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Unit - II
2.7 Thevenin's and Norton's Theorem

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Syllabus

UNIT – II **14 Periods**

DC Circuit Analysis: Voltage source and current sources, ideal and practical, Kirchhoff's laws and applications to network solutions using mesh analysis, - Simplifications of networks using series- parallel, Star/Delta transformation, DC circuits-Current-voltage relations of electric network by mathematical equations to analyse the network (Superposition theorem, Thevenin's theorem, Maximum Power Transfer theorem), Transient analysis of R-L, R-C and R-L-C Circuits.

AC Steady-state Analysis: AC waveform definitions - Form factor - Peak factor - study of R-L - R-C -RLC series circuit - R-L-C parallel circuit - phasor representation in polar and rectangular form - concept of impedance - admittance - active - reactive - apparent and complex power - power factor, Resonance in R-L-C circuits - 3 phase balanced AC Circuits

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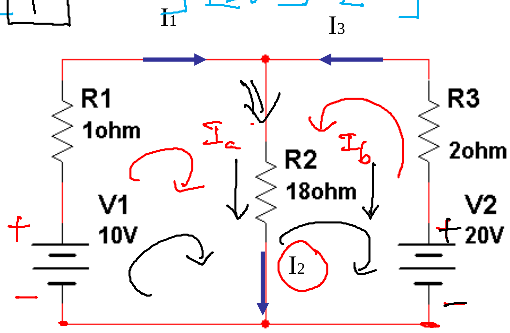
$$\begin{bmatrix} 19 & \boxed{+} \\ \boxed{+} & 20 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \end{bmatrix} = \begin{bmatrix} 10 \\ 20 \end{bmatrix}$$

Example



Mesh (a),

$$+10 - 1I_a - 18(I_a+I_b) = 0$$

$$-19I_a - 18I_b = -10$$

Mesh (b)

$$20 - 2I_b - 18(I_a+I_b) = 0$$

$$-18I_a - 20I_b = -20$$

$$18I_a + 20I_b = 20 \quad \text{--- (2)}$$

$$19I_a + 18I_b = 10 \quad \text{--- (1)}$$

$$\begin{bmatrix} 18 & 20 \\ 19 & 18 \end{bmatrix}$$

$$\boxed{\begin{aligned} I_a &= -2.86 \\ I_b &= 3.571 \end{aligned}}$$

$$\Rightarrow \begin{bmatrix} 19 & \boxed{+18} \\ \boxed{+18} & 20 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \end{bmatrix} = \begin{bmatrix} 10 \\ 20 \end{bmatrix}$$

