Network Analysis and Synthesis

Tutorial

ECL 1022

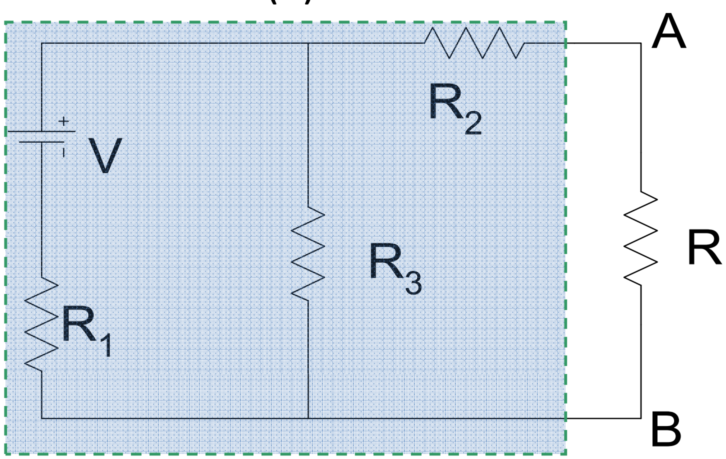
Network Theorems
(as explained in the class)

read it to <u>revise</u> it for clearing any doubuts
Any doubts will be cleared in the next class

Networks to illustrate Thevenin theorem

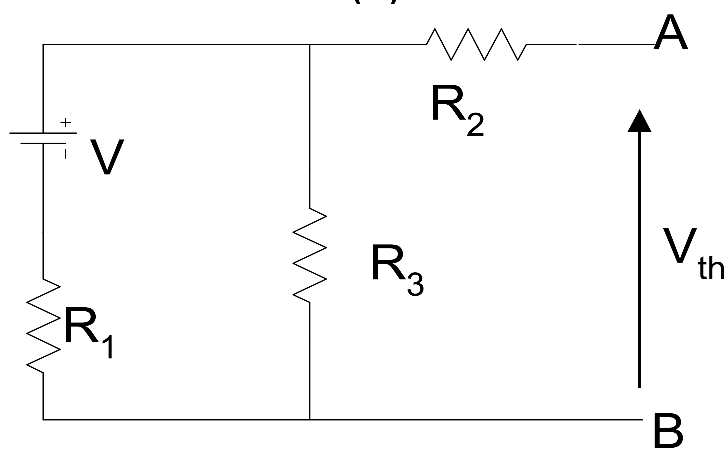
Original (Given) Circuit

(a)

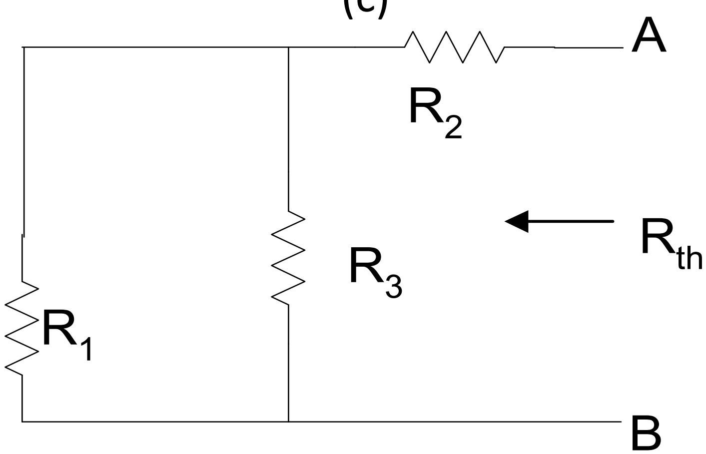


Step I and Step II

(b)

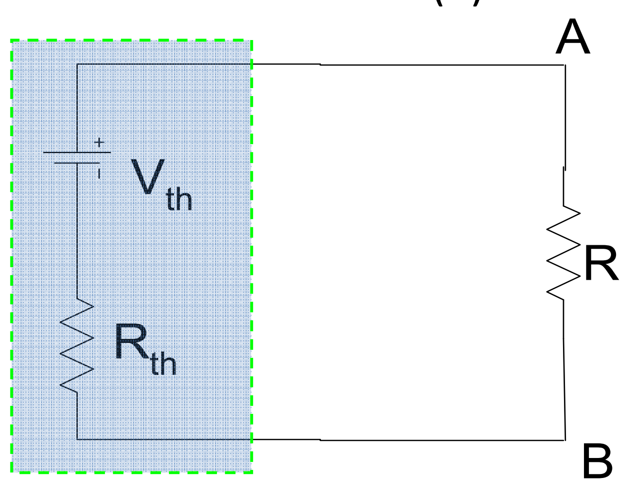


(c)



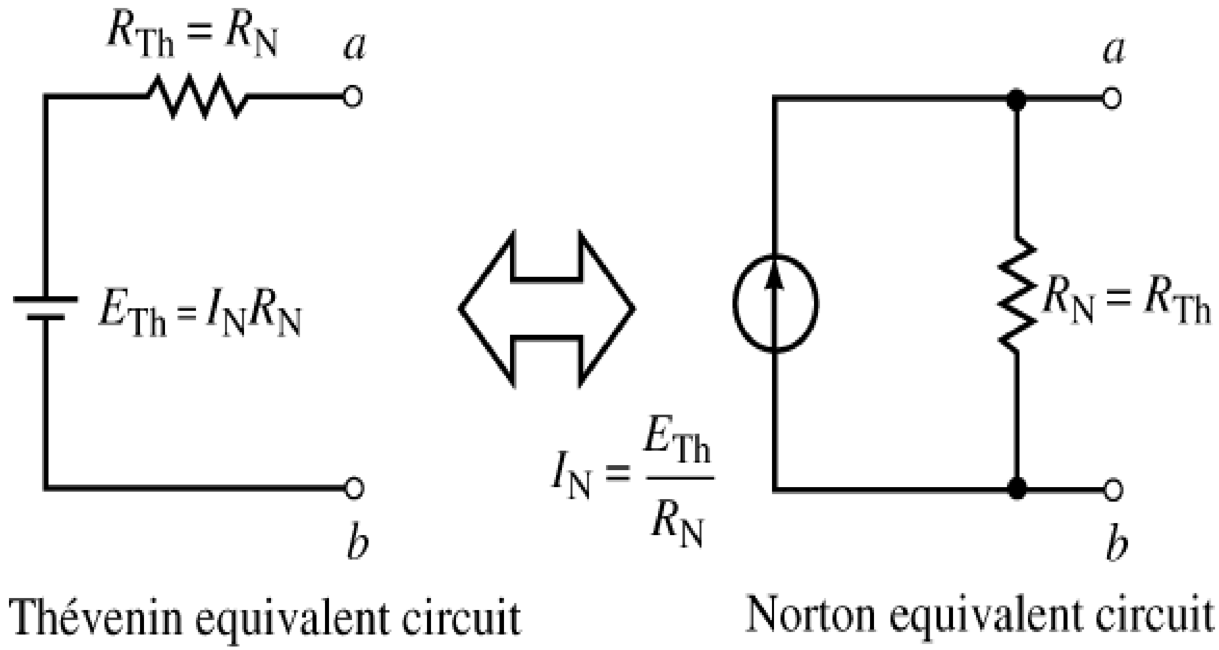
Step III

(d)



Thevenin's Equivalent Circuit

Norton's Theorem



Eth and Vth are used interchangeably

Q. Calculate the current through 8Ω for the network shown in figure (a) **(THEVENIN THEOREM)**

Solution

StepI: Remove 8Ω and replace it with open-circuit (oc) as shown in figure (b)

StepII: With 8Ω disconnected as in figure (b), find Voc using superposition theorem as in figure (c)

Contribution due to E1 (i.e.Eth=Vth=Voc)

$$=> Vth_1 = \frac{12\Omega(18V)}{6\Omega + 12\Omega + 4\Omega} = \frac{216}{22} = 9.82V$$

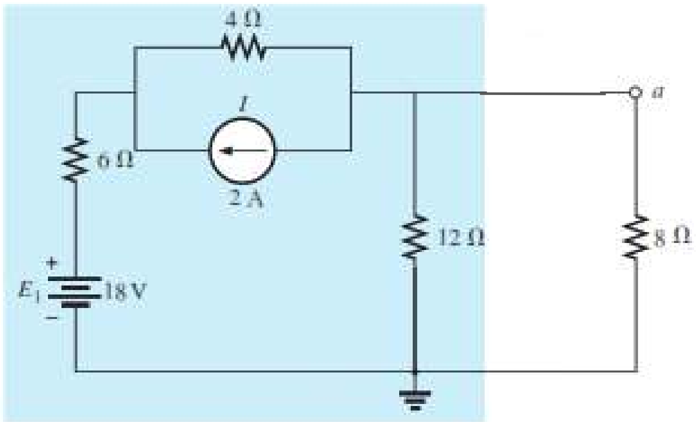
Now contribution due to current source as in figure (d);

Applying current divider rule:

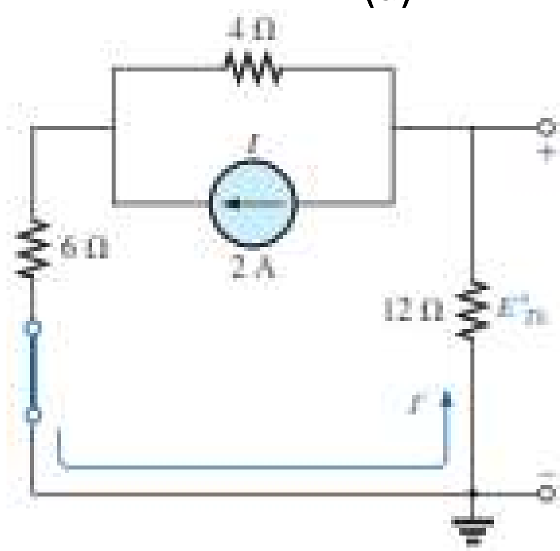
$$I' = \frac{4\Omega(2A)}{4\Omega + 18\Omega} = 0.364A$$

$$=> Vth2 = -I'(12\Omega) = -4.37V$$

$$=> Vth = Vth1 + Vth2 = 9.82V - 4.37V = 5.45V$$



(a)



(b)

continue

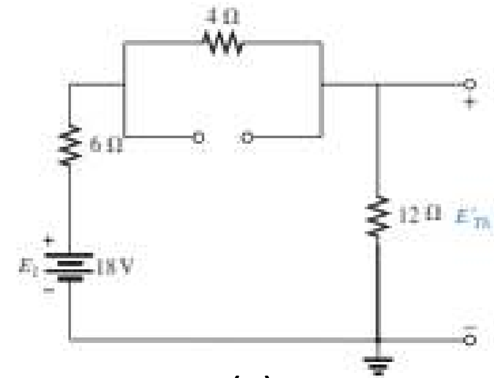
StepIII: Remove the source and replace it with short circuit, and open circuit respectively, and determine the internal resistance (Rth) as in figure (e)

$$Rth = 12\Omega \,||\, (4\Omega + 6\Omega) = 12\Omega \,||\, 10\Omega = 5.45\ \Omega$$

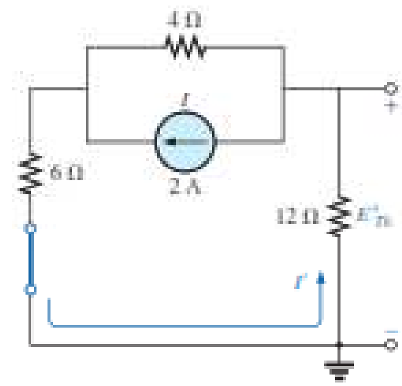
Step IV: Replace the network with V=5.2V and Rth=1.2, then the at terminal CD, R_3, thus the current

$$I = \frac{5.45V}{5.45\Omega + 8\Omega} = 0.4A$$

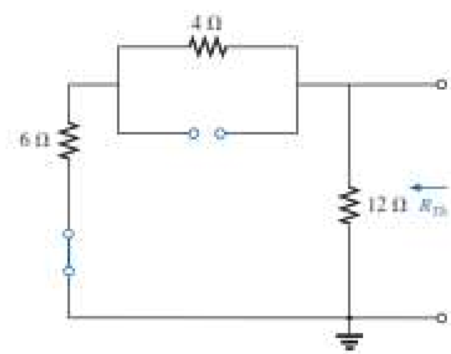
$$Vl = 0.4A * 8\Omega = 3.2V$$



(c)



(d)

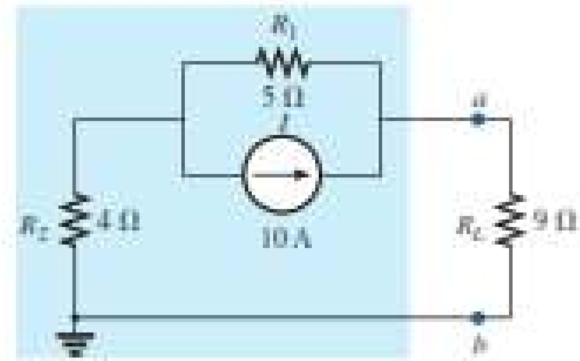


(e)

Q. Calculate the current through 9Ω for the network shown in figure (a) **(NORTON THEOREM)**

Solution

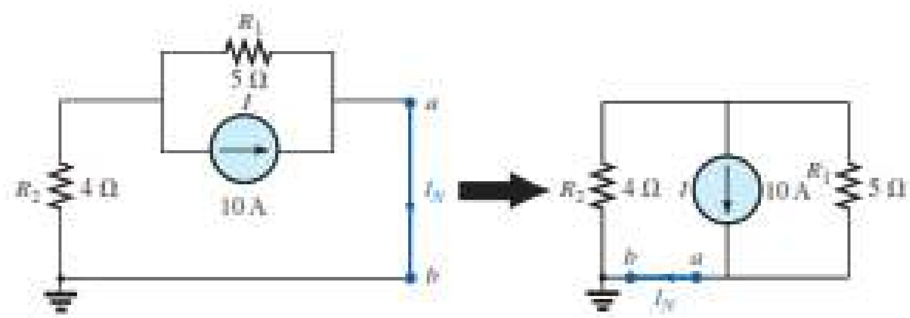
StepI: Remove 9Ω and replace it with short-circuit (sc) as shown in figure (b)



(a)

StepII: With 9Ω disconnected (sc) as in figure (b), find I_N (norton's current) using current divider rule.

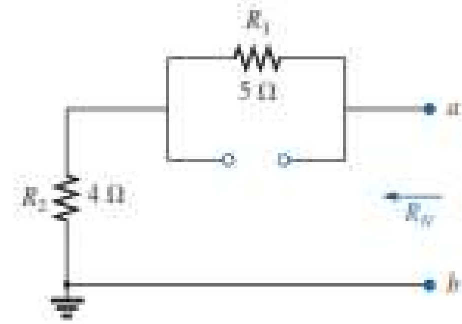
$$=> I_N = \frac{5\Omega(10\,A)}{5\Omega + 4\Omega} = \frac{50\,A}{9} = 5.56\,A$$



(b)

continue

StepIII: Remove the source(s) and replace it with short circuit, and open circuit respectively, and determine the internal resistance (R_N) same way as done for R_{th} as in figure (c)



(c)

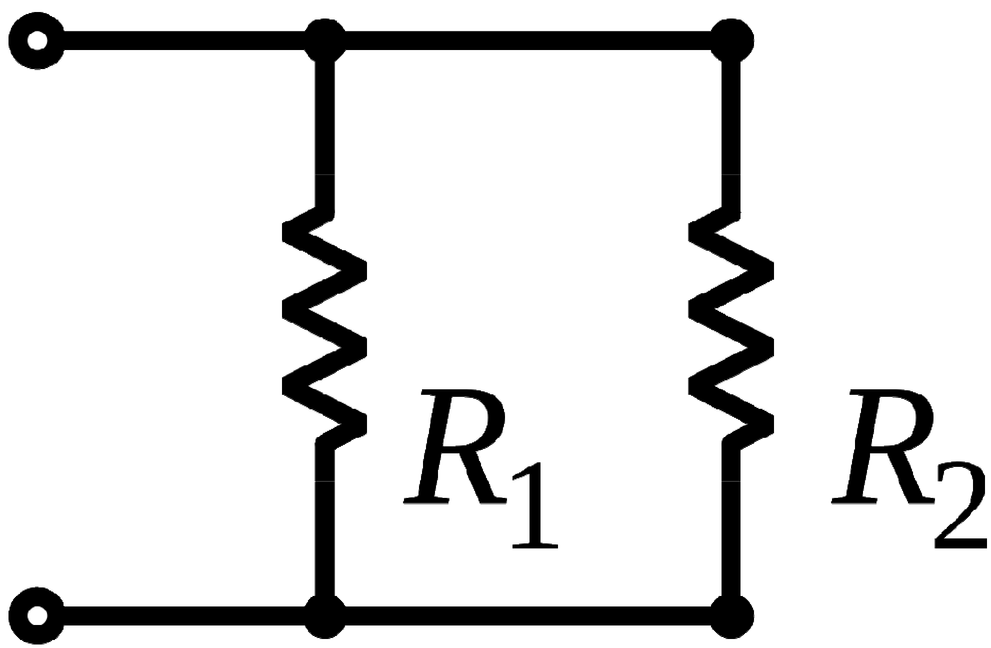
$$R_N = 5\Omega + 4\Omega = 9\Omega$$

Step IV: Norton's Equivalent circuit in figure (d)

Using current divider rule calculate the current in 9Ω.

(d)

Current Divider Rule



Solution

. The equivalent resistance is given by

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

The voltage across the resistances is given by

$$v = R_{eq} i_{total} = \frac{R_1 R_2}{R_1 + R_2} i_{total}$$

Now, we can find the current in each resistance:

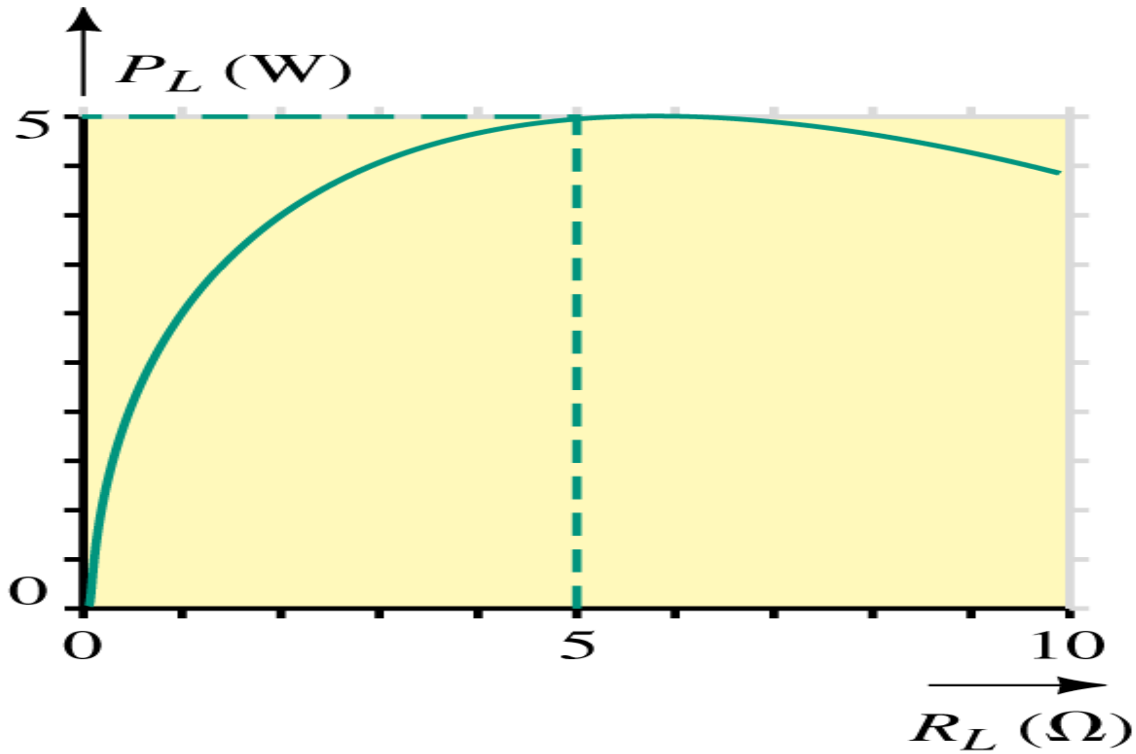
$$\boxed{i_1 = \frac{v}{R_1} = \frac{R_2}{R_1 + R_2} i_{total}}$$

Maximum Power Transfer

- Current through load is one half of Norton equivalent current

$$P_{\max} = \frac{V_{\mathrm{Th}}^{2}}{4R_{\mathrm{Th}}} = \frac{I_{\mathrm{N}}^{2}R_{\mathrm{N}}}{4}$$

Maximum Power Transfer



Efficiency

- To calculate efficiency:

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\%$$

$$\eta = \frac{\dfrac{E_{\text{Th}}{}^{2}}{4R_{\text{Th}}}}{\dfrac{E_{\text{Th}}{}^{2}}{2R_{\text{Th}}}} \times 100\% = 50\%$$

Millman's Theorem

- Used to simplify circuits that have
  - Several parallel-connected branches containing a voltage source and series resistance
  - Current source and parallel resistance
  - Combination of both

Millman's Theorem

- Voltage sources
  - May be converted into an equivalent current source and parallel resistance using source transformation theorem
- Parallel resistances may now be converted into a single equivalent resistance

Millman's Theorem

- **<u>Step I:</u>**
  - First, convert voltage sources into current sources
  - Equivalent current, I_{eq}, is just the algebraic sum of all the parallel currents

Millman's Theorem

- **<u>Step II:</u>**
  - Next, determine equivalent resistance, R_{eq}, the parallel resistance of all the resistors
  - Voltage across entire circuit may now be calculated by:

$$E_{eq} = I_{eq}R_{eq}$$

Millman’s Theorem

- We can simplify a circuit as shown: