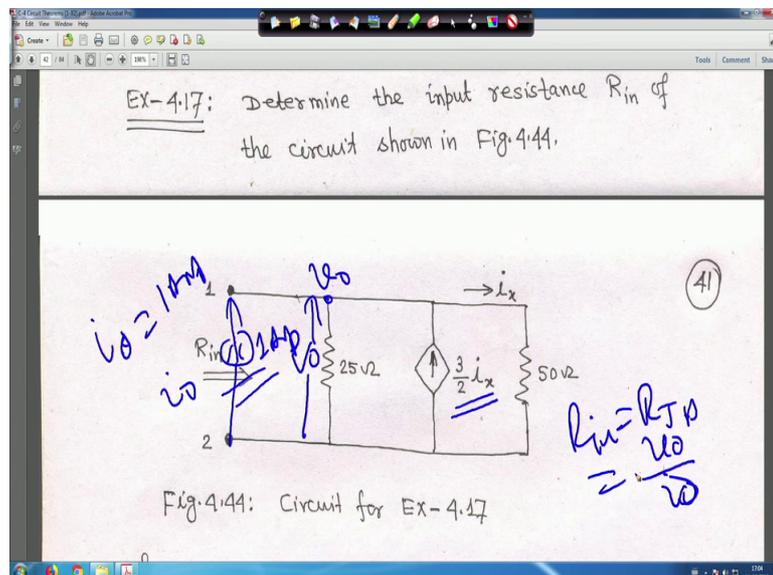


Fundamentals of Electrical Engineering
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 23
Circuit Theorems (Contd.)

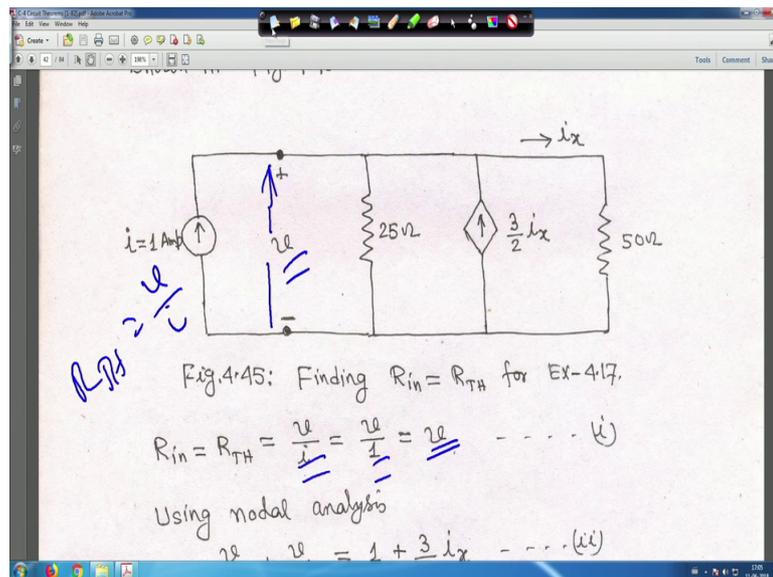
So, we will come back to this another one here.

(Refer Slide Time: 00:19)



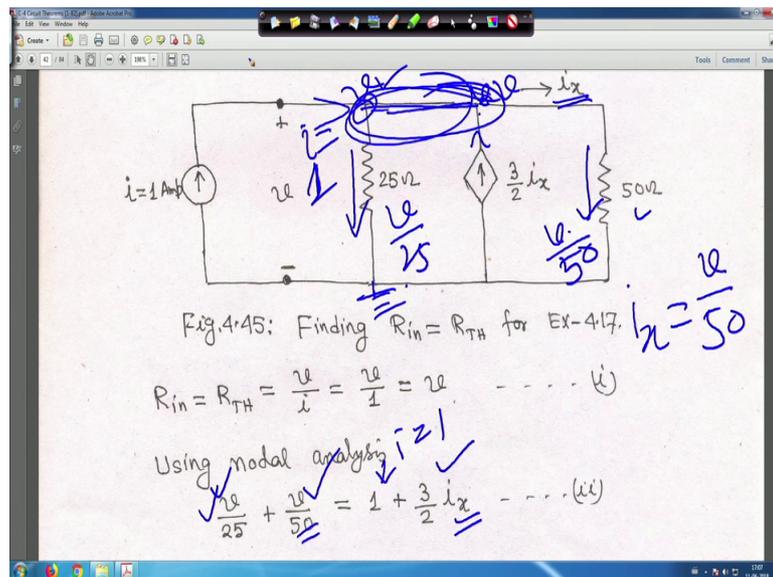
You have to find out your R_{in} that is your $R_{Thevenin}$ between R_{in} means $R_{Thevenin}$, but here one dependent current source is there. If dependent current source is there, so better you put one dependent you depend what you call one independent current source or voltage source, here will put one independent current source right here say here you can put one independent current source, its say it is 1 ampere because right and you have to see the voltage here V_0 and this independent current source current i_0 is equal to 1 ampere say i_0 is equal to 1 ampere; that means, this voltage is be on V_0 ; that means, your R_{input} , that is your $R_{Thevenin}$ $R_{Thevenin}$ is equal to your V_0 by i_0 we will take i_0 is equal to 1 ampere say.

(Refer Slide Time: 01:19)



Therefore let me clear it. So now, if you look into the circuit all explanation are there, but directly you are going here I just told you. So, put 1 ampere here what you call and the independent current source here. So, this voltage actually this voltage your V right this voltage is taken V V and current is i. So, therefore, R Thevenin is equal to will become V by i. So, we have to final you have to get the v. So, question is that. So, if i is equal to you have taken 1 ampere. So, V by i is equal to V by 1 is equal to V i mean if we get the value of v, then we will be knowing what is your what you call that your R R Thevenin. So, let me clear it let it move little bit up.

(Refer Slide Time: 02:00)



So, in this case in this case what you can do is for this circuit for this circuit this is common node this is your anyway common node. So, here your i is equal to 1 ampere current is entering this is a common node and this voltage V means from nodal analysis this is a common node. So, V and V because this this is your nothing is there this is a common node. So, V and V meaning is same here right so; that means, that this i is entering into that your what you call into this if you apply KCL here, if you apply KCL here then i is entering. So, in that case and i is equal to 1 ampere; so this is your i ; i is equal to 1 ampere. So, one right another current 3 by 2 i_x is also entering. So, plus 3 by 2 i_x right these 2 current both are entering and is equal to this current is leaving to this branch it will be V by 25 . So, here it is V by 25 . Another one voltage V is here also and this 50 .

So, here it will be leaving this thing it will be V by 50 because this is actually what you can do is you can ground it right like nodal analysis we are making. So, here it is V by 50 . So, V by 25 plus V by 50 is equal to 1 plus 3 by 2 your i_x , but question is this i_x is given actually this is your i_x . So, i_x actually is equal to your V by 50 right. So, this i_x this is this is actually i_x and this is actually V by 50 ; that means, in this expression you put also 3 by 2 into V by 50 , then we will get the solution for v . So, let me clear it hope you have you are understanding this right hope you are understanding this.

(Refer Slide Time: 03:53)

Fig.4.45: Finding $R_{in} = R_{TH}$ for Ex-4.17.

$$R_{in} = R_{TH} = \frac{v}{i} = \frac{v}{1} = v \quad \dots (i)$$

Using nodal analysis

$$\frac{v}{25} + \frac{v}{50} = 1 + \frac{3}{2} i_x \quad \dots (ii)$$

Also $i_x = \frac{v}{50} \quad \dots (iii)$

42

So, this is if it is so, then we put i_x is equal to v by 50 and you solve it.

(Refer Slide Time: 03:59)

Solving eqn. (ii) and (iii), we get,

$$v = 33.3 \text{ Volts.}$$
$$\therefore R_{in} = R_{TH} = \frac{v}{i} = \frac{33.3}{1} = 33.3 \Omega.$$

Ex-4.18: Find the Thevenin equivalent of the circuit shown in Fig.4.46.

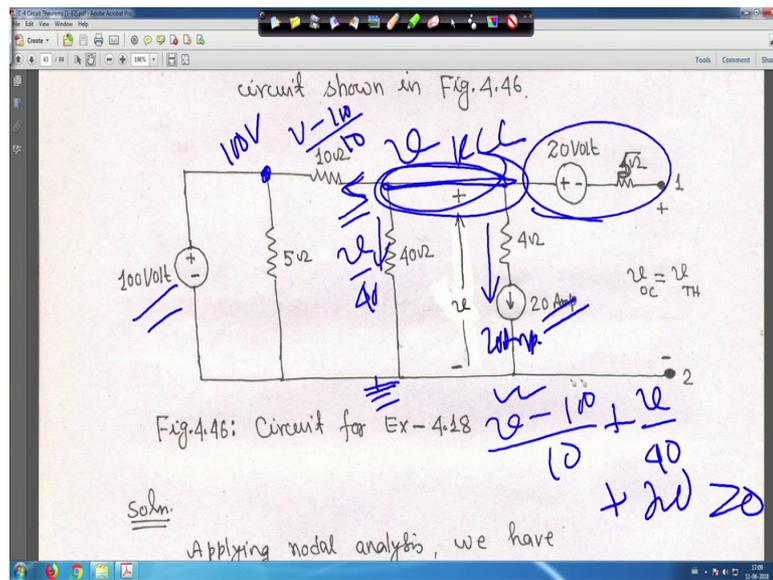
10 Ω 20V 1 Ω

42

You will get V is equal to 33.3 volts and R Thevenin is equal to told you it will be simply v . So, it is 33.3 ohm right.

Next is your 4 point that example 18, the find the Thevenin equivalent of the circuit shown in figure 46.

(Refer Slide Time: 04:13)



So, you have to find out Thevenin equivalent that is V_{oc} is equal to $V_{Thevenin}$ and $R_{Thevenin}$. So, this is open. So, no current is flowing here; no current is flowing here, but at that time of computation of V_{oc} or $V_{Thevenin}$ we have to we have to apply KVL. So, we first we have to obtain your what you call $V_{Thevenin}$ right and no current is flowing here because this is open, and this voltage is V means this is a common terminal. So, your voltage is V right and this is 100 volt. So, no electrical element here means, this point voltage is 100 volt and if I say it is it is grounded. So, with respect to the ground; so, this is there is no electrical element. So, this point voltage is 100 volt right and this 2 this this is actually a common node no electrical element is there.

So, if it is so, then if you take that direction of the current here leaving this node right it will be V minus 100 by 10 current flowing through this 10 ohm resistance will be V minus 100 divided by 10, this is the current flowing through this 10 ohm resistance this [ou/outer] outer direction right. Similarly here also it will be V by 40 this will be V by 40 right. And another thing is that this is current source is here one current source is here, and it is 20 ampere; that means, current flowing through this is 20 ampere. So, it is also leaving right so; that means, your what you call if you now if you apply your this current also leaving, that V minus 100 by 10 this current is also leaving, this current is also leaving; that means, if you apply KCL here this is a common node if you apply KCL because every time I am not bunching it together, it is understandable it is a common node.

So; that means, it will be V minus 100 by 10 because all currents are leaving this is leaving plus V by 40 plus this 20 ampere current is also leaving because this is a current source right is equal to 0 if you solve this you will get the value of V right. So, let me clear it.

(Refer Slide Time: 06:29)

Fig.4.46: Circuit for Ex-4.18

Soln.
Applying nodal analysis, we have

$$\frac{v-100}{10} + \frac{v}{40} + 20 = 0$$

$$\therefore v = -80 \text{ Volt.}$$

Thus,

$$-20 + v - v_{oc} = 0$$

$$v - v_{oc} = -20 - 80 = -100 \text{ Volt}$$

So, if it is so, then V is equal to whatever I wrote, V is equal to we will get minus 80 volt right minus 80 volt. Now V you are getting minus 80 volt; that means, this voltage this is V same thing.

(Refer Slide Time: 06:41)

circuit shown in Fig.4.46.

Fig.4.46: Circuit for Ex-4.18

Soln.
Applying nodal analysis, we have

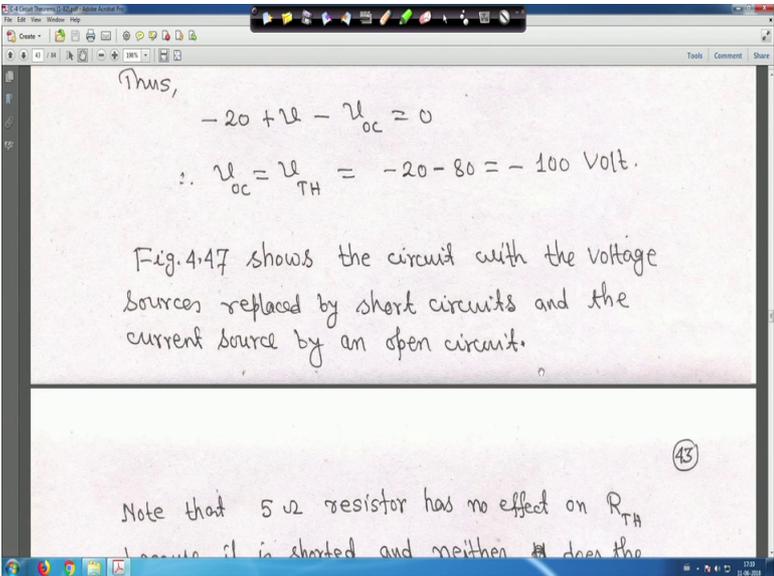
$$V_{TH} = \frac{-100}{-20 + V_{TH}}$$

$$-20 - 80 = V_{TH}$$

Suppose minus whatever we have got we will write this is minus 80 volt and this is your plus minus whatever is there this. Now we apply you apply KVL like this. So, if your moving like this you are encountering minus terminal first.

So, minus 20 plus this is V this is your plus this is plus minus. So, plus minus same thing we are writing plus V right encountering minus terminal first V Thevenin is equal to 0; that means,; that means, minus 20 and V is equal to minus 80 is equal to V thevenin; that means, V Thevenin is equal to minus 100 volt right. So, same thing it is calculation is there later first we have to understand.

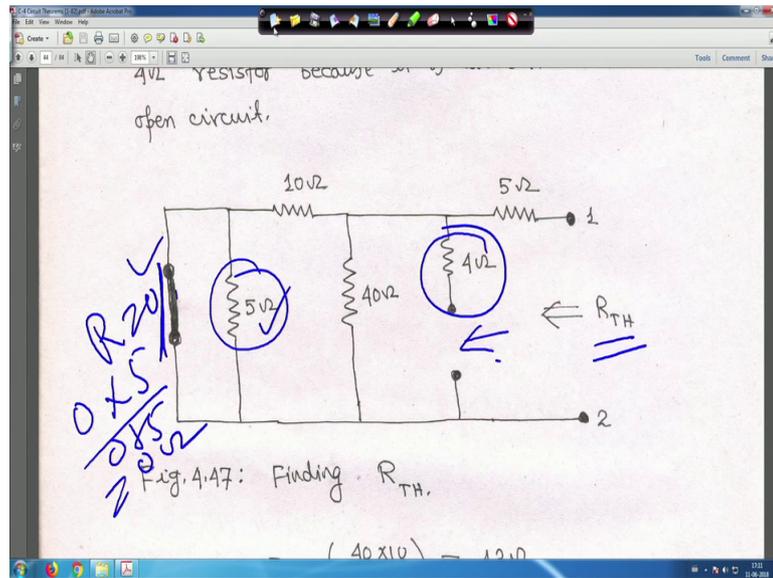
(Refer Slide Time: 07:33)



The image shows a handwritten derivation on a whiteboard. It starts with the word "Thus," followed by the equation $-20 + V - V_{oc} = 0$. Below this, it states $\therefore V_{oc} = V_{TH} = -20 - 80 = -100 \text{ Volt.}$ The next line of text says "Fig. 4.47 shows the circuit with the voltage sources replaced by short circuits and the current source by an open circuit." At the bottom, there is a note: "Note that 5 Ω resistor has no effect on R_{TH} because it is shorted and neither R_1 does the". A circled number "43" is written in the bottom right corner of the whiteboard area.

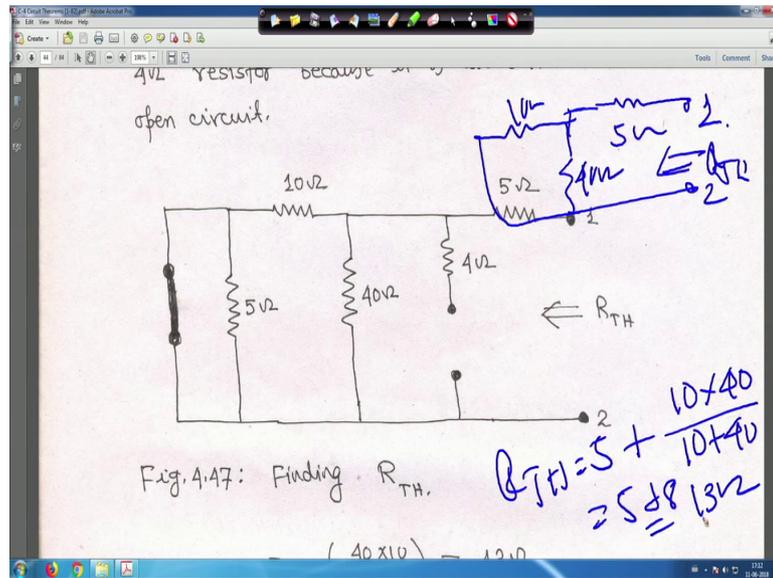
So, this is actually we are getting V_{oc} Thevenin is equal to minus 100 volt now. So, figure 47 the circuit with the voltage sources replaced by short circuit and the current sources by an open circuit right.

(Refer Slide Time: 07:45)



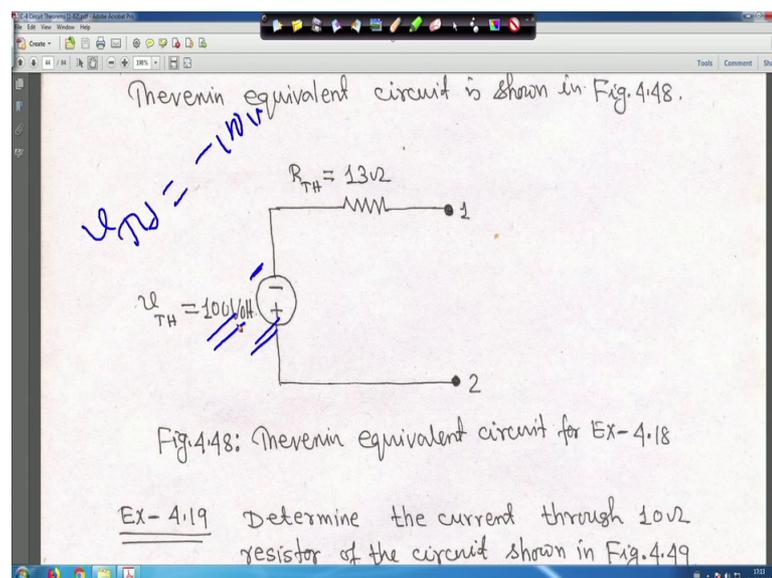
Now, this there was a current source here because we have to get R Thevenin we have to get R thevenin. So, this current source is open and this voltage source here it is short circuited right. So, there will be no effect for this one it is completely isolated right nothing is there and thing is this 5 ohm and your this they it is short circuit; that means, this 5 ohm actually has no value right. Because if for your understanding only suppose if I take R is equal to 0 ohm for this branch. So, 0 ohm and 5 ohm they are in parallel say for your understanding. So, 0 into 5 by 0 plus 5 is equal to 0 ohm. So, R that means, this 5 ohm has no effect right. So, let me clear it so; that means, if you try to find out that that what is the then then what is the equivalent one. So, just for your understanding I am somehow I am making it here say, this is your say 5 ohm, this is your one ampere 1 terminal 1.