$$\boxed{I_2 = I_a + I_b = 0.71}$$

Online Circuit Simulator

https://www.circuitlab.com/editor/#

⇒ https://www.falstad.com/circuit/

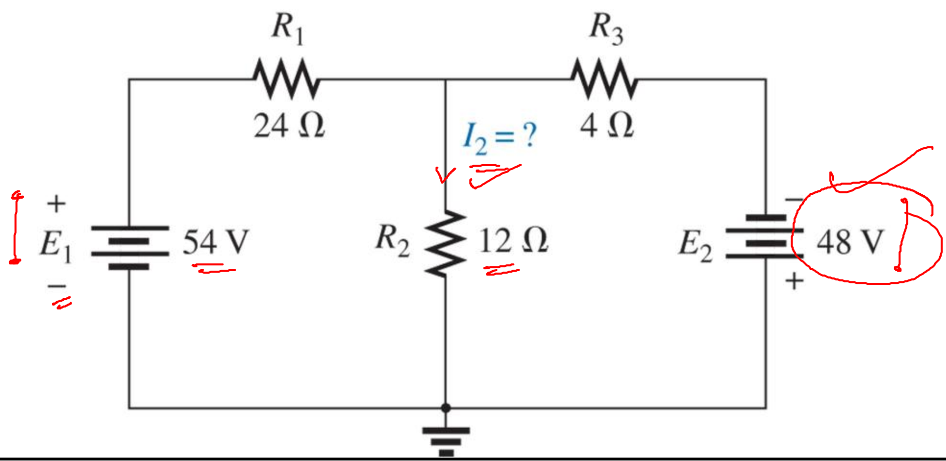
↓

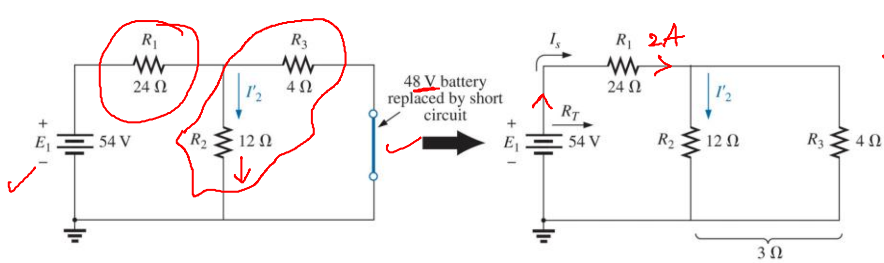
Visualisation

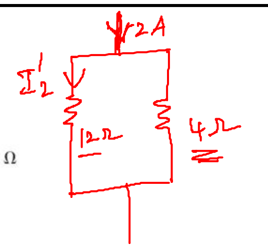
(V) → sc
(I) → oc.

Example

- Determine the current in the 12 Ω resistor using superposition method.

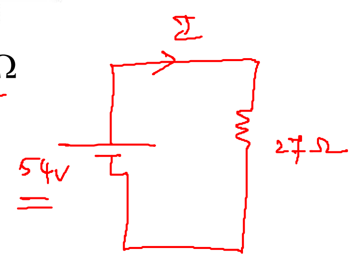






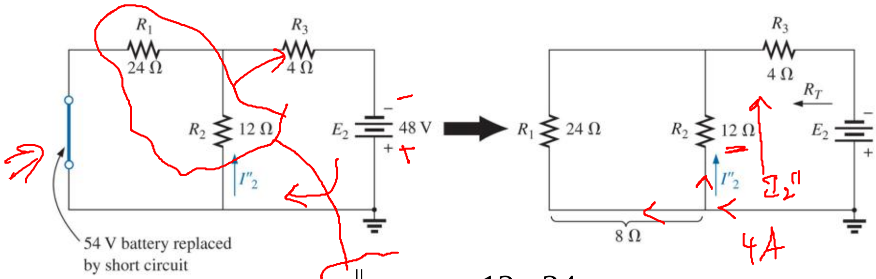
$$R_T = R_1 + R_2 \| R_3 = 24 + \frac{12 \times 4}{12+4} = 24 + 3 = 27\Omega$$

$$I_s = \frac{E_1}{R_T} = \frac{54}{27} = 2A$$



Used current devider rule to determine I'$_2$

$$I'_2 = \left(\frac{R_3}{R_3 + R_2}\right) I_s = \frac{4}{4+12} \times 2 = 0.5A \Leftarrow I_2' = \frac{4}{12+4} \times 2$$



$$R_T = R_3 + R_2 \| R_1 = 4 + \frac{12 \times 24}{12 + 24} = 4 + 8 = 12\Omega$$

$$I_s = \frac{E_1}{R_T} = \frac{48}{12} = 4A$$

Used current devider rule to determine I''$_2$

$$I''_2 = \left(\frac{R_1}{R_1 + R_2}\right) I_s = \frac{24}{24 + 12} \times 4 = 2.677A$$

To determine current I_2 for the network:

