T2-9.6 NORTON THEOREM

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
B.E: Electronics & Communication Engineering / B.E: Electronics & Telecommunication Engineering
NEP, Outcome Based Education (OBE) and Choice Based Credit System (CBCS)
(Effective from the academic year 2021 – 22)

IV Semester

Circuits & Controls			
Course Code	**21EC43**	CIE Marks	50
Teaching Hours/Week (L: T: P: S)	(3:0:2:0)	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 13 Lab slots	Total Marks	100
Credits	04	Exam Hours	03

Module-1	
Basic concepts and network theorems Types of Sources, Loop analysis, Nodal analysis with independent DC and AC Excitations. (Textbook 1: 2.3, 4.1, 4.2, 4.3, 4.4, 10.6) Super position theorem, Thevenin's theorem, Norton's Theorem, Maximum Power transfer Theorem. (Textbook 2: 9.2, 9.4, 9.5, 9.7)	
Teaching-Learning Process	Chalk and Talk, YouTube videos, Demonstrate the concepts using circuits **RBT Level:** L1, L2, L3

Module-2	
Two port networks: Short- circuit Admittance parameters, Open- circuit Impedance parameters, Transmission parameters, Hybrid parameters (Textbook 3: 11.1, 11.2, 11.3, 11.4, 11.5) **Laplace transform and its Applications**: Step Ramp, Impulse, Solution of networks using Laplace transform, Initial value and final value theorem (Textbook 3: 7.1, 7.2, 7.4, 7.7, 8.4)	
Teaching-Learning Process	Chalk and Talk **RBT Level:** L1, L2, L3
Module-3	
Basic Concepts and representation: Types of control systems, effect of feedback systems, differential equation of physical systems (only electrical systems), Introduction to block diagrams, transfer functions, Signal Flow Graphs (Textbook 4: Chapter 1.1, 2.2, 2.4, 2.5, 2.6)	
Teaching-Learning Process	Chalk and Talk, YouTube videos **RBT Level:** L1, L2, L3

Module-4	
Time Response analysis: Time response of first order systems. Time response of second order systems, time response specifications of second order systems (Textbook 4: Chapter 5.3, 5.4) **Stability Analysis:** Concepts of stability necessary condition for stability, Routh stability criterion, relative stability Analysis (Textbook 4: Chapter 5.3, 5.4, 6.1, 6.2, 6.4, 6.5)	
Teaching-Learning Process	Chalk and Talk, Any software tool to show time response **RBT Level:** L1, L2, L3
Module-5	
Root locus: Introduction the root locus concepts, construction of root loci (Textbook 4: 7.1, 7.2, 7.3) **Frequency Domain analysis and stability**: Correlation between time and frequency response and Bode plots (Textbook 4: 8.1, 8.2, 8.4) **State Variable Analysis:** Introduction to state variable analysis: Concepts of state, state variable and state models. State model for Linear continuous –Time systems, solution of state equations. (Textbook 4: 12.2, 12.3, 12.6)	
Teaching-Learning Process	Chalk and Talk, Any software tool to plot Root locus, Bode plot **RBT Level:** L1, L2, L3

Suggested Learning Resources:

Text Books

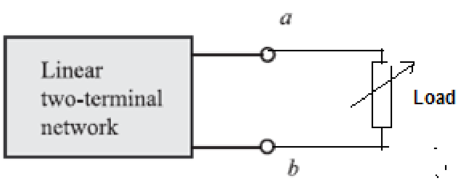
1. Engineering circuit analysis, William H Hayt, Jr, Jack E Kemmerly, Steven M Durbin, Mc Graw Hill Education, Indian Edition 8e.
2. Networks and Systems, D Roy Choudhury, New age international Publishers, second edition.
3. Network Analysis, M E Van Valkenburg, Pearson, 3e.
4. Control Systems Engineering, I J Nagrath, M. Gopal, New age international Publishers, Fifth edition.

