27/06/19

Chapter - 3 : NETWORK THEOREMS :

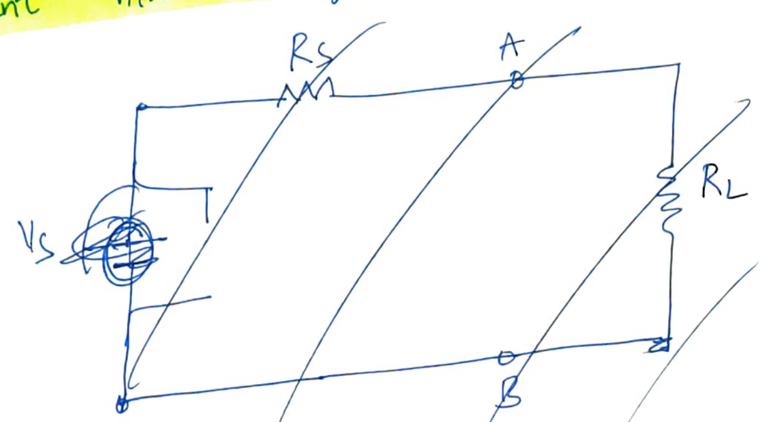
Lecture 1 : INTRODUCTION OF THEVENIN'S THEOREM :

Purpose of learning Network Theorems :

To simplify the network parameters very easily & with less number of steps.

3.1 Thevenin's Theorem :

1. This theorem is valid for both independent and dependent sources n/w's.
2. Equivalent of thevenins n/w is same as practical voltage equivalent n/w. The practical voltage equivalent n/w is given as



Practical voltage source

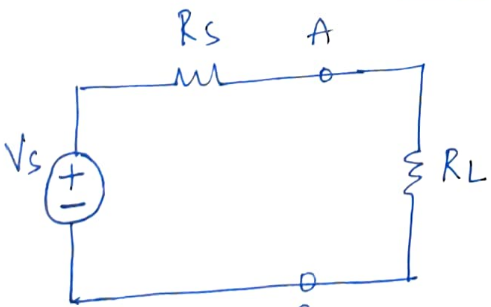
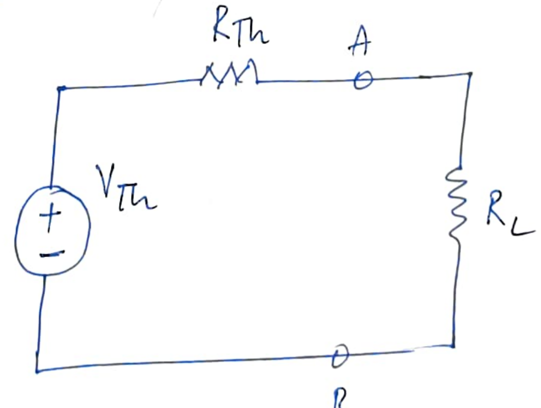


fig: Practical Voltage Source equivalent



Equivalent ckt of Thevenin

3. Thevenin voltage is referred as open ckt voltage across the load terminal, i.e, current across the load terminal is '0'(zero).

i.e, $\boxed{V_{OC} = V_{Th}}$

$\boxed{V_{Th} = V_{OC} = \text{ideal voltmeter reading } (V_m)}$

4. Calculation of R_{Th} ~~to~~ depends on the behaviour of the network.

4 a) When n/w contains only independent sources then

$R_{Th} = R_{eq}|$ across the load terminal with all independent sources value is zero

i.e, Independent sources value is zero

⇓

Voltage source = 0 ⇓ Short ckt

Current source = 0 ⇓ Open ckt

R_{Th} = R_{eq} when voltage source is short circuited (or) current source is open ckt

4b) When n/w contains both dependent and independent sources

$$\boxed{R_{Th} = \frac{V_{dc}}{I_{dc}}}$$

when independent sources value is zero, which means voltage sources is S.C & current source is O.C

where V_{dc} = dc voltage across the load terminal.

I_{dc} = dc current which flowing from V_{dc}.

4c) When n/w contains only dependent source :

$$\boxed{R_{Th} = \frac{V_{dc}}{I_{dc}}}$$

⟶ special case of n/w

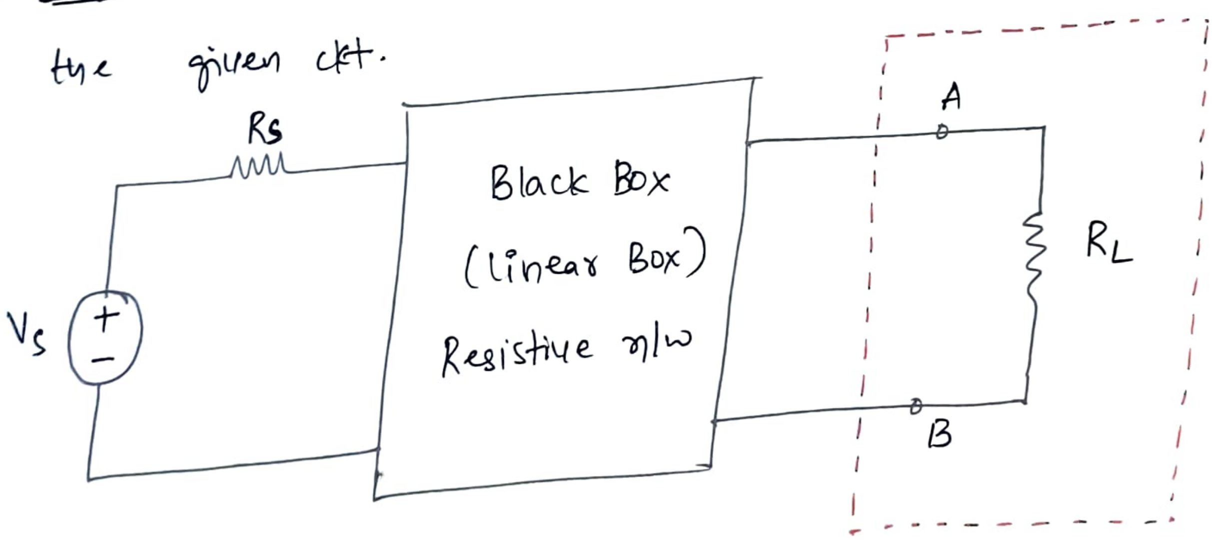
V_{Th} = '0' volt

V_{Th} = (function of Independent sources)

⇓

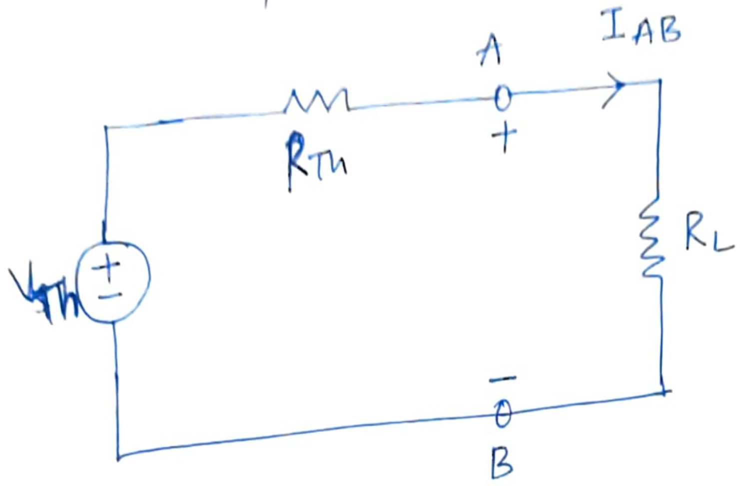
no conditions.

Example: find the thevenin eq of the dotted part of the given ckt.



soln. Let us consider the dotted part of the given n/w.