Superposition

>1 Source

↓

1 Source at a time

↳ other Sources OFF

(V) → SC

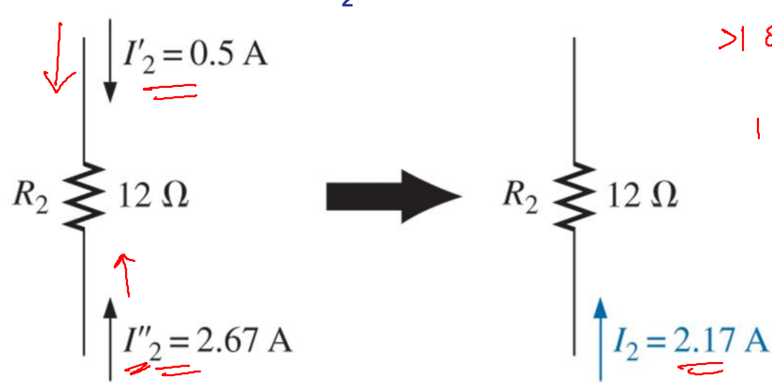
(I) → OC

↓

Individual response

↓

Algebraic Sum



The net current therefore is the difference of the two and in the direction of the larger current:

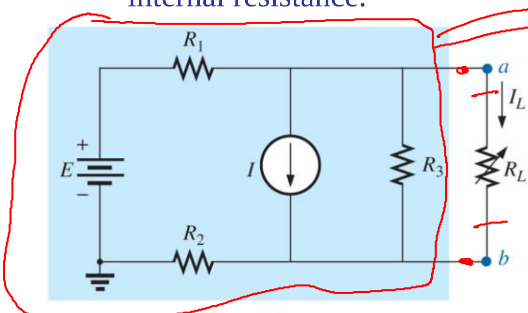
$$I_2 = I''_2 - I'_2 = 2.667 - 0.5 = 2.167A$$

Thevenin's Theorem

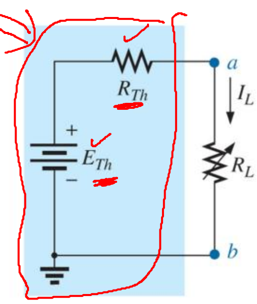
V → SC
I → OC

Thevenin's Theorem state that,

An active network having two terminals A and B can be replaced by a constant-voltage source having an e.m.f 'E' and internal resistance r. The value of E is equal to the open-circuit potential difference between A and B with the load disconnected and the source of e.m.f replaced by their internal resistance.



(a)

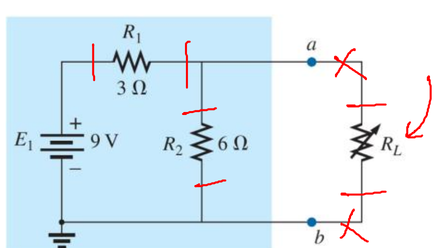


(b)

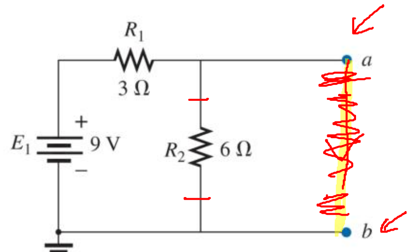
Thevenin's Theorem Procedure

V → SC
V → V=0
I → I=0
I → OC

open circuit →



Original



Step 1 and 2

	OC	SC
I	0	I
V	V	0

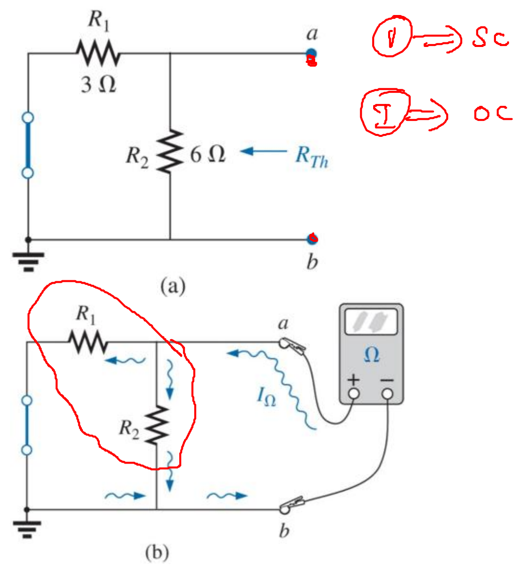
Step 1: Remove the load resistor R_L.

Step 2 : Mark the terminal as a and b. We have an open circuit across terminal a and b.

E_{th} / V_{th}
↓
R_{th}

Thevenin's Theorem Procedure

- Step 3:
  - Replace the voltage source with a short-circuit equivalent.
  - Calculate the R_{TH}



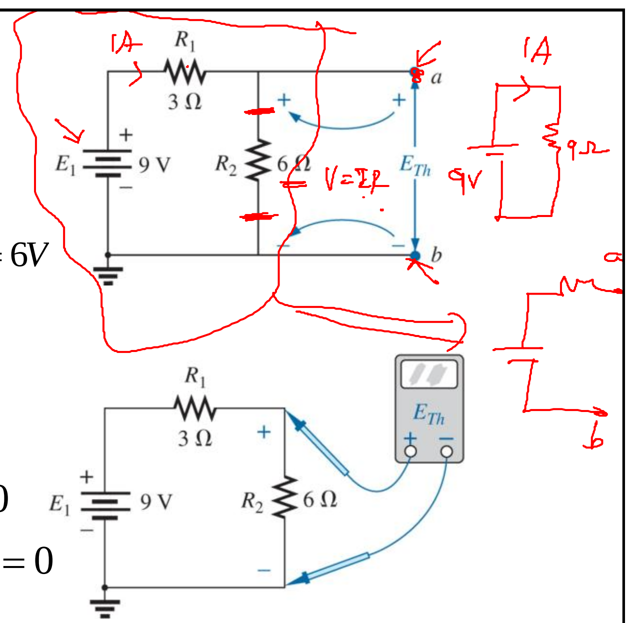
$$R_{TH} = R_1 \| R_2 = \frac{3\times 6}{3+6} = 2\Omega$$

- Step 4:
  - Put back the voltage source. Apply voltage devider rule to find V_{TH}

$$E_{Th} = \frac{R_2}{R_2+R_1}\times E = \frac{6\times 9}{6+3} = \frac{54}{9} = 6V$$

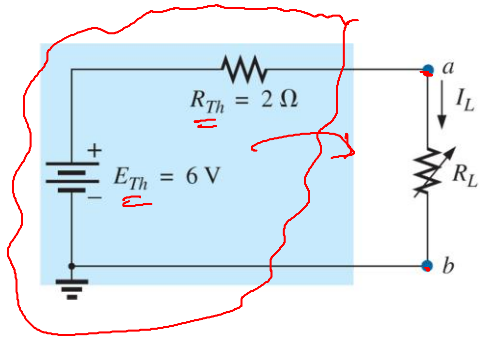
- Or using Mesh current analysis:

Loop 1	Loop2
$9-3I-6I=0$	$-E_{Th}+6I=0$
$9-9I=0$	$-E_{Th}+6(1V)=0$
$9=9I$	$E_{Th}=6V$
$I=1A$	



Thevenin’s Theorem Procedure

- Step 5:
  - Draw the Thevenin equivalent circuit.
  - Placed the R_L. Across terminal a and b.
- Addition:
  - If require to measure current I_L,

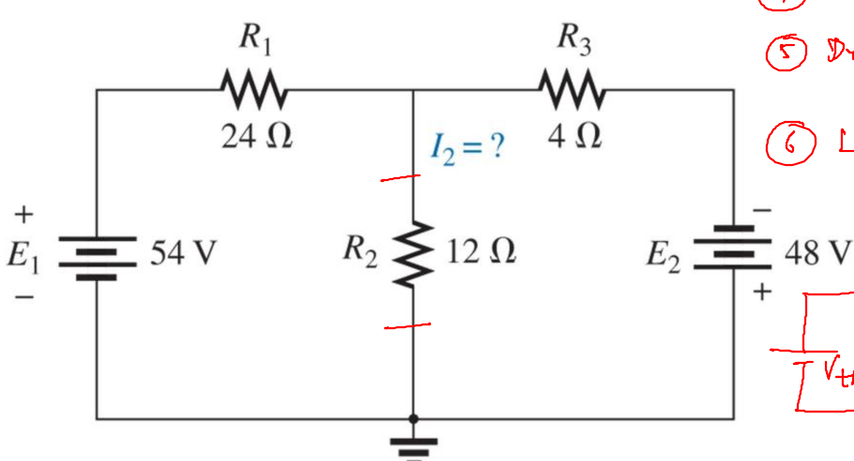


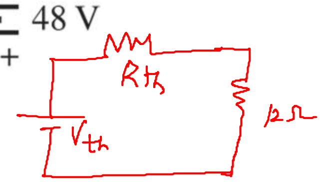
$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

Example 4

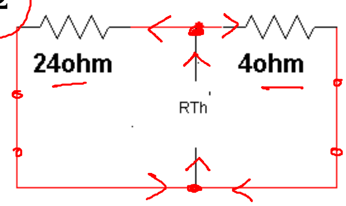
1. Remove R_L
2. Turn-off Sources
3. R_{th}
4. V_{th}
5. Draw Thevenin's equivalent
6. Load current

- Determine the current in the 12 Ω resistor





$$R_{TH} = R_1 \| R_3 = \frac{24 \times 4}{24+4} = 3.42\Omega$$



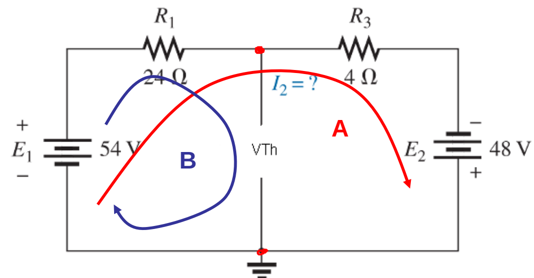
Apply KVL to Loop A

$$54 - 24I - 4I + 48 = 0$$

$$102 - 28I = 0$$

$$I = \frac{102}{28} = 3.643A$$

Apply KVL to Loop B

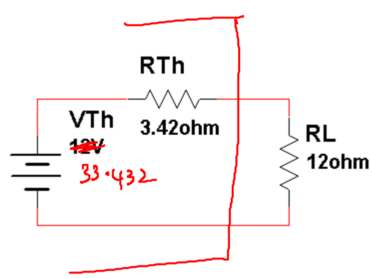


$$54 - 24I + V_{Th} = 0$$

$$V_{Th} = -54 + 24(3.643)$$

$$V_{Th} = 33.432V$$

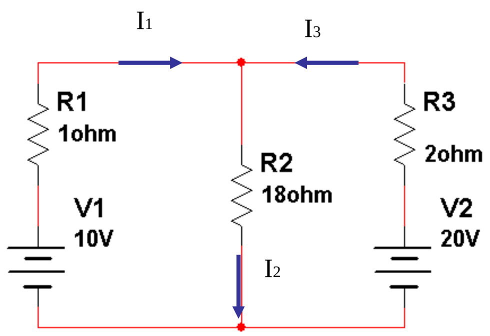
- The Thevenin equivalent circuit



- Current across 12 Ω resistor is:

$$I_{12\Omega} = \frac{33.432V}{3.42+12} = 2.168A$$

Practice Problem



Find the current through 2 ohm resistor using Thevenin's theorem

Summary

Superposition method

↳ Revisited mesh

↳ CW current

Thevenin's theorem

↳ V_{Th}

↳ R_{Th}

$I_L = ?$

online Simulators.