9.5 NORTON THEOREM

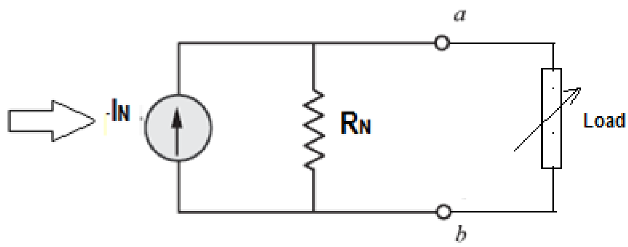
Norton's theorem states that a linear bidirectional two-terminal network can be replaced by an equivalent circuit consisting of a current source I_N in parallel with resistor R_N

$I_N \longrightarrow$ *is the short-circuit current through the terminals*

$R_N \longrightarrow$ *is the input or equivalent resistance at the terminals*



Original circuit



Norton's equivalent circuit

$$R_N = R_{TH}$$

Norton's equivalent resistance = Thevenin's equivalent resistance

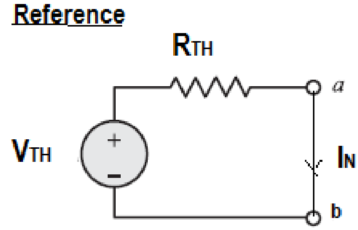
$$R_N = R_{TH}$$

Norton's equivalent resistance = Thevenin's equivalent resistance

$$I_N = \frac{V_{TH}}{R_{TH}} \quad \therefore \quad R_{TH} = \frac{V_{TH}}{I_N}$$

$$R_{TH} = R_N = \frac{V_{TH}}{I_N}$$

Reference



Procedure for finding Norton's equivalent circuit:

(1) <u>If the network contains resistors and independent sources,</u>

(a) Deactivate the sources and find RN by circuit reduction techniques.

(b) Find **iN** with sources activated.

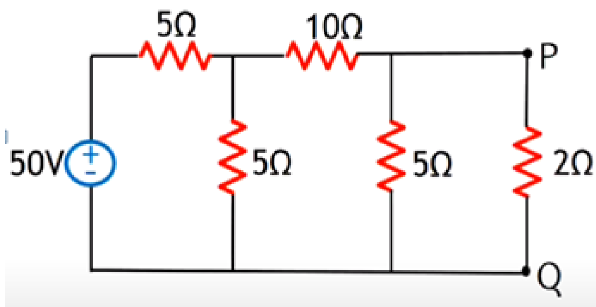
(2) <u>If the network contains resistors, independent and dependent sources,</u>

(a) Determine the short-circuit current **iN** with all sources activated.

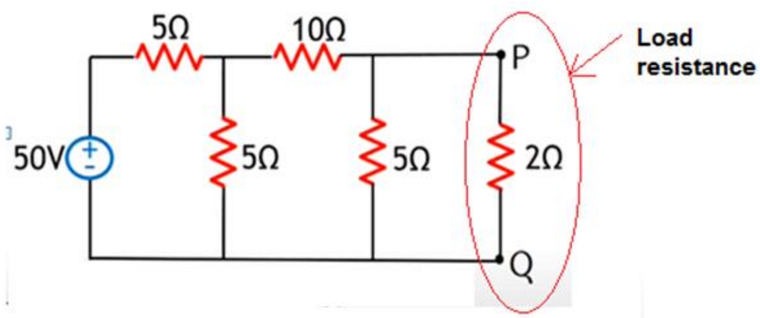
(b) Find the open-circuit voltage **Voc**

$$R_{TH} = R_N = \frac{V_{oc}}{i_N}$$

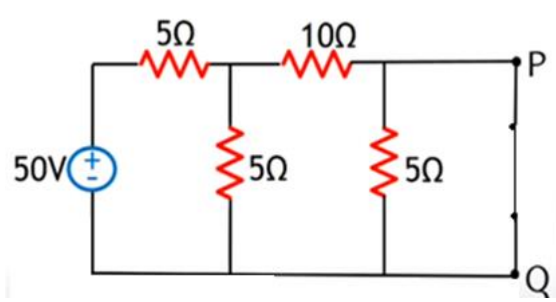
1) Find Norton equivalent circuit for the fig.