The venins equivalent of the dotted part of n/w is as follows



Applying KVL for loop ABA

$$V_{Th} - I_{AB}R_{Th} - I_{AB}R_L = 0$$

$$V_{Th} = I_{AB}(R_{Th} + R_L).$$

$$\boxed{I_{AB} = \frac{V_{Th}}{R_{Th} + R_L}} \longrightarrow (1)$$

We know by ohm's law

$$V_{AB} = I_{AB}R_L = \frac{V_{Th}R_L}{R_{Th} + R_L}$$

$$\boxed{V_{AB} = \frac{V_{Th}R_L}{R_{Th} + R_L}} \longrightarrow (2)$$

Conclusion:

1. If we know thevenin voltage (V_{Th}) & thevenins resistance (R_{Th}) of the given n/w, we can find the load current & load voltage of that particular

n/w. This is the main intention or essence of the thevenins theorem.

2: We can find voltage & current of any branch of n/w if we know thevenins voltage & thevenins resistance of the n/w.

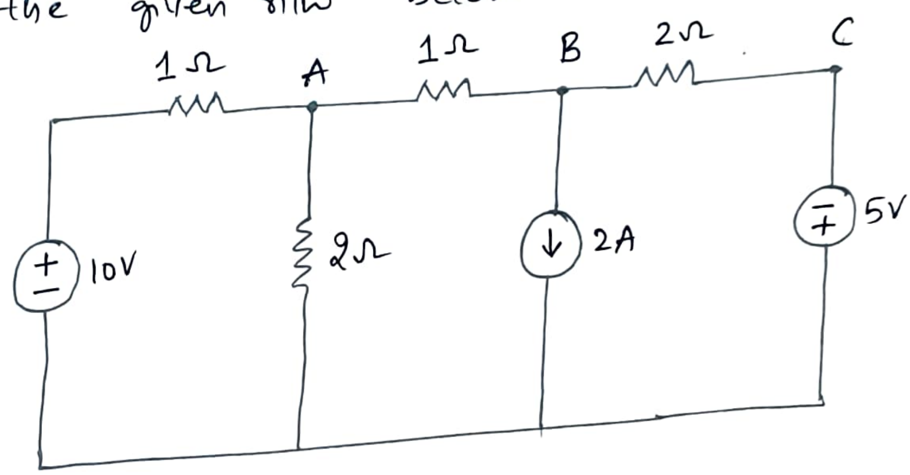
Lecture-2

Example Based On Thevenins Theorem (1) :

Example: Consider the given n/w below

(i) find the thevenin equivalent across 'AB'

(ii) find the thevenin equivalent across 'BC'

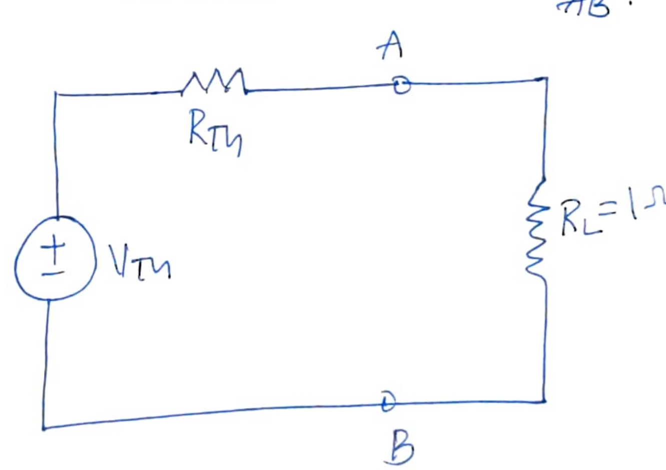


Soln: (i) Thevenin Equivalent Across AB :

Now

(I) To find V_{Th} :

Consider thevenin eq across AB.



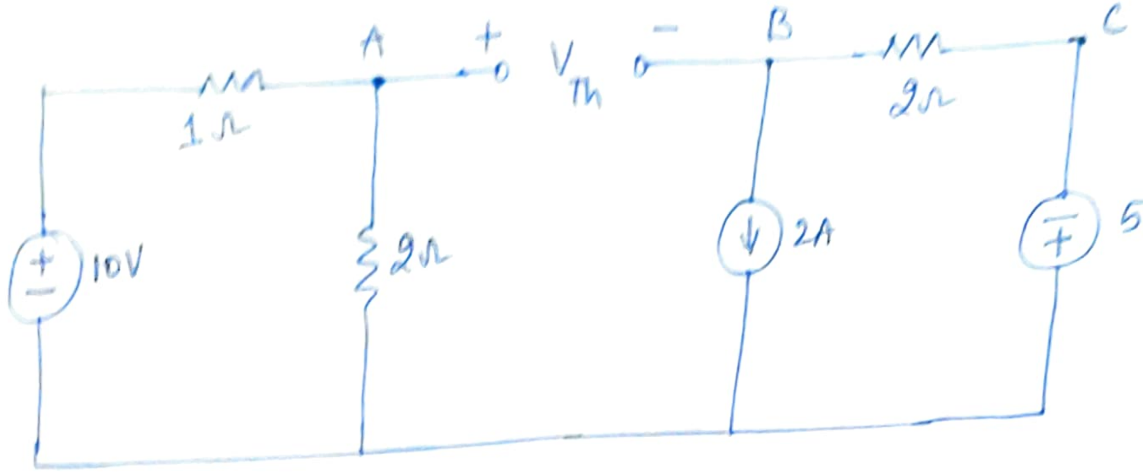
According to the property.

→ Remove the branch resistance across AB. (Open ckt)

→ Find the voltage across AB (i.e V_{AB}). It is also called as open ckt voltage

$$\boxed{V_{AB} = V_{oc} = V_{Th}}$$

V_{AB} is known as thevenin voltage of ~~across~~ AB.



$V_{AB} = V_{Th} = V_A - V_B$.

(a) V_A:

By VDR $\quad V_A = \frac{2}{3} \times 10 = \frac{20}{3}$ volts. ; $\boxed{V_A = \frac{20}{3} \text{ volts}}$

(b) V_B:

~~By KVL → $5 + (V_B \times 2)$~~

By KCL at 'B'

$$\frac{V_B + 5}{2} + 2 = 0$$

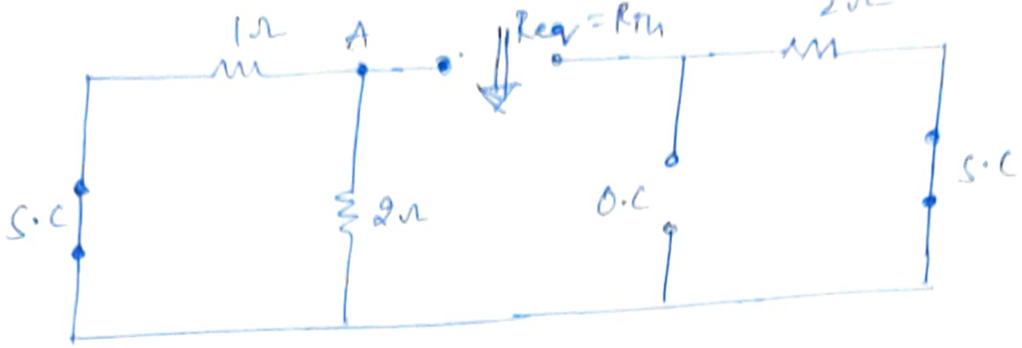
$$\frac{V_B + 5 + 4}{2} = 0$$

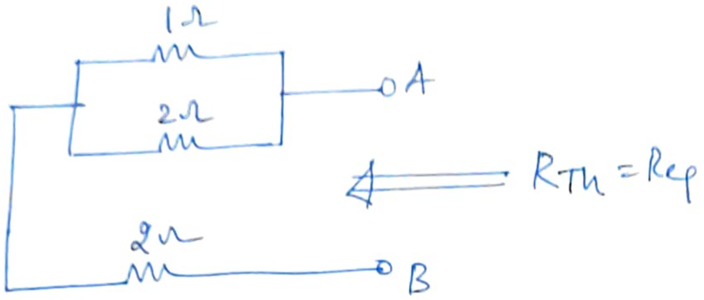
$$\boxed{V_B = -9 \text{ volts}}$$

$$\boxed{V_{Th} = V_{AB} = \frac{20}{3} + 9 = \frac{47}{3} \text{ volts}}$$

To find R_{Th}:

