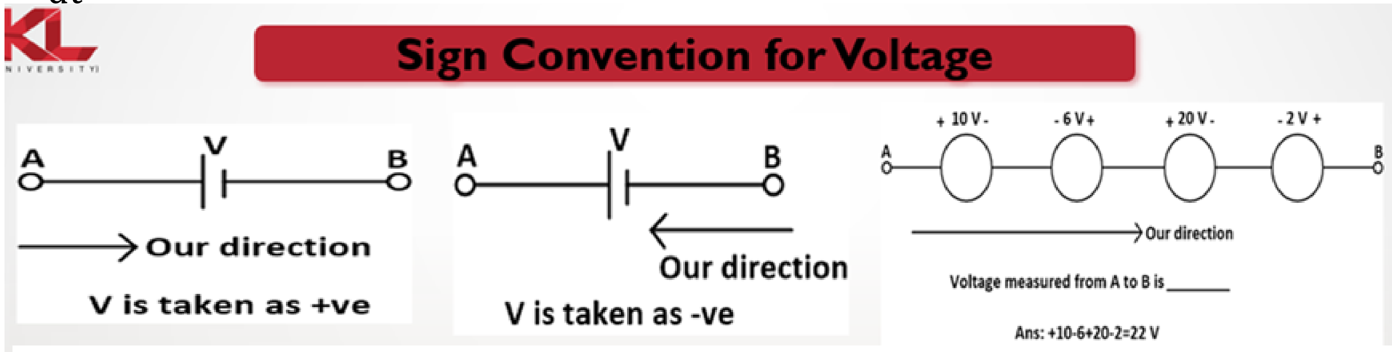
   Voltage $v(t)= L\frac{di(t)}{dt}$

   Current $i(t)= \frac{1}{L}\int v(t)dt$

3. Write the V-I relations of a Capacitor.

Voltage $v(t)= \frac{1}{C}\int i(t)dt$

Current $i(t)= C\frac{dv(t)}{dt}$



Basics

Find Power of any number in calculator

$K\Omega = 10^{3}\Omega$

$mA = 10^{-3} A$

$\mu A = 10^{-6} A$

$pF = 10^{-12} F$

$\mu F = 10^{-6} F$

$nF = 10^{-9} F$

① EX 1:

$= \frac{1}{2\mu F} + \frac{1}{10pF}$

$= 1 \div (2\times10^{-6}) + 1 \div (10\times10^{-12})$

(Use this in the calculator)

$= 1\times10^{11} F$

② EX 2:

$= \frac{1}{4K\Omega} + \frac{1}{6K\Omega}$

$= 1 \div (4\times10^{3}) + 1 \div (6\times10^{3})$

$= 4.1666\times10^{-4}$

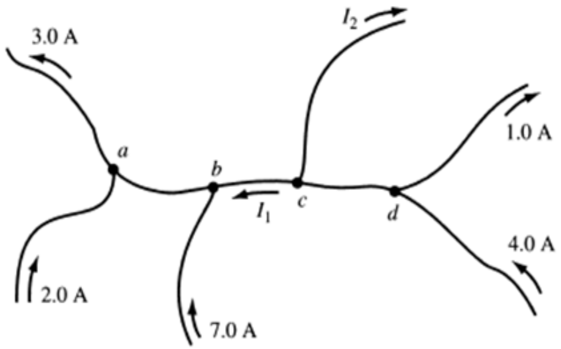
③ EX 3:

$= \frac{1}{2mA} + \frac{1}{4\mu A}$

$= 1 \div (2\times10^{-3}) + 1 \div (4\times10^{-6})$

$= 250500 = 0.250\times10^{-6} A$

1. Obtain the currents I_1 and I_2 for the network shown in Fig.



Sol

KCL at nodes a,b

$-3+2+7+I_1=0$

$\boxed{I_1 = -6A}$

KCL at nodes c,d

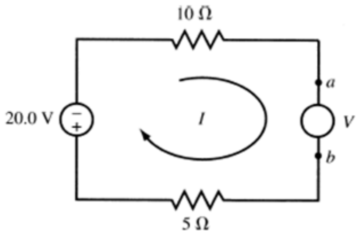
$-I_1 - I_2 - 1 + 4 = 0$

$6 - I_2 - 1 + 4 = 0$

$-I_2 = -9A$

$\boxed{I_2 = 9A}$

3. Find the source voltage V and its polarity in the circuit shown in Fig. if (a) I = 2 A and (b) I = −2A.



Sol

(a) $I = 2A$

Apply KVL

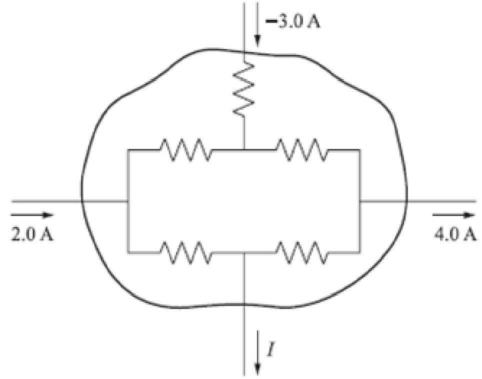
$20 + 10I + V + 5I = 0$

$20 + 15I + V = 0$

$20 + 15 \times 2 + V = 0$

$\boxed{V = -50V}$

2. Find the current I for the circuit shown in Fig.



Sol

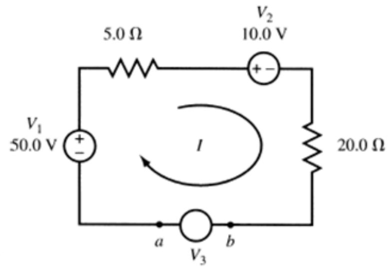
Apply KCL at node

$2-3-I-4=0$

$-5-I=0$

$\boxed{I=-5A}$

4. Find V_3 and its polarity if the current I in the circuit of Fig is 0.4 A.



Sol

$I = 0.4A$

Apply KVL

$-50 + 5I + 10 + 20I + V_3 = 0$

$-50 + 25I + 10 + V_3 = 0$

$-50 + 25 \times 0.4 + 10 + V_3 = 0$

$-50 + 10 + 10 + V_3 = 0$

$\boxed{V_3 = 30V}$

(b) $I = -2A$

Apply KVL

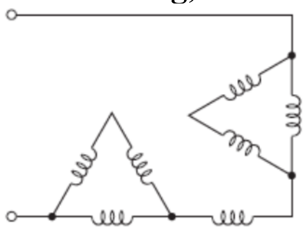
$20 + 10I + V + 5I = 0$

$20 + 15I + V = 0$

$20 + 15 \times -2 + V = 0$

$\boxed{V = 10V}$

6. Determine the equivalent inductance of the network shown in Fig, if each inductor has a value of L.



Sol

$\underbrace{L+L \| L}_{\text{(series)}} + L + \underbrace{L+L \| L}_{\text{(series)}}$

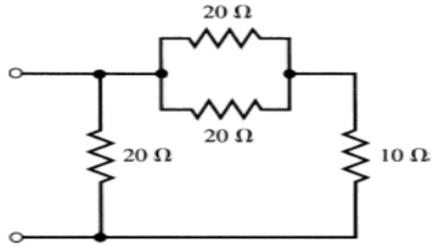
$2L \| L + L + 2L \| L$

$\frac{2L \times L}{2L+L} + L + \frac{2L \times L}{2L+L}$

$\frac{2}{3}L + L + \frac{2}{3}L$

Equivalent inductance $L_{eq} = \frac{7}{3}L$ (H)

5. Find the equivalent resistance for the circuit shown in Fig.

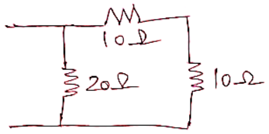


Sol

$20\Omega \| 20\Omega = \frac{20 \times 20}{20+20}$

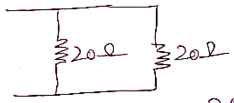
$= \frac{400}{40}$

$= 10\Omega$



10Ω series with right side 10Ω resistor

$10\Omega + 10\Omega = 20\Omega$

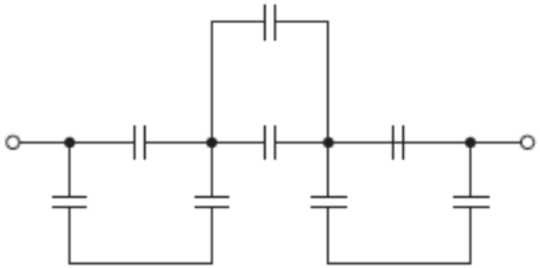


$20\Omega \| 20\Omega = \frac{20 \times 20}{20+20}$

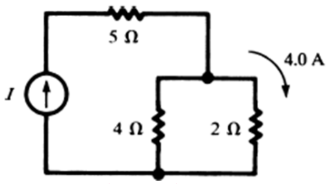
$= \frac{400}{40}$

Equivalent resistance $R_{eq} = 10\Omega$

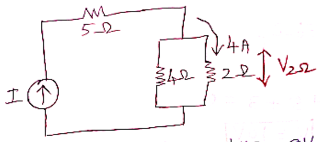
7. Determine the equivalent capacitance of the network shown in Fig. if each capacitor has a value of 1F.



9. Obtain the source current I and the total power delivered to the circuit in Fig.



Sol



$V_{2\Omega} = 4\times 2 = 8V$

Since the 2Ω and 4Ω resistors are in parallel, the voltage across the 4Ω resistor must be the same.

$V_{4\Omega} = V_{2\Omega} = 8V$

$I_{4\Omega} = \frac{V_{4\Omega}}{R_{4\Omega}} = \frac{8}{4} = 2A$

$I = 2+4 = 6A$

$R_{eq} = 5 + 4\|2$

$= 5 + \frac{4\times 2}{4+2}$

$= \frac{19}{3}\ \Omega$

Total power delivered

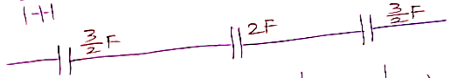
$P_{delivered} = I^2 R_{eq}$

$= 6^2 \times \frac{19}{3}$

$= 228W$

Sol

Capacitor	Capacitor	Capacitor
(Series) $1\|1 + 1$ (parallel)	(parallel) $1+1$	(series) $1\|1 + 1$ (parallel)
$\frac{1\times1}{1+1} + 1$	2	$\frac{1\times1}{1+1} + 1$



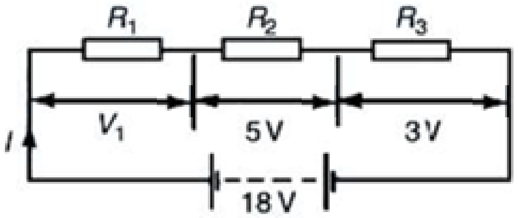
Equivalent Capacitance $\frac{1}{C_{eq}} = \frac{1}{C_{eq1}} + \frac{1}{C_{eq2}} + \frac{1}{C_{eq3}}$

$= \frac{2}{3} + \frac{1}{2} + \frac{2}{3}$

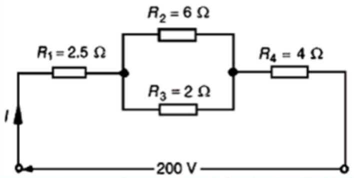
$= \frac{11}{6}$

$\boxed{C_{eq} = \frac{6}{11} F}$

8. For the circuit shown in Fig, determine the value of V_1. If the total circuit resistance is 36 Ω, determine the supply current and the value of resistors R_1, R_2, and R_3.

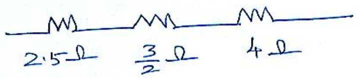


10. For the series-parallel arrangement shown in Fig, find a) supply current, b) the current following through each resistor, and c) the voltage across each resistor.



Sol

$$6\Omega \parallel 2\Omega = \frac{6\times 2}{6+2} = \frac{12}{8} = \frac{3}{2}\ \Omega$$



$$R_{total} = 2.5 + \frac{3}{2} + 4 = 8\ \Omega$$

$$I = \frac{V}{R_{tot}} = \frac{200}{8} = 25A$$

$I_{R_1} = I = 25A$

$I_{R_2} = I \times \frac{2}{R_{total}}$ ← opposite Resistance

$= 25 \times \frac{2}{8} = 6.25A$

$I_{R_3} = I \times \frac{6}{8}$ ← opposite Resistance

$= 25 \times \frac{6}{8} = 18.75A$

$I_{R_4} = I = 25A$

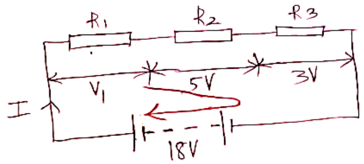
$V_{R_1} = I R_1 = 25 \times 2.5 = 62.5V$

$V_{R_2} = I_{R_2} R_2 = 6.25 \times 6 = 37.5V$

$V_{R_3} = V_{R_2} = 37.5V$ (Due to R_2 is parallel with R_3)

$V_{R_4} = I R_4 = 25 \times 4 = 100V$

Sol



$R_{tot} = 36\ \Omega$

Apply KVL

$-18 + V_1 + 5 + 3 = 0$

$\boxed{V_1 = 10V}$

$I = \frac{18}{36} = 0.5A$

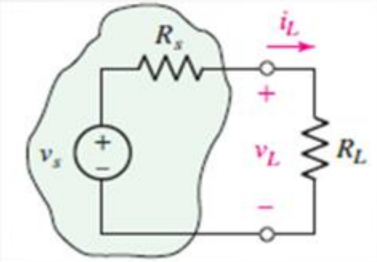
$R_1 = \frac{V_1}{I} = \frac{10}{0.5} = 20\ \Omega$

$R_2 = \frac{5}{0.5} = 10\ \Omega$

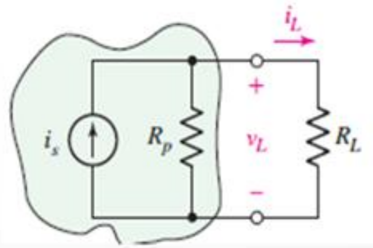
$R_3 = \frac{3}{0.5} = 6\ \Omega$

Source Transformation(Conversion)

A given practical voltage source connected to a load R_L.



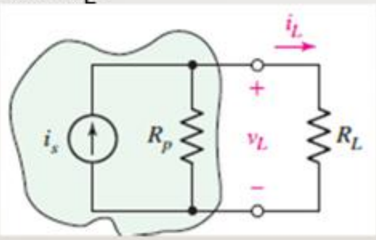
Equivalent practical current source connected to the same load R_L.



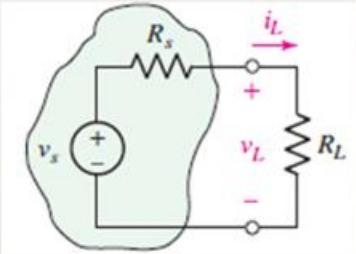
A voltage source with a series resistor can be converted into an equivalent current source with a parallel resistor.

Voltage Source to Current Source Conversion: $R_P = R_S$ and $i_s = \frac{v_s}{R_s} = \frac{v_s}{R_p}$

Equivalent practical current source connected to the same load R_L.



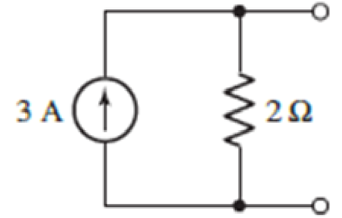
A given practical voltage source connected to a load R_L.



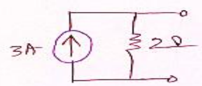
A current source with a parallel resistor can be converted into an equivalent voltage source with a series resistor.

Current Source to Voltage Source Conversion: $R_S = R_P$ and $v_s = R_p i_s = R_s i_s$

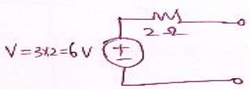
1. For the practical current source shown in Fig, find the equivalent practical voltage source. Also, for R_L = 4 Ω, determine the power delivered by each source and power dissipated by each internal resistor and the load resistor.



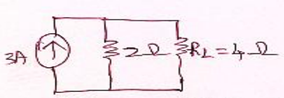
Sol



Convert to practical Voltage Source



Let $R_L = 4\Omega$ attach to Current Source



$2\Omega \parallel 4\Omega = \frac{2\times4}{2+4} = \frac{4}{3}\Omega$

$V = IR = 3\times\frac{4}{3} = 4V$

Current through internal Resistor (Apply current division rule)

$I_{2\Omega} = I \times \frac{4}{R_{total}}$ ← opposite Resistance

$= \frac{3\times4}{6} = 2A$

Current through load resistor (Apply current division rule)

$I_{4\Omega} = I\times\frac{2}{R_{total}}$ ← opposite Resistance

$= \frac{3\times2}{6} = 1A$

Power delivered by current source

$VI = 4\times3 = 12W$

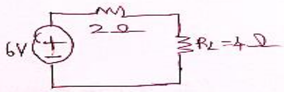
Power dissipated 2Ω internal resistor

$I_{2\Omega}^2 \times R_{2\Omega} = 4\times2 = 8W$

Power dissipated 4Ω load resistor

$I_{4\Omega}^2\times R_{4\Omega} = 1\times4 = 4W$

Let $R_L = 4\Omega$ attach to Voltage Source



$I = \frac{V}{R} = \frac{6}{\underbrace{2+4}_{Series}} = 1A$

Power delivered by Voltage Source

$VI = 6\times1 = 6W$

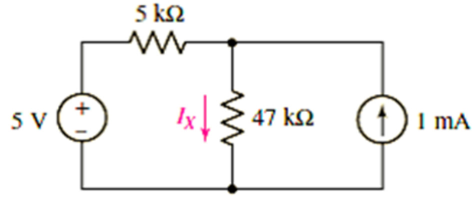
Power dissipated by 2Ω internal resistor

$I_{2\Omega}^2\times R_{2\Omega} = 1\times2 = 2W$

Power dissipated by 4Ω load resistor

$I_{4\Omega}^2\times R_{4\Omega} = 1\times4 = 4W$

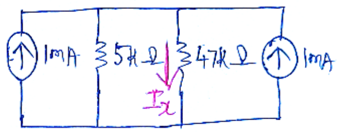
2. For the circuit of Fig, compute the current I_X through the 47kΩ resistor after performing a source transformation on the voltage source.

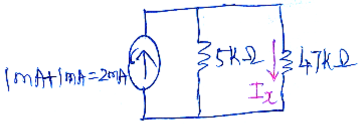


Sol

Apply Source Transformation (Voltage to Current),

$I = \frac{5}{5\times10^3} = 1mA$





Apply Current division rule

$I_x = 2\times10^{-3}\times\frac{5\times10^3}{R_{total}}$ ← opposite Resistance

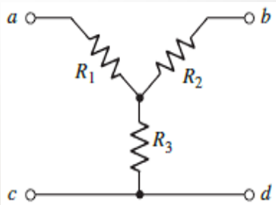
$= \frac{10}{5\times10^3+47\times10^3}$

$\boxed{I_x = 0.192\,mA}$

Star (Y) – Delta (Δ or π) Transformation

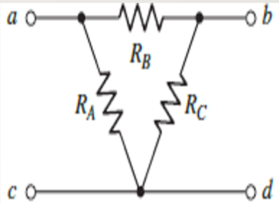
Star (Y) Configuration:

- A star configuration consists of three resistors connected to a common central point, resembling a "Y" shape. The three resistors (R_1, R_2, R_3) connect from this central node to three external nodes.



Delta (Δ or π) Configuration:

- A delta configuration consists of three resistors connected in a triangle or mesh arrangement. The three resistors (R_A, R_B, R_C) connect between each pair of three external nodes, forming a closed loop.



Star (Y) – Delta (Δ or π) Transformation

- To convert from a Y-network to a Δ-network, the new resistor values are calculated using

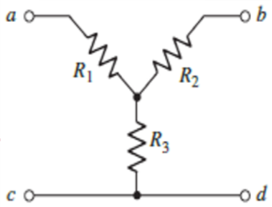
$$R_A = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

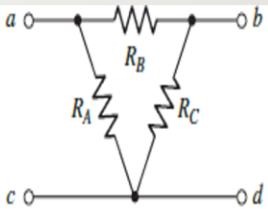
$$R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

$$R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

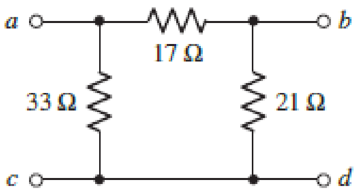
NOTE:

If $R_1 = R_2 = R_3 = R$
then
$R_A = R_B = R_C = 3R$





2. Convert the Δ- (or "Π-") connected network in Fig to Y-connected network.



Delta (Δ or π) – Star (Y) Transformation

- To convert from a Δ-network to a Y-network, the new resistor values are calculated using

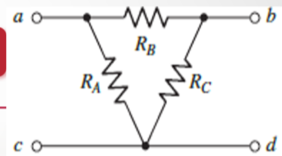
$$R_1 = \frac{R_A R_B}{R_A + R_B + R_C}$$

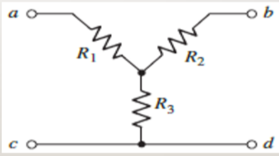
$$R_2 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_C R_A}{R_A + R_B + R_C}$$

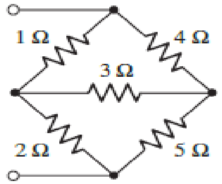
NOTE:

If $R_A = R_B = R_C = R$
then
$R_1 = R_2 = R_3 = R/3$

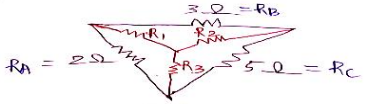




1. Determine the equivalent resistance of the circuit shown in Fig.



Sol



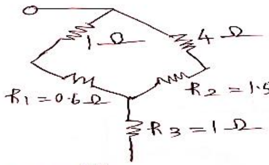
$R_1 = \frac{R_A \cdot R_B}{R_A + R_B + R_C}$

$= \frac{6}{10}$

$= 0.6\ \Omega$

$R_2 = \frac{R_B \cdot R_C}{R_A + R_B + R_C} = \frac{15}{10} = 1.5\ \Omega$

$R_3 = \frac{R_A \cdot R_C}{R_A + R_B + R_C} = \frac{10}{10} = 1\ \Omega$



Series Connection

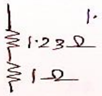
$1\ \Omega + 0.6\ \Omega = 1.6\ \Omega$

$4\ \Omega + 1.5\ \Omega = 5.5\ \Omega$

Now $1.6\ \Omega \parallel 5.5\ \Omega = \frac{1.6 \times 5.5}{1.6 + 5.5} = \frac{8.8}{7.1} = 1.23\ \Omega$

parallel

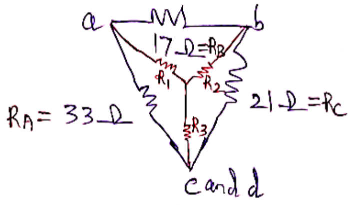
$1.23\ \Omega$ series with $1\ \Omega$ resistor



$1.23\ \Omega + 1\ \Omega = 2.23\ \Omega$ (or) $\frac{159}{71}$ (or) $\frac{15.9}{7.1}$

Sol

Redrawn the circuit



$$R_1 = \frac{R_A R_B}{R_A + R_B + R_C}$$

$$= \frac{561}{71} = 7.90\ \Omega$$

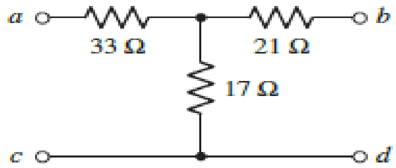
$$R_2 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$= \frac{357}{71} = 5.03\ \Omega$$

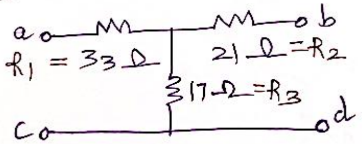
$$R_3 = \frac{R_A R_C}{R_A + R_B + R_C}$$

$$= \frac{693}{71} = 9.76\ \Omega$$

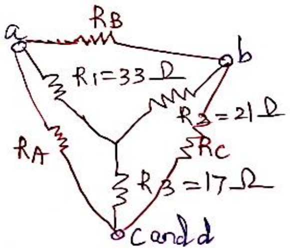
3. Convert the Y- connected network in Fig to Δ-connected networks.



Sol



≡

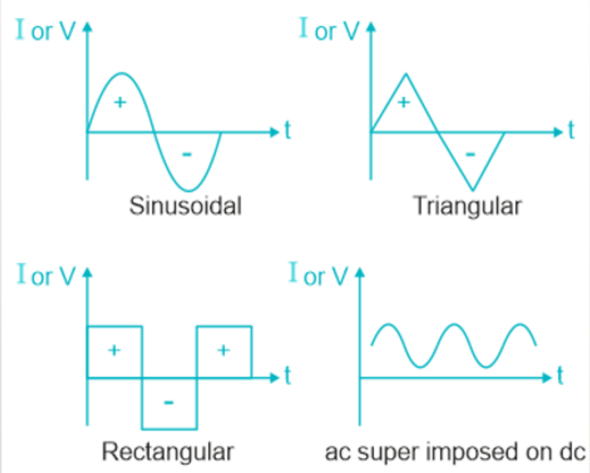
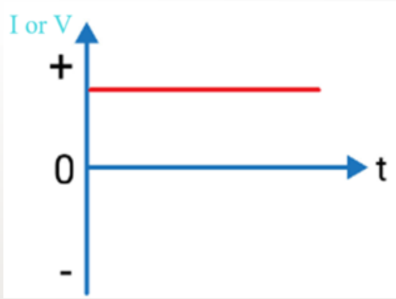


$$R_A = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$= \frac{693 + 357 + 561}{21} = \frac{1611}{21} = 76.71\ \Omega$$

$$R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{1611}{17} = 94.77\ \Omega$$

$$R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{1611}{33} = 48.82\ \Omega$$

AC Signal	DC Signal
The waveform may be either a current (I) or voltage (V) changes continuously in magnitude between zero and a maximum value with alternating directions (positive and negative portion) at regular time intervals. 	The quantity I or V that may change in magnitude but not the direction is known as **DC signal**.  :

PARAMETERS(PROPERTIES) OF AC SIGNALS

Peak/Crest value (Amplitude): It is the maximum value reached by the signal.

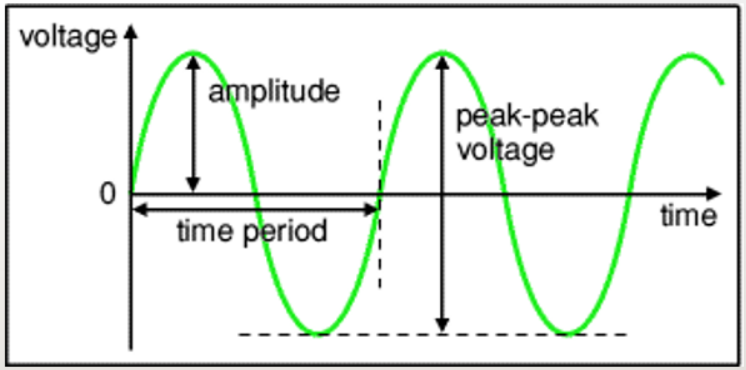
Peak-to- Peak value: The value from positive to negative peak (It is twice the peak value).

Time period (T): The time taken for the signal to complete one cycle. It is measured in seconds (s).

Frequency (f): It is the number of cycles per second. It is measured in **hertz (Hz).**

$$Frequency\ (f) = \frac{1}{Time\ Period\ (T)}$$

$$Time\ Period\ (T) = \frac{1}{Frequency\ (f)}$$



AVERAGE VALUE

It is defined as the average of all instantaneous value of alternating quantities (V or I) **over a half cycle.**

Finding average value of sine wave

$$V_{avg} = \frac{1}{\pi}\int_0^{\pi} v(t)d(\omega t) = \frac{2v_m}{\pi} = 0.637v_m$$

RMS(EFFECTIVE) VALUE

The rms value of a sine wave is the equivalent DC voltage or current that produces the same heating effect (i.e., same power dissipation in a resistor) as the alternating voltage or current does over the same time.

Finding RMS value of sine wave

$$V_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} v(t)^2 d(\omega t)} = \frac{v_m}{\sqrt{2}} = 0.707v_m$$

:

Form Factor and Peak Factor

Alternating quantities such as alternating current or voltage, the form factor is defined as the ratio of the RMS (Root Mean Square) value to the average value of the wave. Therefore,

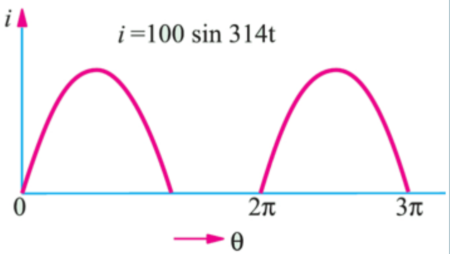
$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}} = \frac{V_{RMS}}{V_{avg}} = \frac{0.707v_m}{0.637v_m} = 1.11$$

Alternating quantities such as alternating current or voltage, the form factor is defined as the ratio of the maximum or peak value to the RMS value of the wave.

$$\text{Peak Factor} = \frac{\text{Peak Value}}{\text{RMS Value}} = \frac{V_m}{V_{RMS}} = \frac{v_m}{0.707v_m} = 1.414$$

SIMPLE STEPS TO SOLVE THE PROBLEMS

Find average and RMS values of the following given waveform. Calculate the form factor and peak factor.



0 $\frac{1}{2\pi}$ 2π

$$\boxed{314t=\theta}$$

$$I_{avg} = \frac{1}{2\pi}\left[\int_0^{\pi} 100\sin\theta d\theta + \int_{\pi}^{2\pi} 0 d\theta\right]$$

$$\vdots$$

$$I_{avg} = \frac{I_m}{\pi} = \frac{100}{\pi}$$

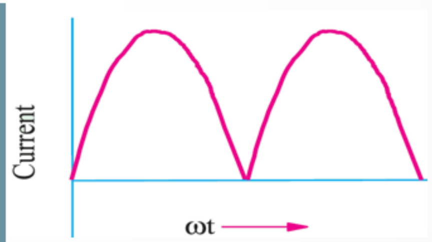
$$I_{RMS} = \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} 100^2\sin^2\theta d\theta + \int_{\pi}^{2\pi} 0^2 d\theta\right]}$$

$$\vdots$$

$$I_{RMS} = \frac{I_m}{2} = \frac{100}{2}$$

Form Factor=1.57

Peak Factor=2



0 $\frac{1}{\pi}$ π

$$I_{avg} = \frac{1}{\pi}\left[\int_0^{\pi} I_m \sin\omega t d(\omega t)\right]$$

$$\vdots$$

$$I_{avg} = \frac{2I_m}{\pi}$$

$$I_{RMS} = \sqrt{\frac{1}{\pi}\left[\int_0^{\pi} I_m^2 \sin^2\omega t d(\omega t)\right]}$$

$$\vdots$$

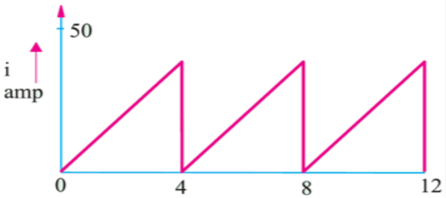
$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

Form Factor=1.11

Peak Factor=1.414

SIMPLE STEPS TO SOLVE THE PROBLEMS

Find average and RMS values of the following given waveform. Calculate the form factor and peak factor.



0 $\frac{1}{4}$ 4

Triangular waveform

Numerical values
Letters

$$\frac{50}{i} = \frac{4}{t}$$

$$50t=4i$$

$$i=12.5t$$

$$I_{avg} = \frac{1}{4}\left[\int_0^{4} 12.5t dt\right]$$

$$\vdots$$

$$I_{avg} = \frac{I_m}{2} = \frac{50}{2}$$

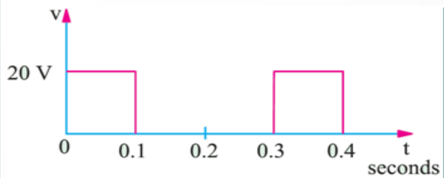
$$I_{RMS} = \sqrt{\frac{1}{4}\left[\int_0^{4} 12.5^2 t^2 dt\right]}$$

$$\vdots$$

$$I_{RMS} = \frac{I_m}{\sqrt{3}} = \frac{50}{\sqrt{3}}$$

Form Factor=1.15

Peak Factor=1.732



0 $\frac{1}{0.3}$ 0.3

$$V_{avg} = \frac{1}{0.3}\left[\int_0^{0.1} 20 dt + \int_{0.1}^{0.3} 0 dt\right]$$

$$\vdots$$

$$V_{avg} = \frac{V_m}{3} = \frac{20}{3}$$

$$V_{RMS} = \sqrt{\frac{1}{0.3}\left[\int_0^{0.1} 20^2 dt + \int_{0.1}^{0.3} 0^2 dt\right]}$$

$$\vdots$$

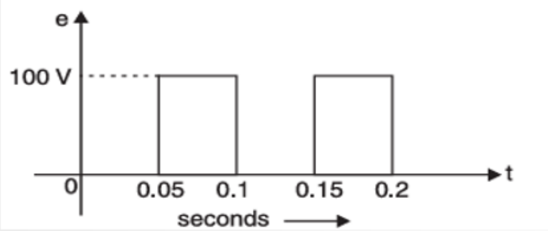
$$V_{RMS} = \frac{V_m}{\sqrt{3}} = \frac{20}{\sqrt{3}}$$

Form Factor=1.732

Peak Factor=1.732

SIMPLE STEPS TO SOLVE THE PROBLEMS

Find average and RMS values of the following given waveform. Calculate the form factor and peak factor.



$0 \quad \frac{1}{0.1} \quad 0.1$

$$e_{avg} = \frac{1}{0.1}\left[\int_0^{0.05} 0dt + \int_{0.05}^{0.1} 100dt\right]$$

$$\vdots$$

$$e_{avg} = \frac{e_m}{2} = \frac{100}{2}$$

$$e_{RMS} = \sqrt{\frac{1}{0.1}\left[\int_0^{0.05} 0^2dt + \int_{0.05}^{0.1} 100^2dt\right]}$$

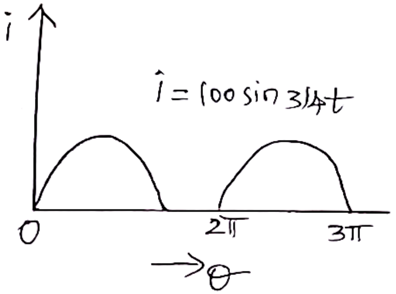
$$\vdots$$

$$e_{RMS} = \frac{e_m}{\sqrt{2}} = \frac{100}{\sqrt{2}}$$

Form Factor=1.414

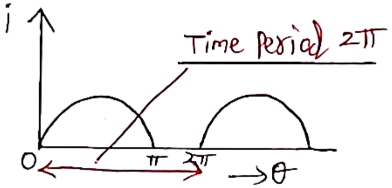
Peak Factor=1.414

① Calculate the form factor and peak factor of the sinewave shown in Figure



Sol

Given $i = 100\sin 314t$



$\therefore I_m = 100A$

From the given Figure $i = \begin{cases} 100\sin\theta & \text{for } 0<\theta<\pi \\ 0 & \text{for } \pi<\theta<2\pi \end{cases}$ Hence $\theta = 314t$

Average value

Time period $= 2\pi$

$$I_{avg} = \frac{1}{2\pi}\left[\int_0^{\pi} i\,d\theta + \int_{\pi}^{2\pi} 0\,d\theta\right]$$

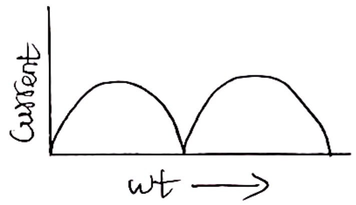
Time period 2π

$$= \frac{1}{2\pi}\left[\int_0^{\pi} 100\sin\theta\,d\theta\right]$$

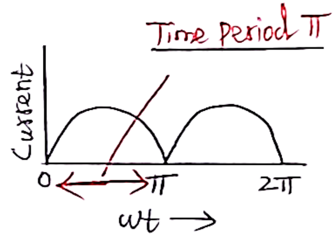
$$= \frac{100}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{-100}{2\pi}\left[\cos\pi - \cos 0\right]$$

② Find the average and RMS value of full wave rectifier (FWR) shown in Figure



Sol



$\boxed{i = I_m \sin\omega t}$

Average Value

Time period $= \pi$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} i\,d(\omega t)$$

Time period π

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t\,d(\omega t)$$

$$= \frac{I_m}{\pi}\int_0^{\pi}(-\cos\omega t)$$

$$= \frac{-I_m}{\pi}\left[\cos\omega t\right]_0^{\pi}$$

$$= \frac{-I_m}{\pi}\left[\cos\pi - \cos 0\right]$$

$$= \frac{-I_m}{\pi}\left[-1-1\right]$$

$$I_{avg} = \frac{2I_m}{\pi}$$

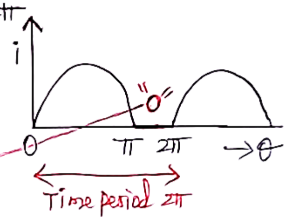
$$= \frac{-100}{2\pi}\left[-1-1\right]$$

$$= \frac{200}{2\pi}$$

$$\boxed{I_{avg} = 31.83\,A}$$

RMS (Effective) Value

It is from 0 to π and π to 2π
(Total is 2π)



$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\,dt}$$

Time period 2π

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} 100^2 \sin^2\theta\,d\theta + \int_{\pi}^{2\pi} 0\,d\theta\right]}$$

$$= \sqrt{\frac{100^2}{2\pi}\int_0^{\pi} \frac{1-\cos 2\theta}{2}\,d\theta + 0}$$

$$\boxed{\therefore \sin^2\theta = \frac{1-\cos 2\theta}{2}}$$

$$= \sqrt{\frac{100^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}}$$

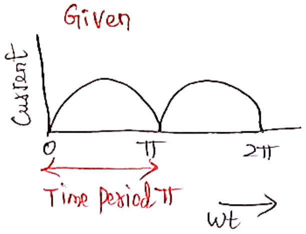
$$= \sqrt{\frac{100^2}{4\pi}\left[\pi - \frac{\sin 2\pi}{2} - 0 + \sin 0\right]}$$

$$= \sqrt{\frac{100^2}{4\pi}(\pi - 0)}$$

$$= \sqrt{\frac{100^2}{4}}$$

RMS (Effective) Value

Time Period π



$$I_{RMS} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2\,dt}$$

Time Period π

$$= \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\,d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \frac{1-\cos 2\omega t}{2}\,d(\omega t)}$$

$$\boxed{\therefore \sin^2 \omega t = \frac{1-\cos 2\omega t}{2}}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\pi - \frac{\sin 2\pi}{2} - 0 + \frac{\sin 0}{2}\right]}$$

$$= \sqrt{\frac{I_m^2}{2\cancel{\pi}}\left[\cancel{\pi} - 0 - 0 - 0\right]}$$

$$= \sqrt{\frac{I_m^2}{2}}$$

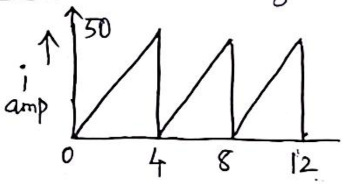
$$\boxed{I_{RMS} = \frac{I_m}{\sqrt{2}}}$$

$\boxed{I_{RMS} = 50A}$

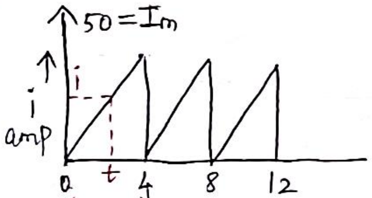
$$\text{Form factor} = \frac{\text{RMS value}}{\text{Average value}} = \frac{I_{RMS}}{I_{avg}} = \frac{50}{31.83} = 1.57$$

$$\text{peak(crest/amplitude)} = \frac{\text{Peak value}}{\text{RMS value}} = \frac{I_m}{I_{RMS}} = \frac{100}{50} = 2$$

3) Find the average and RMS value of triangular waveform shown in Figure



Sol



Time period 4 (T)

Triangular waveform

$$\frac{50}{i} = \frac{4}{t}$$

numbers in numerator

letters in denominator

$$50t = 4i$$

$$i = \frac{50t}{4}$$

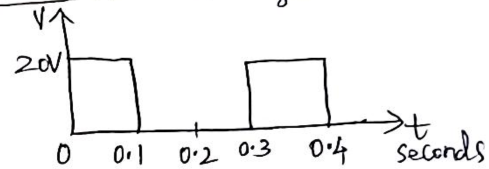
$$i = 12.5t \text{ for } 0 < t < 4$$

Average value

$$I_{avg} = \frac{1}{T}\int_0^T i\,dt$$

Time period $T = 4$

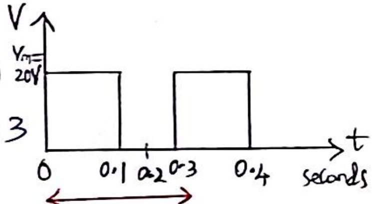
4) Compute the average and effective values of the square voltage wave shown in Figure



Sol

Square waveform

$$V = \begin{cases} 20V & \text{for } 0 < t < 0.1 \\ 0V & \text{for } 0.1 < t < 0.3 \end{cases}$$



Time period 0.3 (T)

Average value

$$V_{avg} = \frac{1}{T}\int_0^T V\,dt$$

Time period $T = 0.3$

$$= \frac{1}{0.3}\int_0^{0.1} 20\,dt + \frac{1}{0.3}\int_{0.1}^{0.3} 0\,dt$$

(Refer Square Voltage Waveform)

Don't consider here $V = V_m \sin\omega t$ because it is square waveform

$$= \frac{20}{0.3}\left[t\right]_0^{0.1} + 0$$

$$= 66.66\left[0.1 - 0\right]$$

$$\boxed{V_{avg} = 6.666V}$$

$$= \frac{1}{4}\int_0^4 12.5t\, dt$$

Don't consider here $i = I_m \sin\omega t$ because it is triangular waveform

$$= \frac{12.5}{4}\int_0^4 \frac{t^2}{2}$$

$$= \frac{12.5}{8}\left[t^2\right]_0^4$$

$$= \frac{12.5}{8}\left[16-0\right]$$

$$\boxed{I_{avg} = 25A}$$

RMS value

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2 dt}$$

$$= \sqrt{\frac{1}{4}\int_0^4 12.5^2 t^2 dt}$$

$$= \sqrt{\frac{12.5^2}{4}\int_0^4 \frac{t^3}{3}}$$

$$= \sqrt{\frac{12.5^2}{12}\left[t^3\right]_0^4}$$

$$= \sqrt{\frac{12.5^2}{12}\left[4^3-0\right]}$$

$$\boxed{I_{RMS} = \frac{50}{\sqrt{3}} = 28.87A}$$

$$\text{Form factor} = \frac{\text{Rms Value}}{\text{Average value}} = \frac{I_{RMS}}{I_{avg}} = \frac{28.87}{25} = 1.154$$

$$\text{Peak (crest/amplitude)} = \frac{\text{Peak Value}}{\text{RMS value}} = \frac{I_m}{I_{RMS}} = \frac{50}{28.87} = 1.732$$

RMS value

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2 dt}$$

$$= \sqrt{\frac{1}{0.3}\int_0^{0.1} 20^2 dt + \frac{1}{0.3}\int_{0.1}^{0.3} 0^2 dt}$$ (Refer square voltage waveform)

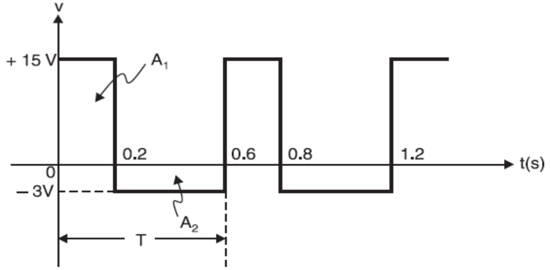
$$= \sqrt{\frac{400}{0.3}\left[t\right]_0^{0.1} + 0}$$

$$= \sqrt{1333.33\left[0.1-0\right]}$$

$$= \sqrt{133.33}$$

$$\boxed{V_{RMS} = 11.54V}$$

5. Analyze the signal given in Fig for its average and RMS values.



Sol

Rectangular waveform (Asymmetric)

$$V = \begin{cases} 15\,V & \text{for } 0 < t < 0.2 \\ -3\,V & \text{for } 0.2 < t < 0.6 \end{cases}$$

Average value

$$V_{avg} = \frac{1}{T}\int_0^T v\,dt$$

Time period $T = 0.6$

$$= \frac{1}{0.6}\int_0^{0.2} 15\,dt + \frac{1}{0.6}\int_{0.2}^{0.6}(-3)\,dt$$

$$= \frac{15}{0.6}\left[t\right]_0^{0.2} - \frac{3}{0.6}\left[t\right]_{0.2}^{0.6}$$

$$= 25[0.2-0] - 5[0.6-0.2]$$

$$= 5 - 5(0.4)$$

$$= 5 - 2$$

$$\boxed{V_{avg} = 3V}$$

RMS value

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2\,dt}$$

$$= \sqrt{\frac{1}{0.6}\int_0^{0.2} 15^2\,dt + \frac{1}{0.6}\int_{0.2}^{0.6}(-3)^2\,dt}$$

$$= \sqrt{\frac{225}{0.6}\left[t\right]_0^{0.2} + \frac{9}{0.6}\left[t\right]_{0.2}^{0.6}}$$

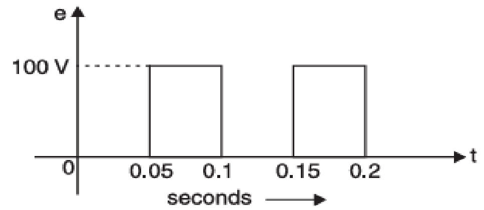
$$= \sqrt{375[0.2-0] + 15[0.6-0.2]}$$

$$= \sqrt{75+6}$$

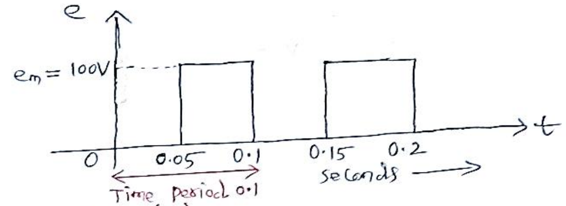
$$= \sqrt{81}$$

$$\boxed{V_{RMS} = 9V}$$

6. Find the Form factor & Peak factor of the signal shown in Fig.



Sol



Rectangular (Pulse) waveform

$$e = \begin{cases} 0 & \text{for } 0 < t < 0.05 \\ 100V & \text{for } 0.05 < t < 0.1 \end{cases}$$

Average value

$$e_{avg} = \frac{1}{T}\int_0^T e\,dt$$

Time period $T = 0.1$

$$= \frac{1}{0.1}\int_0^{0.05} 0\,dt + \frac{1}{0.1}\int_{0.05}^{0.1} 100\,dt$$

$$= \frac{100}{0.1}\left[t\right]_{0.05}^{0.1}$$

$$= \frac{100}{0.1}[0.05]$$

$$\boxed{e_{avg} = 50V}$$

RMS value

$$e_{RMS} = \sqrt{\frac{1}{T}\int_0^T e^2\,dt}$$

$$= \sqrt{\frac{1}{0.1}\int_0^{0.05} 0^2\,dt + \frac{1}{0.1}\int_{0.05}^{0.1} 100^2\,dt}$$

$$= \sqrt{100000\left[t\right]_{0.05}^{0.1}}$$

$$= \sqrt{100000\,(0.05)}$$

$$\boxed{e_{RMS} = 70.7\,V}$$

$$\text{Form factor} = \frac{\text{RMS Value}}{\text{Average Value}} = \frac{e_{RMS}}{e_{avg}} = \frac{70.7}{50} = 1.414$$

$$\text{Peak (crest/amplitude) factor} = \frac{\text{Peak value}}{\text{RMS Value}} = \frac{e_m}{e_{RMS}} = \frac{100}{70.7} = 1.414$$

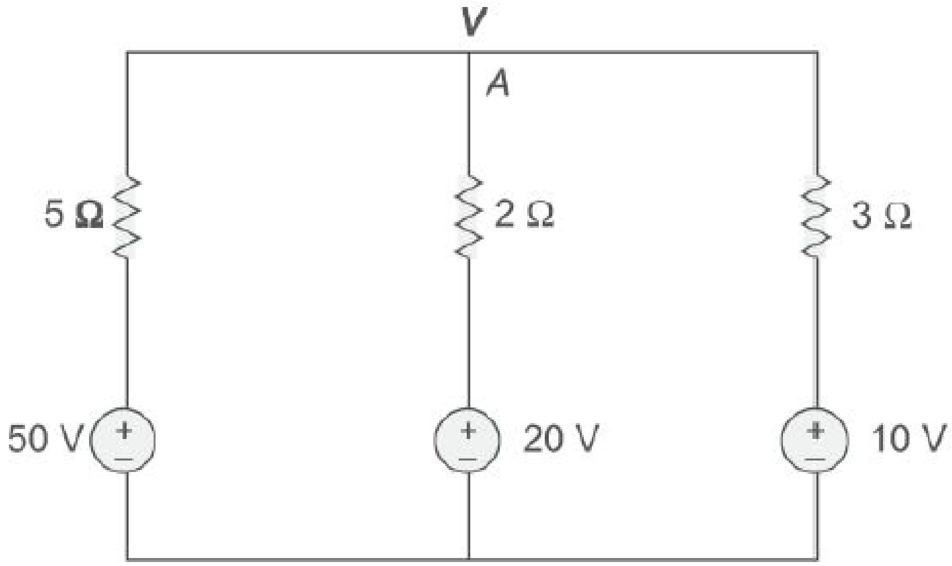
CO2 Terminal Important Questions (2 Marks/4 Marks/5 Marks/6 Marks)

1. What are the limitations of mesh analysis?
2. What is a super mesh?
3. Describe the steps in mesh analysis.
4. What is a super node?
5. Describe the steps in nodal analysis.
6. Describe the step-by-step process of applying the superposition theorem to analyze a circuit with multiple independent sources.
7. Define the superposition theorem and explain the conditions under which it is applicable. Provide an example to illustrate its application in circuit analysis.
8. State Thevenin's theorem.
9. Explain the steps to analyze a circuit using Thevenin's theorem.
10. State Norton's theorem.
11. Explain the steps to analyze a circuit using Norton's theorem.
12. Give the relation between Thevenin's and Norton's equivalent circuits
13. Describe the condition for maximum power transfer to the load in an electrical circuit.
14. State Maximum Power Transfer Theorem.

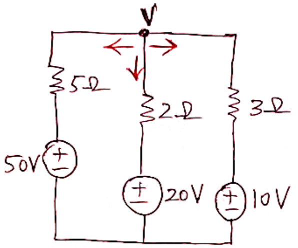
Simple Steps/Procedure to Analyze Electric Circuit Using Nodal Analysis

1. Identify the total number of nodes, assign voltages and Choose the Reference Node
    - Identify the total number of nodes (n) in the circuit. Assign voltages (V_1, V_2, etc.) to all other non reference nodes.
    - Choose one node as the reference (ground) node.
2. Apply Kirchhoff's Current Law (KCL)
    - Write KCL equations at each non-reference node. Use Ohm's Law ($I = V/R$) to express branch currents considering entering/leaving direction.
3. Consider Voltage Sources (Supernode Technique)
    - If a voltage source is between two non-reference nodes, form a Supernode by enclosing the voltage source and its connected nodes.
    - Apply KVL at the branch to form the voltage source equation ($V_S = V_1 - V_2$) as an additional constraint.
4. Solve the simultaneous equations to find unknown Node Voltages
5. Determine Branch Currents
    - Use the calculated node voltages to find branch currents using Ohm's Law ($I = V/R$).

1. Determine the value of V in the circuit shown in Fig using nodal analysis.



Sol



Apply KCL at node V

$$\frac{V-(50)-0}{5}+\frac{V-(20)-0}{2}+\frac{V-(10)-0}{3}=0$$

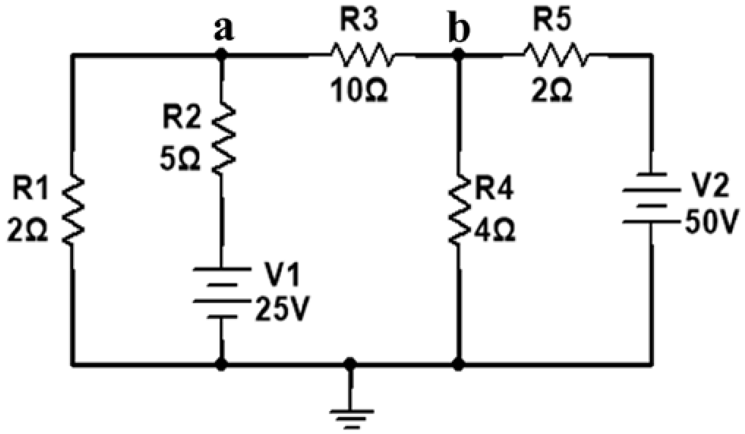
$$V\left(\frac{1}{5}+\frac{1}{2}+\frac{1}{3}\right)-\frac{50}{5}-\frac{20}{2}-\frac{10}{3}=0$$

$$1.033\,V-10-10-3.333=0$$

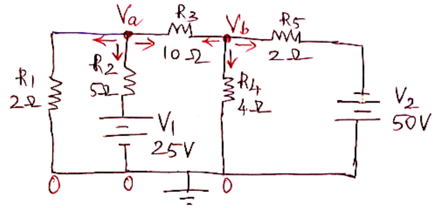
$$1.033\,V=23.333$$

$$\boxed{V=22.58\text{ V}}$$

2. Using the nodal analysis, find the node voltages in the circuit shown in Fig.



Sol



Apply KCL at node Va

$$\frac{Va-0}{2}+\frac{Va-25-0}{5}+\frac{Va-Vb}{10}=0$$

$$Va\left(\frac{1}{2}+\frac{1}{5}+\frac{1}{10}\right)-Vb\left(\frac{1}{10}\right)-\frac{25}{5}=0$$

$$0.8\,Va-0.1\,Vb=5 \quad \text{— (1)}$$

Apply KCL at node Vb

$$\frac{Vb-(-50)}{2}+\frac{Vb-0}{4}+\frac{Vb-Va}{10}=0$$

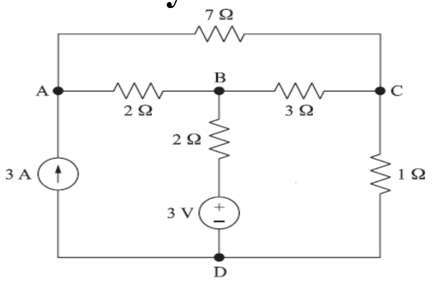
$$-Va\left(\frac{1}{10}\right)+Vb\left(\frac{1}{2}+\frac{1}{4}+\frac{1}{10}\right)+\frac{50}{2}=0$$

$$-0.1\,Va+0.85\,Vb=-25 \quad \text{— (2)}$$

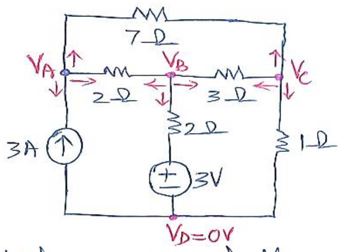
From Eqs (1) and (2) solve for Va and Vb

$$\boxed{\begin{aligned}Va&=2.61\text{ V}\\ Vb&=-29.10\text{ V}\end{aligned}}$$

3. Determine the node voltages at nodes A, B, and C in the circuit shown in Fig using nodal analysis.



Sol



Apply KCL at node V_A

$$\frac{V_A - V_C}{7} + \frac{V_A - V_B}{2} = 3$$

$$V_A\left(\frac{1}{7} + \frac{1}{2}\right) - \frac{V_B}{2} - \frac{V_C}{7} = 3$$

$$0.642V_A - 0.5V_B - 0.142V_C = 3 \quad \text{—(1)}$$

Apply KCL at node V_B

$$\frac{V_B - V_A}{2} + \frac{V_B - (3) - 0}{2} + \frac{V_B - V_C}{3} = 0$$

$$-\frac{V_A}{2} + V_B\left(\frac{1}{2} + \frac{1}{2} + \frac{1}{3}\right) - \frac{V_C}{3} - \frac{3}{2} = 0$$

$$-0.5V_A + 1.333V_B - 0.333V_C = 1.5 \quad \text{—(2)}$$

Apply KCL at node V_C

$$\frac{V_C - V_A}{7} + \frac{V_C - V_B}{3} + \frac{V_C - 0}{1} = 0$$

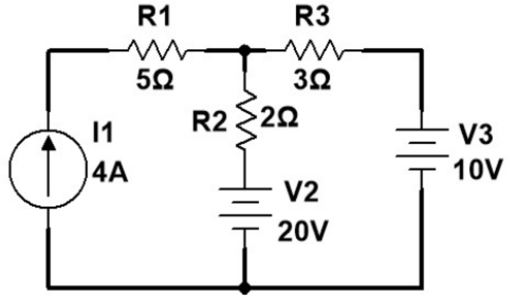
$$-\frac{V_A}{7} - \frac{V_B}{3} + V_C\left(\frac{1}{7} + \frac{1}{3} + 1\right) = 0$$

$$-0.142V_A - 0.333V_B + 1.476V_C = 0 \quad \text{—(3)}$$

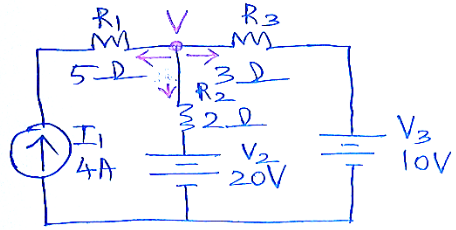
From Eqs (1), (2) and (3) solve for V_A, V_B, V_C

$$\boxed{\begin{aligned} V_A &= 9V \\ V_B &= 5V \\ V_C &= 2V \end{aligned}}$$

4. Use nodal analysis to determine the current flowing in each resistor in the circuit shown in the Fig.



Sol



Apply KCL at node V

$$\frac{V - 20}{2} + \frac{V - 10}{3} = 4$$

$$V\left(\frac{1}{2} + \frac{1}{3}\right) - \frac{20}{2} - \frac{10}{3} = 4$$

$$0.833V - 10 - 3.333 = 4$$

$$0.833V - 13.333 = 4$$

$$0.833V = 17.333$$

$$\boxed{V = 20.80V}$$

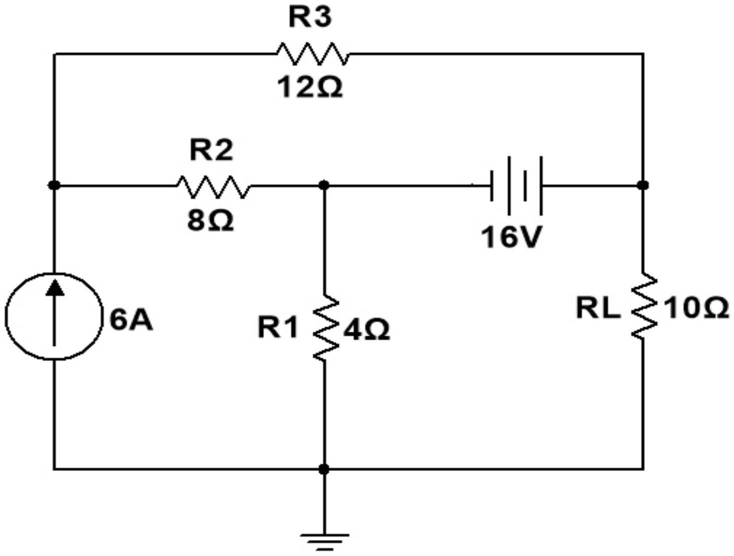
Currents in R_1, R_2 and R_3

$$I_{R1} = I_1 = 4A$$

$$I_{R2} = \frac{V - 20}{2} = \frac{20.80 - 20}{2} = 0.4A$$

$$I_{R3} = \frac{V - 10}{3} = \frac{20.80 - 10}{3} = 3.6A$$

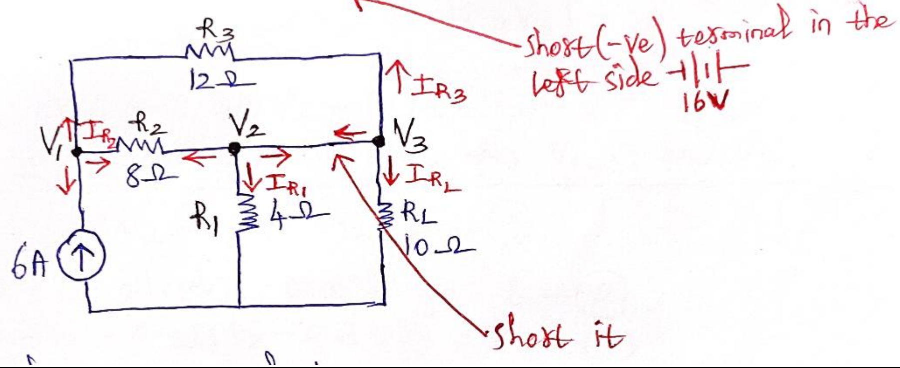
5. Using Nodal analysis, determine current in R_1, R_2, R_3 & R_L in the circuit shown below.



Sol

The voltage between nodes 2 and 3 is,

$$V_2 - V_3 = -16V \quad \text{— (1)}$$



Apply KCL at node 1

$$\frac{V_1-V_2}{8}+\frac{V_1-V_3}{12}=6 \quad \text{(Incoming current)}$$

$$V_1\left(\frac{1}{8}+\frac{1}{12}\right)-\frac{V_2}{8}-\frac{V_3}{12}=6$$

$$0.208V_1-0.125V_2-0.083V_3=6 \quad \text{--- (2)}$$

Apply KCL at node 2 and node 3 (Super node Analysis)

$$\frac{V_2-V_1}{8}+\frac{V_2-0}{4}+\frac{V_3-0}{10}+\frac{V_3-V_1}{12}=0$$

$$-V_1\left(\frac{1}{8}+\frac{1}{12}\right)+V_2\left(\frac{1}{8}+\frac{1}{4}\right)+V_3\left(\frac{1}{10}+\frac{1}{12}\right)=0$$

$$-0.208V_1+0.375V_2+0.183V_3=0 \quad \text{--- (3)}$$

From Eqs (1), (2) and (3) solve for V_1, V_2 and V_3

$$V_2-V_3=-16 \quad \text{--- (1)}$$

$$0.208V_1-0.125V_2-0.083V_3=6 \quad \text{--- (2)}$$

$$-0.208V_1+0.375V_2+0.183V_3=0 \quad \text{--- (3)}$$

Matrix format

$$\begin{bmatrix} 0 & 1 & -1 \\ 0.208 & -0.125 & -0.083 \\ -0.208 & 0.375 & 0.183 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}=\begin{bmatrix} -16 \\ 6 \\ 0 \end{bmatrix}$$

$$\boxed{\begin{aligned} V_1 &= 47.80\,V \\ V_2 &= 12.57\,V \\ V_3 &= 28.57\,V \end{aligned}}$$

Currents in R_1, R_2, R_3 and R_L

$$I_{R_2}=\frac{V_1-V_2}{8}, \quad I_{R_1}=\frac{V_2-0}{4}, \quad I_{R_L}=\frac{V_3-0}{10}, \quad I_{R_3}=\frac{V_1-V_3}{12}$$

$$I_{R_2}=4.40\,A, \quad I_{R_1}=3.14\,A, \quad I_{R_L}=2.85\,A, \quad I_{R_3}=1.60\,A$$

Simple Steps/Procedure to Analyze Electric Circuit Using Mesh Analysis

1. Identify Meshes and Assign Currents

- Identify all independent meshes in the circuit.
- Assign a clockwise mesh current to each mesh.

2. Apply Kirchhoff's Voltage Law (KVL)

- Write KVL equations for each mesh.
- Use Ohm's Law (V = IR) to express voltages in terms of mesh currents.

3. Consider Current Sources (Supermesh Technique)

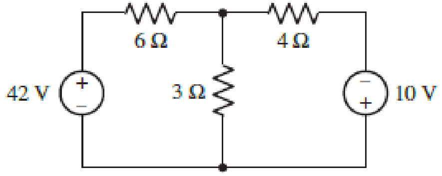
- If a current source is between two meshes, apply the Supermesh technique by forming a larger loop and using KVL.
- Apply KCL at the branch to form the current source equation ($I_s = I_1 - I_2$) as an additional constraint.

4. Use substitution, elimination, or matrix methods solve the simultaneous equations to find mesh currents.

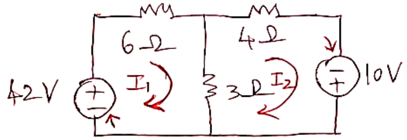
5. Determine Branch Currents

- Use mesh currents to calculate branch currents, considering shared branches.

1. Determine the current flowing in each resistor using mesh analysis.



Sol



Apply KVL and Ohm's Law

$$-42 + 6I_2 + 3(I_1 - I_2) = 0$$

$$-42 + 6I_2 + 3I_1 - 3I_2 = 0$$

$$9I_1 - 3I_2 = 42 \quad \text{— (1)}$$

Apply KVL and Ohm's Law

$$-10 + 3(I_2 - I_1) + 4I_2 = 0$$

$$-10 + 3I_2 - 3I_1 + 4I_2 = 0$$

$$-3I_1 + 7I_2 = 10 \quad \text{— (2)}$$

From Eqs (1) and (2) solve for I_1 and I_2

$$\boxed{\begin{aligned} I_1 &= 6A \\ I_2 &= 4A \end{aligned}}$$

Current in 6Ω

$$\boxed{I_{6\Omega} = I_1 = 6A}$$

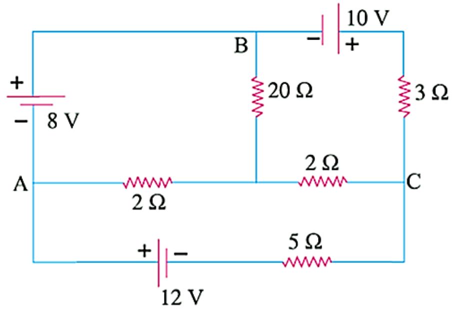
Current in 3Ω

$$\boxed{I_{3\Omega} = I_1 - I_2 = 2A}$$

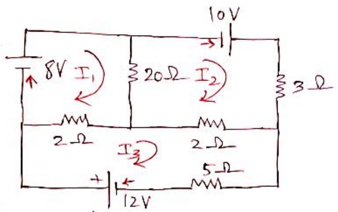
Current in 4Ω

$$\boxed{I_{4\Omega} = I_2 = 4A}$$

2. Determine the current flowing through 5Ω resistor using mesh analysis.



Sol



Apply KVL and Ohm's law

$$-8 + 20(I_1 - I_2) + 2(I_1 - I_3) = 0$$

$$-8 + 20I_1 - 20I_2 + 2I_1 - 2I_3 = 0$$

$$22I_1 - 20I_2 - 2I_3 = 8 \quad \text{— (1)}$$

Apply KVL and Ohm's Law

$$-10 + 3I_2 + 2(I_2 - I_3) + 20(I_2 - I_1) = 0$$

$$-10 + 3I_2 + 2I_2 - 2I_3 + 20I_2 - 20I_1 = 0$$

$$-20I_1 + 25I_2 - 2I_3 = 10 \quad \text{— (2)}$$

Apply KVL and Ohm's Law

$$-12 + 2(I_3 - I_1) + 2(I_3 - I_2) + 5I_3 = 0$$

$$-12 + 2I_3 - 2I_1 + 2I_3 - 2I_2 + 5I_3 = 0$$

$$-2I_1 - 2I_2 + 9I_3 = 12 \quad \text{— (3)}$$

From Eqs (1), (2) and (3) solve for I_1, I_2 and I_3

Matrix format

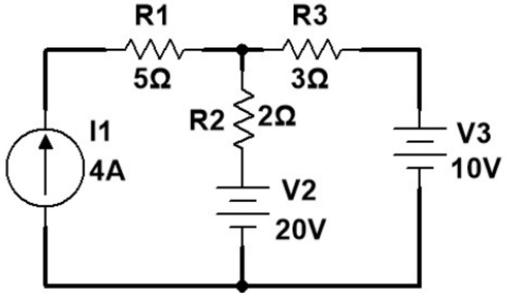
$$\begin{bmatrix} 22 & -20 & -2 \\ -20 & 25 & -2 \\ -2 & -2 & 9 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 8 \\ 10 \\ 12 \end{bmatrix}$$

$$\boxed{\begin{aligned} I_1 &= 4.67A \\ I_2 &= 4.41A \\ I_3 &= 3.35A \end{aligned}}$$

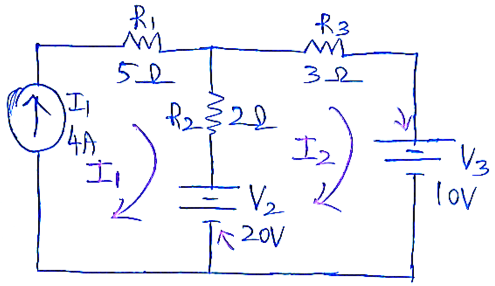
Current flowing through 5ohm resistor

$$\boxed{I_{5\Omega} = I_3 = 3.35A}$$

3. Use mesh analysis to determine the current flowing in each resistor in the circuit shown in the Fig.



Sol



$I_1 = 4A$ (No voltage source present it) — ①

Apply KVL and Ohm's Law

$$10 - 20 + 2(I_2 - I_1) + 3I_2 = 0$$

$$-10 + 2I_2 - 2I_1 + 3I_2 = 0$$

$$-2I_1 + 5I_2 = 10 \quad \text{— ②}$$

Sub $I_1 = 4A$ in Equ ②

$$-8 + 5I_2 = 10$$

$$5I_2 = 18$$

$$\boxed{I_2 = 3.6A}$$

Current in 5Ω resistor

$$\boxed{I_{5\Omega} = I_1 = 4A}$$

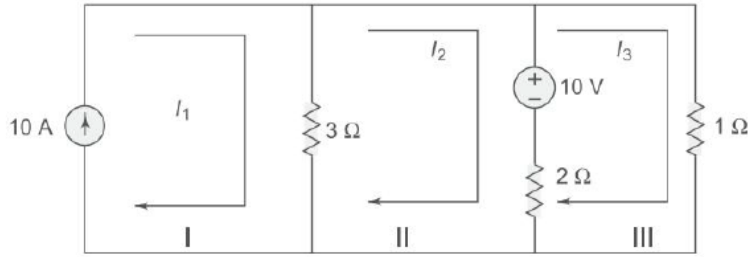
Current in 2Ω resistor

$$\boxed{I_{2\Omega} = I_1 - I_2 = 0.4A}$$

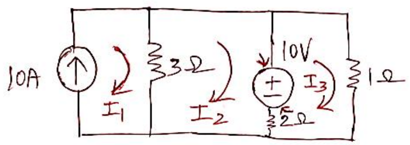
Current in 3Ω resistor

$$\boxed{I_{3\Omega} = I_2 = 3.6A}$$

4. Write the mesh equations for the circuit shown in Fig. and determine the mesh currents.



Sol



$I_1 = 10A$ (No voltage source present it) — ①

Apply KVL and Ohm's Law

$$10 + 2(I_2 - I_3) + 3(I_2 - I_1) = 0$$

$$10 + 2I_2 - 2I_3 + 3I_2 - 3I_1 = 0$$

$$-3I_1 + 5I_2 - 2I_3 = -10 \quad \text{— ②}$$

Apply KVL and Ohm's Law

$$-10 + 1I_3 + 2(I_3 - I_2) = 0$$

$$-2I_2 + 3I_3 = 10 \quad \text{— ③}$$

Sub $I_1 = 10A$ in Equ ②

$$-30 + 5I_2 - 2I_3 = -10$$

$$5I_2 - 2I_3 = +20 \quad \text{— ②}$$

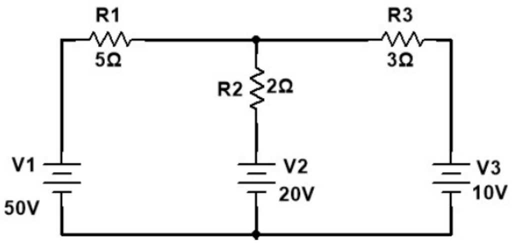
From Eqs ② and ③ solve for I_2 and I_3

$$5I_2 - 2I_3 = 20$$

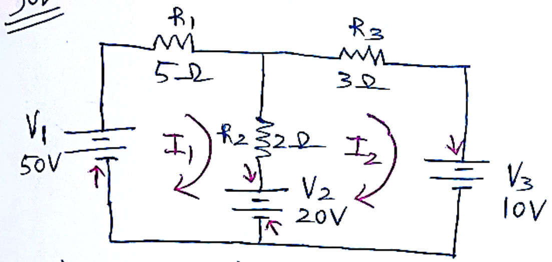
$$-2I_2 + 3I_3 = 10$$

$$\boxed{\begin{aligned} I_2 &= 7.27A \\ I_3 &= 8.18A \end{aligned}}$$

5. Determine the current flowing in each resistor in the circuit shown in Fig using mesh analysis.



Sol



Apply KVL and ohm's Law

$$-50 + 5I_1 + 2(I_1 - I_2) + 20 = 0$$

$$5I_1 + 2I_1 - 2I_2 - 30 = 0$$

$$7I_1 - 2I_2 = 30 \quad \text{—(1)}$$

Apply KVL and Ohm's Law

$$-20 + 10 + 2(I_2 - I_1) + 3I_2 = 0$$

$$2I_2 - 2I_1 + 3I_2 - 10 = 0$$

$$-2I_1 + 5I_2 = 10 \quad \text{—(2)}$$

From Eqs (1) and (2) solve for I_1 and I_2

$$\boxed{\begin{aligned} I_1 &= 5.48A \\ I_2 &= 4.19A \end{aligned}}$$

Current in 5Ω resistor

$$\boxed{I_{5\Omega} = I_1 = 5.48A}$$

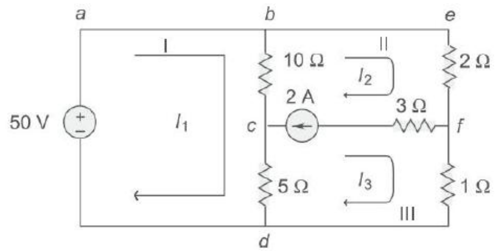
Current in 2Ω resistor

$$\boxed{I_{2\Omega} = I_1 - I_2 = 1.29A}$$

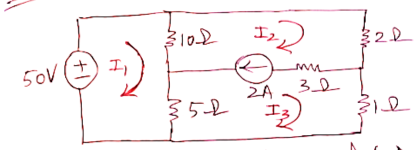
Current in 3Ω resistor

$$\boxed{I_{3\Omega} = I_2 = 4.19A}$$

6. Determine the current in the 5Ω resistor in the network given in Fig.

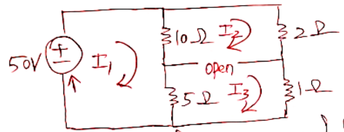


Sol



The currents between loop 2 and loop 3

$$I_2 - I_3 = 2 \quad \text{—(1)}$$



Form a supermesh for loop 2 and loop 3 (Apply KVL and ohm's Law)
(Entire branch (2A and 3Ω) is excluded)

$$10(I_2 - I_1) + 2I_2 + 1I_3 + 5(I_3 - I_1) = 0$$

$$10I_2 - 10I_1 + 2I_2 + I_3 + 5I_3 - 5I_1 = 0$$

$$-15I_1 + 12I_2 + 6I_3 = 0 \quad \text{—(2)}$$

Loop 1 (Apply KVL and ohm's Law)

$$-50 + 10(I_1 - I_2) + 5(I_1 - I_3) = 0$$

$$-50 + 10I_1 - 10I_2 + 5I_1 - 5I_3 = 0$$

$$+15I_1 - 10I_2 - 5I_3 = 50 \quad \text{—(3)}$$

From Eqs (1), (2) and (3) solve for I_1, I_2 and I_3

Matrix format

$$\begin{bmatrix} 0 & 1 & -1 \\ -15 & 12 & 6 \\ +15 & -10 & -5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \\ 50 \end{bmatrix}$$

$$\boxed{\begin{aligned} I_1 &= 20A \\ I_2 &= 17.33A \\ I_3 &= 15.33A \end{aligned}}$$

Current in the 5Ω resistor

$$I_{5\Omega} = I_1 - I_3$$

$$= 4.67A$$

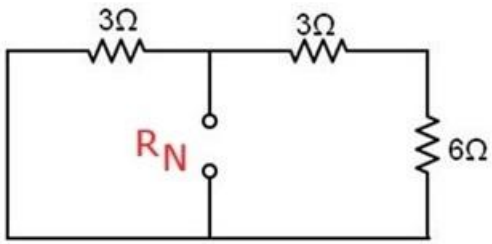
What are the limitations of mesh analysis?

- Applicable only to **planar circuits** (cannot be used directly for non-planar circuits).
  Ex: A simple triangle or square circuit with resistors.
- Becomes **complex for circuits with many meshes** or circuits containing current sources.

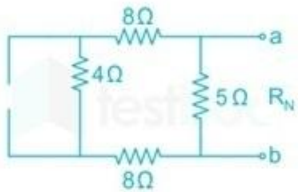
List out the differences between supermesh and Supernode.
What is supermesh and Supernode?

Feature	Supermesh	Supernode
Concept (Definition)	The two meshes are combined into a larger loop (supermesh) by excluding the current source and writing KVL around it. **Use:** Supermesh is used when a current source is present between two meshes.	A supernode is made by combining two nodes, then applying KCL along with the voltage source relation between them. **Use:** Supernode is used when a voltage source is present between two nodes.
	Supermesh → Current source (mesh analysis) Refer above 6th problem in mesh analysis.	**Supernode → Voltage source (nodal analysis) Refer above 5th problem in nodal analysis.**

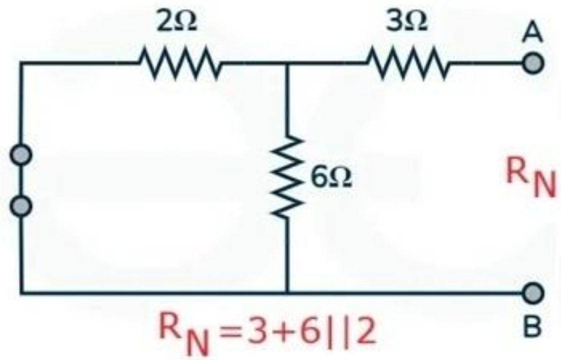
To find the Resistance of Thevenin's, Maximum Power Transfer, Norton's Theorems



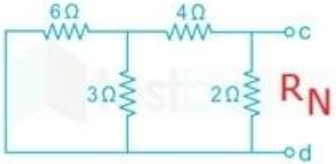
$R_N = 3 \,||\, (3+6)$



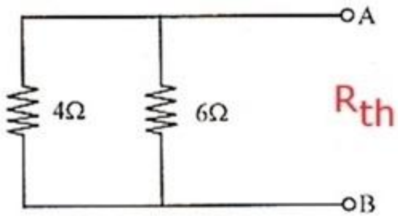
$R_N = 5 \,||\, (8+4+8)$



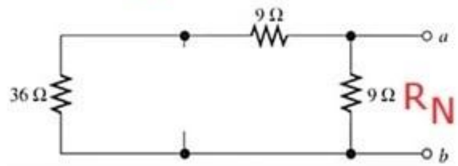
$R_N = 3 + 6 \,||\, 2$



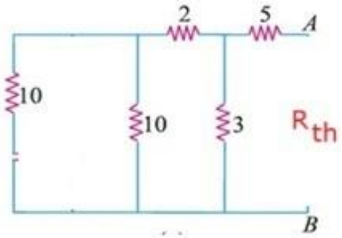
$R_N = 2 \,||\, (4 + 3 \,||\, 6)$



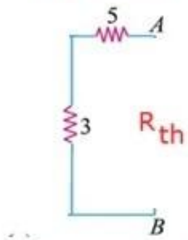
$R_{th} = 6 \,||\, 4$



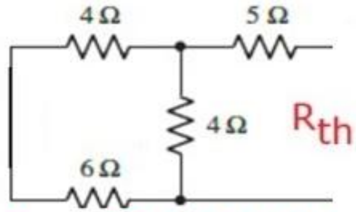
$R_N = 9 \,||\, (9+36)$



$R_{th} = 5 + (3 \,||\, (2 + 10 \,||\, 10))$



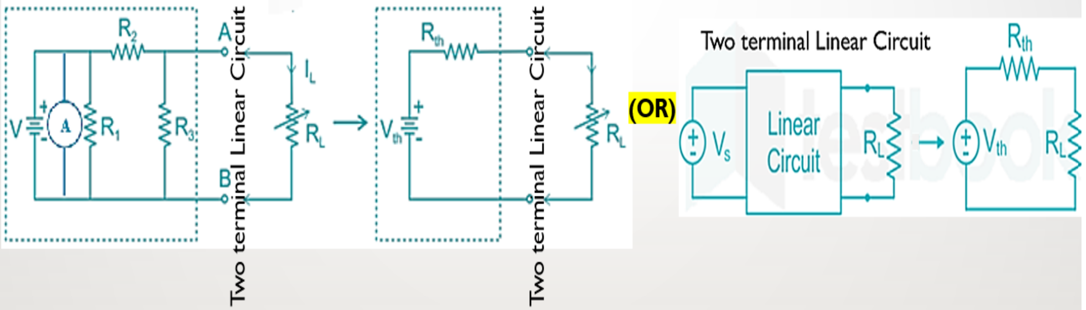
$R_{th} = 5 + 3$



$R_{th} = 5 + 4 \parallel (4 + 6)$

THEVENIN'S THEOREM

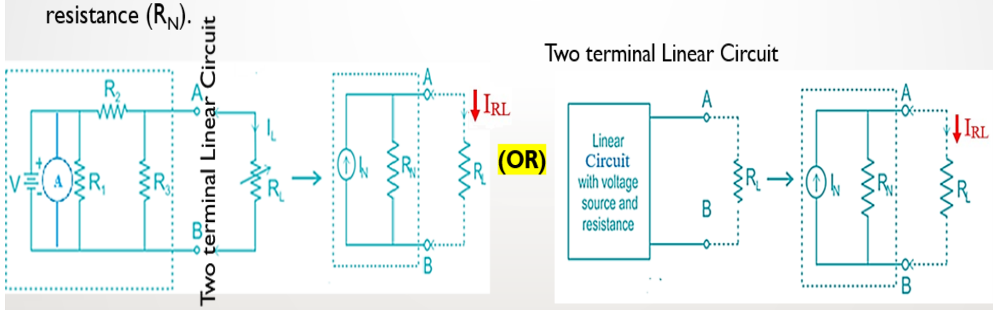
Statement: Any two-terminal linear circuit having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a single voltage source (V_{th}) in series with a resistance (R_{th}).



- V_{th} is equal to the open-circuit voltage at the terminals.
- R_{th} is equal to open current sources and short voltage sources.

NORTON'S THEOREM

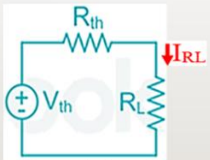
Statement: Any two-terminal linear circuit having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a Norton current source (I_N) in parallel with a resistance (R_N).



- V is equal to the short-circuit voltage at the terminals and find I_N.
- R_N is equal to open current sources and short voltage sources.

SIMPLE STEPS/PROCEDURE TO ANALYZE ELECTRIC CIRCUIT THROUGH THEVENIN'S THEOREM AND DETERMINE V_{TH}, R_{TH}, AND I_{RL}

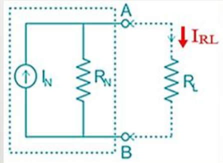
1. Open/remove the load resistor (R_L).
2. Calculate the Thevenin Voltage (V_{th}) (Open Circuit Voltage).
3. Open Current Sources and Short Voltage Sources. Calculate the Thevenin Resistance (R_{th}) (Open Circuit Resistance).
4. Now, Redraw the circuit with (V_{th}) in Step (2) as the thevenin voltage source and (V_{th}) in step (3) as a series resistance and connect the load resistor (R_L) which we had removed in Step (1). This is the Equivalent Thevenin Circuit.



Now find the total current flowing through load resistor by using the Ohm's Law $I_{RL} = \frac{V_{th}}{(R_{th}+R_L)}$.

SIMPLE STEPS/PROCEDURE TO ANALYZE ELECTRIC CIRCUIT THROUGH NORTON'S THEOREM AND DETERMINE I_N, R_N, AND I_{RL}

1. Remove the load resistor (R_L) and replace it with a short circuit ($I_{SC}=I_N$).
2. Calculate the Norton current (I_N)-the current through the short circuit.
3. All voltage sources are replaced with short circuits, and all current sources are replaced with open circuits. Calculate the Norton resistance (R_N)-the total resistance between the open circuit connection points.
4. Now, Redraw the circuit with the Norton current source (I_N) in parallel with the Norton resistance (R_N). The load resistor (R_L) re-attaches between the two open points of the equivalent circuit.

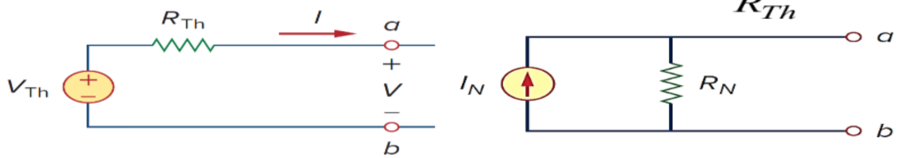


Now find the total current flowing through the load resistor by using $I_{RL} = I_N \frac{R_N}{(R_N + R_L)}$.

Close relationship between Norton's and Thevenin's theorems:

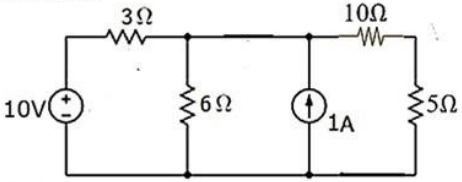
$$R_N = R_{Th}$$

$$I_N = \frac{V_{Th}}{R_{Th}}$$



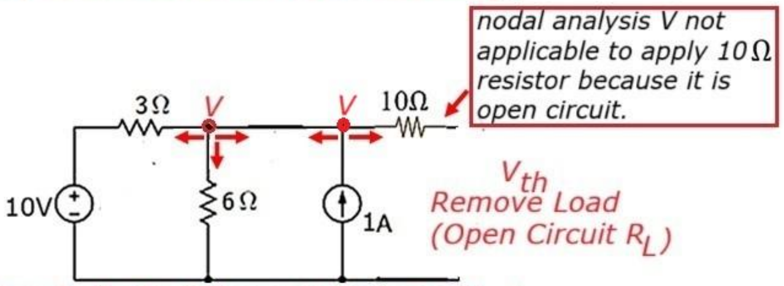
Thevenin Theorem and Norton Theorem Problem Steps (FOR UNDERSTANDING STUDENTS PERSPECTIVE)

Find the current in the 5Ω resistor for the circuit shown in Figure using Theveni theorem



Sol:

Step 1: Remove load (Open CircuitR_L)



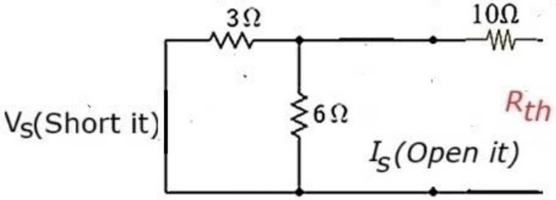
Step 2: To find Thevenin Voltage (V_{th})

Apply KCL at node V

$\boxed{\therefore V_{th} = V}$

Step 3: To find Thevenin Resistance (R_{th})

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from Step 1 Diagram



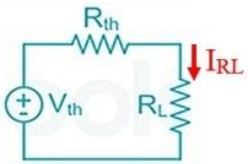
$R_{th} = 3 \parallel 6 + 10$ (OR) $10 + 6 \parallel 3$

EX: $3 \parallel 6 = \frac{3\times6}{3+6} = 2$

$\boxed{\therefore R_{th} = \quad \Omega}$

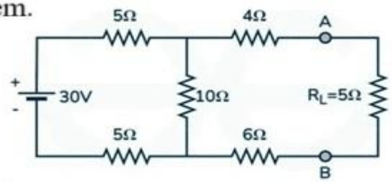
Step 4: To find load current (I_{R_L})

$\boxed{I_{RL} = \frac{V_{th}}{(R_{th}+R_L)}}$



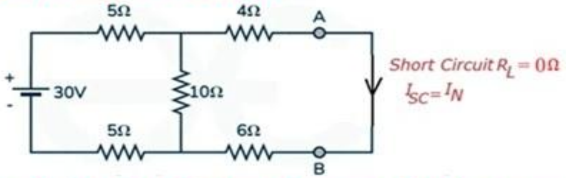
$\boxed{I_{RL} = \quad A}$

Find the value of current across the load branch in the given circuit using Norton's Theorem.

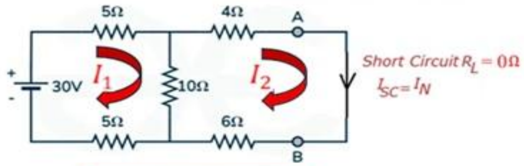


Sol:

Step 1: Short Circuit R_L



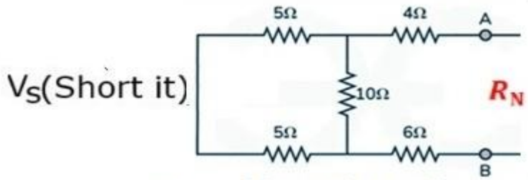
Step 2: To find Norton Current (I_N) by using mesh (or) nodal analysis



$\boxed{I_{SC} = I_N = \quad A}$

Step 3: To find Norton Resistance (R_N)

Deactivate the sources ($V_s = 0 \rightarrow$short, $I_s = 0 \rightarrow$open) and Remove R_L from Step 1 Diagram



$R_N = [(5+5) \parallel 10] + 4 + 6$

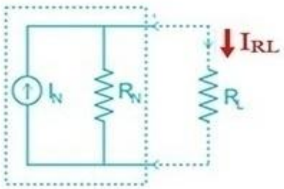
$\boxed{R_N = \quad \Omega}$

EX: $10 \parallel 10 = \frac{10\times10}{10+10} = 5$

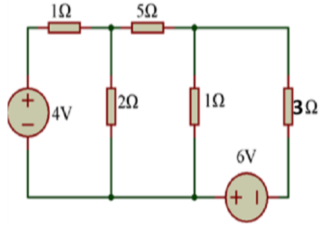
Step 4: To find load current (I_{R_L})

$\boxed{I_{RL} = I_N \frac{R_N}{(R_N+R_L)}}$

$\boxed{I_{RL} = \quad A}$

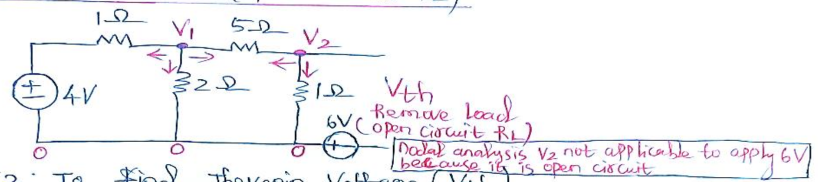


1. Find the current flowing through the 3Ω Resistor using Thevenin's Theorem.



Sol

Step 1 : Remove load (open circuit R_L)



Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V_1

$$\frac{V_1-4}{1}+\frac{V_1-0}{2}+\frac{V_1-V_2}{5}=0$$

$$V_1\left(1+\frac{1}{2}+\frac{1}{5}\right)-\frac{V_2}{5}=4$$

$$1.7V_1-0.2V_2=4 \quad \text{--- (1)}$$

Apply KCL at node V_2

$$\frac{V_2-V_1}{5}+\frac{V_2-0}{1}=0$$

$$-\frac{V_1}{5}+V_2\left(\frac{1}{5}+1\right)=0$$

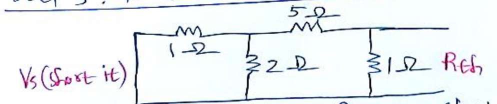
$$-0.2V_1+1.2V_2=0 \quad \text{--- (2)}$$

From Eqs (1) and (2) solve for V_1 and V_2

$$V_1=2.4V$$
$$V_2=0.4V$$

$$\boxed{\therefore V_{th}=V_2+6=6.4V}$$

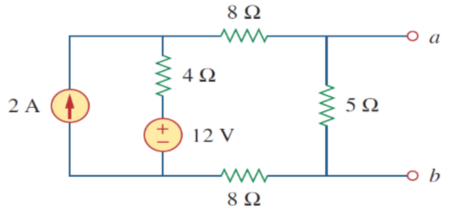
Step 3 : To find Thevenin Resistance (R_{th})



Deactivate the sources ($V_s=0 \to$ Short, $I_s=0 \to$ Open) from step 1 Diagram

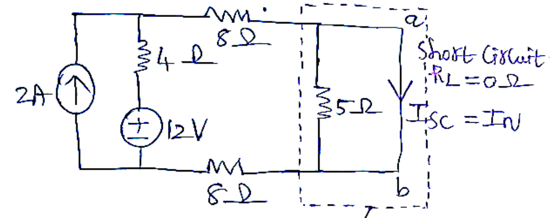
$$R_{th}=1\,||\,(5+2\,||\,1)$$
$$=1\,||\left(5+\frac{2\times1}{2+1}\right)$$
$$=1\,||\,(5+0.666)$$
$$=1\,||\,5.666$$

1.Find the Norton's equivalent for the circuit shown below



Sol

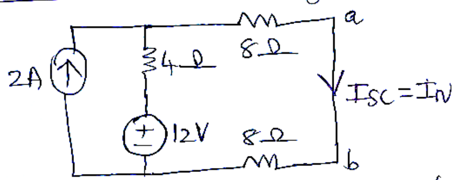
Step 1 : Short Circuit R_L



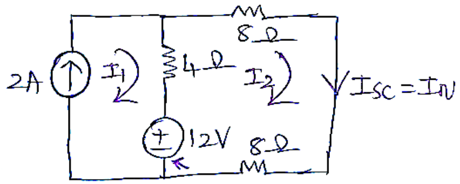
Short Circuit $I_{SC}=I_N\,||\,5\Omega$

$$\because 0\Omega\,||\,5\Omega=\frac{0\times5}{0+5}=0\Omega$$

Redraw the above diagram



Step 2 : To find Norton Current (I_N)



$$I_1=2A \text{ (No Voltage Source present it)} \quad \text{--- (1)}$$

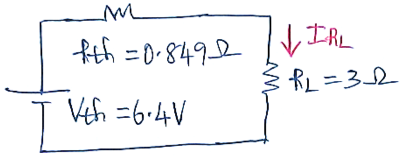
Apply KVL and Ohm's Law

$$-12+4(I_2-I_1)+8I_2+8I_2=0$$
$$-12+4I_2-4I_1+8I_2+8I_2=0$$
$$-4I_1+20I_2=12$$
$$20I_2=20$$
$$\boxed{\therefore I_N=I_2=1A}$$

$$= \frac{1 \times 5.666}{1 + 5.666}$$

$$\boxed{R_{th} = 0.849\,\Omega}$$

Step 4 : To find load Current (I_{RL})

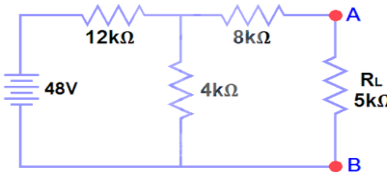


$$\boxed{I_{RL} = \frac{V_{th}}{R_{th} + R_L}}$$

$$= \frac{6.4}{0.849 + 3}$$

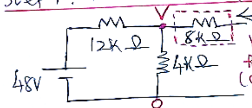
$$\boxed{I_{RL} = 1.66A}$$

2. Find the current flowing through 5KΩ Resistor using Thevenin's Theorem.



Sol

Step 1 : Remove load (open circuit R_L)



nodal analysis V not applicable to apply 8Ω resistor because it is open circuit

V_{th} Remove load (open circuit R_L)

Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V

$$\frac{V-48}{12} + \frac{V-0}{4} = 0$$

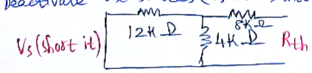
$$V\left(\frac{1}{12} + \frac{1}{4}\right) - \frac{48}{12} = 0$$

$$0.333V = 4$$

$$\boxed{\therefore V_{th} = V = 12V}$$

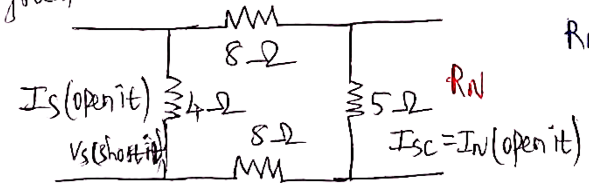
Step 3 : To find Thevenin Resistance (R_{th})

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from step 1 Diagram



Step 3 : To find Norton Resistance (R_N)

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from step 1 diagram



Parallel

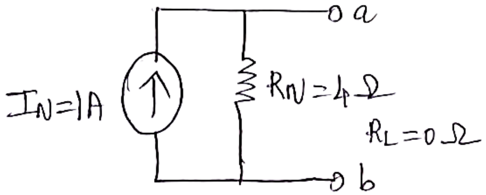
$$R_N = 5 \parallel (8+4+8) \text{ (OR) } (4+8+8) \parallel 5$$

$$= 5 \parallel 20$$

$$= \frac{5 \times 20}{5 + 20}$$

$$= 4\,\Omega$$

Step 4 : To find load Current (I_{RL})

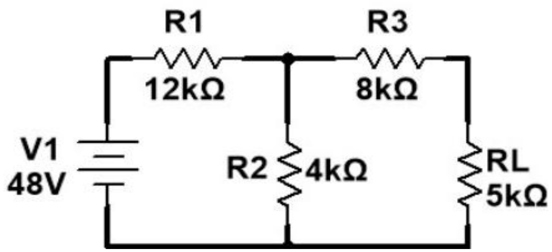


$$\boxed{I_{RL} = I_N \frac{R_N}{R_N + R_L}}$$

$$= 1 \times \frac{4}{4+0} \qquad \because R_L = 0\,\Omega$$

$$\boxed{I_{RL} = 1A}$$

2. Find the current in R_L resistor in the circuit shown in Fig using Norton's Theorem.



$R_{th} = 8k\Omega + 4k\Omega \,||\, 12k\Omega$

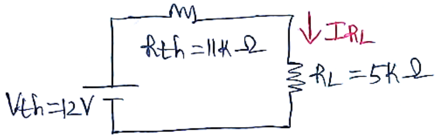
Parallel

$= 8k\Omega + \frac{4k\Omega \times 12k\Omega}{4k\Omega + 12k\Omega}$ $\qquad \frac{48k^2}{16k} = 3k$

$= 8k\Omega + 3k\Omega$

$\boxed{R_{th} = 11k\Omega}$

Step 4: To find load current (I_{RL})



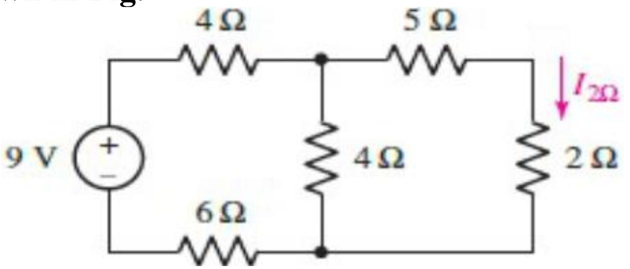
$\boxed{I_{RL} = \frac{V_{th}}{R_{th} + R_L}}$

$= \frac{12}{11k\Omega + 5k\Omega}$

$= \frac{12}{16k\Omega}$

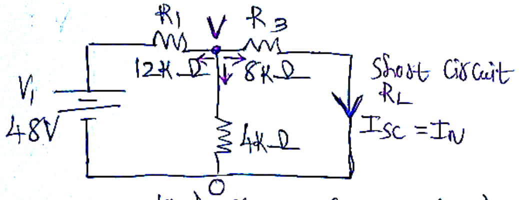
$\boxed{I_{RL} = 0.75mA}$

3. Use Thevenin's Theorem to find current in 2Ω resistor in the circuit shown in Fig.



Sol

Step 1: Short Circuit R_L



Step 2: To find Norton Current (I_N)

Apply KCL at node V

$$\frac{V-48}{12k\Omega} + \frac{V-0}{4k\Omega} + \frac{V-0}{8k\Omega} = 0$$

$$V\left(\frac{1}{12k\Omega} + \frac{1}{4k\Omega} + \frac{1}{8k\Omega}\right) - \frac{48}{12k\Omega} = 0$$

$$4.583 \times 10^{-4}\, V = \frac{48}{12k\Omega}$$

$$= \frac{4 \times 10^{-3}}{4.583 \times 10^{-4}}$$

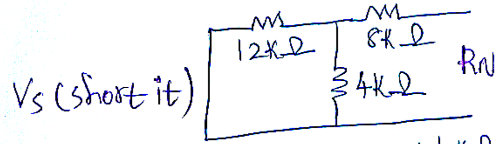
$$V = 8.727V$$

$$\therefore I_{sc} = I_N = \frac{V-0}{8k\Omega} = \frac{8.727}{8000}$$

$$\boxed{I_{sc} = I_N = 1.09 \times 10^{-3} = 1.09mA}$$

Step 3: To find Norton Resistance (R_N)

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from and Remove R_L from step 1 Diagram.



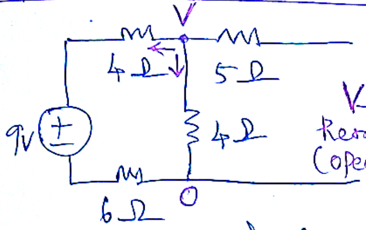
$R_N = 8k\Omega + 4k\Omega \,||\, 12k\Omega$

$= 8k\Omega + \frac{4k\Omega \times 12k\Omega}{4k\Omega + 12k\Omega}$

$= 8k\Omega + \frac{48k^2\Omega}{16k\Omega}$

Sol

Step 1 : Remove Load (open Circuit R_L)



nodal analysis V not applicable to apply 5Ω resistor

V_{th} Remove load (open Circuit R_L)

Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V

$$\frac{V-9}{\underbrace{4+6}_{\text{Series}}} + \frac{V-0}{4} = 0$$

$$V\left(\frac{1}{10}+\frac{1}{4}\right) - \frac{9}{10} = 0$$

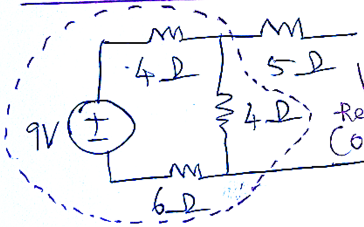
$$0.35V - 0.9 = 0$$

$$0.35V = 0.9$$

$$\boxed{V = V_{th} = 2.57V}$$

OR

Alternate method (Voltage division rule)



5Ω resistor is in open circuit

V_{th} Remove load (open circuit R_L)

$$V_{th} = V \times \frac{4}{R_{total}} \leftarrow \text{Same resistance}$$

$$= 9 \times \frac{4}{4+6+4}$$

$$= \frac{36}{14}$$

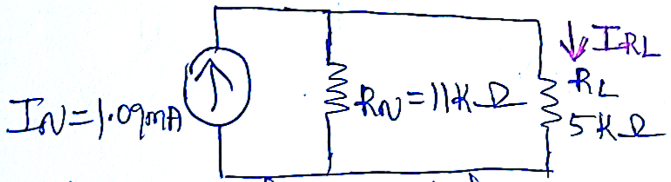
$$\boxed{V_{th} = 2.57V}$$

$$= 8K\Omega + 3K\Omega$$

$$\boxed{R_N = 11K\Omega}$$

$$\boxed{\frac{K^2\Omega}{K\Omega} = K\Omega}$$

Step 4 : To find load Current (I_{RL})



Current division rule,

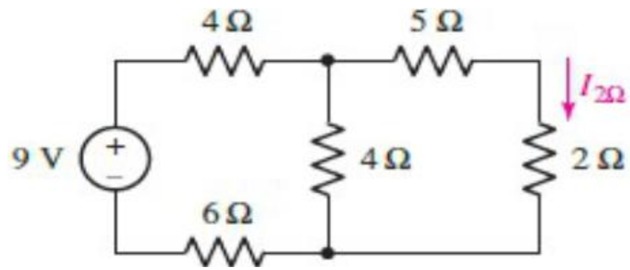
$$I_{RL} = I_N \times \frac{R_N}{R_N + R_L}$$

$$= 1.09\times10^{-3} \times \frac{11\times10^{3}}{11\times10^{3}+5\times10^{3}}$$

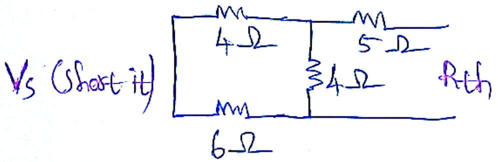
$$= \frac{11.99}{16\times10^{3}}$$

$$\boxed{I_{RL} = 0.749\times10^{-3} = 0.749mA}$$

3. Use Norton's Theorem to find current in 2Ω resistor in the circuit shown in Fig.



Step 3 : To find Thevenin Resistance (R_{th})



Deactivate the Sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from Step 1 Diagram

$$R_{th} = 5 + 4 \parallel (4+6)$$

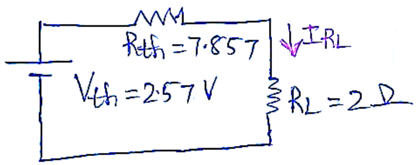
$$= 5 + 4 \parallel 10$$

$$= 5 + \frac{4 \times 10}{4+10}$$

$$= 5 + 2.857$$

$$\boxed{R_{th} = 7.857\,\Omega}$$

Step 4 : To find load Current (I_{RL})



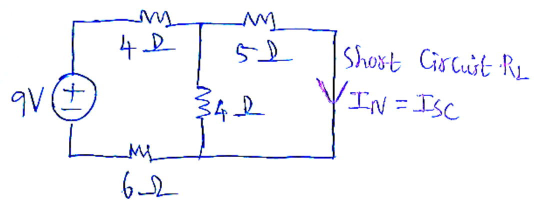
$$I_{RL} = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{2.57}{7.857 + 2}$$

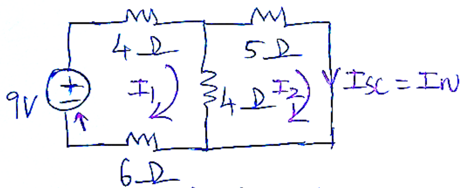
$$\boxed{I_{RL} = 0.260\,A}$$

Sol

Step 1 : Short Circuit R_L



Step 2 : To find Norton Current (I_N)



Apply KVL and Ohm's Law

$$-9 + 4I_1 + 4(I_1 - I_2) + 6I_1 = 0$$

$$-9 + 4I_1 + 4I_1 - 4I_2 + 6I_1 = 0$$

$$14I_1 - 4I_2 = 9 \quad \text{---} (1)$$

Apply KVL and Ohm's Law

$$5I_2 + 4(I_2 - I_1) = 0$$

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

$$-4I_1 + 9I_2 = 0 \quad \text{---} (2)$$

From Eqs (1) and (2) Solve for I_1 and I_2

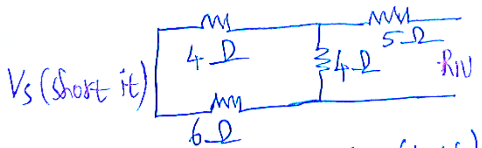
$$I_1 = 0.736\,A$$

$$I_2 = 0.327\,A$$

$$\boxed{\therefore I_N = I_2 = 0.327\,A}$$

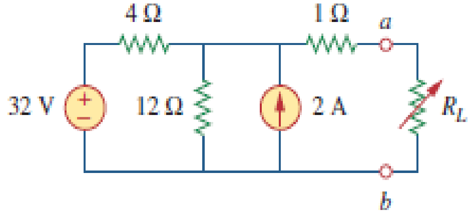
Step 3 : To find Norton Resistance (R_N)

Deactivate the Sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) and Remove R_L from Step 1 Diagram



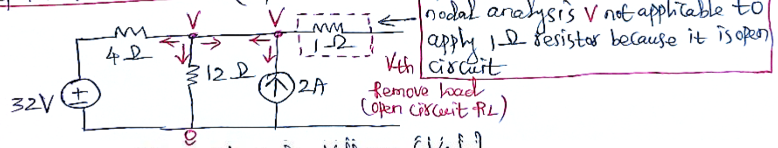
$$R_N = 5 + 4 \parallel (4+6)$$

4. Find the Thevenin equivalent circuit of the circuit shown in Fig, to the left of the terminals a-b. Then find the current through $R_L = 6\Omega$, 16Ω, and 36Ω. (With independent sources)



Sol

Step 1 : Remove load (Open circuit R_L)



Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V

$$\frac{V-32}{4} + \frac{V-0}{12} = 2$$

$$V\left(\frac{1}{4} + \frac{1}{12}\right) - \frac{32}{4} = 2$$

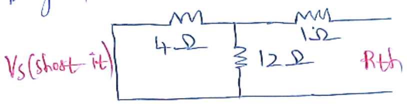
$$0.333V - 8 = 2$$

$$0.333V = 10$$

$$\boxed{\therefore V_{th} = V = 30V}$$

Step 3 : To find Thevenin Resistance (R_{th})

Deactivate the Sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from Step 1 Diagram



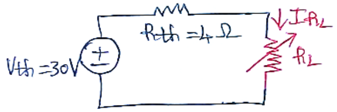
$$R_{th} = 1 + 12 \parallel 4$$

$$= 1 + \frac{12 \times 4}{12+4}$$

$$= 1 + \frac{48}{16}$$

$$\boxed{R_{th} = 4\,\Omega}$$

Step 4 : To find load Current (I_{RL})



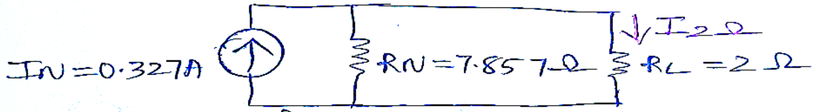
$$= 5 + 4 \parallel 10$$

$$= 5 + \frac{4 \times 10}{4+10}$$

$$= 5 + 2.857$$

$$\boxed{R_N = 7.857\,\Omega}$$

Step 4 : To find load Current (I_{RL})



Current division rule

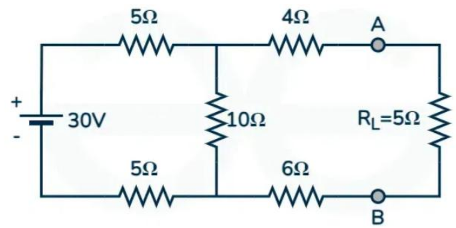
$$I_{2\Omega} = I_N \frac{R_N}{R_N + R_L}$$

$$= 0.327 \times \frac{7.857}{7.857 + 2}$$

$$= \frac{2.569}{9.857}$$

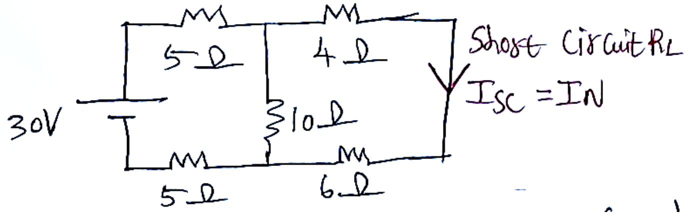
$$\boxed{I_{2\Omega} = 0.260\,A}$$

4. Find the value of current across the load branch in the given circuit using Norton's Theorem.



Sol

Step 1 : Short Circuit R_L



If $R_L = 6\,\Omega$

$$I_{RL} = \frac{V_{th}}{R_{th} + R_L} = 3A$$

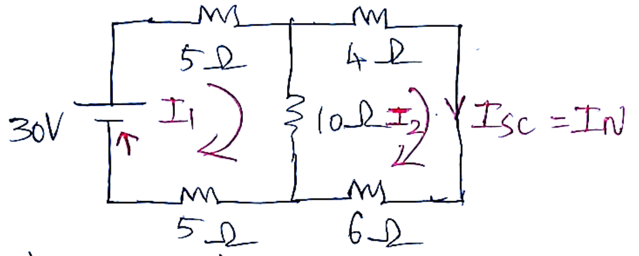
If $R_L = 16\,\Omega$

$$I_{RL} = \frac{V_{th}}{R_{th} + R_L} = 1.5A$$

If $R_L = 36\,\Omega$

$$I_{RL} = \frac{V_{th}}{R_{th} + R_L} = 0.75A$$

Step 2 : To find Norton Current (I_N)



Apply KVL and Ohm's Law

$$-30 + 5I_1 + 10(I_1 - I_2) + 5I_1 = 0$$

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

$$20I_1 - 10I_2 = 30 \quad \text{—— (1)}$$

Apply KVL and Ohm's Law

$$4I_2 + 6I_2 + 10(I_2 - I_1) = 0$$

$$4I_2 + 6I_2 + 10I_2 - 10I_1 = 0$$

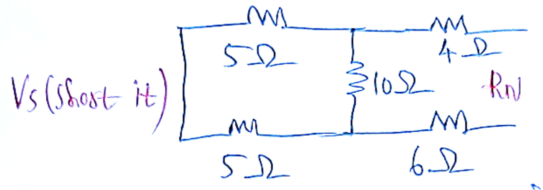
$$-10I_1 + 20I_2 = 0 \quad \text{—— (2)}$$

From Eqs (1) and (2) solve for I_1 and I_2

$$\boxed{\begin{aligned} I_1 &= 2A \\ I_2 &= 1A \\ \therefore I_N &= I_2 = 1A \end{aligned}}$$

Step 3 : To find Norton Resistance (R_N)

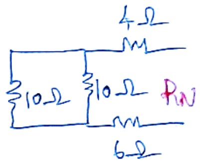
Deactivate the sources ($V_s = 0 \rightarrow$ short , $I_s = 0 \rightarrow$ open) and remove R_L from step 1 Diagram



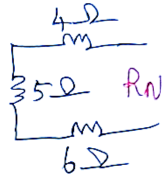
5Ω series with 5Ω resistor

$5\Omega + 5\Omega = 10\Omega$

Now, $10\Omega \parallel 10\Omega = \frac{10 \times 10}{10+10} = \frac{100}{20} = 5\Omega$

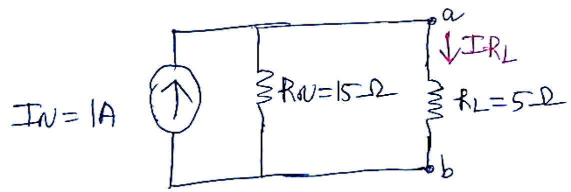


$4\Omega + 5\Omega + 6\Omega = 15\Omega$



$\boxed{\therefore R_N = 15\Omega}$

Step 4 : To find load Current (I_{RL})



Current division rule

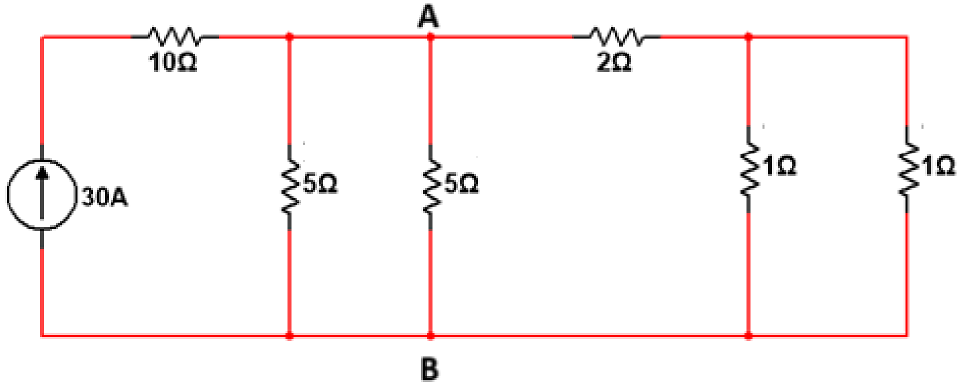
$$I_{RL} = I_N \frac{R_N}{R_N + R_L}$$

$$= 1 \times \frac{15}{15+5}$$

$$= \frac{15}{20}$$

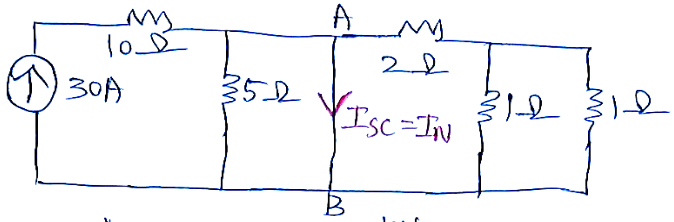
$$\boxed{I_{RL} = 0.75\,A}$$

5. Find the current in the branch AB using Norton's Theorem and find the Norton's equivalent circuit.



Sol

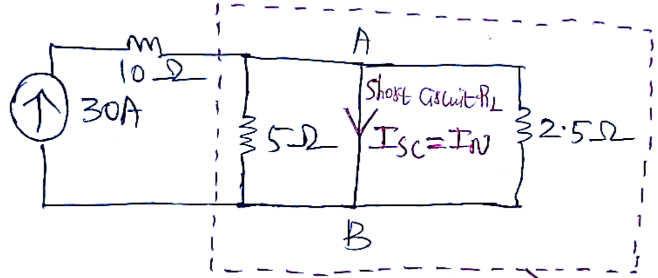
Step 1: Short Circuit R_L



$1\Omega \parallel 1\Omega = \frac{1\times1}{1+1} = 0.5\Omega$

0.5Ω Series with 2Ω resistor

$0.5+2 = 2.5\Omega$



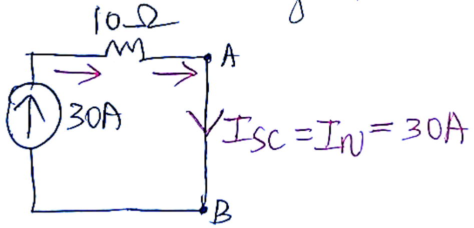
$I_{sc} = I_N \parallel 5\,\Omega \parallel 2.5\,\Omega$

Parallel Parallel

So, $5\,\Omega$ and $2.5\,\Omega$ resistor is "0" (Don't consider)

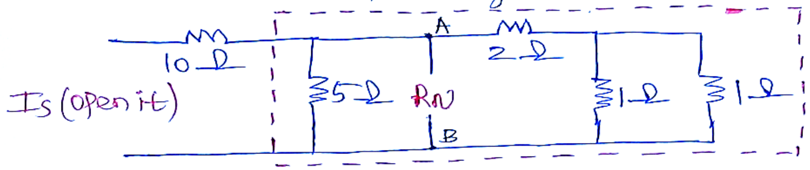
Step 2: To find Norton Current (I_N)

Redraw the above diagram



Step 3: To find Norton Resistance (R_N)

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) and remove R_L from step 1 Diagram



$1\,\Omega \parallel 1\,\Omega = \frac{1 \times 1}{1+1} = 0.5\,\Omega$

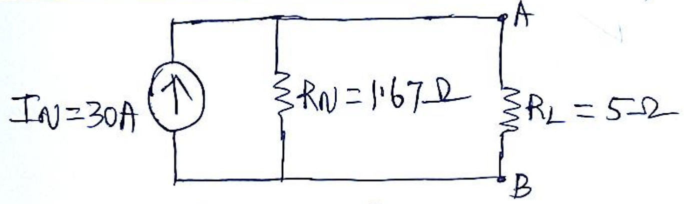
$0.5\,\Omega$ series with $2\,\Omega$ resistor

$0.5\,\Omega + 2\,\Omega = 2.5\,\Omega$

Now, $2.5\,\Omega \parallel 5\,\Omega = \frac{2.5 \times 5}{2.5 + 5} = 1.67\,\Omega$

$\boxed{\therefore R_N = 1.67\,\Omega}$

Step 4 : To find load Current (I_{RL})



Current division rule

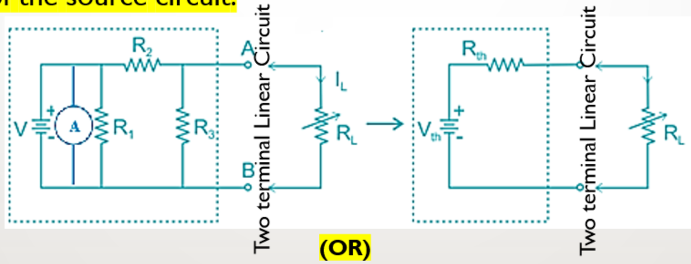
$$I_{RL} = I_N \frac{R_N}{R_N + R_L}$$

$$= 30 \times \frac{1.67}{1.67 + 5}$$

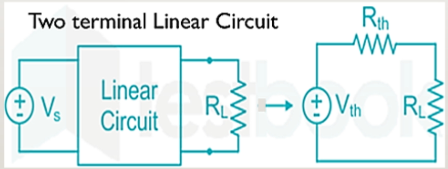
$$\boxed{I_{RL} = 7.5A}$$

Maximum Power Transfer Theorem

The maximum power transfer theorem states that maximum power is transferred (delivered) from a source to a load when the load resistance (R_L) is equal to the Thevenin's equivalent resistance(R_{th}) of the source circuit.



(OR)



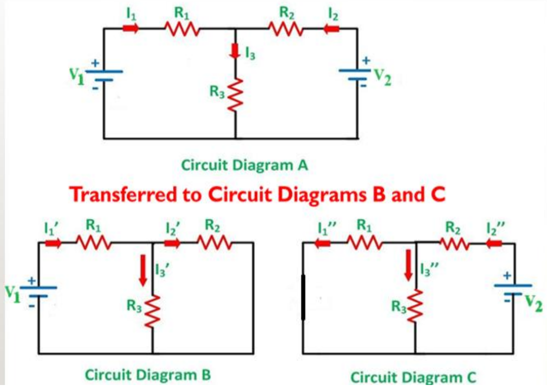
According to the maximum power transfer theorem, $R_{th} = R_L$

The maximum power is given by

$$P_{max} = \frac{V_{th}^2}{4R_L} = \frac{V_{th}^2}{4R_{th}}$$

Superposition Theorem

The response in any two-terminal linear circuit with multiple independent sources is the sum of the individual responses, considering one source at a time while the other sources are non-operative.



SIMPLE STEPS/PROCEDURE TO ANALYZE ELECTRIC CIRCUIT THROUGH MAXIMUM POWER TRANSFER THEOREM AND DETERMINE V_{TH}, R_{TH}, AND P_{MAX}

1. Open/remove the load resistor R_L
2. Find the Thevenin's equivalent circuit across the open circuited load terminals (V_{th}).
3. According to maximum power transfer theorem, $R_{th} = R_L$
4. The maximum power is given by

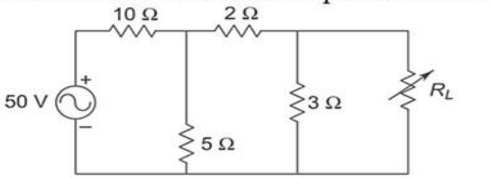
$$P_{max} = \frac{V_{th}^2}{4R_L} = \frac{V_{th}^2}{4R_{th}}$$

Steps of Applying Superposition Principle:

1. Deactivate all independent sources except one source. If the internal resistance of the sources is neglected then the deactivated voltage source is replaced with a "Short Circuit" (R= 0 Ω) and the deactivated current source is replaced with an open circuit (R = ∞) respectively then find the corresponding (V or I) due to that active source.
2. Repeat step (1) for each of the other independent sources.
3. Find the total contribution (V or I) by adding algebraically all the voltages or currents due to the independent sources.

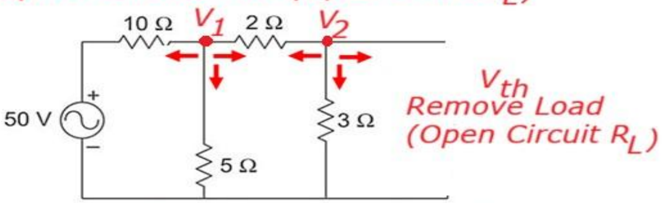
Maximum Power Transfer Theorem and Superposition Theorem Problem Steps (FOR UNDERSTANDING STUDENTS PERSPECTIVE)

Determine the maximum power delivered to the load in the circuit shown in Fig



Sol:

Step 1: Remove load (Open Circuit R_L)



Step 2: To find Thevenin Voltage (V_{th})

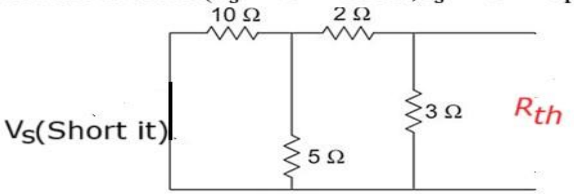
Apply KCL at node V_1

Apply KCL at node V_2

$\boxed{\therefore V_{th} = V_2}$

Step 3: To find Thevenin Resistance (R_{th})

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from Step 1 Diagram



$R_{th} = 3 \parallel (2 + 5 \parallel 10)$ (OR) $(10 \parallel 5 + 2) \parallel 3$

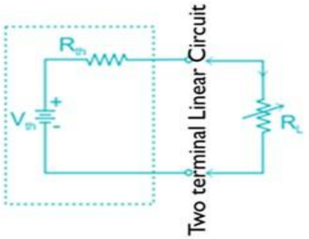
EX: $5 \parallel 10 = \frac{5\times10}{5+10} = 3.333$

$\boxed{\therefore R_{th} = R_L = \quad \Omega}$

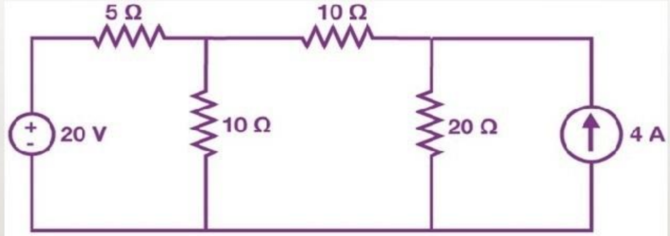
Step 4: To find maximum power transfer to the load (P_{max})

$$P_{max} = \frac{V_{th}^{2}}{4R_L}$$

$\boxed{P_{max} = \quad W}$

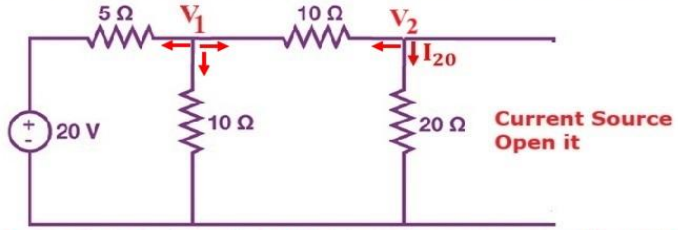


Find the current flowing through 20 Ω using the superposition theorem in the circuit shown in Fig.2.



Sol:

Step 1: Deactivate all independent sources except one source



Step 2: To find nodal voltage V_1, V_2 and current pass through the 20 Ω resistor

Apply KCL at node V_1

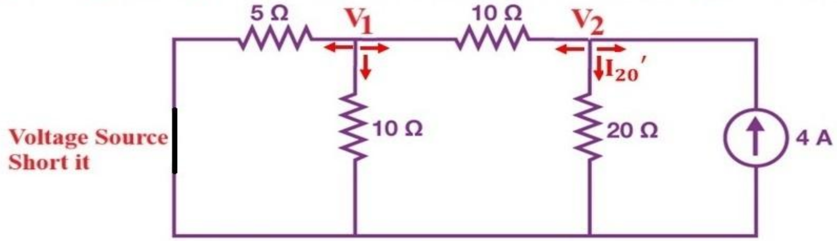
Apply KCL at node V_2

$\boxed{\therefore V_2 = \quad V}$

Current passes through 20 Ω resistor

$$I_{20} = \frac{V_2 - 0}{20} = \frac{V_2 - 0}{20} = \quad A$$

Step 3: Repeat Step 1 and Step 2 for each of the other independent sources



Apply KCL at node V_2

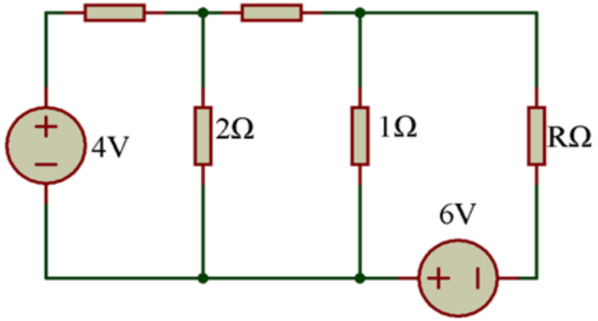
$\boxed{\therefore V_2 = \quad V}$

Current passes through 20 Ω resistor

$$I_{20}' = \frac{V_2 - 0}{20} = \frac{V_2 - 0}{20} = \quad A$$

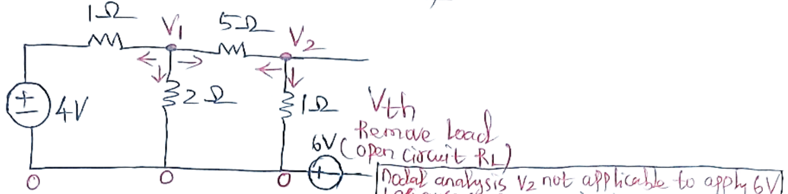
Summation of currents $I = I_{20} + I_{20}' = \quad A$

1. Find the value of R in the circuit of figure such that maximum power transfer takes place. What is the amount of this power?



Sol

Step 1 : Remove load (open circuit R_L)



Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V_1

$$\frac{V_1-4}{1}+\frac{V_1-0}{2}+\frac{V_1-V_2}{5}=0$$

$$V_1\left(1+\frac{1}{2}+\frac{1}{5}\right)-\frac{V_2}{5}=4$$

$$1.7V_1-0.2V_2=4 \quad \text{—} (1)$$

Apply KCL at node V_2

$$\frac{V_2-V_1}{5}+\frac{V_2-0}{1}=0$$

$$-\frac{V_1}{5}+V_2\left(\frac{1}{5}+1\right)=0$$

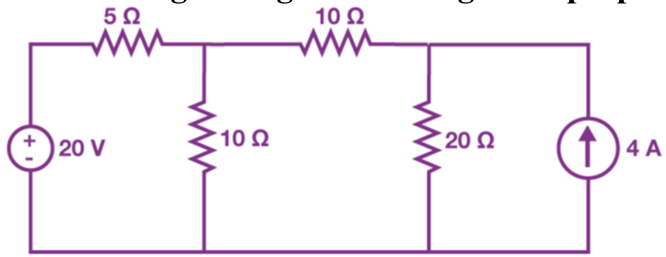
$$-0.2V_1+1.2V_2=0 \quad \text{—} (2)$$

From Eqs (1) and (2) solve for V_1 and V_2

$$V_1=2.4V$$
$$V_2=0.4V$$

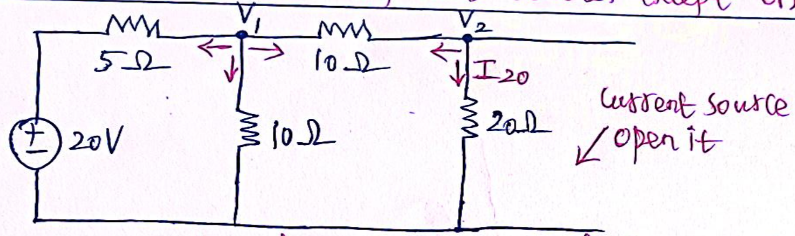
$$\boxed{\therefore V_{th}=V_2+6=6.4V}$$

1. Find the current flowing through 20 Ω using the superposition theorem.



Sol

Step 1: Deactivate all independent sources except one source



Step 2: To find nodal voltage V_1, V_2 and current passes through the 20Ω resistor

Apply KCL at node V_1

$$\frac{V_1-20}{5}+\frac{V_1-0}{10}+\frac{V_1-V_2}{10}=0$$

$$V_1\left(\frac{1}{5}+\frac{1}{10}+\frac{1}{10}\right)-\frac{V_2}{10}-\frac{20}{5}=0$$

$$0.4V_1-0.1V_2=4 \quad \text{—} (1)$$

Apply KCL at node "V_2"

$$\frac{V_2-V_1}{10}+\frac{V_2-0}{20}=0$$

$$-\frac{V_1}{10}+V_2\left(\frac{1}{10}+\frac{1}{20}\right)=0$$

$$-0.1V_1+0.15V_2=0 \quad \text{—} (2)$$

From Eqs (1) and (2) solve for V_1 and V_2

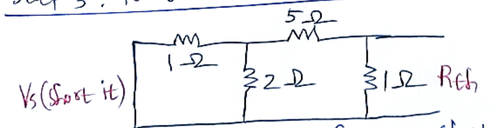
$$\boxed{\begin{matrix}V_1=12V\\ V_2=8V\end{matrix}}$$

Current passes through 20Ω resistor

$$I_{20\Omega}=\frac{V_2-0}{20}=\frac{8}{20}$$

$$\boxed{I_{20\Omega}=0.4A}$$

Step 3: To find Thevenin Resistance (R_{th})

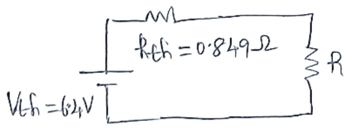


Deactivate the Sources ($V_s=0 \rightarrow$ Short , $I_s=0 \rightarrow$ Open) from step 1 Diagram

$$R_{th} = 1 \parallel (5+2\parallel 1)$$
$$= 1 \parallel \left(5 + \frac{2\times 1}{2+1}\right)$$
$$= 1 \parallel (5+0.666)$$
$$= 1 \parallel 5.666$$
$$= \frac{1\times 5.666}{1+5.666}$$
$$\boxed{R_{th} = 0.849\,\Omega}$$

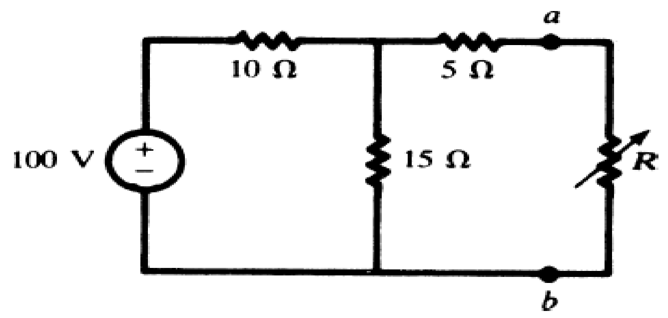
Step 4: To find maximum power transfer to the load (P_{max})

$$\boxed{P_{max} = \frac{V_{th}^2}{4R}}$$

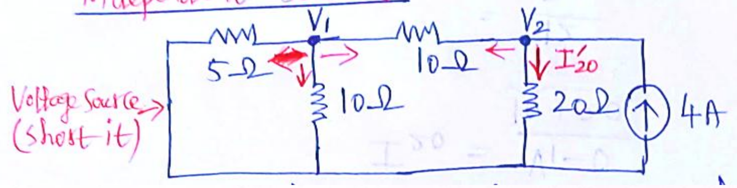


$$= \frac{6.4^2}{4\times 0.849}$$
$$= \frac{40.96}{3.396}$$
$$\boxed{P_{max} = 12.06\,W}$$

2. Find the value of the adjustable resistor R which results in maximum power transfer across the terminals a-b of the circuit shown in Fig. Also, compute the value of maximum power across the terminals a-b.



Step 3: Repeat Step 1 and Step 2 for each of the other independent Sources



Apply KCL at node V_1

$$\frac{V_1-0}{10} + \frac{V_1-0}{5} + \frac{V_1-V_2}{10} = 0$$
$$V_1\left(\frac{1}{10}+\frac{1}{5}+\frac{1}{10}\right) - \frac{V_2}{10} = 0$$
$$0.4V_1 - 0.1V_2 = 0 \quad \text{—(1)}$$

Apply KCL at node V_2

$$\frac{V_2-V_1}{10} + \frac{V_2-0}{20} = 4 \text{ (Incoming Current)}$$
$$-0.1V_1 + V_2\left(\frac{1}{10}+\frac{1}{20}\right) = 4$$
$$-0.1V_1 + 0.15V_2 = 4 \quad \text{—(2)}$$

From Eqs (1) and (2) solve for V_1 and V_2

$$\boxed{\begin{aligned} V_1 &= 8V \\ V_2 &= 32V \end{aligned}}$$

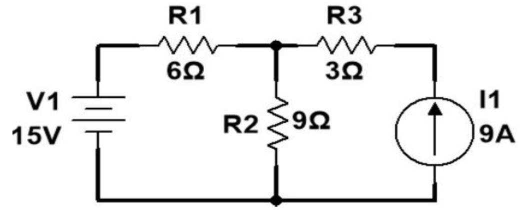
Current passes through 20Ω resistor

$$I'_{20\Omega} = \frac{V_2-0}{20}$$
$$= \frac{32}{20}$$
$$\boxed{I'_{20\Omega} = 1.6A}$$

Summation of Currents $\boxed{I = I_{20\Omega} + I'_{20\Omega}}$

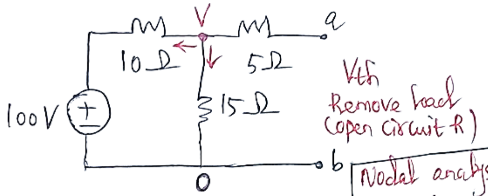
$$= 0.4+1.6$$
$$\boxed{I = 2A}$$

2. Find the current through R_2 resistor in the circuit shown in the Fig using Superposition Theorem.



Sol

Step 1: Remove Load (open circuit R)



Nodal analysis V not applicable to apply 5 Ω resistor because it is open circuit

Step 2: To find Thevenin Voltage (V_{th})

Apply KCL at node V

$$\frac{V-100}{10} + \frac{V-0}{15} = 0$$

$$V\left(\frac{1}{10} + \frac{1}{15}\right) - \frac{100}{10} = 0$$

$$0.1666\, V = 10$$

$$\boxed{\therefore V_{th} = V = 60\,V}$$

Step 3: To find Thevenin Resistance (R_{th})

Deactivate the sources ($V_s = 0 \rightarrow$ short, $I_s = 0 \rightarrow$ open) from step 1 Diagram

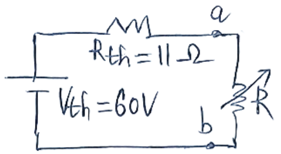
$$R_{th} = 5 + 15 \parallel 10$$

$$= 5 + \frac{15 \times 10}{15 + 10}$$

$$\boxed{R_{th} = R = 11\,\Omega}$$

Step 4: To find maximum power transfer to the load (P_{max})

$$\boxed{P_{max} = \frac{V_{th}^2}{4R}}$$

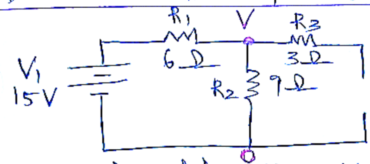


$$= \frac{60^2}{4 \times 11}$$

$$\boxed{P_{max} = 81.82\,W}$$

Sol

Step 1: Deactivate all independent Sources except one Source



3 Ω resistor is in open circuit

Current Source open it

Step 2: To find nodal Voltage V and current passes through $R_2 = 9\,\Omega$ resistor

Apply KCL at node V

$$\frac{V-15}{6} + \frac{V-0}{9} = 0$$

$$V\left(\frac{1}{6} + \frac{1}{9}\right) - \frac{15}{6} = 0$$

$$0.277\,V - 2.5 = 0$$

$$V = \frac{2.5}{0.277}$$

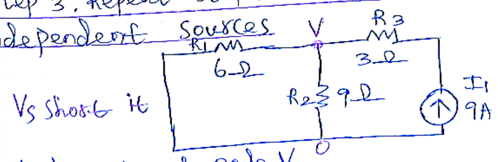
$$V = 9.02\,V$$

Current passes through $R_2 = 9\,\Omega$ resistor

$$I_{9\Omega} = \frac{V-0}{9}$$

$$\boxed{I_{9\Omega} = 1\,A}$$

Step 3: Repeat Step 1 and step 2 for each of the other Independent sources



Apply KCL at node V

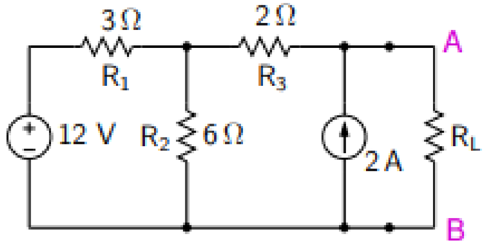
$$\frac{V-0}{6} + \frac{V-0}{9} = 9$$

$$V\left(\frac{1}{6} + \frac{1}{9}\right) = 9$$

$$0.277\,V = 9$$

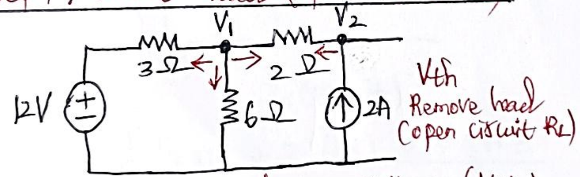
$$V = 32.49\,V$$

3. Find R_L for which P_L is maximum in the circuit shown in Fig using maximum power transfer theorem.



Sol

Step 1 : Remove load (open circuit R_L)



Step 2 : To find Thevenin Voltage (V_{th})

Apply KCL at node V_1

$$\frac{V_1-12}{3}+\frac{V_1-0}{6}+\frac{V_1-V_2}{2}=0$$

$$V_1\left(\frac{1}{3}+\frac{1}{2}+\frac{1}{6}\right)-\frac{V_2}{2}-\frac{12}{3}=0$$

$$V_1-0.5V_2=4 \quad \text{—— (1)}$$

Apply KCL at node V_2

$$\frac{V_2-V_1}{2}=2 \quad \text{(Incoming Current)}$$

$$-0.5V_1+0.5V_2=2 \quad \text{—— (2)}$$

From Eqs (1) and (2) solve for V_1 and V_2

$$\boxed{\begin{aligned}V_1&=12V\\ V_2&=16V\end{aligned}}$$

$$\boxed{\therefore V_{th}=V_2=16V}$$

Current passes through $R_2=9\Omega$ resistor

$$I'_{9\Omega}=\frac{V-0}{9}$$

$$=\frac{32.49}{9}$$

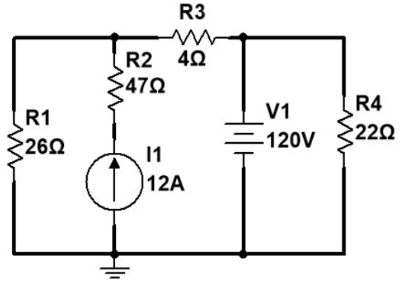
$$\boxed{I'_{9\Omega}=3.61A}$$

Summation of Currents $\boxed{I=I_{9\Omega}+I'_{9\Omega}}$

$$=1+3.61$$

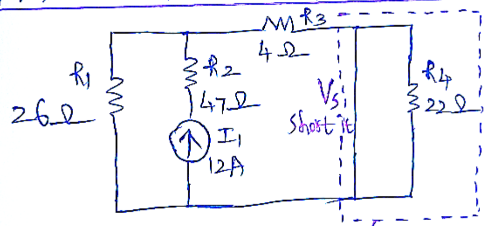
$$\boxed{I=4.61A}$$

3. Compute the current in the 26Ω resistor of Fig, by applying the superposition principle.



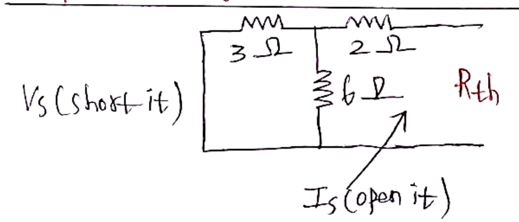
Sol

Step 1 : Deactivate all independent sources except one source



$$0\,||\,22=\frac{0\times22}{0+22}=0$$

Step 3: To find Thevenin Resistance (R_{th})



Deactivate the sources ($V_s \to$ short, $I_s = 0 \to$ open) from step 1 Diagram

$R_{th} = 3 \parallel 6 + 2$ (OR) $\underline{2 + 6 \parallel 3}$

parallel

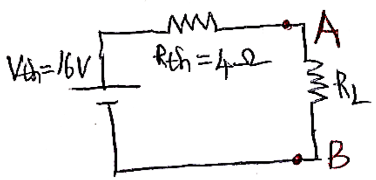
$= \frac{3 \times 6}{3+6} + 2$

$= 4\,\Omega$

$\boxed{\therefore R_{th} = R_L = 4\,\Omega}$

Step 4: To find maximum power transfer to the load (P_{max})

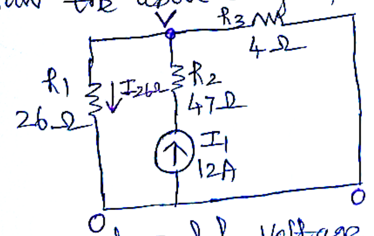
$$\boxed{P_{max} = \frac{V_{th}^2}{4R_L}}$$



$$= \frac{16^2}{4 \times 4}$$

$$\boxed{P_{max} = 16\,W}$$

Redraw the above diagram



Step 2: To find nodal voltage V and Current passes through 26 Ω resistor

Apply KCL at node V

$$\frac{V-0}{26} + \frac{V-0}{4} = 12$$

$$V\left(\frac{1}{26} + \frac{1}{4}\right) = 12$$

$$0.288\,V = 12$$

$$V = 41.66\,V$$

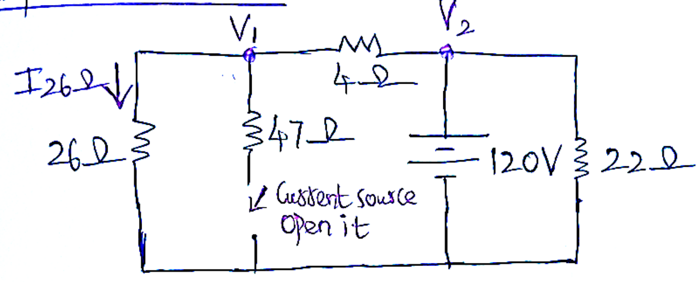
Current passes through 26 Ω resistor

$$I_{26\Omega} = \frac{V-0}{26}$$

$$= \frac{41.66}{26}$$

$$\boxed{I_{26\Omega} = 1.60\,A}$$

Step 3: Repeat step 1 and step 2 for each of the other independent sources



$\therefore V_2 = 120\,V$

Current passes through 26 Ω resistor

$$I'_{26\Omega} = \frac{V_2 - 0}{26+4}$$

$$= \frac{120}{30}$$

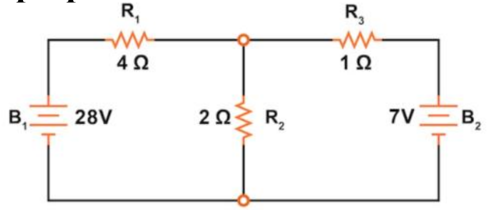
$$\boxed{I'_{26\Omega} = 4A}$$

Summation of currents $\boxed{I = I_{26\Omega} + I'_{26\Omega}}$

$$= 1.60 + 4$$

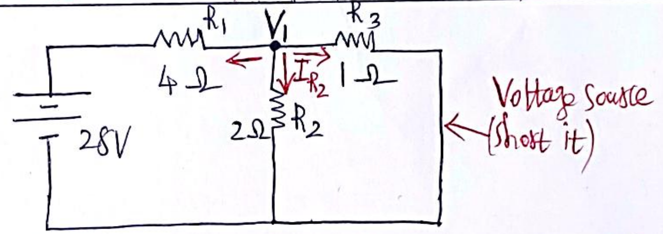
$$\boxed{I = 5.60A}$$

4. Calculate the current passes through the 2Ω resister in the given network using the superposition theorem.



Sol

Step 1: Deactivate all independent Sources except one Source



Step 2: To find nodal Voltage V_1 and current passes through the 2Ω resistor

Apply KCL at node V_1

$$\frac{V_1-28}{4}+\frac{V_1-0}{2}+\frac{V_1-0}{1}=0$$

$$V_1\left(\frac{1}{4}+\frac{1}{2}+1\right)-\frac{28}{4}=0$$

$$1.75V_1=7$$

$$\boxed{V_1=4V}$$

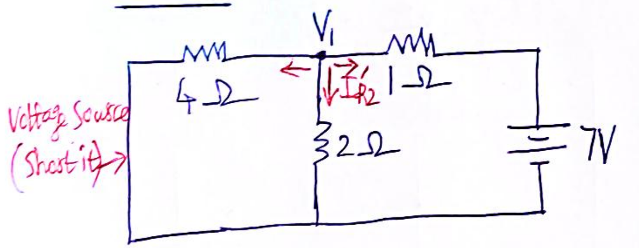
Current passes through 2Ω resistor

$$I_{R_2}=\frac{V_1-0}{R_2}$$

$$=\frac{4}{2}$$

$$I_{R_2}=2A$$

Step 3: Repeat Step 1 and Step 2 for each of the other independent sources.



Apply KCL at node V_1

$$\frac{V_1-0}{4}+\frac{V_1-0}{2}+\frac{V_1-7}{1}=0$$

$$V_1\left(\frac{1}{4}+\frac{1}{2}+1\right)-7=0$$

$$1.75V_1=7$$

$$\boxed{V_1=4V}$$

Current passes through 2Ω resistor

$$\boxed{I'_{R_2}=\frac{V_1-0}{R_2}}$$

$$=\frac{4}{2}$$

$$\boxed{I'_{R_2}=2A}$$

Summation of currents,

$$\boxed{I=I_{R_2}+I'_{R_2}}$$

$$=2+2$$

$$\boxed{I=4A}$$