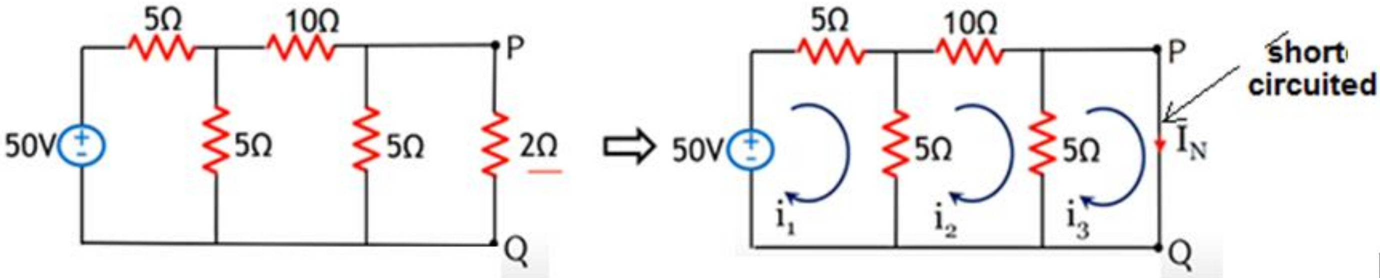


First step is identification of load resistance

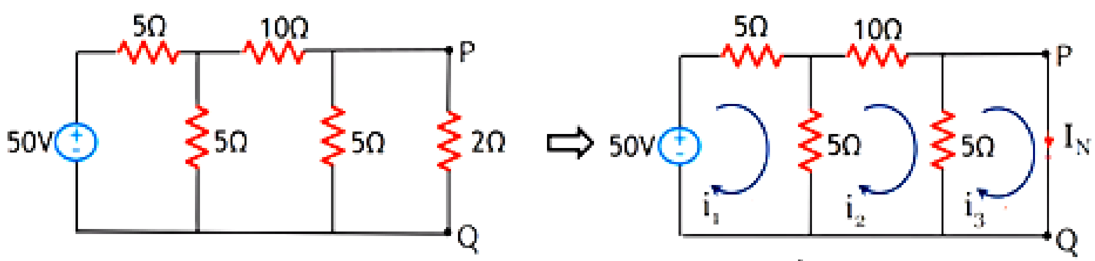


Second step is to replace load resistance by short circuit





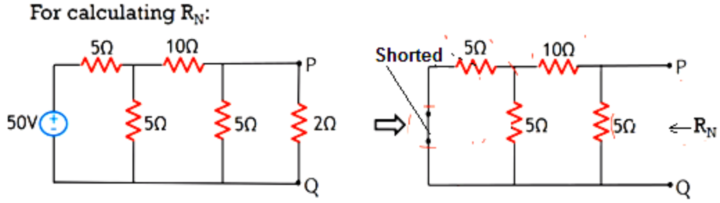
To find the Norton's current apply any network simplification technique in this ckt, apply KVL



For mesh 1,	For mesh 2,	For mesh 3,
$50 = 5\,i_1 + 5\,(i_1 - i_2)$	$0 = 10\,i_2 + 5\,(i_2 - i_1) + 5\,(i_2 - i_3)$	$0 = 5\,(i_3 - i_2)$
$50 = 10 i_1 - 5\,i_2$	$0 = 5\,i_1 - 20\,i_2 + 5\,i_3$	$\boxed{i_2 = i_3 = I_N = 2\text{ A}}$

To find the Norton equivalent resistance deactivate the source and open circuit the load

For calculating R_N:



$R_N = \{(5 \text{ II } 5) + 10\} \text{ II } 5$

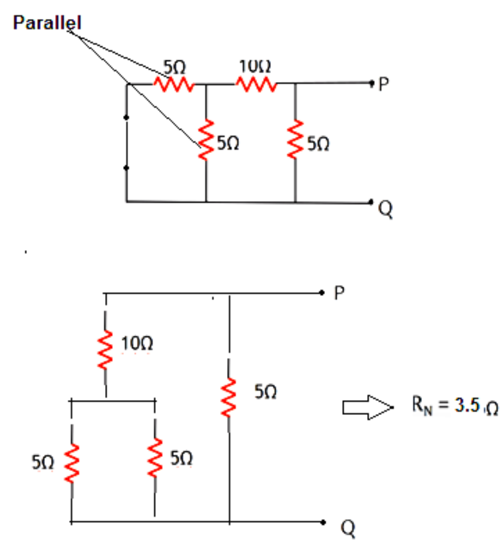
$R_N = \{(\frac{5 * 5}{5+5}) + 10\} \text{ II } 5$

$R_N = \{(2.5) + 10\} \text{ II } 5$

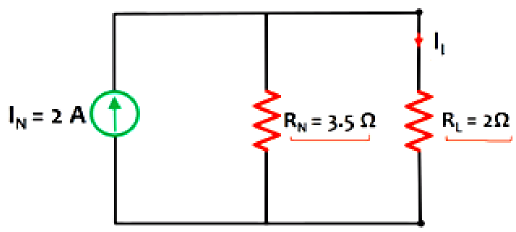
$R_N = (12.5) \text{ II } 5$

$R_N = (\frac{12.5 * 5}{12.5+5})$

$R_N = 3.5\ \Omega$



Norton's Equivalent Circuit:

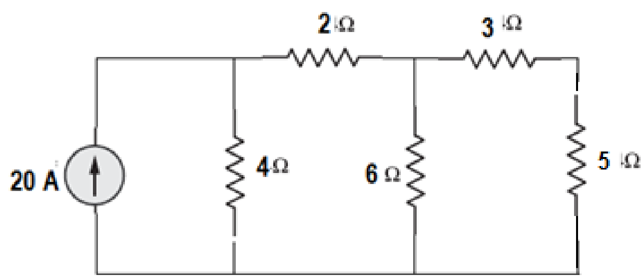


$$I = \frac{I_N R_N}{R_N + R_L}$$

$$I = \frac{2*3.5}{3.5+2} = 1.27 \text{ A}$$

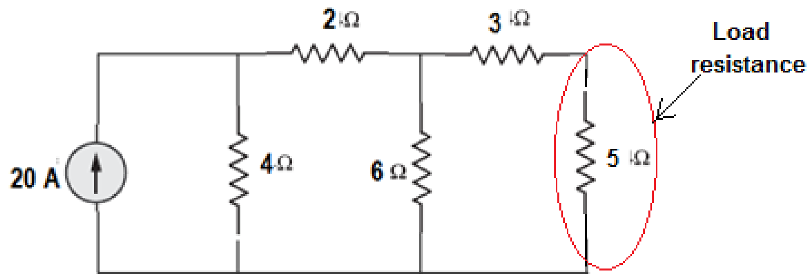
$$\boxed{I = 1.27\ A}$$

2)Find the current flowing through 5Ω resistor

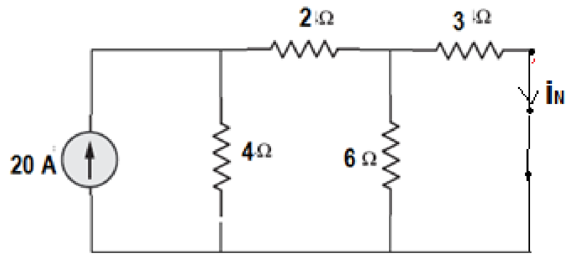


<u>First find in and then find RN</u>

First step identify the load resistance and short

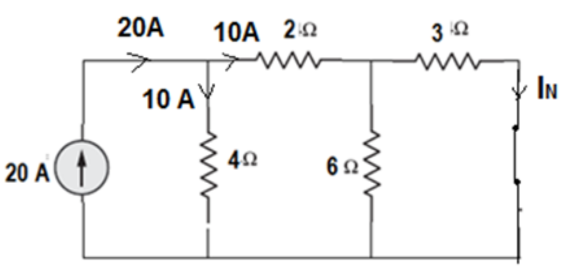


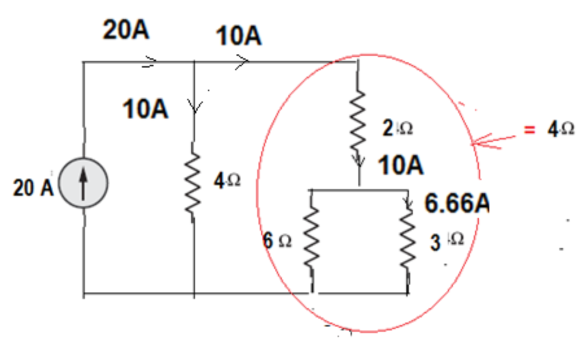
Short circuit the load



The direction of the short circuit current and source current must be the same

The circuit is ready for calculation

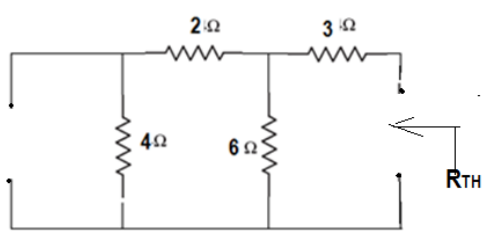


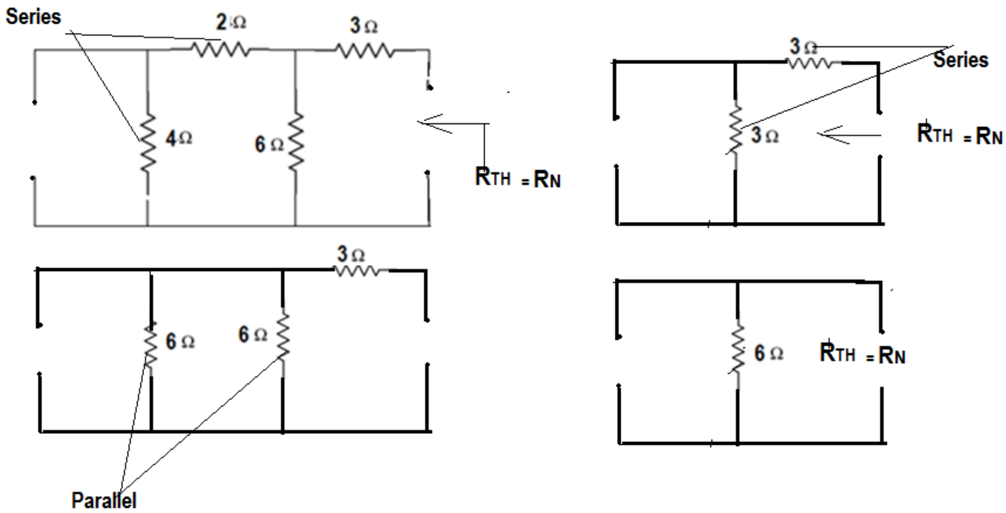


$$I_N = 10 \times \frac{6}{6+3} = 6.66A$$

<u>**To find R_{TH}**</u> **1) Deactivate current source**

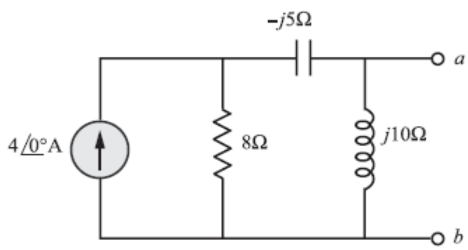
2) Remove load resistance



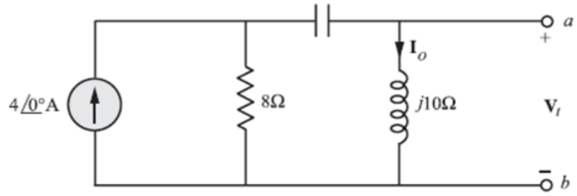


$R_{TH} = R_N = 6\ \Omega$

3)Find the Thevenin and Norton equivalent circuits at the terminals a- b for the circuit



As a first step in the analysis, let us find V_{Th}

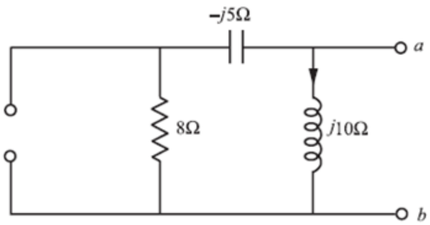


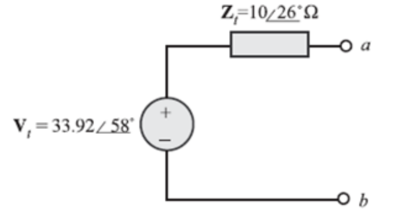
Using the principle of current division,

$$I_o = \frac{8(4\angle 0^\circ)}{8 + j10 - j5} = \frac{32}{8 + j5}$$

$$V_{TH} = I_o(j10) = \frac{j320}{8 + j5} = 33.92\angle 58^\circ \text{ V}$$

To find $\mathbf{Z}_{TH}$ deactivate all the independent sources.





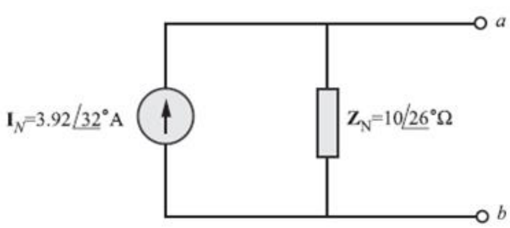
Thevenin equivalent circuit

$$\mathbf{Z}_{TH} = j10 \,||\, (8 - j5)\ \Omega$$

$$= \frac{(j10)(8 - j5)}{j10 + 8 - j5}$$

$$= 10\,\underline{/26^\circ}\ \ \Omega$$

Performing source transformation on the Thevenin equivalent circuit, we get the Norton equivalent circuit.



Norton equivalent circuit

$$\mathbf{I}_N = \frac{\mathbf{V}_{TH}}{\mathbf{Z}_{TH}} = \frac{33.92\,\underline{/58^\circ}}{10\,\underline{/26^\circ}}$$

$$= 3.392\,\underline{/32^\circ}\ \ \mathrm{A}$$

$$\mathbf{Z}_N = \mathbf{Z}_{TH} = 10\,\underline{/26^\circ}\ \ \Omega$$

....

$$\mathbf{Z}_t = j10 \| (8 - j5)\ \Omega$$
$$= \frac{(j10)(8 - j5)}{j10 + 8 - j5}$$
$$= 10\,\underline{/26^\circ}\ \ \Omega$$

The Thevenin equivalent circuit as viewed from the terminals $a - b$ is as shown in Fig 3.103(b). Performing source transformation on the Thevenin equivalent circuit, we get the Norton equivalent circuit.

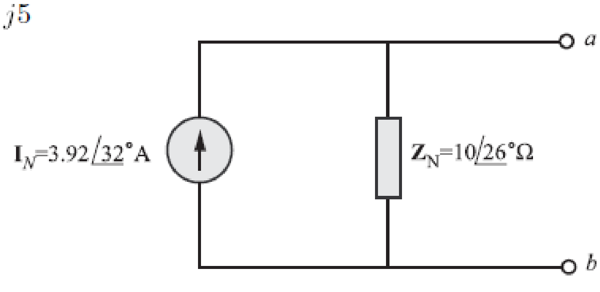


Figure : Norton equivalent circuit

$$\mathbf{I}_N = \frac{\mathbf{V}_t}{\mathbf{Z}_t} = \frac{33.92\,\underline{/58^\circ}}{10\,\underline{/26^\circ}}$$
$$= 3.392\,\underline{/32^\circ}\ \ \mathrm{A}$$
$$\mathbf{Z}_N = \mathbf{Z}_t = 10\,\underline{/26^\circ}\ \ \Omega$$