Here we observe only independent sources. So we have to use first case i.e., $R_{Th} = R_{eq}\Big|_{\text{across } AB}$ when voltage sources are S.C & current sources are O.C

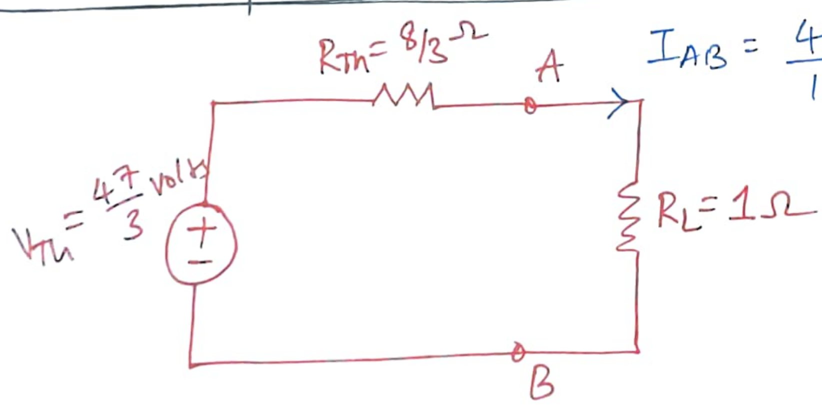




$$R_{Th} = (1 \| 2) + (2) = \left(\frac{1\times 2}{1+2}\right) + (2) = \frac{2}{3} + 2 = \frac{8}{3}\,\Omega$$

$$\boxed{\therefore\ R_{Th} = \frac{8}{3}\,\Omega}$$

Thevenin eq across AB :



$I_{AB} = \frac{47}{11}$ A

I_{AB} :

$$\frac{47}{3} - I_{AB}\times\frac{8}{3} - I_{AB}\times 1 = 0$$

$$I_{AB}\left[1 + \frac{8}{3}\right] = \frac{47}{3} \Rightarrow I_{AB}\left[\frac{11}{\cancel{3}}\right] = \left[\frac{47}{\cancel{3}}\right]$$

$$\boxed{I_{AB} = \frac{47}{11} A}$$

$$V_{AB} = I_{AB} \times R_L = \frac{47}{11} \times 1 = \frac{47}{11} \text{ volts}$$

$$\boxed{\therefore V_{AB} = \frac{47}{11} \text{ volts}}$$

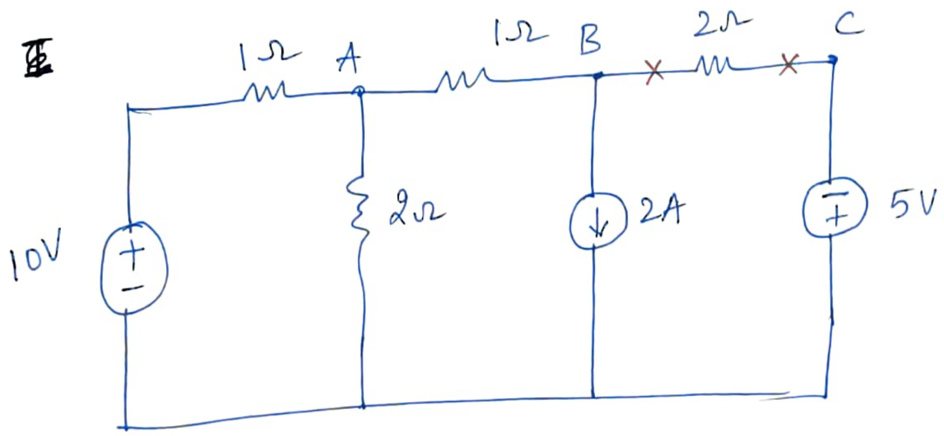
<u>NOTE:</u>

→ We can find I_{AB} using nodal analysis also.

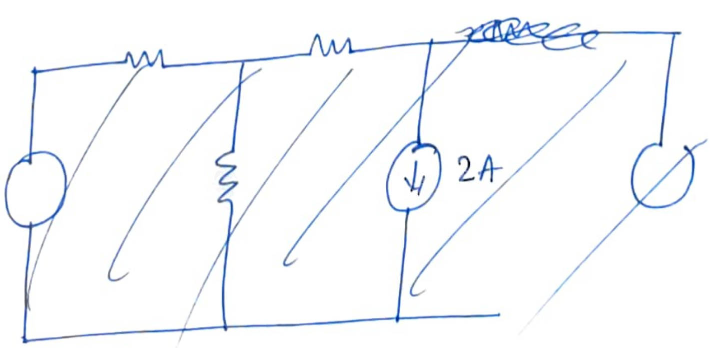
→ But here we've used thevenins theorem to find I_{AB}.

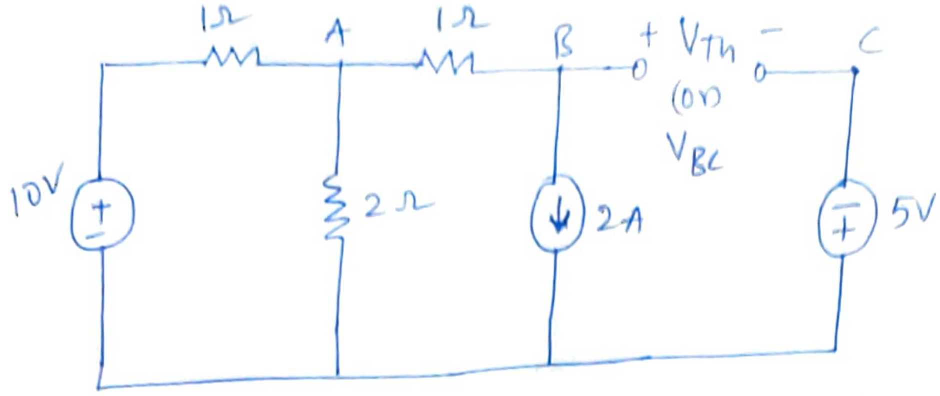
→ Both methods can be used according to the convienience of student.

(ii) Thevenins Equivalent across BC:



(I) To find V_{Th}:





By applying nodal analysis at 'A'.

$$\left(\frac{V_A-10}{1}\right)+\left(\frac{V_A}{2}\right)+\left(\frac{V_A-V_B}{1}\right)=0.$$

$$2.5V_A - V_B = 10 \longrightarrow (1)$$

By applying nodal analysis at 'B'

$$\frac{(V_B-V_A)}{1}+2=0$$

$$V_A - V_B = 2 \longrightarrow (2)$$

Solving (1) & (2) $\quad 1.5V_A = 8 \Rightarrow V_A = \frac{8\times10}{15} = \frac{8\times2}{3} = \frac{16}{3}$

$$\boxed{\therefore V_A = \frac{16}{3} \text{ volts}} \text{ — } (3)$$

$$V_B = V_A - 2 = \frac{16}{3} - 2 = \frac{16-6}{3} = \frac{10}{3} \text{ volts}$$

$$\boxed{\therefore V_B = \frac{10}{3} \text{ volts}} \text{ — } (4)$$

We have from ckt

$$\boxed{\therefore V_C = -5 \text{ volts}} \rightarrow (5)$$

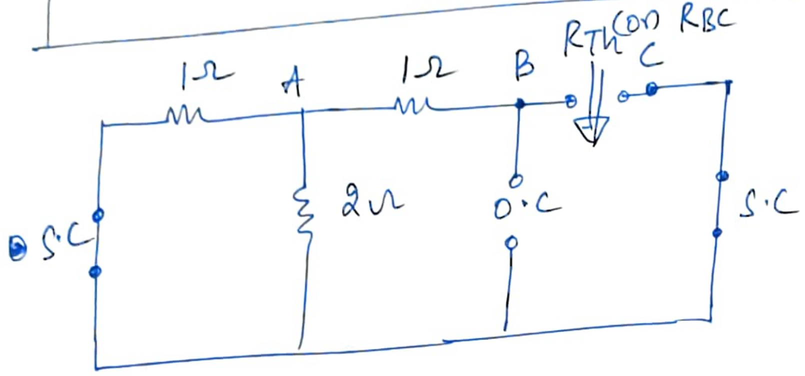
$$\boxed{V_{Th} = V_{BC} = V_B - V_C = \frac{10}{3}+5 = \frac{25}{3} \text{ volts}} \rightarrow (6).$$

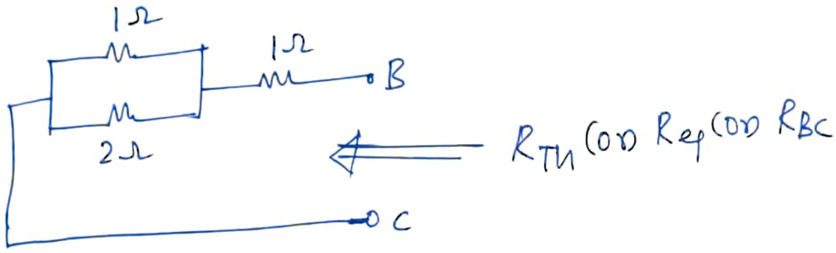
II To find R_{Th}:

The given ckt consissts only independent sources.