(Refer Slide Time: 08:41)



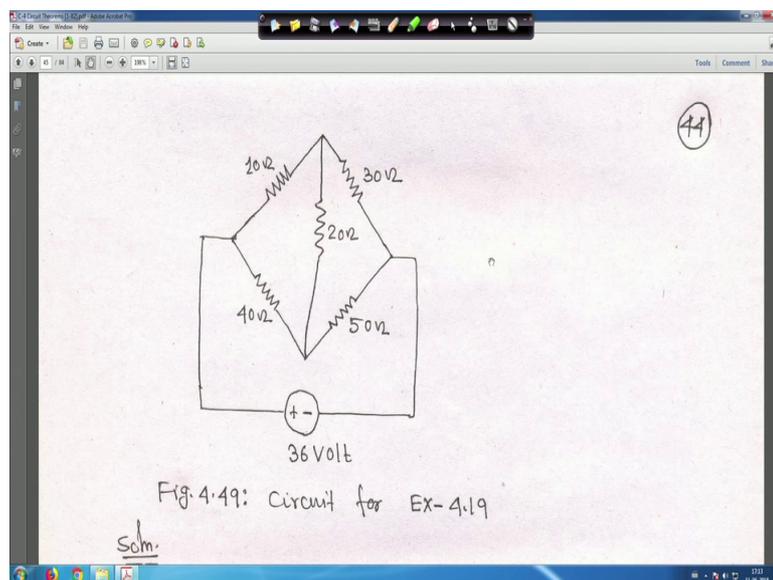
Then this is your your what you call 40 ohm, and this is your 10 ohm right and this is connected and this is your terminal 2 and this is your R thevenin; that means, 40 and 10 are in parallel with that 5 is in series; that means, your R Thevenin will be is equal to 5 plus 10 into 40 divided by your 10 plus 40 right; that means, 5 plus 8 is equal to 13 ohm right. Because 400 by 50 it will be 8 ohm plus 5 is equal to 30 ohm. So, let me clear it. So, that means, this one will be 13 ohm and this is your Thevenin equivalent circuit right.

(Refer Slide Time: 09:34)



So, next one is another one is that. So, this is hope you have understood this is V Thevenin this is R Thevenin it was ask to find out V Thevenin, we will got only one thing I have to tell you here we got V Thevenin is equal to minus 100 volt right that is why this plus polarities at the bottom and minus is here right. So, that is why I have written V is equal to 100 volts. So, there should not be any confusion and this is your 13 ohm. So, let me clear it. So, next is you are determine the current through 10 ohm resistor of the circuit shown in figure 49 using Thevenin's theorem right.

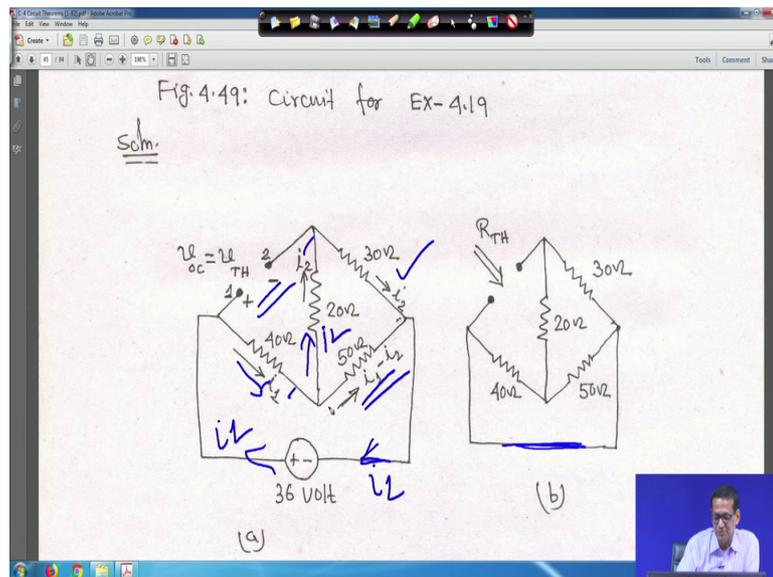
(Refer Slide Time: 10:21)



You have to find out the current through 10 ohm resistance; that means, here you have to find out the current through 10 ohm resistance that mean you have to open 10 ohm resistance to get the V Thevenin and similarly you have to find out the R Thevenin there.

So, and this is 36 volt and this is no other thing is there this is no electrical other (Refer Time: 10:36) just just in between these terminal this 36 volt source is connected. So, first you take it take 10 ohm resistance open. So, if we open it. So, circuit looks like this if you open it. So, this is 1 this is 2.

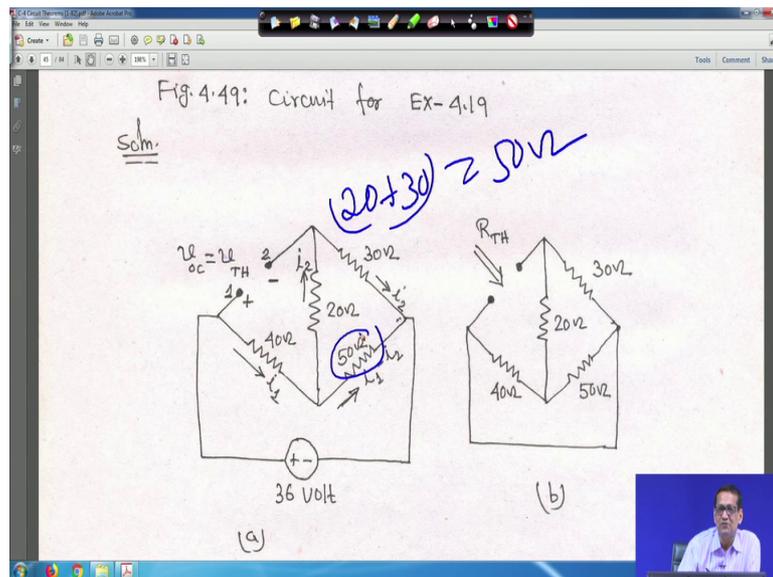
(Refer Slide Time: 10:50)



So, this is my V_{oc} is equal to $V_{Thevenin}$ right and for $R_{Thevenin}$ that voltage source is shorted this these voltage source is shorted here, this voltage source is shorted here right. So, it is shorted this is for $R_{Thevenin}$ and this is for your what you call that your $V_{thevenin}$, we have to solve this circuit for $V_{thevenin}$. Now before moving further if you look into that this current, this current right this suppose this current this is open this side is open.

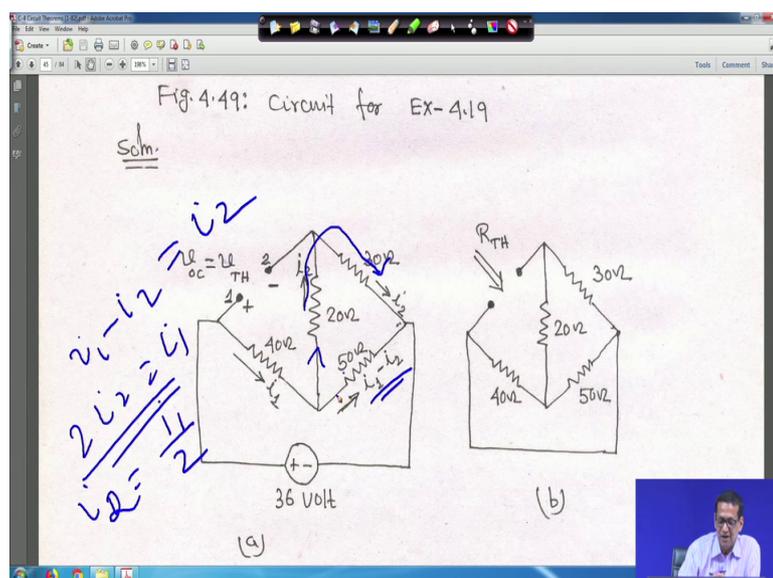
So, basically from this source the current i_1 is flowing this current this is open nothing is going. So, this i_1 is coming here this is your i_1 . Now part from part of the current i_1 i_2 is flowing like this. So, in this circuit it is i_1 minus i_2 right and finally, i_1 minus i_2 and that this i_2 this side is open. So, same i_1 same i_2 current is flowing here right and finally, when they are meeting it here. So, finally, this i_1 current will return to the this source right. So, this way first we have to make the circuit. So, after this you have to solve for your what you call i_1 and i_2 . Now question is that if you look into this circuit let me I hope you have understood this right.

(Refer Slide Time: 12:19)



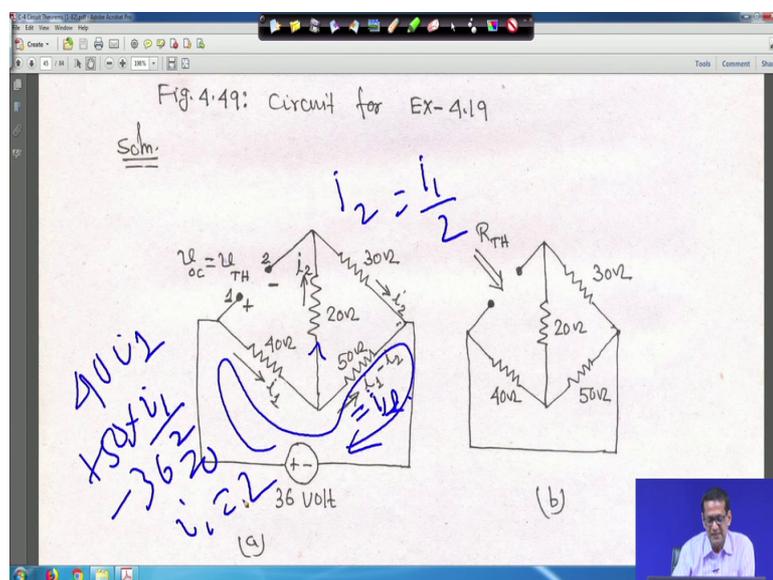
Now, question is let me clear it. So, as your this 20 ohm and 30 ohm it is in series. So, 20 plus 30 is equal to 50 ohm right and the another and this another 50 ohm is here; that means, this 20 plus 30 50 ohm and this 50 ohm they are in parallel; that means, 50 and 50 both 50 are in parallel; that means, equal amount of current will flow through both. So, let me clear it; that means, whatever current is flowing your this i_2 current is flowing here right 20 and 30 both are in series and i_1 minus i_2 also flowing through 50; that means, i_1 minus i_2 is equal to i_2 .

(Refer Slide Time: 12:52)



Because both current this current and i_2 current both have to be same because both are 50 ohm because 20 plus 30 50 ohm; that means, i_2 is equal to your i_1 . This is; that means, i_1 is equal to sorry i_2 is equal to your i_1 by 2 right because it is a current division right it is a current division. So, that means, here also flowing i_1 by 2 here also effectively flowing i_1 by 2. Once it is done so, easily you can your what you call easily you can your what you call apply your KVL right for example, you can apply KVL like this, you can apply KVL like this; that means, if it is i_1 then this current will be basically i_2 is equal to i_1 by 2.

(Refer Slide Time: 13:37)



And here i_1 minus i_2 means it is also i_1 by 2. So, easily you can get it. So, if you apply KVL here, it will be look your what you call if I make it like this $40i_1$ right this one and here it is your this current is actually i_1 by 2 because current division is there.

So, plus 50 I am writing like this plus 50 into i_1 by 2 minus 36 is equal to 0, from which we will get what is i_1 right. So, if you get i_1 let me let me go through this let me clear it first. So, if you go through this.

(Refer Slide Time: 14:25)

Fig. 4.50: (a) finding V_{TH} (b) finding R_{TH} .

Fig. 4.50 shows the circuit for finding V_{TH} and R_{TH} .

From Fig. 4.50(a),

$$i_1 = 2i_2 \quad \dots (i)$$

$$40i_1 + 50(i_1 - i_2) - 36 = 0 \quad \dots (ii)$$

Solving eqn. (i) & (ii), we get,

$$i_1 = \frac{36}{65} \text{ Amp}; \quad i_2 = \frac{18}{65} \text{ Amp.}$$

Then you will get if you solve the way I told you i_1 is equal to you will get 36 by 65 ampere and i_2 is just i_1 by 2. So, it is 18 by 65 ampere that you got. So, i_1 i_2 you have got then easily you can find it find it out that what is my $V_{Thevenin}$. So, this is plus this is minus again I am not marking it it is understandable. Now if you apply your KVL here like this, if you apply KVL here right anticlockwise.

(Refer Slide Time: 14:56)

Diagram (a) shows a circuit with a 36V DC source, a 40Ω resistor, a 50Ω resistor, and a 20Ω resistor. A 30V potential difference is indicated across the 20Ω resistor. Currents i_1 and i_2 are labeled. The open-circuit voltage is labeled $V_{oc} = V_{TH}$. Handwritten notes on the left indicate: $40i_1$, $+ 20i_2$, $- 50i_1$, and $- 36$.

Diagram (b) shows the equivalent circuit for finding R_{TH} , consisting of a 30V resistor, a 20Ω resistor, a 40Ω resistor, and a 50Ω resistor.

Fig. 4.50: (a) finding V_{TH} (b) finding R_{TH} .

So, it is 40 i 1 right plus we are moving like this plus 20 i 2 minus V Thevenin is equal to 0 right. So, put i 1 value i 2 value we will get V thevenin. So, that is that is whatever we have done it here. So, whatever we have done.

(Refer Slide Time: 15:15)

Handwritten mathematical derivation on a whiteboard:

$$i_1 = \frac{36}{65} \text{ Amp}; \quad i_2 = \frac{18}{65} \text{ Amp.}$$

$$\therefore v_{TH} = 20i_2 + 40i_1 = 100i_2 = 100 \times \frac{18}{65} \text{ Volt} \quad (45)$$

$$\therefore v_{TH} = \frac{360}{13} \text{ Volt.}$$

From Fig. 4.50(b),

$$R_{TH} = (40 \parallel 50 + 20) \parallel 30 = \frac{228}{13} \Omega$$

It will be it will becoming 360 by 13 volt right that is my V Thevenin 360 by 13 volt. Now you have to find out what is that your what you call that R r R thevenin. So, if you if you redraw the circuit like this; this terminal is 1 and this terminal is 2 because this is 1, this is 2, this is 1, this is 2.

(Refer Slide Time: 15:49)

Handwritten circuit diagrams on a whiteboard:

Fig. 4.49: Circuit for EX-4.19

Sch.

(a) Original circuit diagram with a 36V DC source, resistors of 40Ω, 50Ω, 20Ω, and 30Ω, and current variables i_1 and i_2 . A handwritten note says $(50 \parallel 40) \times \frac{20}{130} = ?$.

(b) Equivalent circuit diagram for finding R_{TH} , showing the 30Ω resistor in parallel with the series combination of 20Ω and the parallel combination of 40Ω and 50Ω.

Now, this two these two point is a common point. So, basically the circuit I am trying to make it like this; this is 2 right. This is 2 and this is your 20 ohm resistance right.

This is your 20 ohm resistance now basically this 40 and 50 this 40 and 50 actually are in parallel. So, this is 40 ohm and this is your 50 ohm right and this point is your this point is 2 sorry this point is 1 and then your what you call this 30 ohm is connected like this. I mean what i did i bring this point bring this point here right; that means, 40 and 50 in parallel because no other electrical element is here. So, 40 and 50 in parallel right whatever it will come with that 20 ohm is in series whatever it will come with that again 30 are in parallel to this; that means, if i make it like this, it will be actually whatever it comes 50 i making like this parallel to 40 right whatever it is plus this 20 will come making on it only plus 20 will come. Whatever will be there you add it with that 30 30 again is in parallel to that right.

Whatever it will come you find it out right. So, that is that is your what you call that will become your R Thevenin I hope you have understood this right so; that means, let me let me clear it.

(Refer Slide Time: 17:20)

From Fig. 4.50(b),

$$R_{TH} = (40 \parallel 50 + 20) \parallel 30 = \frac{228}{13} \Omega$$

current through 10 Ω resistor,

$$i = \frac{V_{TH}}{R_{TH} + 10} = \frac{360/13}{\left(\frac{228}{13} + 10\right)} = \frac{360}{358} \text{ Amp.}$$

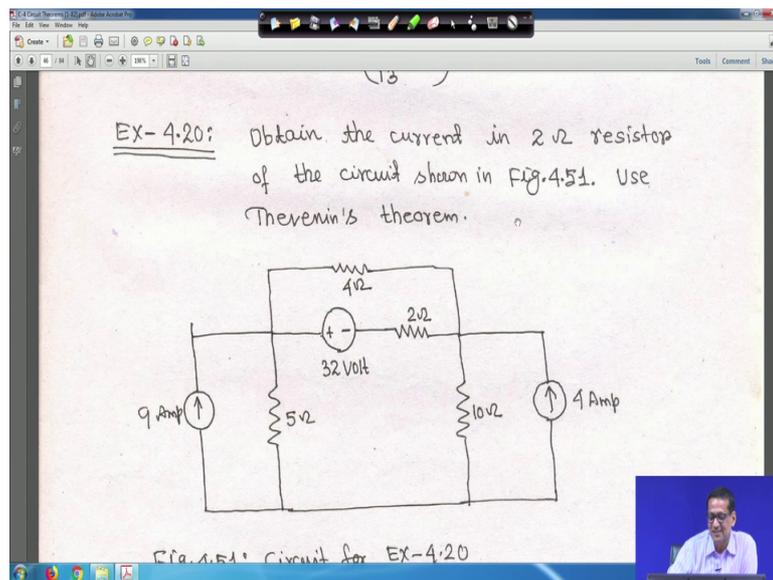
EX-4.20: Obtain the current in 2 Ω resistor of the circuit shown in Fig. 4.51. Use Thevenin's theorem.

So, what I have done it here same thing. So, I have just put directly that 40 and 50 are in parallel with that 20 is in series and along with that 30 ohm again in parallel. So, it will become your 228 by 13ohm right. And I will be V Thevenin because it has been asked to find out current through 10 ohm resistance 10 ohm resistance. So, your circuit is not V

Thevenin R Thevenin not shown directly given, the i is equal to V Thevenin by R Thevenin plus 10. So, your R Thevenin is becoming this much and V Thevenin we got 360 upon 13.

So, ultimately it is 360 upon 358 ampere approximately 1 ampere that is i right. So, let me clear it sorry let me clear it. So, I hope you have understood this right.

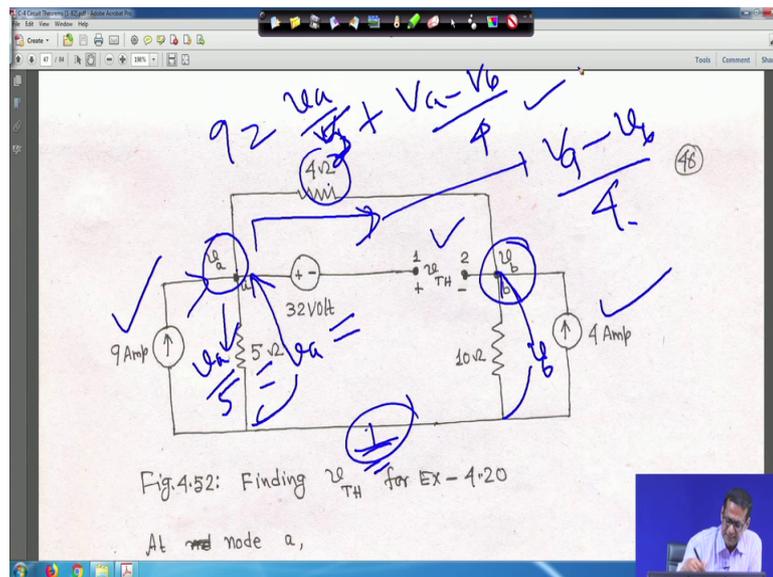
(Refer Slide Time: 18:08)



You will not get much difficult one in this one. So, just for your understanding only I have taken varieties of problem, but remember for a circuit, see this too many problems will not be taken because time is restricted. So, example 20 obtain the current in 2 ohm resistor of the circuit shown in figure 51, use Thevenin's theorem also super position also you will use to get the Thevenin voltage. So, in this case you have to find out what is that current through 2 ohm resistance.

That means what is the current through 2 ohm resistance. So, we have to take it off first 2 ohm resistance right and you have to find out R Thevenin and V Thevenin.. So, go to the your sorry go to the equivalent circuit. So, in this case what will happen that 2 ohm resistance is taken off.

(Refer Slide Time: 18:51)

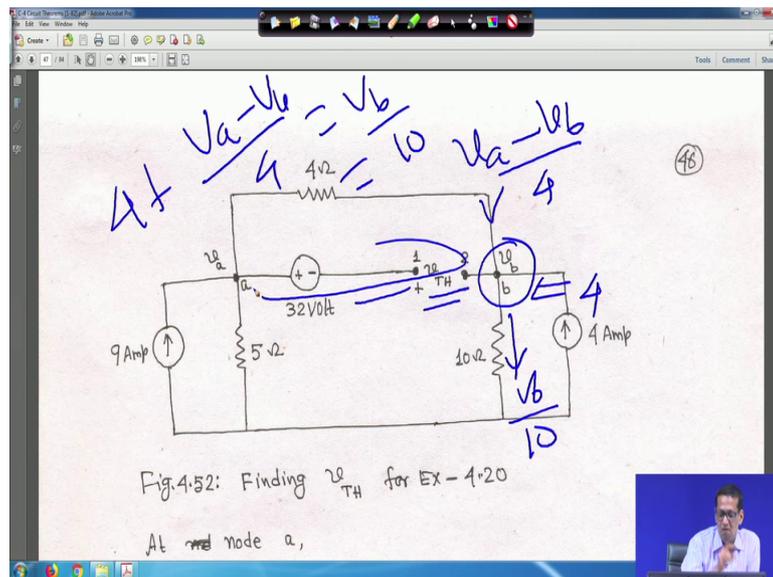


So, it will be open 2 ohm resistance is open, and we have marked one voltage here V_a another voltage is V_b . V_a means this voltage this is your V_a and this voltage say meeting it here this is V_b V_b right. If you assume it is ground in nodal analysis you will apply right. So, question is that that these 2 voltage have been taken, but you have to ultimately obtain $V_{Thevenin}$ and this is a 30 volt source one 9 ampere source independent source is there, one 4 ampere independent current source is there 2 cu[rrent] independent current source is there and one independent voltage source of 32 volt is there. Now what you do is you apply KCL at node at this point.

If you apply KCL so, this 9 ampere current is entering into this. So, you can make 9 right then you this 9 is entering then it is 5 ohm resistance this voltage is V_a . So, this current is leaving. So, it is V_a by 5 right. So, 9 is equal to you can make V_a by 5 this current is leaving, and another current if you take in this direction, this 4 ohm resistance is here. So, it will be your making it here, it will be V_a this voltage is V_b minus V_b divided by your 4 because this 4 ohm resistance. So, plus V_a minus V_b divided by 4. This is V_a by your 5; this is V this is your 9 is equal to V_a by your 5 right. So, it is V_a by 5 plus V_a minus this is one equation this is one equation you will get. So, let me clear this one. So, this later later equations are there right.

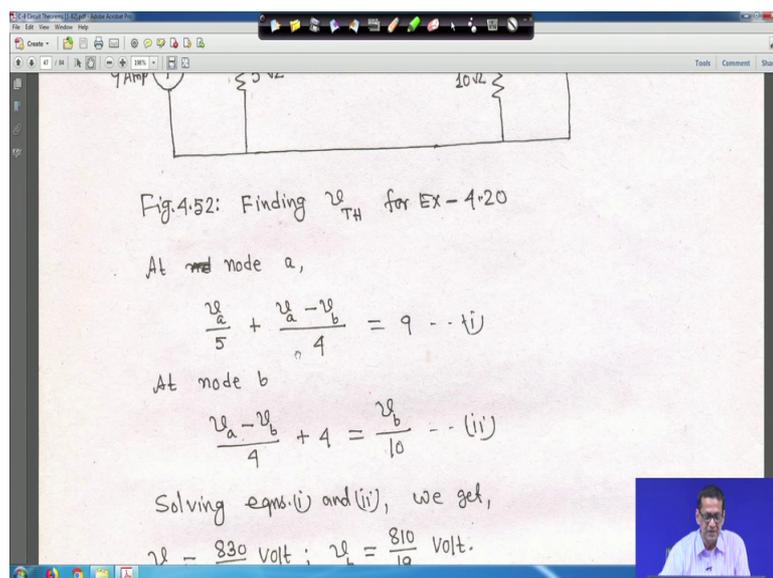
Now, another one is if you apply your what you hope I have not missed anything if you apply your what you call KCL at node b.

(Refer Slide Time: 20:51)



So, this current we saw it is entering V_a minus V_b by 4, because this 4 ohm resistance current through this is V_b by 10 right and this 4 ampere current it is entering. So, it is basically 4 plus V_a minus V_b divided by 4, because this current is also entering and this current is leaving is equal to your V_b by 10. So, 2 equations we got and you can solve using 2 equation V_a and V_b ; hope I have not missed anything and there is no current flowing here because this is open. So, no current is flowing here right sorry.

(Refer Slide Time: 21:32)



So, those 2 equations I have written here, here is one equation at node a another equation at node b and solve this equation 1 and 2 for V a and V b. If you do so, you will get V a is equal to 830 upon 19 volt and V b is equal to 810 by 19 volt.

(Refer Slide Time: 21:46)

At node a

$$\frac{V_a - V_b}{4} + 4 = \frac{V_b}{10} \quad \dots (ii)$$

Solving eqns. (i) and (ii), we get,

$$V_a = \frac{830}{19} \text{ volt}; \quad V_b = \frac{810}{19} \text{ volt.}$$

Thus,

$$V_a - V_b - V_{TH} - 32 = 0$$

$$\therefore V_{TH} = \frac{830}{19} - \frac{810}{19} - 32 = -30.947 \text{ Volt.}$$

For determining R_{TH} , resulting circuit is shown in Fig. 4.52

Therefore your V therefore, you apply your what you call that your KVL for getting the Thevenin. So, this voltage is V a. So, this is actually arrow in plus this is V a and this voltage this is your V b right.

(Refer Slide Time: 21:59)

Fig. 4.52: Finding V_{TH} for Ex-4.20

At node a,

If you assume this is grounded. So, that; that means, this is plus minus and this is also plus minus. So, if i if we apply KVL like this in this in this mesh, then if you move like this if you move like this, it will be minus 32 because minus terminals is coming first plus V a because V a is coming first right.

Then here it is minus right. So, minus V b right and there it is minus V Thevenin is equal to 0 right; that means, V Thevenin is equal to V a minus V b minus 32 right so; that means, let me clear it.

(Refer Slide Time: 22:53)

$$\frac{V_a - V_b}{4} + 4 = \frac{V_b}{10} \quad \dots (i)$$

Solving eqns. (i) and (ii), we get,

$$V_a = \frac{830}{19} \text{ Volt}; \quad V_b = \frac{810}{19} \text{ Volt.}$$

Thus,

$$V_a - V_b - V_{TH} - 32 = 0$$

$$\therefore V_{TH} = \frac{830}{19} - \frac{810}{19} - 32 = -30.947 \text{ Volt.}$$

For determining R_{TH} , resulting circuit is shown in Fig 1.50

4V

So; that means, your whatever you have wrote that V v a minus V b minus V Thevenin minus 32 what I wrote, V Thevenin is equal to V a minus V b minus 32 is equal to I wrote there. So, you put all this things you will get V Thevenin is equal to minus 30.947 volt right. So, minus means; so, we will make the polarity it will be at the downwards right.

(Refer Slide Time: 23:13)

$$r_{TH} = \frac{830}{19} - \frac{810}{19} - 32 = -30.947 \text{ Volt}$$

For determining R_{TH} , resulting circuit is shown in Fig.4.53.

$$(5+10) = 15$$

$$R_{TH} = \frac{15 \times 4}{15+4} = \frac{60}{19} = 3.157 \Omega$$

Fig.4.53: Finding R_{TH} for EX-4.20

And similarly for R Thevenin that your R Thevenin that this one voltage source is here it is shorted and current source is open right. So, basically what happen this 5 and 10 ohm are in series.

So, it is 5 plus 10 is equal to 15 ohm. So, this is open. So, 5 and 10 are in series with that the 4 ohm is in parallel. So, R Thevenin will be 15 into 4 divided by 15 plus 4 whatever it comes, that will be your R Thevenin right because this one and 2 Ii mean it is something like this, This is your one these 2 are open this is 1 and this terminal is 2 this is one right. So, this is actually 4 ohm and here its 5 plus 10. So, here it is actually 15 ohm right and this is 1 2. So, 4 and 15 are in parallel. So, whatever it comes. So, So, in this case, so R Thevenin will coming 60 by 19 ohm right.

(Refer Slide Time: 24:16)

From Fig. 4.53, we have, (47)

$$R_{TH} = \frac{(10+5) \times 4}{(10+5) + 4} = \frac{60}{19} \Omega$$

Thevenin equivalent circuit is shown in Fig. 4.54.

The diagram shows a circuit with a voltage source $V_{TH} = 30.947$ V (positive terminal at the bottom) in series with a resistor $R_{TH} = \frac{60}{19} \Omega$. This combination is connected to a 2Ω resistor. The current i is shown as a clockwise arrow in the loop.

So, therefore, Thevenin equivalent you will be your.

(Refer Slide Time: 24:20)

Thevenin equivalent circuit is shown in Fig. 4.54.

The diagram shows a circuit with a voltage source $V_{TH} = 30.947$ V (positive terminal at the bottom) in series with a resistor $R_{TH} = \frac{60}{19} \Omega$. This combination is connected to a 2Ω resistor. The current i is shown as a clockwise arrow in the loop.

Fig. 4.54: Thevenin equivalent circuit for Ex-4.20

$$\therefore i = \frac{V_{TH}}{R_{TH} + 2} = \frac{30.947}{\left(\frac{60}{19} + 2\right)} = 6 \text{ Amp.}$$

If you look into this that it is plus because V Thevenin was minus 30.947; so, it is plus is here bottom here right and it is moving like this, and this is R Thevenin with that 2 ohm resistance you connect now and you will get the value of the current. So, i is equal to V Thevenin by R Thevenin plus 2 ohm this 2 ohm right and put all these value. So, it is approximately 6 ampere. So, this is the answer right.

(Refer Slide Time: 24:58)

The screenshot shows a whiteboard with the following content:

$$\therefore i = \frac{V_{TH}}{R_{TH} + 2} = \frac{30.947}{\left(\frac{60}{19} + 2\right)} = 6 \text{ Amp.}$$

Ex-4.21 : Obtain the Thevenin voltage shown in the circuit of Fig. 4.51- for Ex-4.20

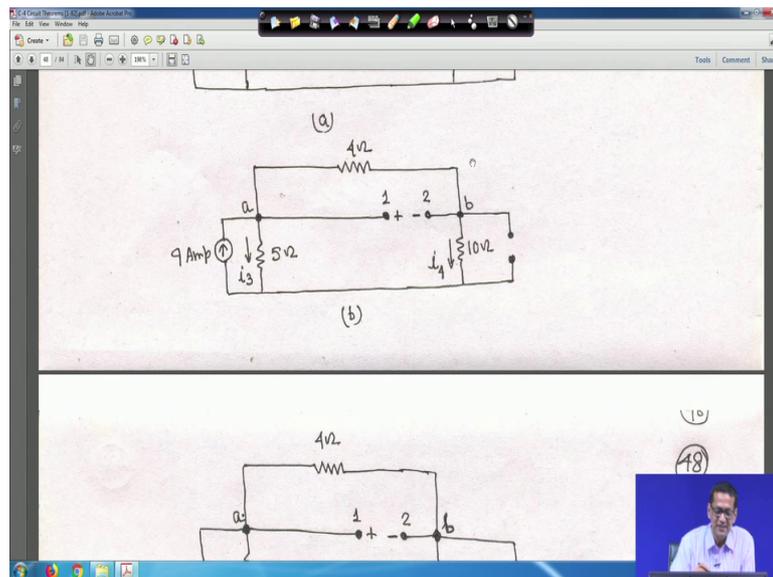
Soln.

The circuit diagram shows a network with a 32V DC voltage source (positive terminal at the top) in series with a 4Ω resistor. This combination is connected to terminals 'a' and 'b'. A 5Ω resistor is connected between terminals 'a' and a common ground. A 10Ω resistor is connected between terminals 'b' and the same common ground. The current through the 5Ω resistor is labeled i_1 and the current through the 10Ω resistor is labeled i_2 . The terminals 'a' and 'b' are also labeled with '1' and '2' respectively, indicating a load connection point.

So, now next one is you obtain the Thevenin voltage shown in the circuit of this thing, now what to what Thevenin voltage also you can obtain by using super position theorem? Because you have 3 sources just to show you something, 3 sources one voltage source 2 current source you consider only one source at a time same example this same example you obtain Thevenin voltage using your super position theorem.

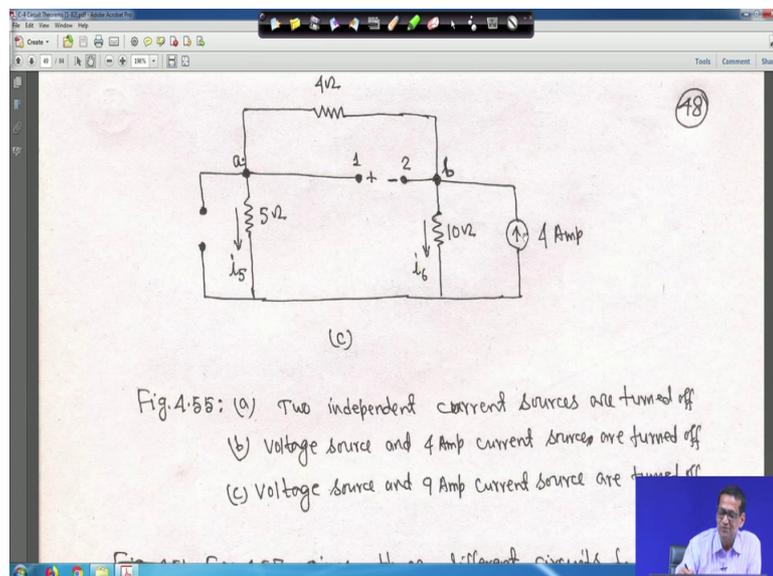
Because you have 3 sources take only one at a time, just to show you right. So, in this case your if it is so, then in this case first we have consider the voltage source and your this only voltage source, this current 2 sources are turned off and current is here i_1 i_2 you solve for i_1 and i_2 later I will give you the solution. So, otherwise it will consume more time; so, i_1 and i_2 .

(Refer Slide Time: 25:54)



So, next one is next one is that you consider only 9 ampere current source, this is your 9 ampere current source right; this 9 ampere current source and this voltage source is shorted and this current source is open only one at a time and current is here i_3 and i_4 you solve for you have to solve for i_3 and i_4 .

(Refer Slide Time: 26:17)



Next is your this one that next is this one that your 4 ampere is there current source, but the other 2, but other 2 it is shorted voltage source is shorted voltage source was here and this is current right this is open. So, this is i_5 and i_6 that all this things, you have to

obtain. So, all the all the all the all the a b c 3 circuits were there a b c, a b c everything is written here. So, it is just to show you the super position theorem. That next is you when you solve it look from figure a that is all this things solutions are given to you right.

(Refer Slide Time: 26:54)

From Fig. 4.55(a),
 $i_1 = 0.0$; $i_2 = 0.0$

From Fig. 4.55(b),
 $i_3 = \left(\frac{10+4}{20+4+5}\right) \times 9 = 6.63 \text{ Amp}$; $i_4 = 9 - i_3 = 9 - 6.63 = 2.37 \text{ Amp}$

From Fig. 4.55(c),
 $i_5 = \frac{10}{(10+5+4)} \times 4 = 2.11 \text{ Amp}$; $i_6 = 4 - 2.11 = 1.89 \text{ Amp}$

$\therefore i_{502} = i_1 + i_3 + i_5 = 0 + 6.63 + 2.11 = 8.74 \text{ Amp}$

$i_{102} = i_2 + i_4 + i_6 = 0 + 2.37 + 1.89 = 4.26 \text{ Amp}$

And similarly figure b figure a it is given i 1 0 i 2 0.

(Refer Slide Time: 27:01)

$i_3 = \left(\frac{10+4}{20+4+5}\right) \times 9 = 6.63 \text{ Amp}$; $i_4 = 9 - i_3 = 9 - 6.63 = 2.37 \text{ Amp}$

From Fig. 4.55(c),
 $i_5 = \frac{10}{(10+5+4)} \times 4 = 2.11 \text{ Amp}$; $i_6 = 4 - 2.11 = 1.89 \text{ Amp}$

$\therefore i_{502} = i_1 + i_3 + i_5 = 0 + 6.63 + 2.11 = 8.74 \text{ Amp}$

$i_{102} = i_2 + i_4 + i_6 = 0 + 2.37 + 1.89 = 4.26 \text{ Amp}$

$\therefore V_a = 5 \times i_{502} = 5 \times 8.74 = 43.7 \text{ Volt}$

$V_b = 10 \times i_{102} = 10 \times 4.26 = 42.6 \text{ Volt}$

Thus

Similarly, figure b your i_3 is equal to 6.63 ampere i_4 is 2.37 ampere, you please solve it everything I have written here for you, but you please solve it. And similarly for figure c i_5 is given we got 2.1 ampere and i_6 1.89 ampere.

(Refer Slide Time: 27:19)

Handwritten calculations on a whiteboard:

$$i_5 = \frac{26}{(10+5+4)} \times 4 = 2.11 \text{ Amp}; \quad i_6 = 4 - 2.11 = 1.89 \text{ Amp}$$

$$\therefore i_{5\Omega} = i_1 + i_3 + i_5 = 0 + 6.63 + 2.11 = 8.74 \text{ Amp}$$

$$i_{10\Omega} = i_2 + i_4 + i_6 = 0 + 2.37 + 1.89 = 4.26 \text{ Amp}$$

$$\therefore V_a = 5 \times i_{5\Omega} = 5 \times 8.74 = 43.7 \text{ Volt}$$

$$V_b = 10 \times i_{10\Omega} = 10 \times 4.26 = 42.6 \text{ Volt}$$

Thus

$$V_{TH} = V_a - V_b - 32 = 43.7 - 42.6 - 32 = -30.9 \text{ Volt.}$$

Now, i_5 that current flowing through 5 ohm resistance that is i_5 ohm we are writing; i_1 plus i_3 plus i_5 . You just add it super position 8.74 ampere, similarly current flowing through 10 ohm resistance here it is i_2 plus i_4 plus i_6 it is coming 4.26 ampere. So, V_a is equal to 5 into current flowing through i_5 your 5 ohm resistance that is i_5 ohm we are writing, that is 5 into 8.74 43.7 volt and V_b is equal to your 10 into $i_{10\Omega}$, we are writing that is current flowing through 10 ohm resistance; so, 10 into 4.26. So, 42.6 volt therefore, $V_{Thevenin}$ is equal to V_a minus V_b minus 3. Initially I have written for you. So, put V_a V_b and you will get minus 30.9 volt same thing using super super position takes lot of time right.

(Refer Slide Time: 28:10)

4.5: NORTON'S THEOREM

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

where,
 i_N = short circuit current through the terminals
 $R_N = R_{Th}$

Next is your Norton theorem. So, Norton's theorem this is Norton's theorem. So, Norton theorem states that a linear 2 terminal circuit can be replaced by an equivalent circuits consisting of a current source i_N in parallel with a resistor R_N . In the Norton circuit case R_N and R_{Th} . They are same at the beginning I am telling that R_N is equal to R_{Th} , that begin things I think Thevenin give these thing eighteen 100 I think 92 he gave and Norton probably 1933 or 37 exact I have forgotten exact thing and I am; that means, are nearly after more than 40 years right. So, sometimes the source transformation we call Thevenin Norton transformation.

Because Thevenin gives on voltage source and resistance, when you transform into Norton it will be a current source and resistance in the parallel in Thevenin resistance is in series with the voltage source right. So, philosophy is that your.

(Refer Slide Time: 29:12)

equivalent circuit consisting of a current source i_N in parallel with a resistor R_N .

where,

i_N = short circuit current through the terminals

R_N = input or equivalent resistance at the terminals when the independent sources are turned off.

consider the circuit given in Fig.4.56(a). This circuit can be replaced by the one given in Fig.4.56(b)

in the same way we find R_N

So, where i_N is short circuit current to the terminals that will give and R_N is equal to input or equivalent resistance at the terminal when the independent sources are turned off right it is same like your $R_{Thevenin}$ is equal to R_{Norton} .

(Refer Slide Time: 29:26)

consider the circuit given in Fig.4.56(a). This circuit can be replaced by the one given in Fig.4.56(b). We find R_N in the same way we find R_{TH} . In fact, Thevenin and Norton resistances are equal, that is

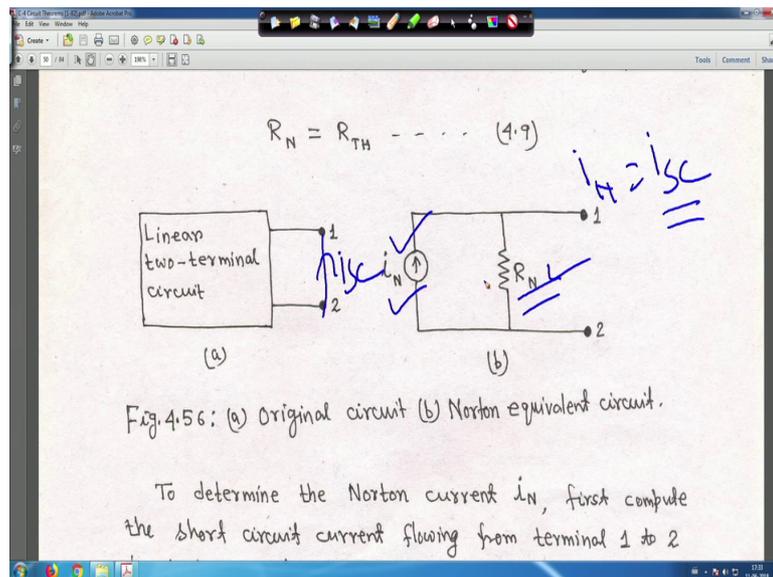
$$R_N = R_{TH} \dots (4.9)$$

Linear two-terminal circuit

(a) (b)

So; that means, R_{Norton} is equal to $R_{Thevenin}$. So, idea is for Thevenin's theorem we got open circuit voltage in this case, we will get your what you call that short circuit current.

(Refer Slide Time: 29:36)



That means, this is a linear 2 terminal circuit right this is a linear this is your i_N Norton actually i_N is equal to i_{SC} right and Norton resistance is nothing, but a Thevenin resistance is same right.

So, i_N i_{SC} means if you short circuit it and if this is your short circuit current. So, i_N will be is equal to i_{SC} right. So, in this case what we will do we have to find out that what is short circuit current right and then we have to find out Thevenin resistance and this Norton and your Thevenin Norton resistance (Refer Time: 30:11) current source both will be in parallel right. So, that is just a just in the case of Thevenin it was open circuit, in the case of Norton it will be your what you call it will be in the it will be short circuit right. So, and then we have to find out short circuit current i_{SC} that is nothing, but is equal to i_N and for R_N is a identical to your $R_{Thevenin}$ same. So, let me clear it right.

(Refer Slide Time: 30:39)

It is evident that the short circuit current in Fig. 4.56(b) is i_N and this must be the same short circuit current from terminal 1 to 2 in Fig. 4.56(c). Since the circuits of Fig. 4.56(c) and Fig. 4.56(b) are equivalent, thus,

$$i_N = i_{sc} \quad \dots (4.10)$$

Fig. 4.57 shows the circuit for finding Norton current i_N .

Linear

1

2

So, with this so, all all this write up is here you can you can go through it. So, i whatever told i Norton is equal to i SC right.

(Refer Slide Time: 30:48)

Linear two-terminal circuit

1

2

$i_{sc} = i_N$

Fig. 4.57: Finding Norton current i_N

Also

$$i_N = \frac{V_{TH}}{R_{TH}} \quad \dots (4.11)$$

Note that dependent and independent sources

So; that means, whatever i told the terminal 1 2 you short it and make it i SC is equal to your i Norton right. So, that is your what you call short circuit current. So, finding Norton current; that means, i Norton basically is equal to V Thevenin by R thevenin.

(Refer Slide Time: 31:03)

Fig4.57: Finding Norton current i_N

Also

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

Note that dependent and independent sources are treated the same way as in Thevenin's theorem.

The Thevenin and Norton equivalent circuits are related by a source transformation. For this reason, this transformation is often called Thevenin-Norton transformation.

The idea is sometimes we call that it is basically Thevenin Norton transformation suppose Thevenin's theorem making it here only suppose Thevenin theorem, this is your V_{TH} Thevenin you got right this is your V_{TH} Thevenin you got and your this is your R_{TH} Thevenin, this is your R_{TH} Thevenin and this is terminal one and this is terminal two this is your R_{TH} Thevenin right. And if you go for source transformation, so, it will be your i_N Norton right and this will be your basically R_{TH} Thevenin is equal to R_{TH} Norton both are same and this is terminal 1 2.

That means i_N Norton is equal to source transformation V_{TH} Thevenin by R_{TH} Thevenin right. So, sometimes we call that it is basically your Thevenin Norton transformation right. So, because it is voltage source in series resistance, there it will be current source in parallel with the resistance.

(Refer Slide Time: 32:05)

Note that dependent and independent sources are treated the same way as in Thevenin's theorem.

The Thevenin and Norton equivalent circuits are related by a source transformation. For this reason, source transformation is often called Thevenin - Norton transformation.

To determine the Thevenin or Norton equivalent circuits require that we find:

1. The open circuit voltage V_{oc} across terminals 1 and 2.

So, all this things are written here all this things are written here for you you go through it, but I have told you what is the essence of it right.

(Refer Slide Time: 32:14)

(51)

2. The short circuit current i_{sc} at terminals 1 and 2.
3. The equivalent or input resistance R_{in} at terminals 1 and 2 when all independent sources are turned off.

We summarize the relationships:

$$V_{TH} = V_{oc} \quad \dots (4.12)$$

So, So, all this things and same way the way you got thevenins theory or resistance same way Norton resistance. So, V Thevenin is equal to V o c and i Norton is equal to i s c. So, R Thevenin basically V Thevenin by i SC is equal to R Norton V o c is V thevenin.

(Refer Slide Time: 32:21)

3. The equivalent or input resistance R_{in} at terminals 1 and 2 when all independent sources are turned off.

We summarize the relationships:

$$V_{TH} = V_{oc} \quad \dots (4.12)$$
$$I_N = I_{sc} \quad \dots (4.13)$$
$$R_{TH} = \frac{V_{oc}}{I_{sc}} = R_N \quad \dots (4.14)$$

Open circuit and short circuit tests are sufficient

So, R Thevenin is equal to basically your V Thevenin by i SC, you will get the your what you call that Norton resistance same philosophy right.

(Refer Slide Time: 32:43)

to find any Thevenin or Norton equivalent.

Ex-4.22: Determine Norton equivalent circuit of the circuit shown in Fig.4.58

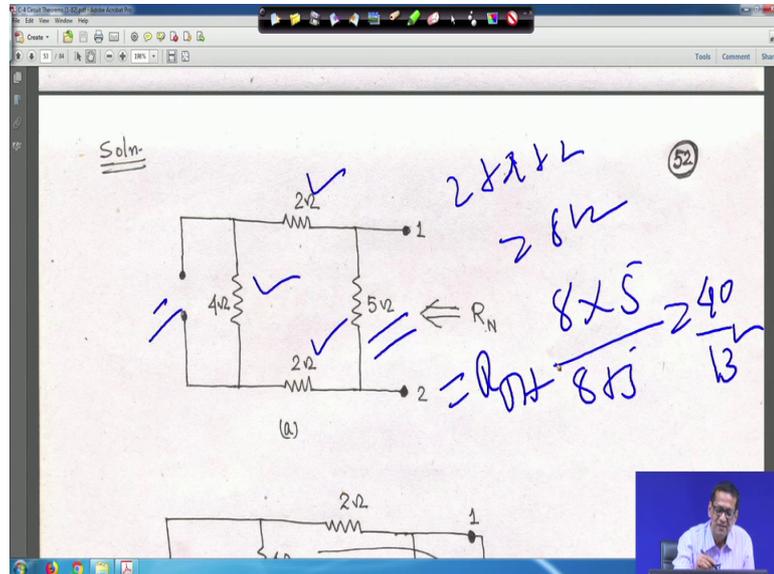
Fig.4.58: Circuit for Ex-4.22

The circuit diagram shows a 2 Amp current source pointing upwards in parallel with a 4 ohm resistor. This combination is in series with a 10 Volt DC voltage source (positive terminal at the top). This series combination is connected to a 2 ohm resistor in series with a 5 ohm resistor. The terminals 1 and 2 are located at the output of the 5 ohm resistor.

So, with this just one example, determine Norton equivalent circuit of the circuit shown in figure 58. So, we have to get the Norton equivalent circuit of this one 2 ampere independent source is there and a 10 volt source is there at 4 ohm 2 ohm 5 ohm and 2 ohm resistance are there. To get the Norton equivalent circuit first what you do R Norton R Norton is equal to R thevenin; that means, current source is open and voltage source is

shorted right; that means, if you if you now if it is like this, then you can see that this is open. So, 2 ohm 4 ohm and 2 ohm this 3 resistors are in series.

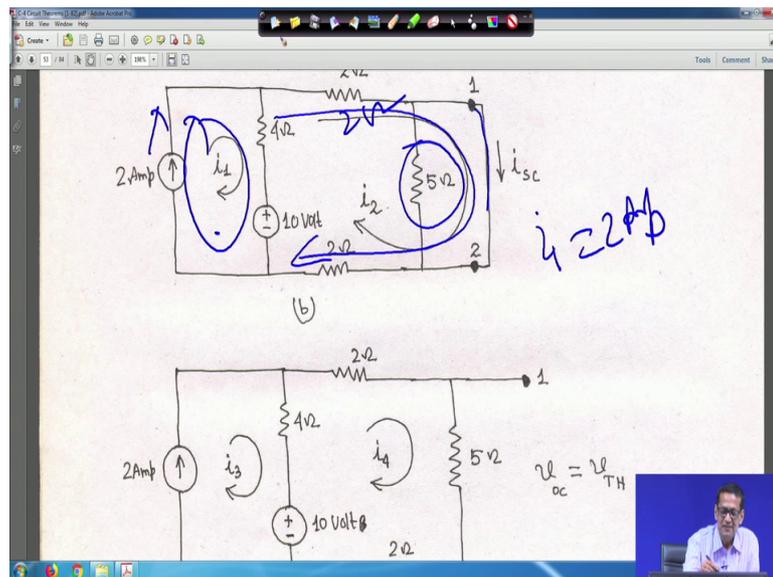
(Refer Slide Time: 33:20)



So, total will be 2 plus 4 plus 2 is equal to 8 ohm are with that 5 is in parallel. So, R Norton will be is equal to your 8 plus 5. So, it is 40 by 13 ohm.

So, R Norton is nothing, but R Thevenin same thing the way you get Thevenin same way you got R Norton it is same thing right. Just one minute then you come to this you have to find out the short circuit current. So, what you do in Thevenin thevenin equivalent circuit 1 and 2 are open, but here it is shorted and we got i_{SC} . So, this is the short circuit current i_{SC} right and in this case in this case we at here we are taking i_1 and it is i_1 also this basically it is 2 ampere going upwards.

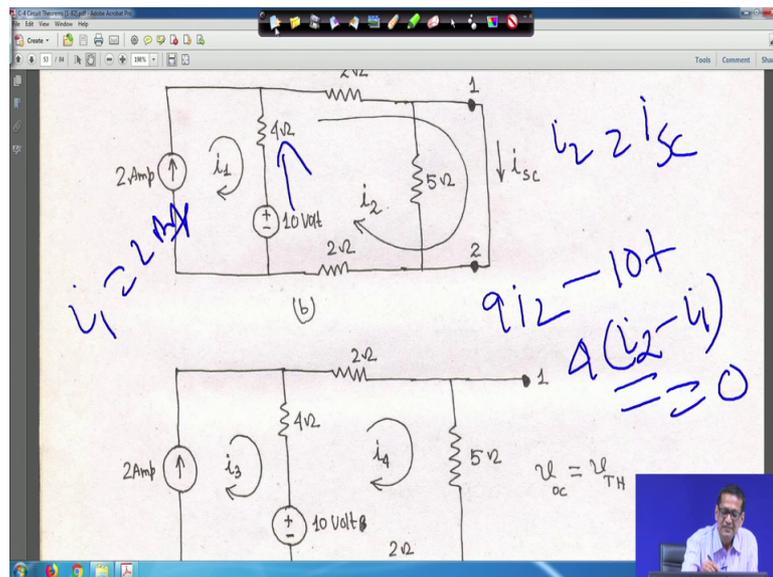
(Refer Slide Time: 34:01)



So, i_1 is equal to 2 ampere right. So, in this case if you apply what you call this is your 2 ohm. So, in this case if you apply your KVL suppose if I go like this and I apply your KVL.

So, this current we are taking i what you call that your short circuit current; that means, here no current here 5 ohm this thing resistance actually it will be ineffective because this is shorted. So, current will flow like this so, that is why that is why this is shown like this because it is shorted. Now you apply what you call KVL here, you will get your i what you call i_2 . If I write it for you it is 2 plus 2 ohm plus 5 ohm plus 2 ohm.

(Refer Slide Time: 34:55)



So, 2 plus 5 plus 2 so, it will be 9 i 2 moving like this 9 i 2 and then and your i 2 basically is equal to i SC, because this is i SC we have taken i 2 is equal to i s c.

Then minus 10 because encountering minus terminal first then your plus 4 into i 2 minus i 1 is equal to 0 because we are moving like this. So, 4 into i 2 minus i 1 and I told you earlier i 1 is equal to 2 ampere. So, put i 1 here is equal to 2 ampere and then you solve for i 2 and this is and shaken circuit shaken circuit is given for your what you call for Thevenin, here it is given i 3 and i 4 V o c is equal to just for the purpose of computation V thevenin.

(Refer Slide Time: 35:41)

(c)
Fig.4.59: (a) finding R_N (b) finding $i_N = i_{sc}$
(c) finding $v_{oc} = v_{TH}$

We determine R_N in the same way we find R_{TH} in the Thevenin equivalent circuit. All the independent sources are turned off and this leads to the circuit in Fig.4.59(a). Thus

$$R_N = \frac{5 \times (2+4+2)}{5 + (2+4+2)} = 3.077 \Omega = R_{TH}$$

Now, you can easily solve it after solving so, many things. So, Norton is given I told you 3.007 I told you right how it will come.

(Refer Slide Time: 35:50)

To determine i_N , terminals 1 and 2 are short circuited - as shown in Fig.4.59(b). 5 Ω resistor is ignored because it has been short circuited. (53)

Applying mesh analysis, we get,

$$i_1 = 2 \text{ Amp and } 8i_2 - 4i_1 = 10$$
$$\therefore 8i_2 = 4 \times 2 + 10 \quad \therefore i_2 = 2.25 \text{ Amp.}$$
$$\therefore i_{sc} = i_2 = 2.25 \text{ Amp.}$$

And similarly i_1 I told you 2 ampere and I gave the equation how to get it, $8i_2 - 4i_1 = 10$, but i_1 is equal to 2 so, you will get i_2 is equal to 2.25 ampere.

(Refer Slide Time: 35:59)

$i_1 = 2 \text{ Amp}$ and $8i_2 - 4i_1 = 10$

$\therefore 8i_2 = 4 \times 2 + 10 \quad \therefore i_2 = 2.25 \text{ Amp.}$

$\therefore i_{sc} = i_2 = 2.25 \text{ Amp.}$

Alternatively, we can determine $i_N = \frac{V_{TH}}{R_{TH}}$.

We obtain V_{TH} as the open circuit voltage across terminals 1 and 2 in Fig. 4.59(c). Using mesh analysis, we obtain,

$i_3 = 2 \text{ Amp};$

$13i_4 - 4i_3 = 10 \quad \therefore 13i_4 = 4 \times 2 + 10$

That means I told you also i short circuit is equal to i_2 is equal to 2.25 ampere. Alternatively we can determine i_N is equal to $V_{Thevenin}$ by $R_{Thevenin}$ same thing right because source transformation I told you from Thevenin Norton transformation actually. So, I told you i_N is equal to $V_{Thevenin}$ by $R_{Thevenin}$. So, if you solve the Thevenin equivalent this circuit, if you solve this if you solve this circuit right you solve it because now you know how to solve it right.

(Refer Slide Time: 36:36)

analysis, we obtain,

$i_3 = 2 \text{ Amp};$

$13i_4 - 4i_3 = 10 \quad \therefore 13i_4 = 4 \times 2 + 10$

$\therefore i_4 = 1.384 \text{ Amp.}$

$\therefore V_{TH} = V_{oc} = 5i_4 = 5 \times 1.384 = 6.923 \text{ Volt.}$

Hence,

$i_N = \frac{V_{TH}}{R_{TH}} = \frac{6.923}{3.077} = 2.25 \text{ Amp.}$

as obtained previously.

So, if you solve this circuit you will get your i_3 is equal to i_4 you will i_3 will get 2 ampere and i_4 is equal to 1.38 ampere. So, $V_{Thevenin}$ you will get 5 i_4 that is 6.923 volt.

Therefore i_{Norton} is equal to $V_{Thevenin}$ by $R_{Thevenin}$ $R_{Thevenin}$ is equal to 6.923 by 3.007 is equal to 2.25 ampere. Similarly here also we got $i_{short\ circuit\ current}$ that is is equal to that is is equal to your i_{Norton} right.

(Refer Slide Time: 37:03)

Ignored because it has been short circuited.
 Applying mesh analysis, we get,
 $i_1 = 2 \text{ Amp}$ and $8i_2 - 4i_1 = 10$
 $\therefore 8i_2 = 4 \times 2 + 10 \quad \therefore i_2 = 2.25 \text{ Amp.}$
 $\therefore \underline{i_{sc} = i_2 = 2.25 \text{ Amp.}} = i_N = i_{sc}$
 Alternatively, we can determine $i_n = \frac{V_{TH}}{R_{TH}}$.
 We obtain V_{TH} as the open circuit voltage across terminals 1 and 2 in Fig. 4.59(c). Using mesh

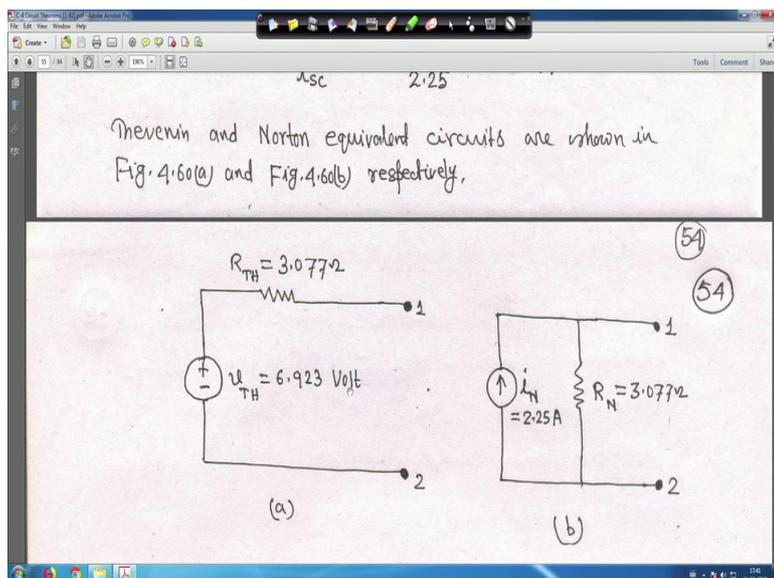
Because this is short circuit current i_n is equal to your $i_{short\ circuit}$, that is your Norton current right 2.25 ampere. So, here also we got that your what you call here using your same thing.

(Refer Slide Time: 37:17)

Hence,
$$i_N = \frac{V_{TH}}{R_{TH}} = \frac{6.923}{3.077} = 2.25 \text{ Amp.}$$
as obtained previously.
(This also serves to confirm eqn(4.14), that
$$R_{TH} = R_N = \frac{V_{oc}}{I_{sc}} = \frac{6.923}{2.25} = 3.077 \Omega.$$
Thevenin and Norton equivalent circuits are shown in Fig.4.60(a) and Fig.4.60(b) respectively.

That Thevenin R Thevenin your i Norton is equal to basically it is short circuit current. So, basically it is a V Thevenin by R thevenin. So 2.25, and R r Thevenin R Norton same it is V o c by [i o c / i s c] i SC; that means, V Thevenin by short circuit current here also 3.007.

(Refer Slide Time: 37:38)



just to verify this the Thevenin and Norton you are shown in this thing so, this is actually Thevenin equivalent right and this is Norton equivalent; that means, if you divide V_{Thevenin} by R_{Thevenin} you will get i_{Norton} that is 2.25 ampere. And R_n is equal to 3.007 ohm this is in parallel and i_{Norton} is equal to V_{Thevenin} by R_{Thevenin} I hope you have understood this. So, basically Thevenin's Norton transformation or Norton Thevenin's transformation right source transformation is so.

Thank you very much we will be back again