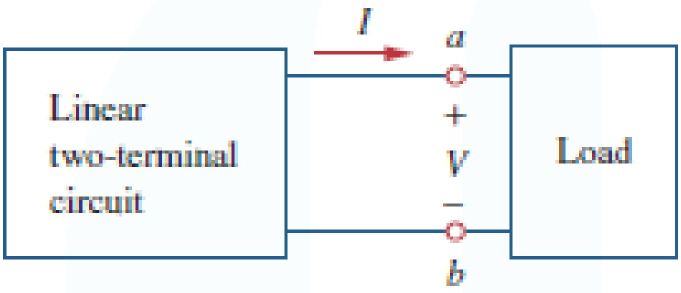
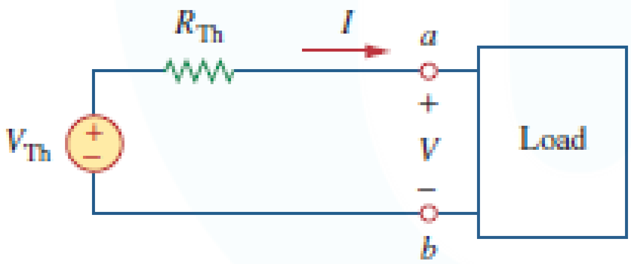
MODULE 1

Thevenin's Theorem

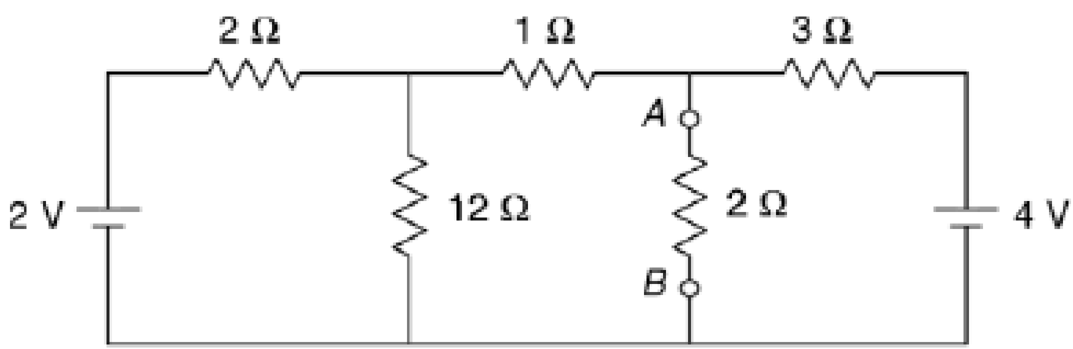
Thevenin's theorem states that any two terminal linear network having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a **single voltage source in series with a resistance**, where the value of the voltage source is equal to the open-circuit voltage across the two terminals of the network, and resistance is equal to the equivalent resistance measured between the terminals with all the energy sources are replaced by their internal resistances.





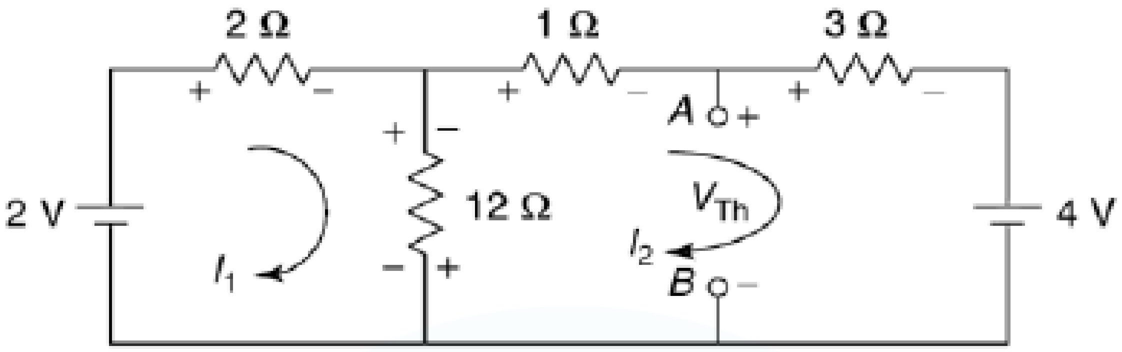
Problem :

Find current through the load across A &B



Solution:

Step 1: Calculation of V_{TH}



Apply KVL on mesh 1

$- 2 + 2(I_1) + 12\ (I_1\text{-}I_2) = 0$

$14I_1$ - $12I_2$ = 2 …….(i)

Apply KVL on mesh 2

$12(I_2\text{-}\ I_1)\text{+}\ 1I_2 + 3I_2 + 4 = 0$

$-12I_1 + 16I_2$ = -4 …….(ii)

Solving (i) and (ii)

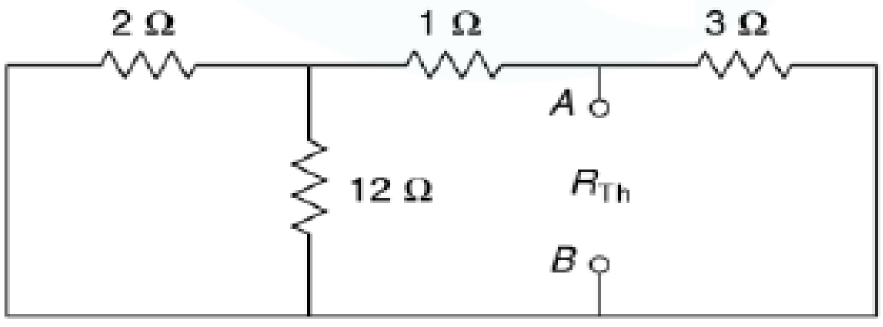
I_1 = -0.2 A $\quad\quad$ I_2 = -0.4 A

Writing V_{TH} equation

$-V_{TH} + 3\ I_2 + 4 = 0$

$V_{TH} = 3\ I_2 + 4 = 3(-0.4) + 4 = 2.8V$

Step 2: Calculation of R_{TH}

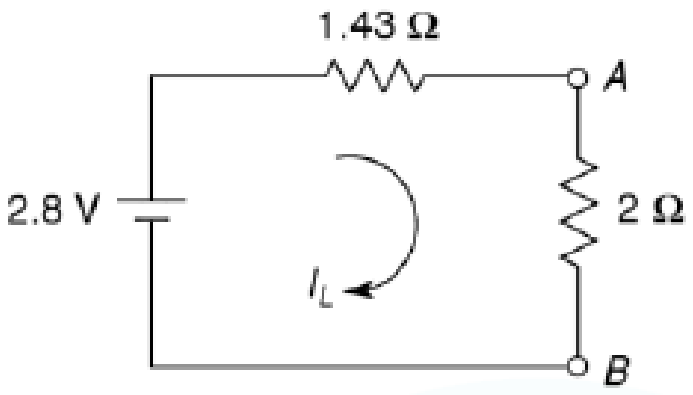


R_{TH} = [(2 || 12) + 1] || 3

= (38/14) || 3

= 1.43 Ω

Step 3: Calculation of I_L

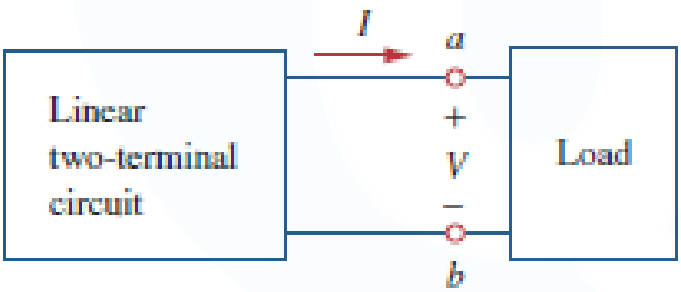


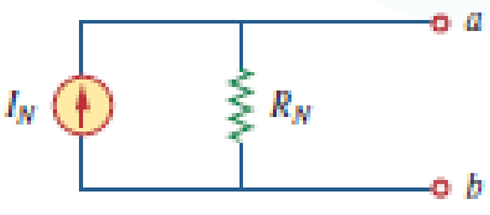
$$I_L = \frac{2.8}{1.43+2}$$

$$= 0.82 \text{ A}$$

Norton's Theorem

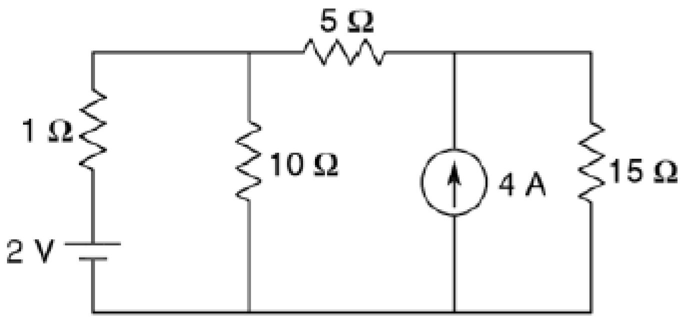
Which states that any two terminal linear network with current sources, voltage sources and resistances can be replaced by an equivalent circuit consisting of a **current source in parallel with a resistance**. The value of the current source is the short-circuit current between the two terminals of the network and the resistance is the equivalent resistance measured between the terminals of the network with all the energy sources are replaced by their internal resistance.





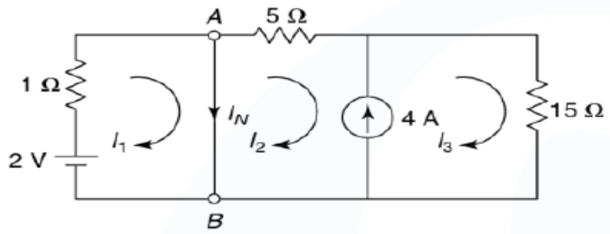
Problem:

Find current through 10 Ohm resistor



Solution:

<u>Step 1: Calculation of I_N</u>



Apply KVL on mesh 1

$-2 + 1I_1 = 0$

I_1 = 2 …….(i)

mesh 2 and 3form super mesh

I_3- I_2 = 4 …..(ii)

Apply KVL on super mesh

5 I_2+ 15I_3 = 0…….(iii)

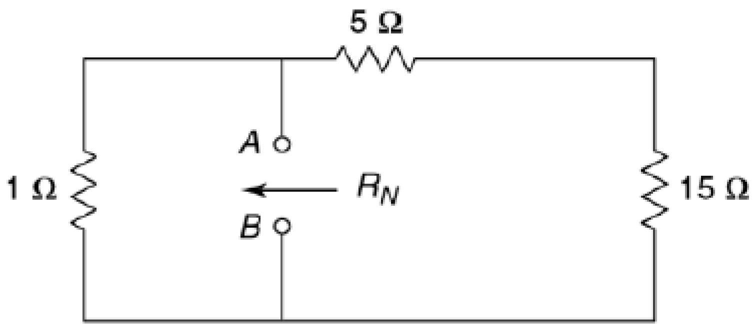
Solving (i) (ii) and (iii)

I_1 = 2 A I_2 = -3 A I_3 = 1 A

Writing I_N equation

$I_N = I_1 - I_2 = 5$ A

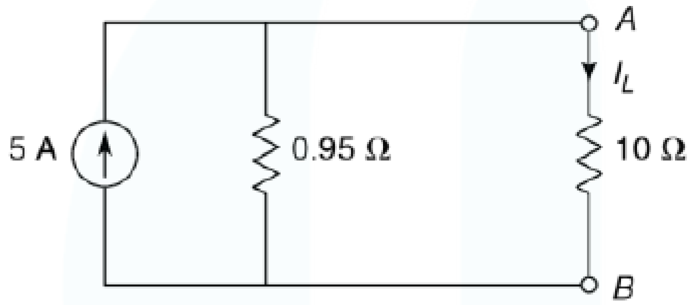
<u>Step 2: Calculation of R_N</u>



R_{TH} = 1 || (5+15)

= 0.95 Ω

Step 3: Calculation of I_L



$$I_L = I_N \times \frac{R_N}{R_N+R_L}$$

$$= 5 \times \frac{0.95}{0.95+10}$$

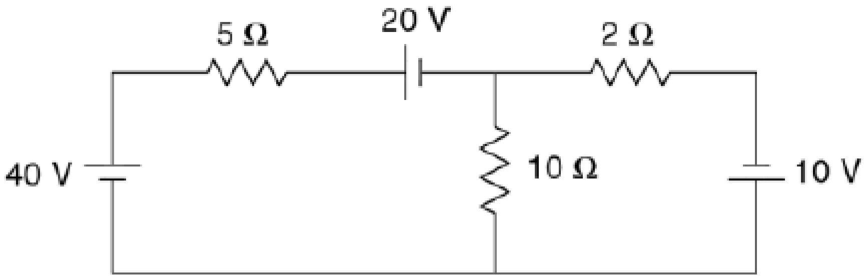
= 0.43 A

SUPERPOSITION THEOREM

The superposition theorem states that in any linear network containing two or more sources, the response in any element is equal to the algebraic sum of the responses caused by individual sources acting alone, while the other sources are non-operative; that is, while considering the effect of individual sources, other ideal voltage sources and ideal current sources in the network are replaced by short circuit and open circuit across their terminals. This theorem is valid only for linear systems.

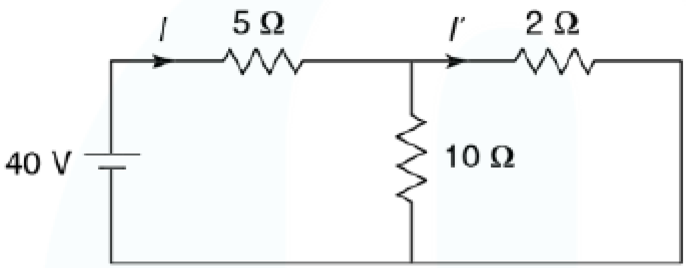
Problem:

Find current through 2 Ohm resistor



Solution:

Step 1: When 40V acting alone



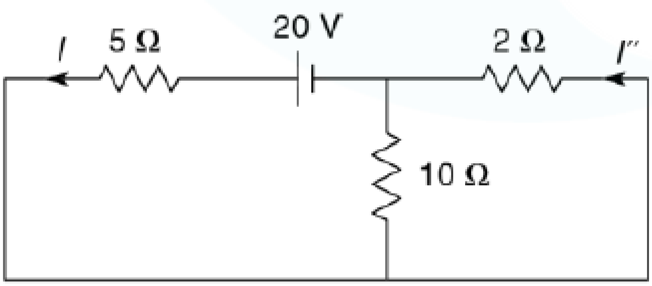
By series parallel reduction technique

I = $\frac{40}{[2||10]+5}$ = 6 A

By current division rule

I' = 6 x $\frac{10}{2+10}$ = 5A (→)

Step 2: When 20V acting alone



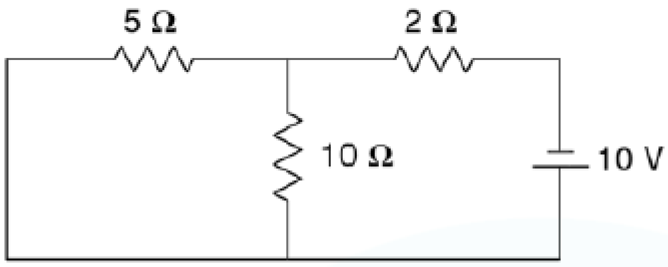
By series parallel reduction technique

I = $\frac{20}{[2||10]+5}$ = 3 A

By current division rule

$I'' = 3 \times \frac{10}{2+10}$ = 2.5 A (←) = -2.5A (→)

Step 3: When 10V acting alone



By series parallel reduction technique

$I''' = \frac{10}{[5||10]+2}$ = 1.88 A(→)

Step 4: By superposition theorem

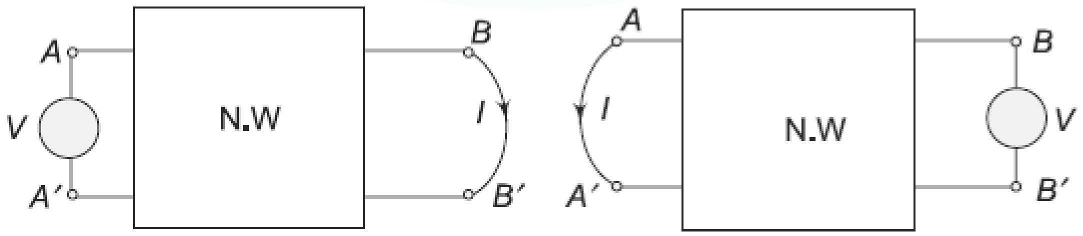
I = I' + I" + I''' = 5-2.5+1.88

= 4.38 A (→)

RECIPROCITY THEOREM

In any linear bilateral network, if a single voltage source Va in branch 'a' produces a current Ib in branch 'b', then if the voltage source Va is removed and inserted in branch 'b' will produce a current Ib in branch 'a'. The ratio of response to excitation is same for the two conditions mentioned above. This is called the reciprocity theorem.

Consider the network shown in Fig. AA' denotes input terminals and BB' denotes output terminals.

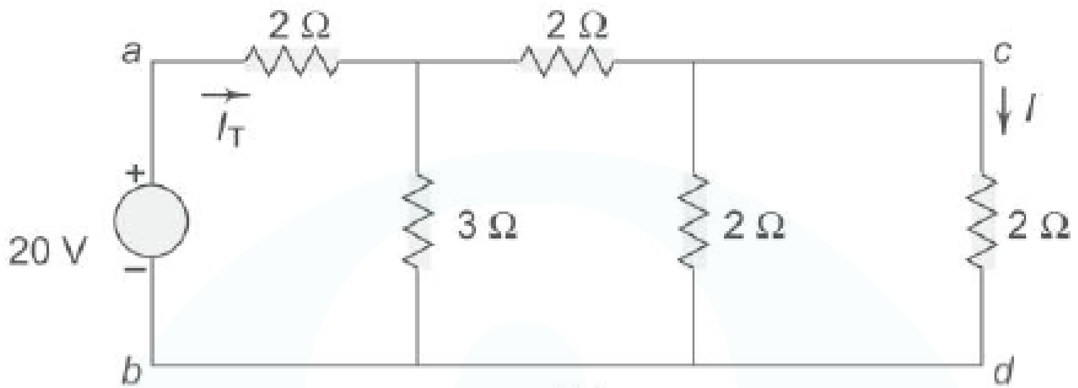


(a) (b)

The application of voltage V across AA' produces current I at BB'. Now if the positions of the source and responses are interchanged, by connecting the voltage source across BB', the resultant current I will be at terminals AA'. According to the reciprocity theorem, the ratio of response to excitation is the same in both cases.

Problem:

Verify the reciprocity theorem for the network shown in Fig



(a)

Solution:

<u>Step 1: Calculation of current when not interchanged</u>

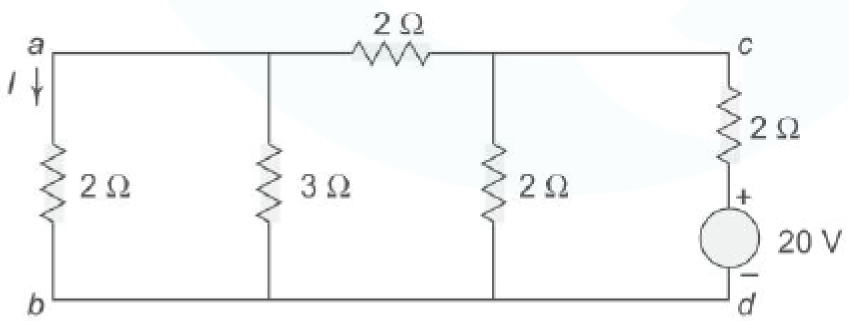
Total resistance in the circuit = {[2 || 2 + 2] || 3 }+ 2 =3.5Ω

By series parallel reduction technique

I_T = $\frac{20}{3.5}$ = **5.71 A**

The current in the 2 Ω branch cd is = 1.43 A.

<u>Step 2: Calculation of current after interchanged</u>



(b)

Total resistance in the circuit = {[2 || 3 + 2] || 2 }+ 2 =3.23Ω

By series parallel reduction technique

I_T = $\frac{20}{3.23}$ = **6.19 A**

The current in the branch ab is 1.43 A

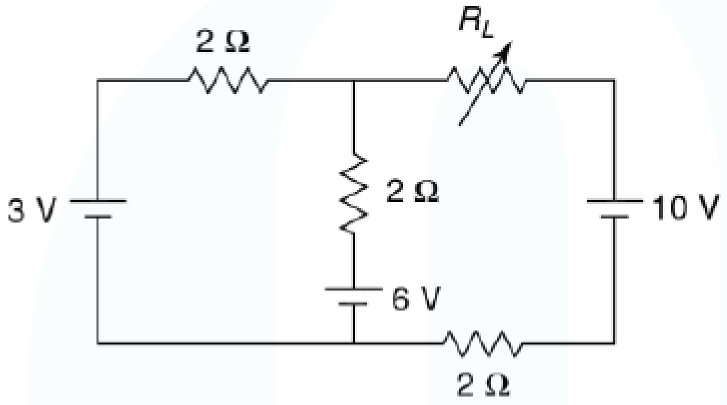
If we compare the results in both cases, the ratio of input to response is the same, i.e. (20/1.43) = 5 13.99

MAXIMUM POWER TRANSFER THEOREM

The maximum power transfer theorem states that maximum power is delivered from a source to a load when the load resistance is equal to the source resistance

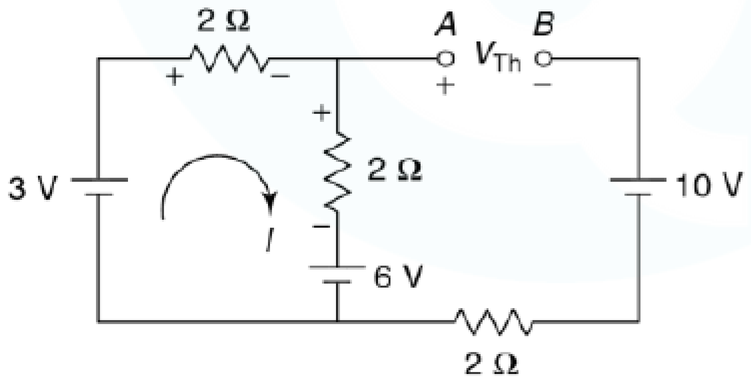
Problem:

Find the value of R_L for maximum power transfer and calculate maximum power



Solution:

Step 1: Calculation of V_{TH}



Apply KVL in first loop

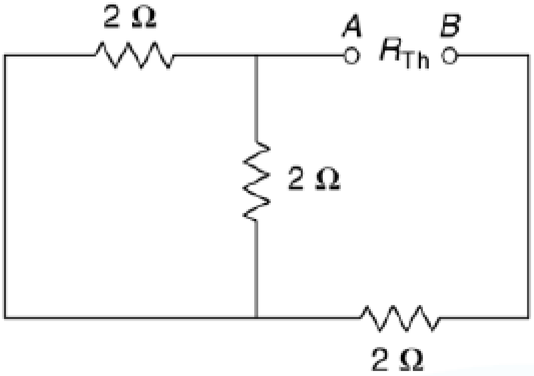
-3 + 2I + 2I +6 =0

I = -0.75A

Writing V_{TH} equation

V_{TH} = 2I +6 -10 = -5.5V

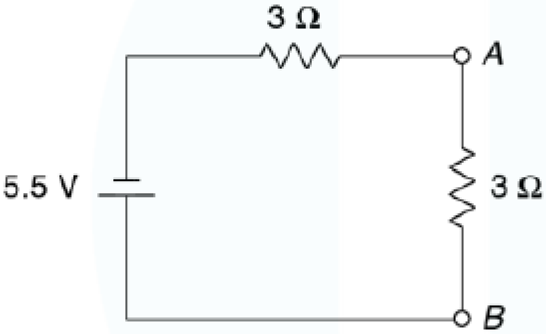
Step 2: Calculation of R_{TH}



R_{TH} = {2 || 2} + 2

= 3 Ω

Step 3: Calculation of R_L



For maximum power transfer

$R_{TH} = R_L$ = 3 Ω

Step 4: Calculation of P_{max}

$\boldsymbol{P_{max}} = \frac{{V_{TH}}^2}{4R_{TH}} = \frac{5.5^2}{4\ x\ 3}$ = 2.52W

https://www.youtube.com/channel/UClorWwmi7GhAt4W9I2z04gA