We have to use 1st case, i.e,

$$\boxed{R_{Th} = R_{eq}\Big|_{\text{at } BC} \quad \text{when} \quad \begin{array}{l}\text{Voltage source is S.C} \\ \text{current source is O.C}\end{array}}$$

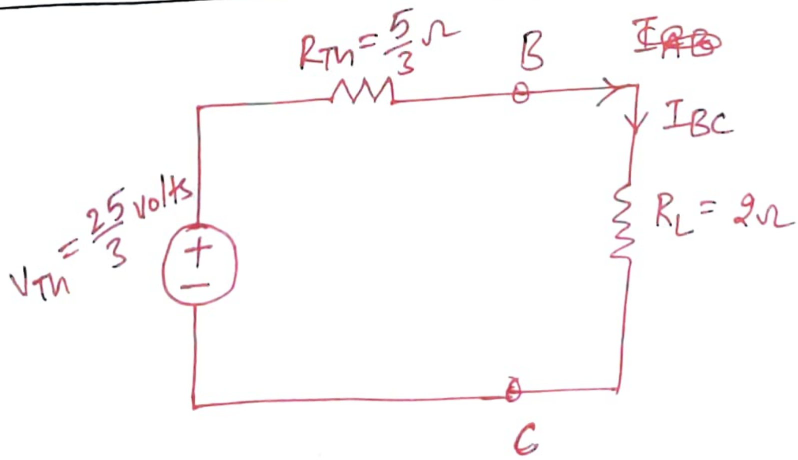




$$R_{Th} = (1 \| 2) + 1 = \frac{2}{3} + 1 = \frac{5}{3}\Omega$$

$$\boxed{\therefore \quad R_{Th} = \frac{5}{3}\Omega}$$

Thevenins eq. across BC:



Applying KVL in above loop

$$\frac{25}{3} - \left(I_{BC} \times \frac{5}{3}\right) - \left(I_{BC} \times 2\right) = 0$$

$$I_{BC}\left(2 + \frac{5}{3}\right) = \frac{25}{3}$$

$$I_{BC}\left[\frac{11}{3}\right] = \frac{25}{3}$$

$$\boxed{I_{BC} = \frac{25}{11}\ A}$$

from ohms law

$$V_{BC} = I_{BC} \times R_L$$

$$V_{BC} = \frac{25}{11} \times 2 = \frac{50}{11} \text{ volts}$$

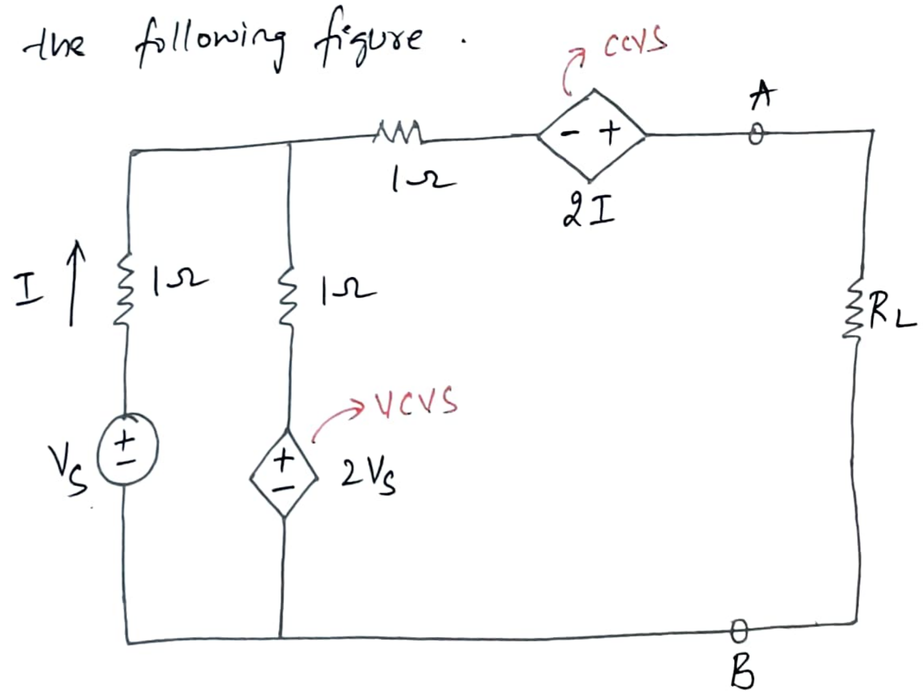
$$\boxed{\therefore\ V_{BC} = \frac{50}{11} \text{ volts}}$$

Lecture - 3 :

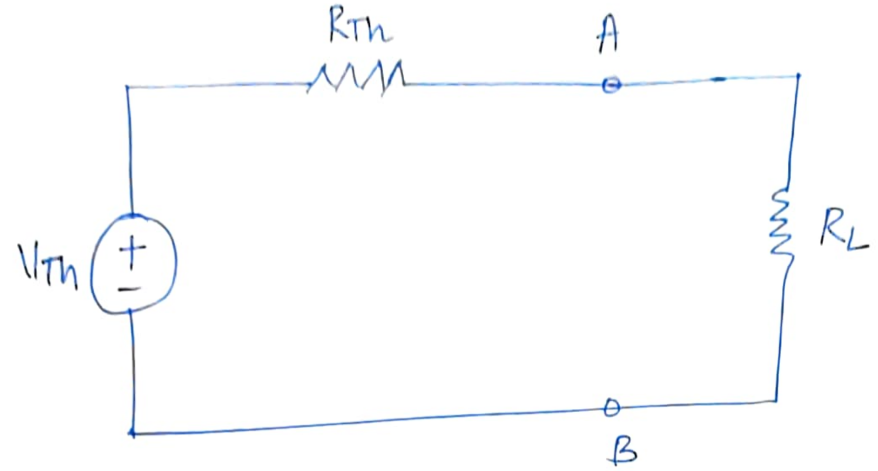
Example Based On Thevenins Theorem (2)

Example : Consider the following figure.

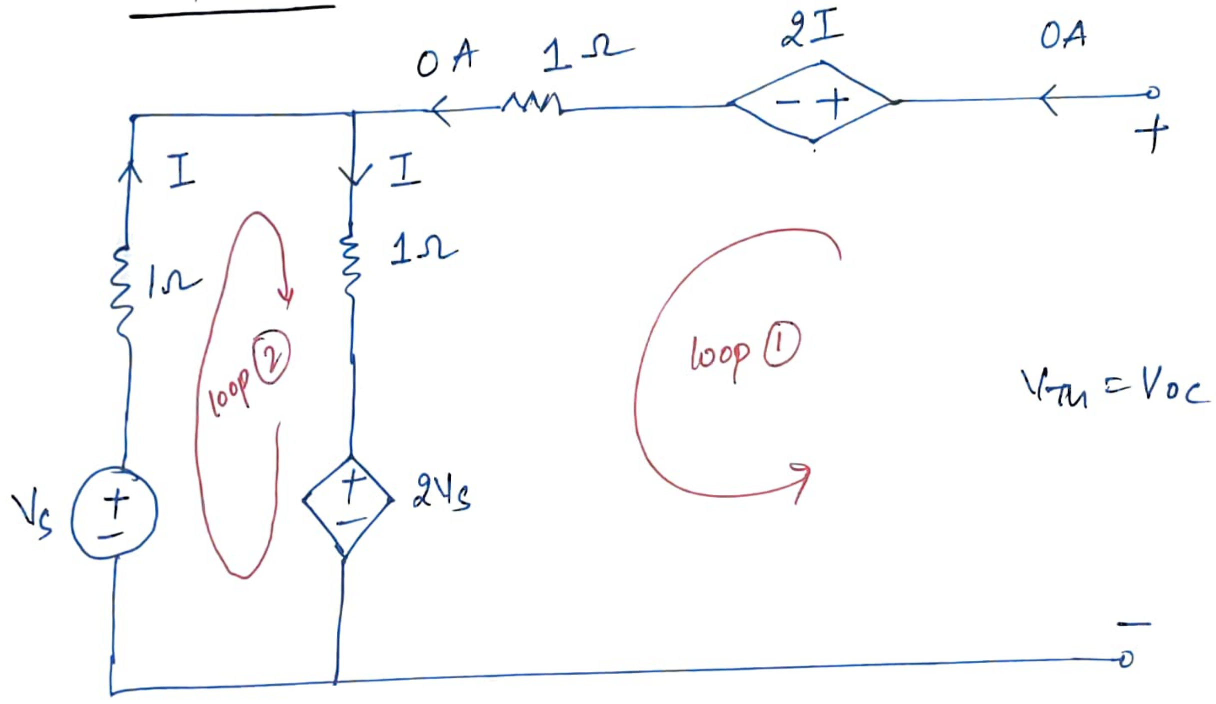
find the thevenins eq. i.e, thevenin voltage (V_{TH}) & thevenin resistance (R_{TH}) across the terminal AB ?



sol. The thevenin eq. of given ckt across AB is



Now <u>To find</u> V_{Th} :



Applying KVL in the lopp ①..

$$V_{Th} - 2I - I - 2V_s = 0$$

$$V_{Th} = 2V_s + 3I \longrightarrow ①$$

Apply KVL in loop ②

$$V_s - I - I - 2V_s = 0$$

$$-V_s - 2I = 0$$

$$V_s = -2I \longrightarrow ②$$

$V_s = -2I$

$I = \frac{-V_s}{2} \longrightarrow (2)$

put (2) in (1)

$V_{Th} = 2V_s + 3\left[\frac{-V_s}{2}\right]$

$V_{Th} = 2V_s - \frac{3V_s}{2} = \frac{V_s}{2}$.

$$\boxed{\therefore V_{Th} = \frac{V_s}{2} \text{ volts}}$$

NOTE:

finding the V_{Th} is in same style for both (only independent sources) & (combination of independent & dependent sources).

Steps to find V_{Th}:

1. Open the branch which is our area of interest & find the voltage across that particular branch.

2. i.e, open circuit voltage is to be evaluated ~~at~~ for the branch which is our area of interest. It is equal to V_{Th} (Thevenins voltage).

$$\boxed{V_{Th} = V_{oc}}$$

To find R_{Th}:

Steps to calculate R_{Th} in a n/w with both independent & dependent sources:

Step-1: Remove the branch b/w the terminals where R_{Th} is to be evaluated.

Step-2: Place the dc voltage 'V_{dc}' across the terminals where R_{Th} is to be evaluated.

Step-3: Let "I_{dc}" current be flown ~~to~~ from the dc voltage "V_{DC}".

Step-4: Make the independent sources value as '0' i.e. & for ~~a~~ ~~voltage~~ an independent ~~source~~ voltage source apply (S.C) on it.
i.e. for an independent current source apply (O.C) on it.

Step-4: Do not disturb (or (remove)) any dependent source.
Note that any dependent sources must not be removed.

Step-5: For in some special cases, like if the variable in dependent sources depends on the variable of independent sources;

In that case that particular ~~in~~ dependent source value should be made '0'.

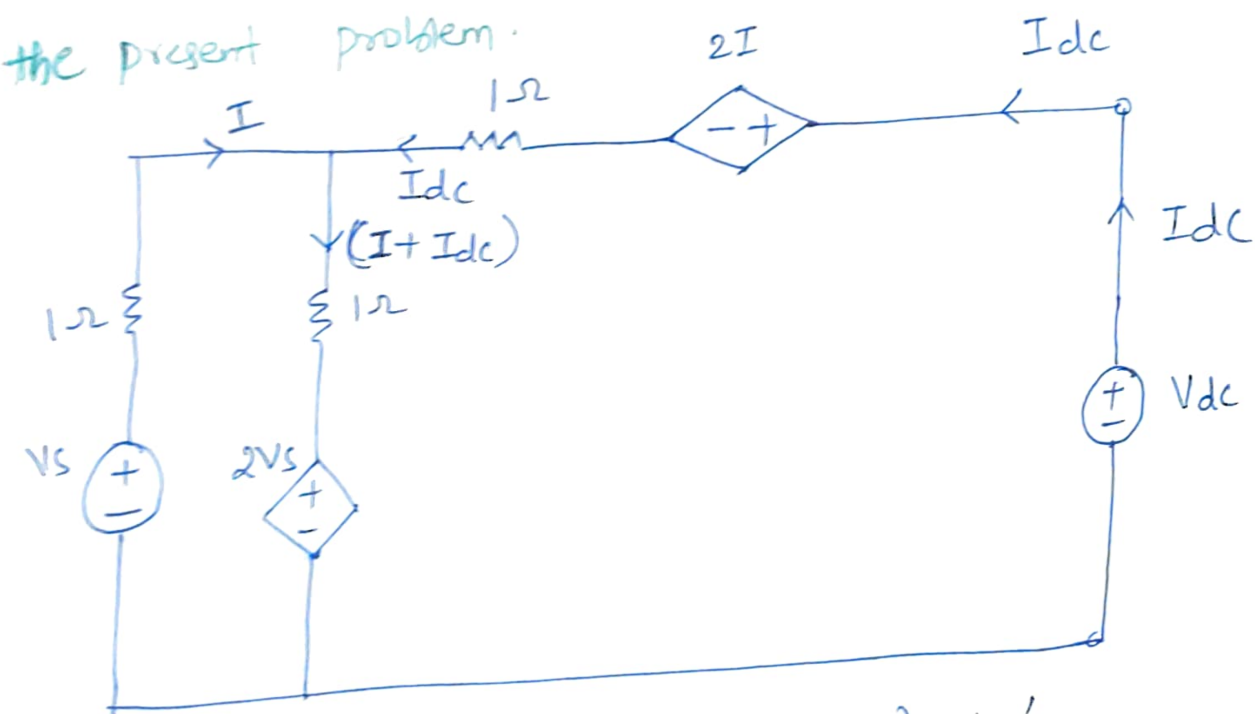
i.e, the voltage of dependent source should be mades as (S.C)

& the current of dependent should be made (O.C).

Step 6: The ratio of Vdc & Idc is called as R_{Th} (Thevenin resistance)

$$\boxed{R_{Th} = \frac{V_{dc}}{I_{dc}}}$$

Now let us apply the above working rule for the present problem.



Now make 'V_s' voltage (independent) '0' i.e, S.C

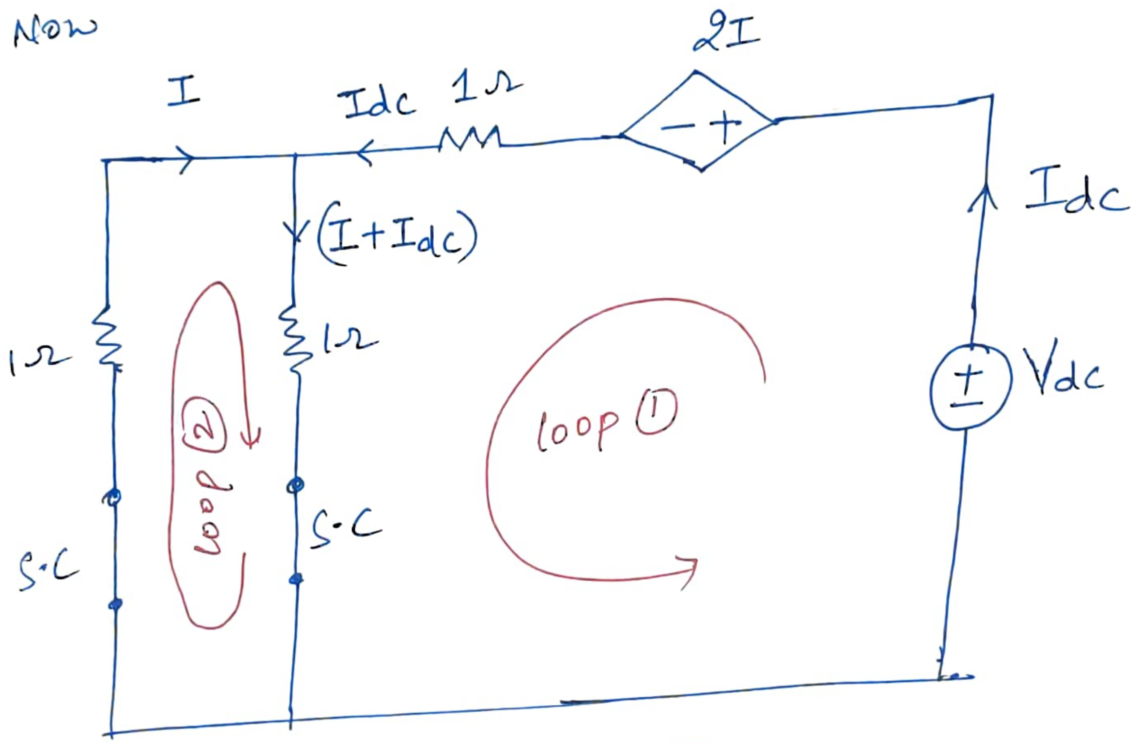
"$2V_s$" ~~indepent~~ dependent voltage source must ~~be~~ be made S.C because its magnitude depends on the independent voltage source variable V_s

So, '$2V_s$' dependent voltage source is made S.C

→ '$2I$' dependent voltage source must not be made S.C because 'I' variable does not depend on the independ voltage variable V_s.

→ '$2I$' dependent voltage source is <u>not</u> made S.C

Now



Apply KVL in loop ①

$$V_{dc} - 2I - I_{dc} - (I + I_{dc}) = 0$$

$$V_{dc} - 2I - I_{dc} - I - I_{dc} = 0$$

$$V_{dc} = 3I + 2I_{dc} \longrightarrow ①$$

Apply KVL in loop ②

$$-I - (I + I_{dc}) = 0$$

$$-2I - I_{dc} = 0$$

$$I_{dc} = -2I$$

$$I = -\frac{I_{dc}}{2} \longrightarrow (2)$$

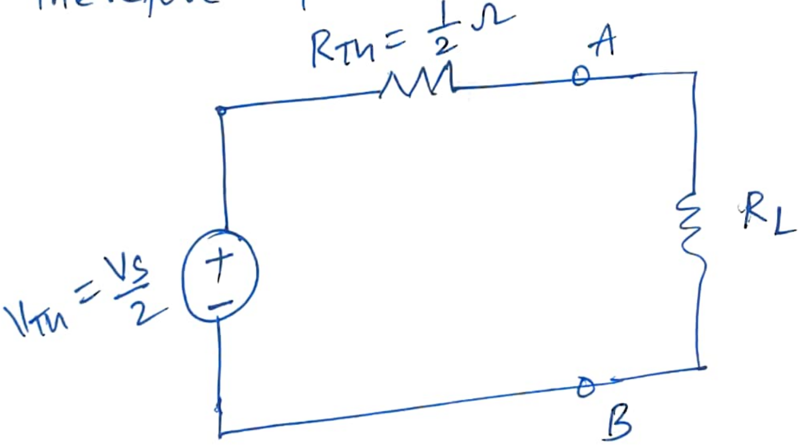
put (2) in (1)

$$V_{dc} = 3\left[-\frac{I_{dc}}{2}\right] + 2I_{dc} = \frac{-3I_{dc} + 4I_{dc}}{2}$$

$$V_{dc} = \frac{I_{dc}}{2}$$

$$\boxed{\frac{V_{dc}}{I_{dc}} = R_{Th} = \frac{1}{2}\,\Omega}$$

Therefore final thevenin equivalent is as follows

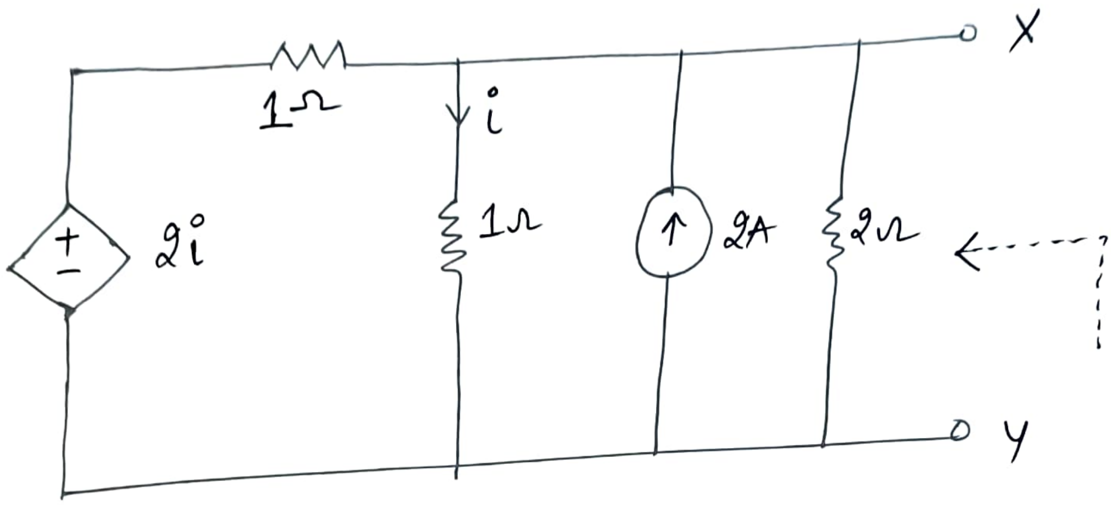


Lecture - 4:

Questions Based On Thevenin's Theorem (1)

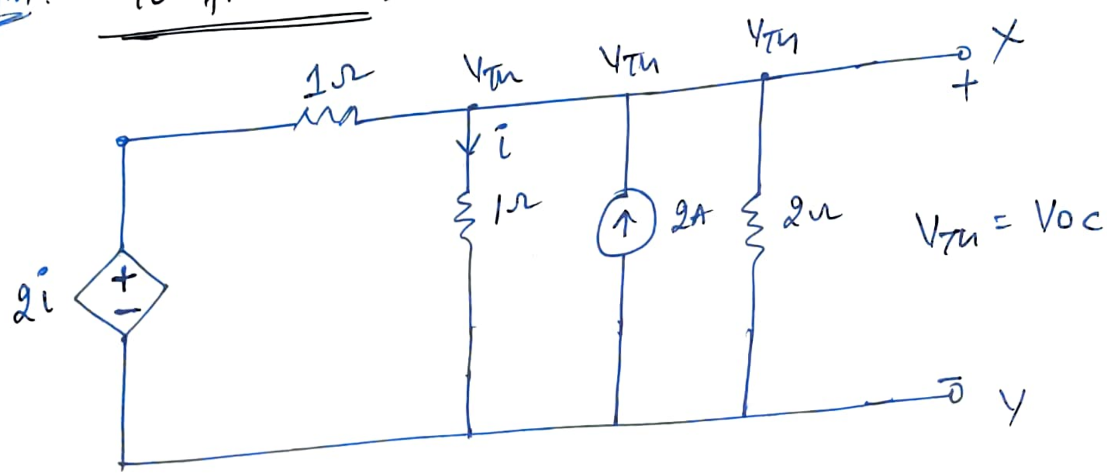
Q) For the ckt shown in figure the thevenin voltage and resistance looking into X - Y are

GATE 2007



A) $\frac{4}{3}$ V, 2Ω B) 4 V, $\frac{2}{3}$ Ω c) $\frac{4}{3}$ V, $\frac{2}{3}$ Ω c) 4V, 2Ω

Sol'n: To find V_{Th}:



Applying ~~KCL~~ Nodal analysis at V_{Th}.

$$\frac{V_{Th} - 2i}{1} + \frac{V_{Th}}{1} - 2 + \frac{V_{Th}}{2} = 0$$

$$\frac{5}{2} V_{Th} = 2i + 2$$

$$5 V_{Th} = 4i + 4 \quad \text{——} \; (1)$$

$V_{Th} = i \times 1 = i$ ——— (2)

put (2) in (1).

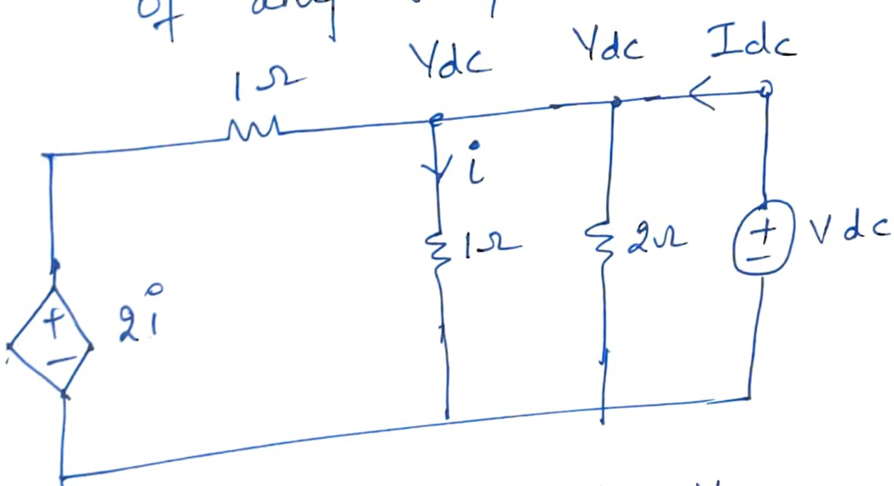
$5V_{Th} = 4V_{Th} + 4$

$$\boxed{V_{Th} = 4 \text{ volts}}$$

<u>To find R_{Th}:</u>

2A independent current source should be O.C

$2i$ ~~should~~ dependent voltage source should not be removed because 'i' is indepent of any independent source.



Apply Nodal analysis at Vdc.

$$\left(\frac{V_{dc} - 2i}{1}\right) + \frac{V_{dc}}{1} + \frac{V_{dc}}{2} - I_{dc} = 0$$

$$\frac{5}{2}V_{dc} - 2i = I_{dc}$$

$5V_{dc} = 2I_{dc} + 4i$ ——— (1)

$V_{dc} = i$ ⟶ (2)

put (2) in (1)

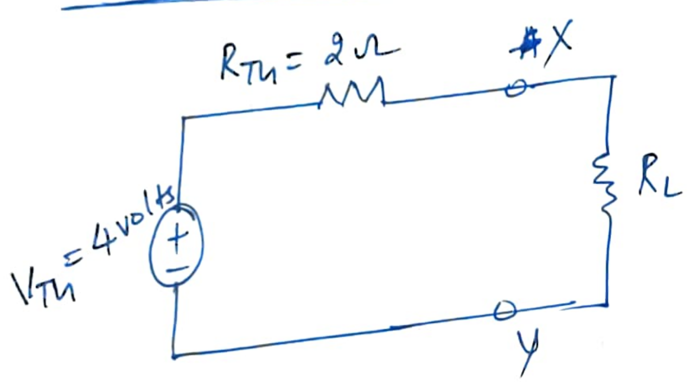
$$5V_{dc} = 2I_{dc} + 4V_{dc}$$

$$V_{dc} = 2I_{dc}$$

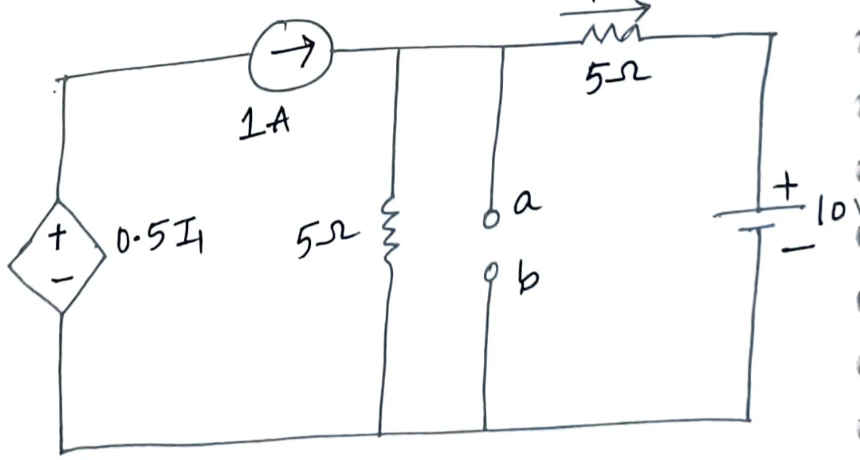
$$\boxed{R_{Th} = \frac{V_{dc}}{I_{dc}} = 2\,\Omega}$$

Option (D) is correct.

Thevenin equivalent:



Q) GATE For the ckt shown in fig, Thevenin's voltage & Thevenins equivalent resistance at terminal a-b is



A) 5V & 2Ω

B) 7.5V & 2.5Ω

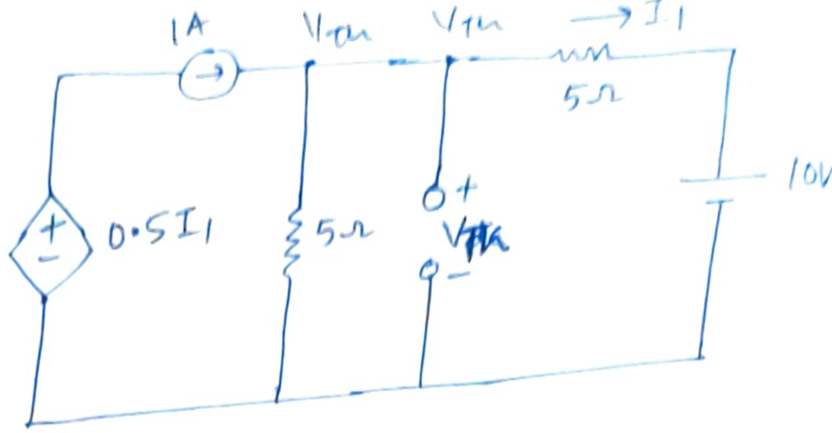
C) 4V & 2Ω

D) 3V & 2.5Ω

Soln: To find V_{Th}:

Consider the fig given below

Apply KCL at V_{Th}



$$\frac{V_{Th}}{5} - 1 + \frac{V_{Th} - 10}{5} = 0$$

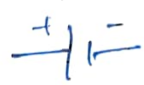
$$2V_{Th} - 10 = 5$$

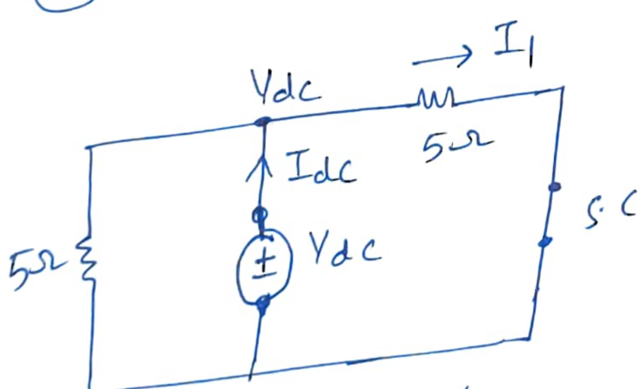
$$2V_{Th} = 15$$

$$\boxed{V_{Th} = 7.5 \text{ volts}}$$

To find R_{Th} :

~~Open~~ Here we have both dependent & independent source. So, we have to consider V_{dc} ~~at~~ b/w a & b terminal & let I_{dc} current ~~floo~~. flow from V_{dc}.

(i) Open  & (ii) ~~Ope~~ S.C the  source



Apply ~~nodal~~ nodal at V_{DC}

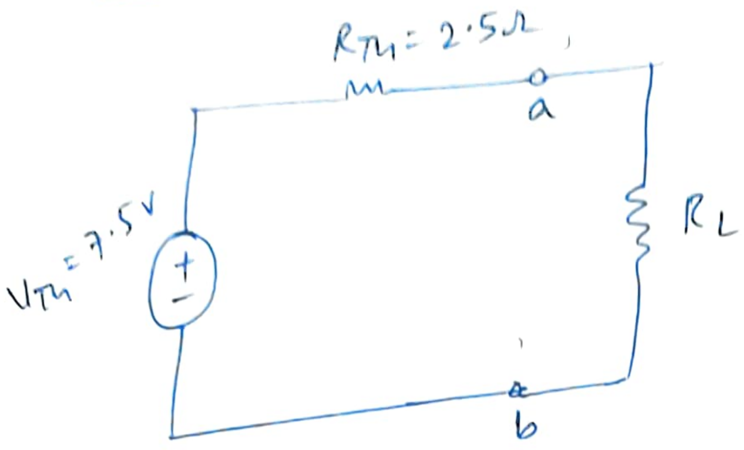
$$\frac{V_{dc}}{5} - I_{dc} + \frac{V_d}{5} = 0$$

$$2V_{dc} = 5I_{dc}$$

$$\frac{V_{dc}}{I_{dc}} = R_{Th} = 2.5\Omega$$

$$\boxed{\therefore R_{Th} = 2.5\Omega}$$

Equivalent Thevinin :



$\therefore$ Option (B) is correct.

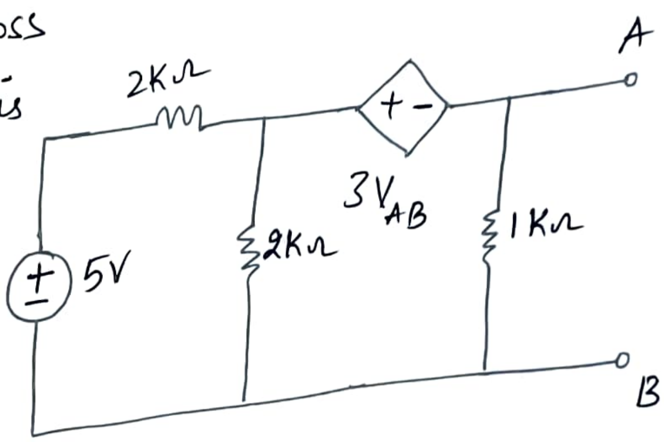
Lecture-5 :

Questions Based on Thevenins Theorem (2)

Q1) Thevenin's resistance across the terminals A and B is

A) $0.5 K\Omega$ B) $0.2 K\Omega$

C) $1 K\Omega$ D) $0.11 K\Omega$



Q2) The thevenin voltage across the terminals A & B is

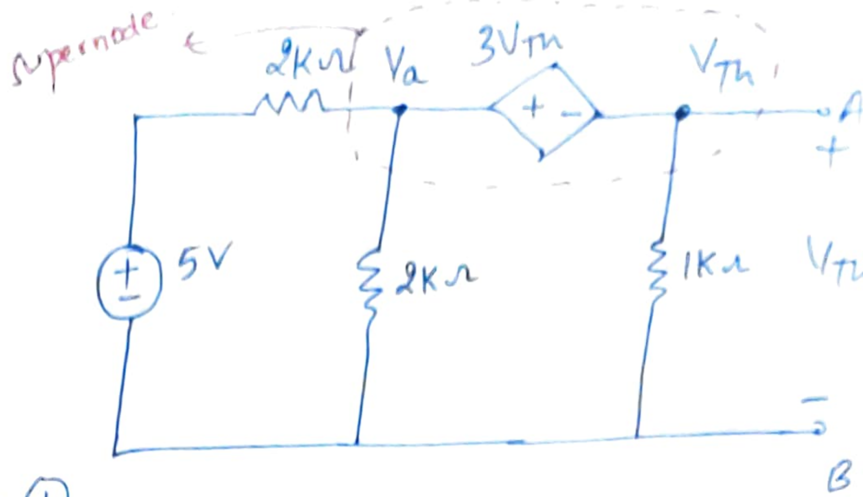
A) $1.25V$ B) $0.25V$

C) $1V$ D) $0.5V$

Sol^n: To find V_{Th} :

Consider the fig as follows

$$\frac{V_a - 5}{2K} + \frac{V_a}{2K} + \frac{V_{Th}}{1K} = 0$$



$$V_a - 5 + V_a + 2V_{Th} = 0$$

$$2V_a + 2V_{Th} = 5$$

$$V_a + V_{Th} = 2.5 \longrightarrow (1)$$

Now. KVL at supernode

$$V_a - 3V_{Th} - V_{Th} = 0$$

$$V_a = 4V_{Th} \longrightarrow (2)$$

put (2) in (1)

$$5V_{Th} = 2.5$$

$$V_{Th} = \frac{25}{50} = \frac{1}{2} = 0.5 \text{ volts}$$

$$\boxed{\therefore \; V_{Th} = 0.5 \text{ volts}}$$

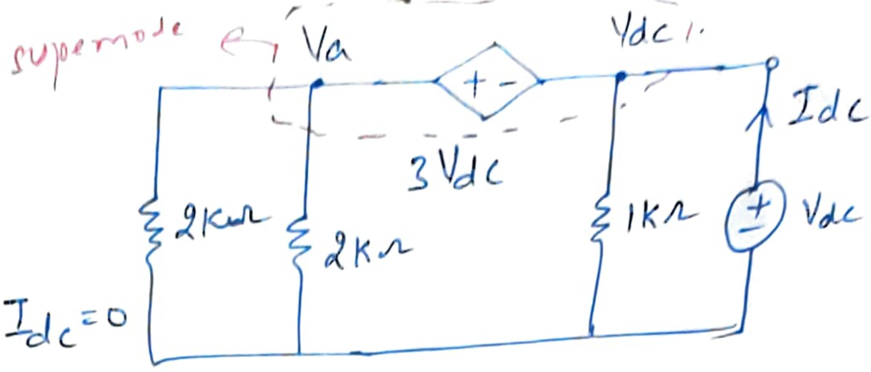
To find R_{Th}:

→ Clearly 5V becomes S.C

→ Apply Vdc b/w 'A & B' and allow Idc current to flow from Vdc.

→ The ckt n/w will be modified as follows

Applying supernode analysis:



$$\frac{V_a}{2K} + \frac{V_a}{2K} + \frac{V_{dc}}{1K} - I_{dc} = 0$$

$$2V_a + 2V_{dc} = (2K) \times I_{dc}.$$

$$V_a + V_{dc} = (1K \times I_{dc}) \longrightarrow (1)$$

Now $\quad V_a - 3V_{dc} - V_{dc} = 0$

$$V_a = 4V_{dc} \longrightarrow (2).$$

put (2) in (1)

$$4V_{dc} + V_{dc} = (1K \times I_{dc})$$

$$5V_{dc} = 1K \times I_{dc}.$$

$$\frac{V_{dc}}{I_{dc}} = \frac{1}{5} K\Omega = R_{Th} = 0.2K\Omega$$

$$\boxed{\therefore \quad R_{Th} = 0.2K\Omega}$$

Thevenin Equivalent: