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

Lecture – 21
Circuit Theorems (Contd.)

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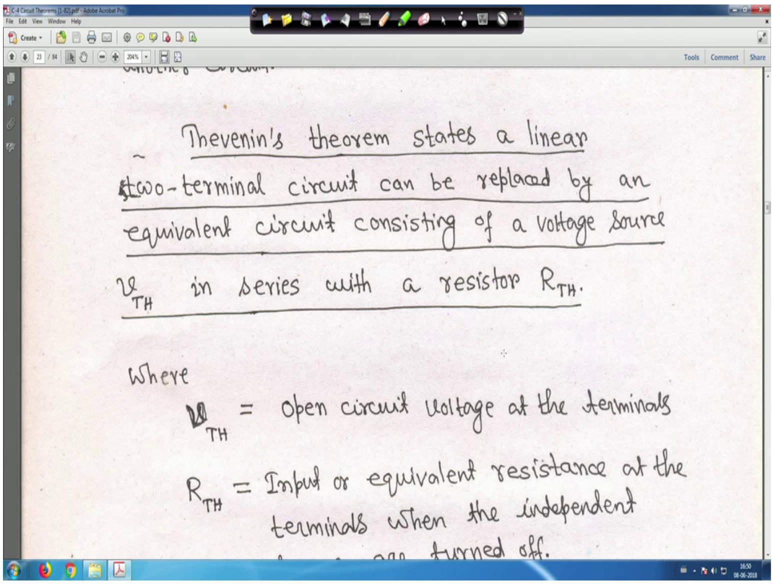

So, come back again. So, in this now in this case, Thevenin's theorem actually states a linear 2 terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V Thevenin in series with your resistor R Thevenin.

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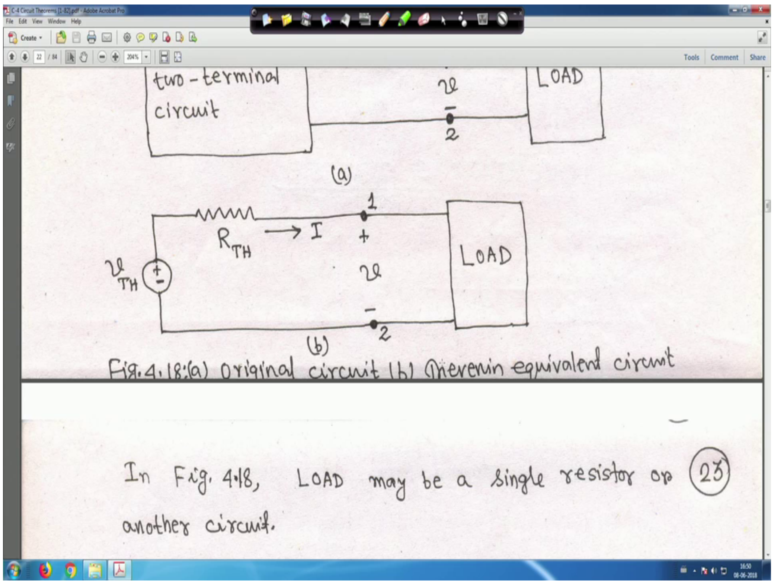

That is your this circuit V Thevenin right. This is your V Thevenin and this is your R Thevenin right, this is your R Thevenin. So, where V Thevenin, I told you it is open circuit voltage at the terminal. We have to know how to obtain it and R Thevenin is input or equivalent resistance at the terminal when the independent sources are turned off right. So, we will see that how to obtain that open circuit voltage at the terminal 1 and 2 that at the terminal right and input or equivalent resistance at the terminals when the independent your sources are turned off.

So, all the independent if it is a voltage source, you have to short it. If you have a current source, you have to open it that is turned off and find out what is R Thevenin, right. So, our major objective is now to find V Thevenin and R Thevenin; that is the that you have to obtain..

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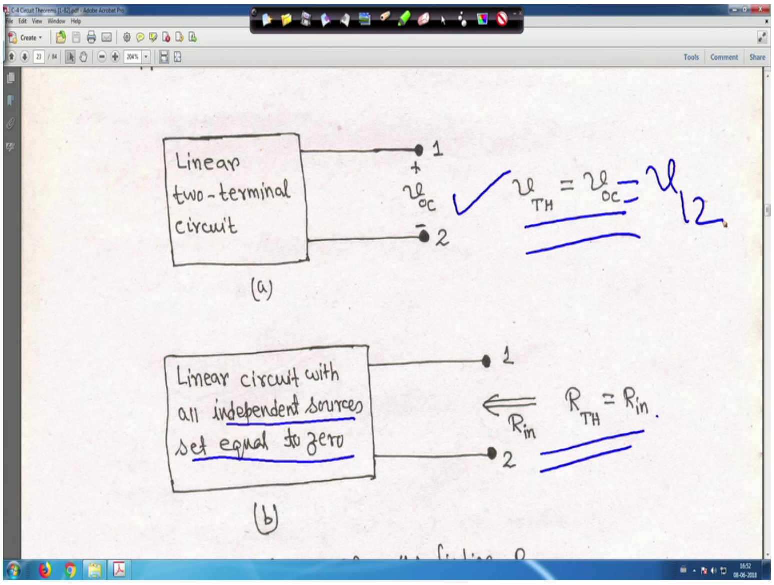

Now go to this; that means, figure in figure this figure 4 point your 18 are equivalent (Refer Time: 01:38) V TH is suppose 2 circuits in figure equivalent to this; that is, this is your linear 2 terminal circuit that is your; that means this circuit, if you take this one that figure 4 this is figure 14.18 a, this pass upper one this 18 a. Now, if you try to find out that V Thevenin and R Thevenin, then this circuit you are represented like this is linear 2 terminal circuit. This is your this is your V oc; that is your V Thevenin and this is your R Thevenin; that is R input resistance right.

So, linear 2 terminal circuit, this whole thing you have to solve keeping that all the sources intact right. So, you from where you will get V Thevenin or V oc and here, linear circuit with all independent sources set equal to 0; that means, there have to be turned off and after that, you find out what is your equivalent resistance R Thevenin right or R input; this looking from terminal 1 and 2 right. And here also, you have to find out you what you call V oc V Thevenin that also we can make V 1 2 1 positive to negative; so, also V 1 2. This way you can make it. So, let me clear this.

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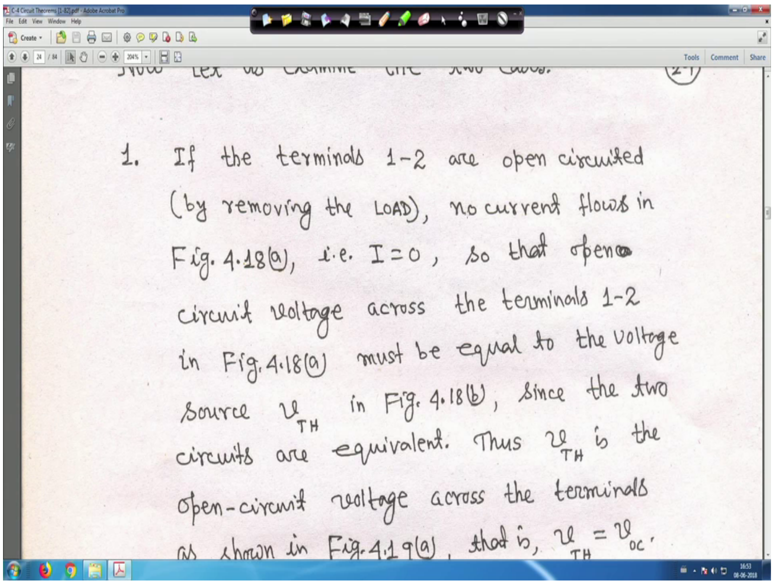

So now, let us examine the 2 cases. If the terminal 1 and 2 are open circuited that is by removing the load; that means, if you if you make this terminal, I am going to the this thing.

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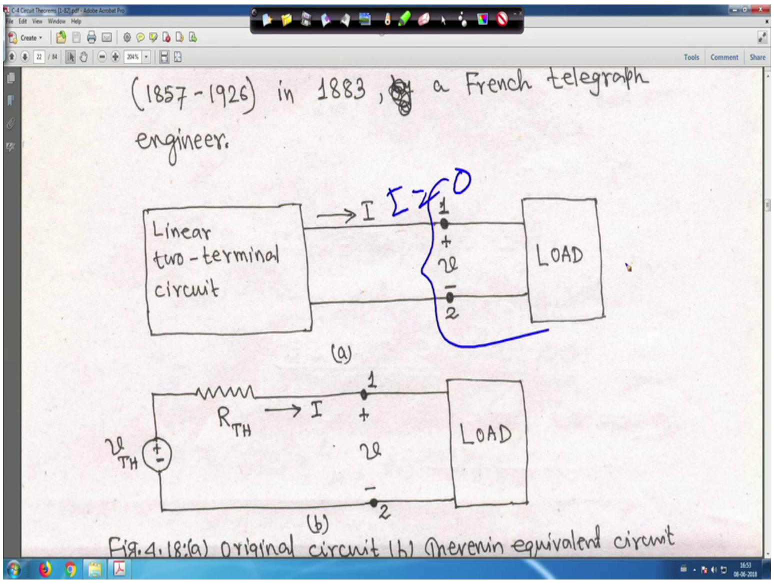

If you open this for example, if you open this, suppose this is disconnected, if it is open this then load is disconnected. That means, your i will be is equal to is equal to 0, right. If you open this, I mean from terminal 1 and 2, this load is disconnected. Then i will be 0. So, let me clear it. So, again we will go back right. So, that open circuit voltage across the terminal 1 2 must be equal to the voltage source V Thevenin. So, this voltage across the terminal 1 2 in must be equal to the voltage source V Thevenin in figure 4.18 b that is 18 b. since the 2 circuits are equivalent right.

Similarly, thus V Thevenin is the open circuit voltage across the terminal as shown in figure 19 a; that is V Thevenin is equal to V oc right. Therefore, let me clear it; here it is right. Therefore, V Thevenin is equal to V oc. I mean, if you disconnected the load; you have disconnected the load from the terminal 1 and 2.

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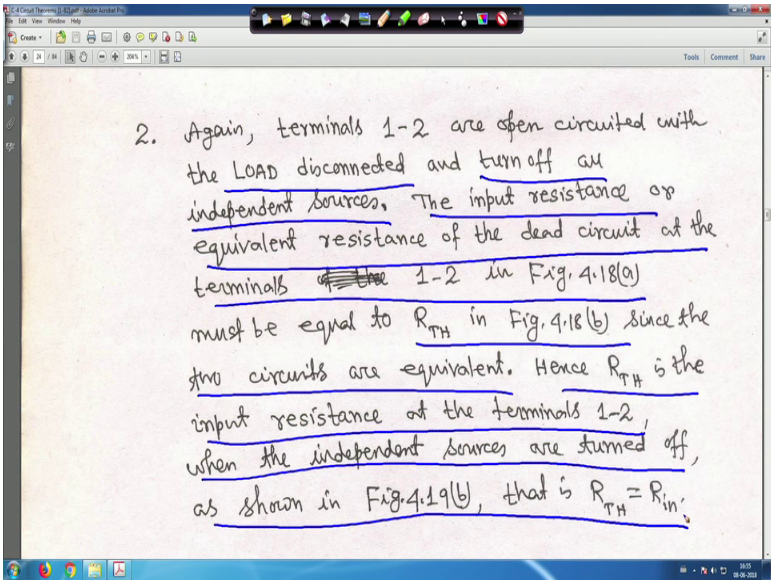

Similarly, linear circuit independent when you will find out the input resistance or R Thevenin right, then all this independent sources must be turned off right. So, in this case, your again terminals 1 and 2 are open circuited with the load disconnected and turned off all the independent sources. So, when will find out load is disconnected and you turned off all the independent sources, right.

So, the input resistance or equivalent resistance of the dead circuit at the terminal 1 and 2 in figure 4.18 a must be equal to R Thevenin in figure 4 point your 18 b, right. Since the 2 circuits are equivalent, hence R Thevenin is the input resistance at the terminal 1 and 2 right; that means, when the independent sources are turned off as shown in figure this R Thevenin will be R in that means, idea actually here I am telling when I will give you an example, you will be knowing everything. So, that means, in this case in the circuit 19 b that you just redraw the circuit by turning up all the independent sources and from looking from terminal 1 and 2, you find out what is the resistance R input or R Thevenin right. We call R input is equal to R Thevenin right. So, that is why, this is in language I have given this is in language I have given rather than going to the numerical directly.

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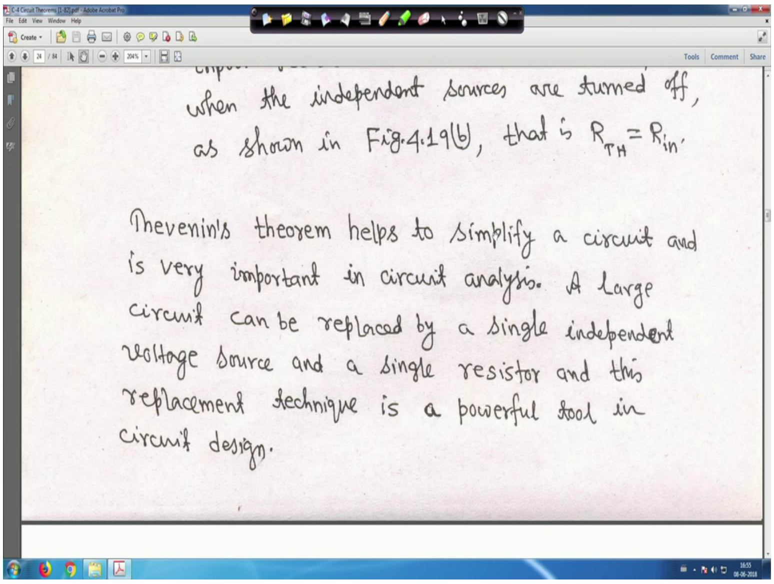

So, Thevenin theorems actually help to simplify by a circuit and is very important in circuit analysis. So, a large circuit can be replaced by a single independent voltage source and a single resistor for single resistor means for DC circuit right and this replacement technique is a powerful tool in circuit design, right.

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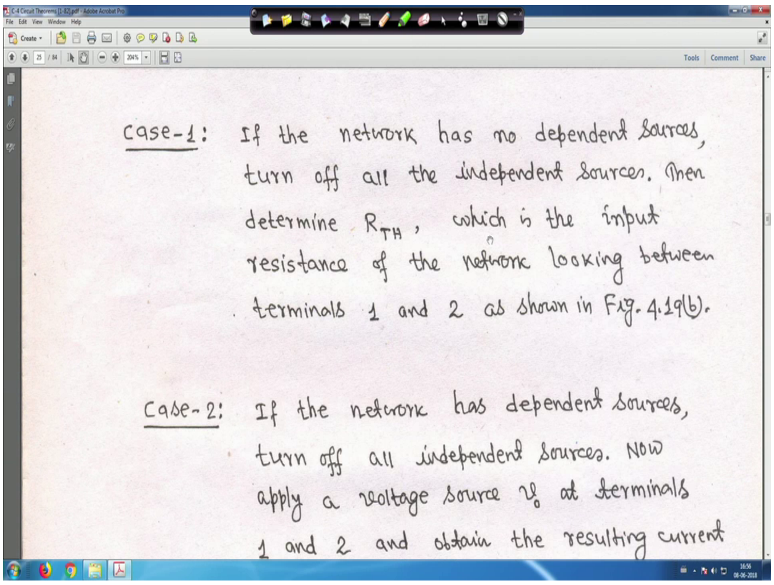

So, for finding your Thevenin resistance R Thevenin, we need to consider 2 cases. Case 1, if the network has no dependent sources right, then turn off all the independent sources; then determine R Thevenin which is the input resistance of the network looking between terminals 1 and 2 and shown as shown in figure 19 b that I have that circuit as I have told you right.

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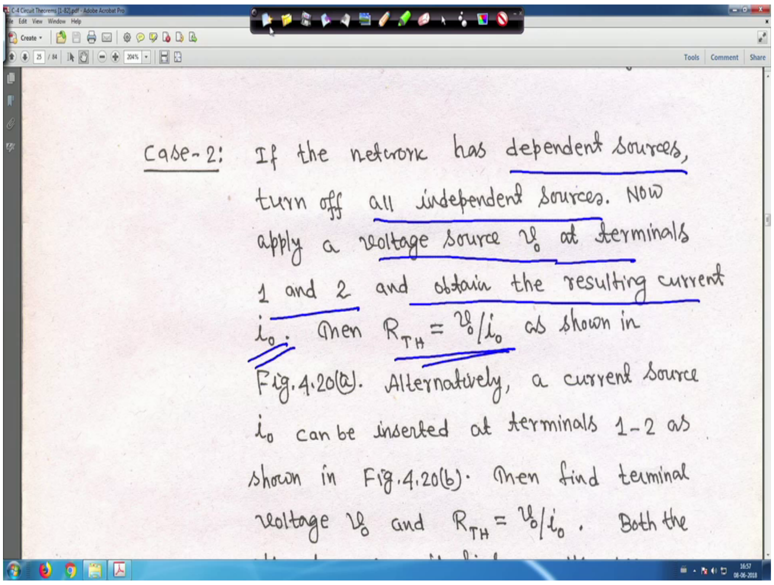

Now, if the network has dependent sources, turn off all independent sources right. If you are a dependent sources look if you have dependent sources, you will turn off all independent sources done. Now, this when dependent sources is there, technique of getting R Thevenin is slightly different. It is in words I am telling, but when you will take numerical, it will be totally transparent right. But you have to turn off all independent sources, but not the dependent sources right.

Now, apply now what you have to do is, now you have to apply a voltage source V 0 at terminals 1 and 2. This voltage source; this voltage V 0 you apply a terminal 1 and 2. This value of V 0 is up to you can put any value V 0 is equal to 0.1 volt or 1 volt or 2 volt any volt, any value you put it right. And obtain the resulting current, then, you obtain the i 0. After putting this, later we will see circuit another thing; after putting this, you find out what is i 0 then, R Thevenin will be V 0 by i 0. If you put your voltage, your what you call that your voltage source V 0 right.

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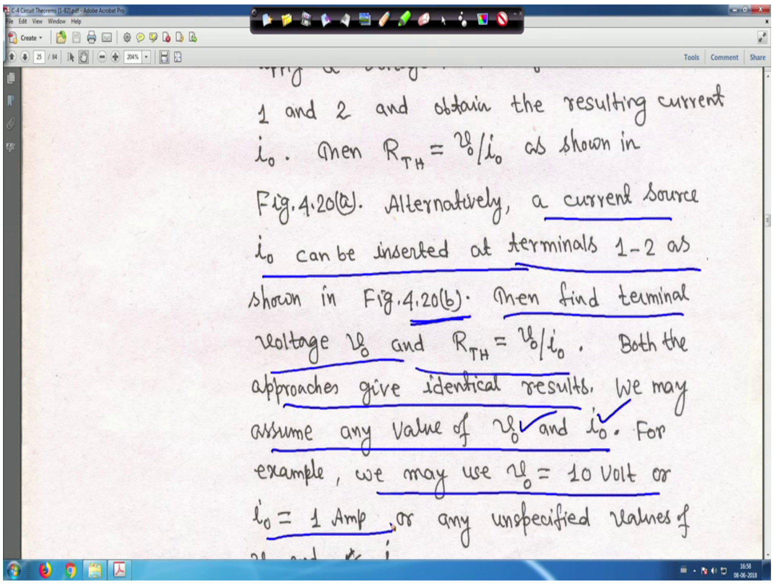

Similarly, just let me clear it. Similarly, you can do it alternatively current source also you can make it. For example, a current source also i 0 can be inserted at terminal 1 and 2 either voltage or current; it does not matter as shown in 20 b, I will come to that. Then, find the voltage V 0 and R Thevenin is equal to V 0 by R 0. Any value of i 0 1 ampere 2 ampere it does not matter. It is up to you, but ultimately, your R Thevenin will remain same right from your linearity property; Both the approaches give identical results. We may assume any value of V 0 and i 0 that any value of V 0 and i 0, you can assume.

For example, we may use V 0 is equal to 10 volt or i 0 is equal to 1 ampere or any unspecified values of V 0 or i 0 right.

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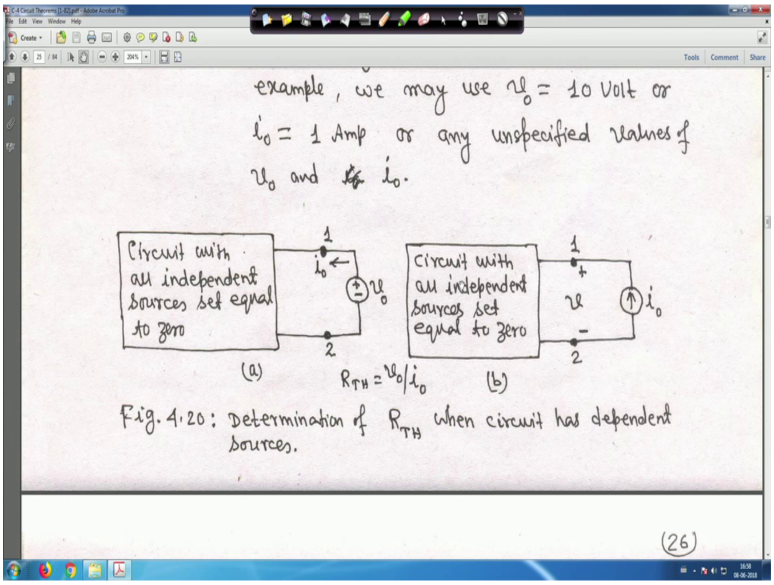

So; that means whenever you have this circuit; suppose this circuit you have all the independent sources are set equal to 0 is turned off, but here you have a dependent source right, in that case you can connect a voltage source V 0 across 1 and 2 and find out your i 0. This current and this V 0 you can assume whatever you want 1 volt 2 volt. It does not matter. Ultimately, R Thevenin will be V 0 by R 0 I sorry i 0 right.

Similarly, your either you can put a current source across 1 and 2 and solve the circuit. Then find out what is V right and then, you can find out what is R Thevenin. It should be V here. It is V 0 and here it is after making this i 0 you find out; suppose, this suffix should be taken as V 0 right.

So, you find out R Thevenin is equal to V 0 by i 0. So, then this i 0 value can be any value 0.1 ampere, 0.51 ampere. It is up to you and you will get whatever value you take R Thevenin, you will get the same thing. But, if you have a your what you call that dependent voltage or current sources right. So, only independent sources will be turned off, but dependent sources for dependent sources you have to add out this technique; if circuit contents dependent sources that is dependent voltage or dependent current sources right; so, to get this R Thevenin. So, let me clear it.

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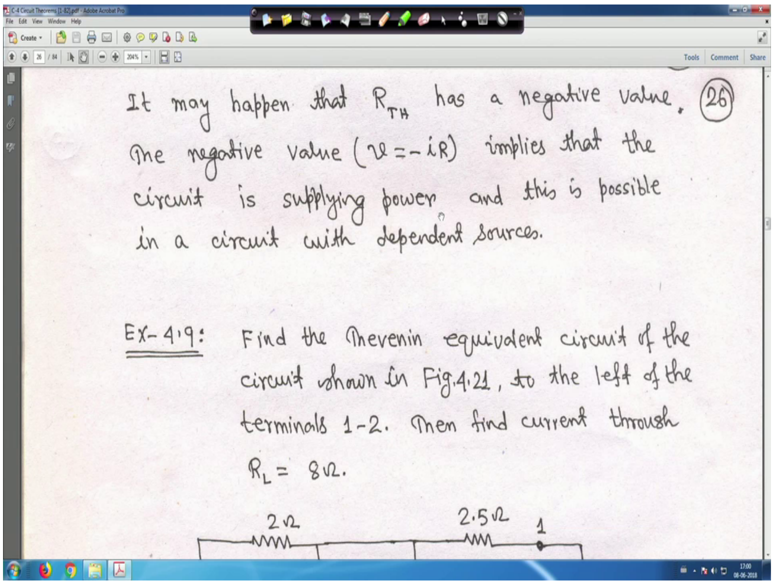

So, but one interesting thing is, there it may happen, it may happen that for the this may happen if the circuit has your dependent sources. So, so R Thevenin may have a negative value. The negative value means, it is written V is equal to minus i R implies that the circuit is supplying power and right. So, and this is possible in a circuit with dependent sources.

So, in the in that case, it may happen that Thevenin theorem. If the circuit has dependent sources and you trying to find out R Thevenin, so R Thevenin may become negative also in; that means, the circuit actually is your what you call that supplying power and this is possible in a circuit with dependent sources. So, dependent with dependent sources, R Thevenin may become negative also; one example is there later right, there where R Thevenin is negative. It may happen.

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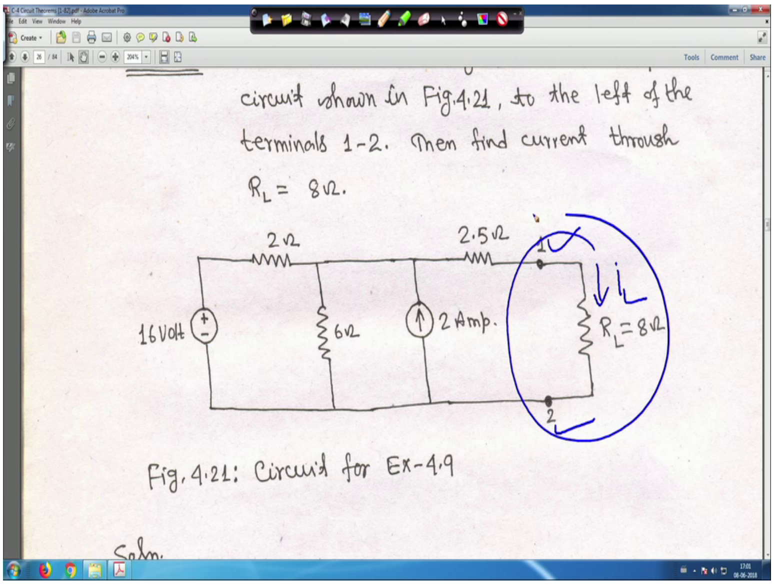

So, this example, say for example, find the Thevenin equivalent circuit of the circuit shown in figure 21 to the left of the terminals 1 2 right, then find current through R L is equal to 8-ohm resistance, right. So, this is the circuit, this is your circuit. So, this is terminal 1 and 2. Using Thevenin theorem, you have to find out the current through this. that means, you have to find out the current i L say, through 8-ohm resistance; your 8-ohm resistance using Thevenin's theorem.

So, first what you have to do is, you have to open this one; you have to open this right. And then, after that you have to find out your Thevenin voltage V Thevenin is equal to V oc, the open circuit voltage. Because, as soon as you will open it, it will be open and you have to find out R input; that is R Thevenin. So, how we will do it? So, if you go to this right equivalent of 2 step, you have to 2 things; you have to obtain one is V Thevenin, another is R thevenin. But, first you have to open this R L from terminal 1 and 2.

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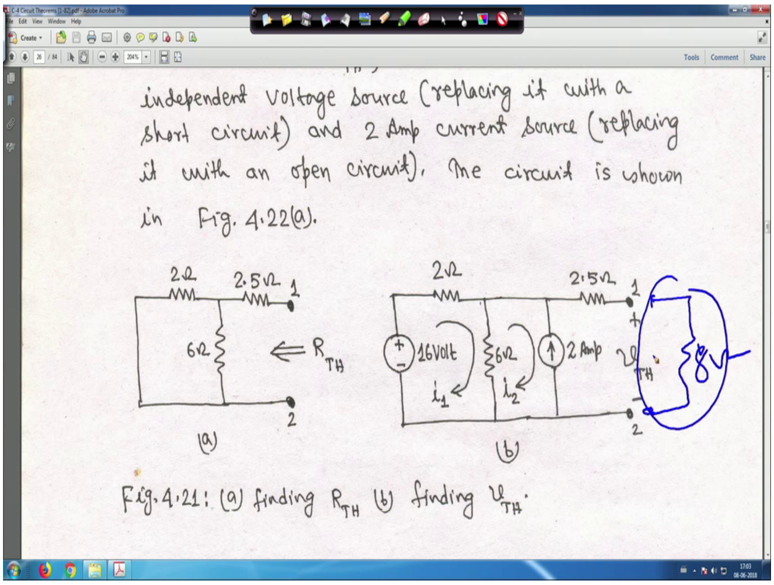

And if you open this one, for this one you open and for getting your R Thevenin, all the independent sources are turned off right; that means, here this voltage source to get this is open, this is open, right. And you have to get that input resistance R Thevenin, right. You have to get it.

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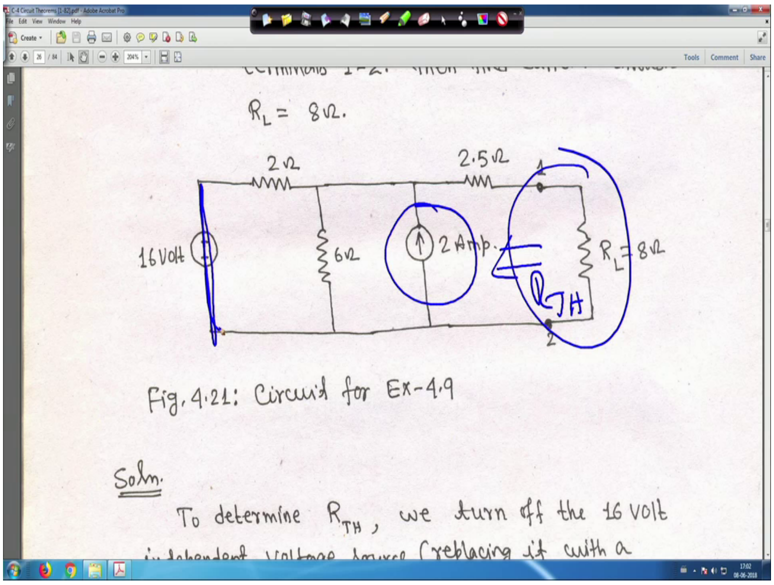

So, this should be open because, current source should be open and this voltage source it has to be shorted; it has to be shorted. Then only you will get that equivalent circuit. Because, all independent sources must be turned off. So, this has to be removed and this has to be shorted. Then you find out what is the equivalent resistance R Thevenin. So, let me clear it. So, this is what this is what we have drawn it here.

So, current sources open and this voltage sources is voltage sources shorted right and looking from in between terminal 1 and 2, you will get the R Thevenin right. And other case, that you have to find out that this V Thevenin you have to obtain. So, across this, across this thing, there was a 8-ohm resistance; the this 8-ohm resistance was there know in that, that is actually open this is open. So, as soon as you open it, this is V Thevenin means V o c that is open circuit.

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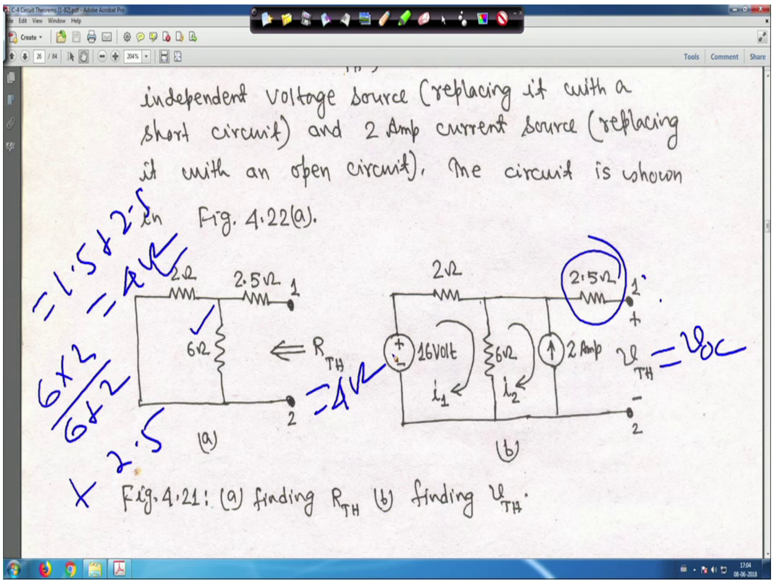

So, let me clear it. So, this is actually V oc and rest of the circuit will remain intact. We have 2 your this 2 ampere independent current source and this thing. So, you have from here, you will get R Thevenin and from here solving this circuit, you will get V Thevenin. Note that as it is open, no current is flowing through this to a flowing through the 2.5-ohm resistor right. So, what now what is R Thevenin?

So, this 2 ohm and 6 ohm, this 2 are in parallel right. Therefore, their equivalent to; that means, total R Thevenin will be your 6 into 2 divided by your 6 plus 2 this 12 with that 2.5 is in series plus 2.5 right. So, that is actually is equal to it is 12 by 8 so that is 3 by 2.15. So, that is 1.5 plus 2.5 is equal to 4 ohm; that means, this R Thevenin is equal to 4 ohm right. So, for independent sources should be turned off to get your R Thevenin. So, this is your R Thevenin. Later solution is there; later, I have made it, but this is R Thevenin.

Now, let me clear it and when we will come here for V Thevenin, we have taken the loop current right and you have to find out what you have to solve this circuit and you have to find out what is your V Thevenin. So, many circuits we have solved right and your So, easily you can find out what is the voltage, right. So for example, here I have written for your this thing mesh equation.

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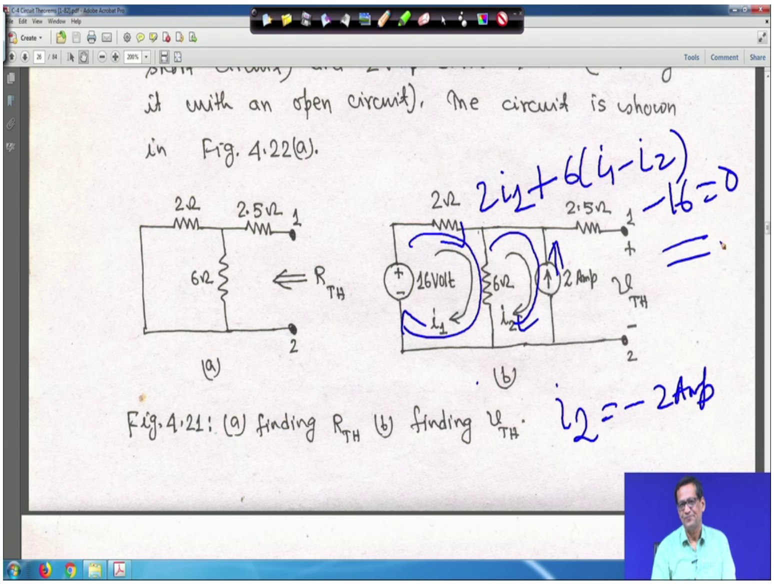

So, here your if you apply your K V L in this loop, this current is 2 ampere upwards. We have taken i 2 like this; i 2 like this. So, basically i 2 going downwards; so i 2 actually is equal to minus 2 ampere right. So, if you apply; so, i 2 is known, so, only next is you have to find out i 1. So, I have to apply your K V L in this loop. So, in this mesh, so it will be your 2 and i 1 is flowing like this 2 i 1. It will be 2 i 1 plus it will be i 1 downwards i 2 upwards. So, it will be 6 into i 1 minus i 2 right. And it is encountering minus terminal first minus 16 is equal to 0. Hope I have not missed anything right.

So, from this i 2 is known. If you put i 2 is equal to minus 2 here, it will be 6 into i 1 plus 2 and from that you can solve it what is i 1 right. So, let me clear it. So, this is your i 1 is solved.

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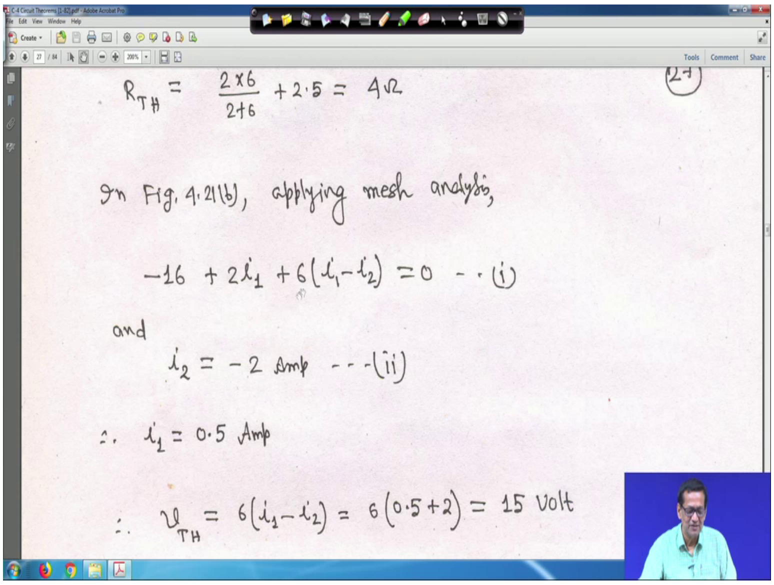

So, i 1 we got we use write in same equation. We got that i 1 is equal to 0.5 ampere, right; so that much we got

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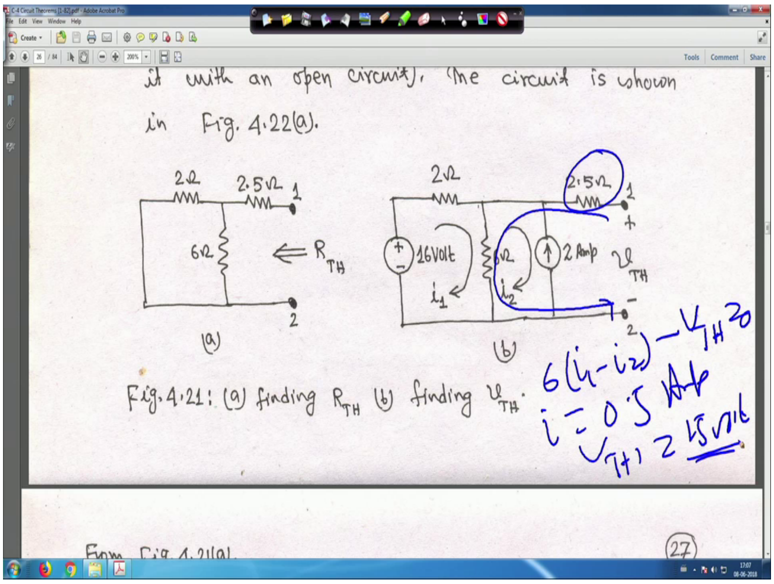

Next is that, you have to what you call you have to find out. So, i 1 is equal to your i 1 we got is equal to 0.5 ampere. So, now you have now you can easily find out what will be your, what will be your V Thevenin. The way you want, you can the way you want you can find it out, right.

For example, they are in that in that problem, I have taken your that your K V L like your K V L like this. So, if you make it current through this is 0 right. So, it is open circuit; so, nothing is there. So, if you make it like this take your what you call in the downwards, it will be 6 into that i 1 minus i 2 minus V Thevenin is equal to 0. Because, minus your terminal encountering fast right. So, you can easily find out your i 2 is minus 2 that is your what you call it will be 2 and i 1 is 0.5, so, 2.5 into 6. So, V Thevenin will be is equal to 15 volt, V Thevenin will be 15 volt right.

So, similarly, if you want to find out, we can put K V L in the in this loop also, the way you want you can do it, you will get the same result. So, let me clear it. So, that is why, V Thevenin we got your 15 volt here.

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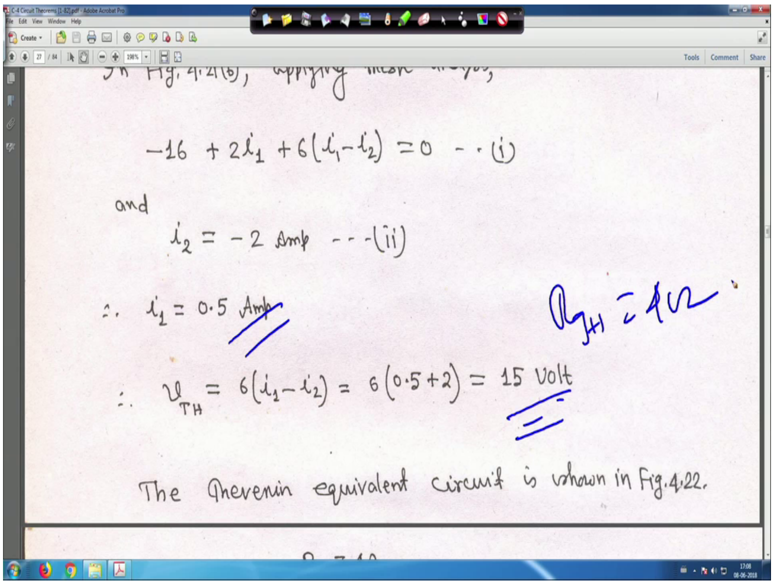

It is 15 volt. I showed you that here it is 15 volt right. Here and current i 1 is 0.5 ampere. So, after getting V Thevenin and R Thevenin, R Thevenin we have got your 4 ohm right. So, after getting V Thevenin and R Thevenin, let me clear it. So, this is the Thevenin equivalent, Thevenin equivalent circuit.

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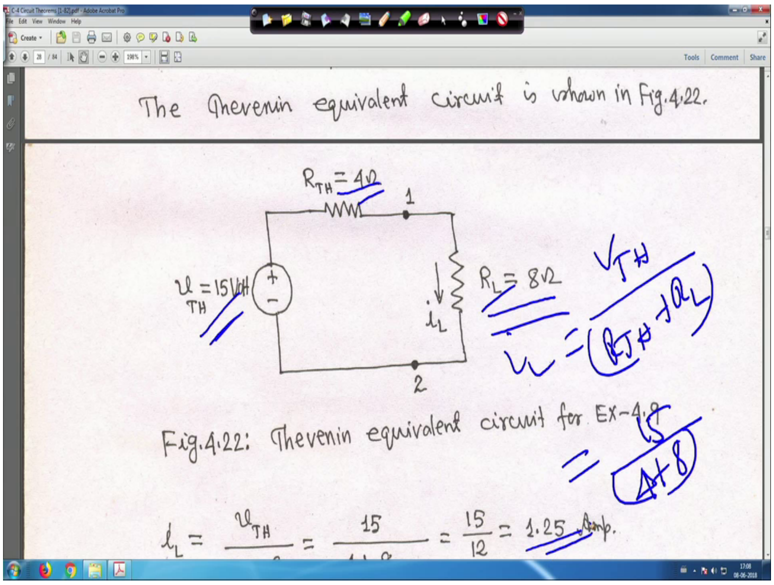

So, this V Thevenin; your V Thevenin 15 volt we got and R Thevenin this 2 are there along with that this R L is equal to 8 ohm will be in series right; that means, i L will be is equal to your i L will be is equal to V Thevenin divided by R Thevenin plus your R L right that is your i L R Thevenin plus your R L right.

So, that that one V Thevenin is your 15 volt divided by R Thevenin is 4 plus it is 8. So, 15 by your 12; So, that is 1.25 ampere, right. So, this way you will get the current through R L using Thevenin's theorem. So, now, this is what. Similarly, if you this is you got whatever using Thevenin's theorem. Now, this circuit, the way we have earlier learned nodal analysis or mesh analysis, same way you solve and find out what is the your what you call R R L current through R L, you will get the same answer, identical answer right. And if this R L is variable, if this R L is changing again and again. Suppose, R L is 8; suppose, why Thevenin's theorem is important?

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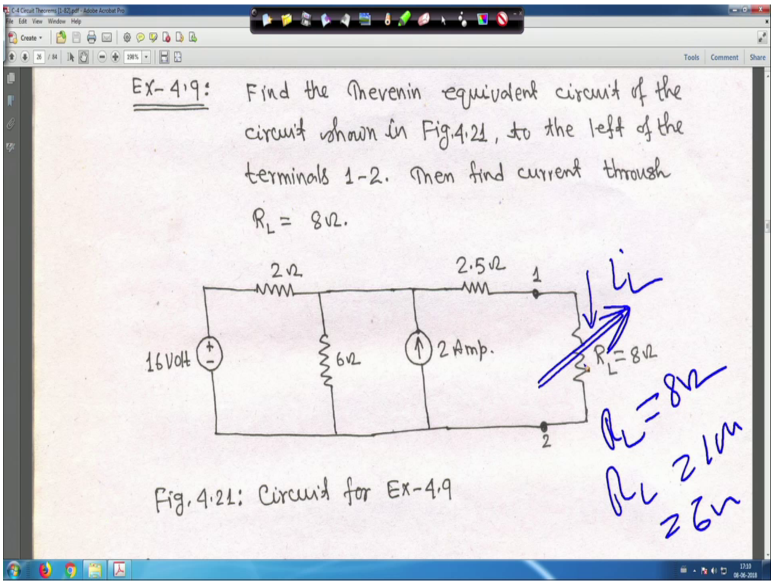

Suppose R L is 8 ohm you have taken, now if you change the R L is equal to 10 or R L is equal to say 6 right, every time you are changing R L that means, previous analysis, nodal analysis or mesh analysis or super position whatever we have done; every time you have to solve the whole circuit every time you have solving the whole circuit, right. But in this case, suppose our interest to find out what is current i L for different values of R L, then equivalent V Thevenin and R Thevenin we have got. So, using the simple series circuit by just changing R L, we can get the current through R L' if it is if R L is a variable; variable symbol is like this, right. So, that is the advantage of Thevenin's theorem. So, let me go to this thing. So, this is your Thevenin equivalent.

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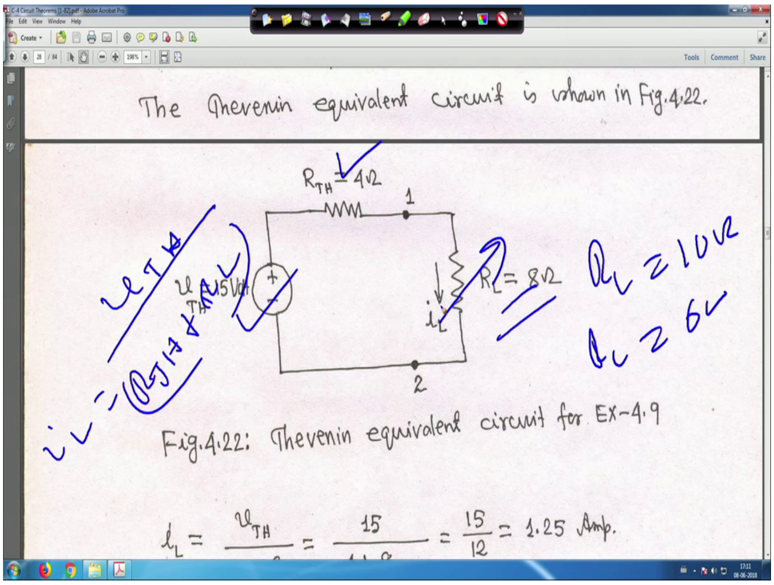

Now question is, if suppose this R L is change, suppose R L you take 10 ohm, R L you can take 6 ohm, suppose this R L is changing. So, using this your using this i L is equal to V Thevenin right divided by R Thevenin plus your R L right. So, V Thevenin is fixed R Thevenin is fixed only R L is changing. Using the simple circuit, you can calculate the current. So, no need to solve the whole circuit again and again. So, this is the advantage major advantage of Thevenin's equivalent circuit, ok. So, let me clear it. So; that means, only R L you are changing again and again. So, if you do. So, you will get this thing.

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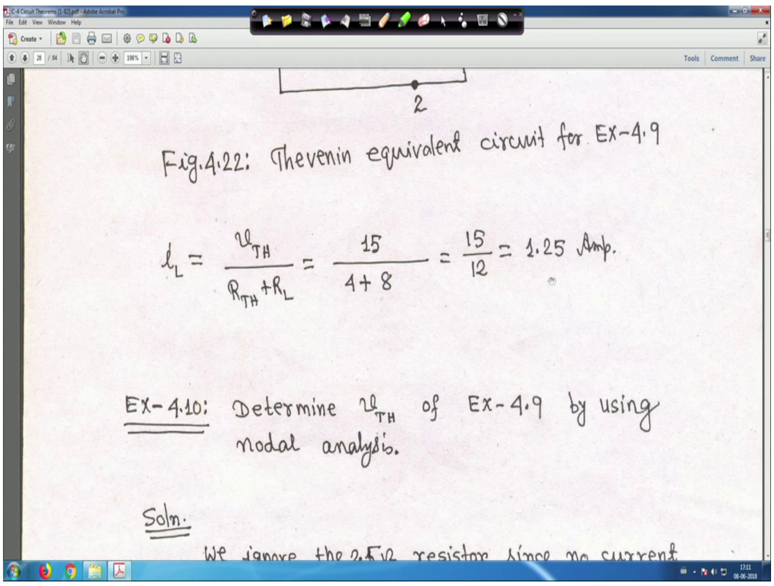

Now, another thing is determine V Thevenin of example 9 using nodal analysis right. So, this is actually example nine this is your example 9 right. So, you have been ask that for this thing you find out V Thevenin using nodal analysis using your what you call the this circuit only. So, a circuit remain same example 10 circuit remain same only. Thing is that, you have to obtain V Thevenin using nodal analysis right. So, let us go to that.

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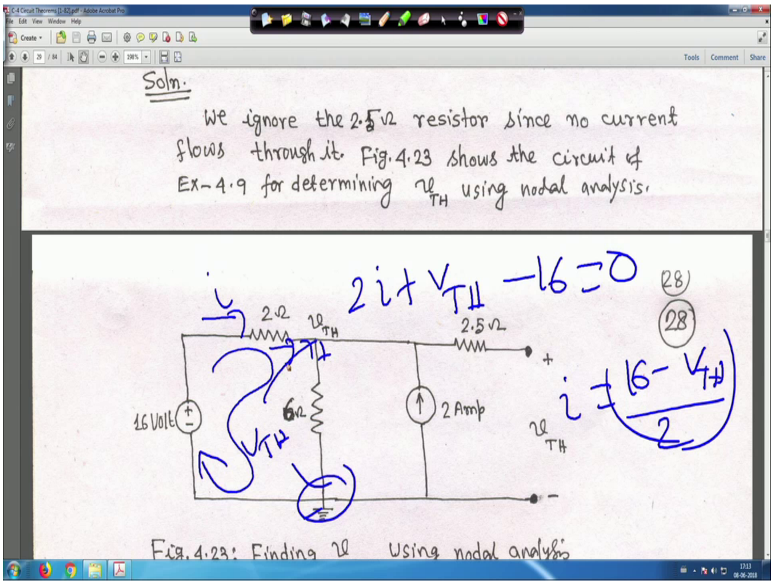

So, in this case, you ignore that 2.5 ohm resistors in no current flows through figure 23 right. Because this your what you call this is your, this is no current is flowing through this because it is open. So, you can ignore this and whenever we take V Thevenin your like this; that means, that means this is your V Thevenin arrow means I told you plus. So, it is V Thevenin and it no current is flowing through this. So, you can ignore this; this is not require you can ignore this. For example, right and this is here this terminal is a common terminal. So, whatever V Thevenin is here, V Thevenin is here same thing no electrical your devices or element is connected here, right. So, this is your V Thevenin. So, this will be your V Thevenin. So, easily you can easily you can find out how using nodal analysis.

So, let me clear it. So, in that case, what you what you can do is, so, this is V Thevenin means, this is your plus and this is your V Thevenin and this is your ground minus. So, first you apply your K V L here say current flowing through this is i. For example, say current flowing in this direction is i, then same as before for nodal analysis we have seen.

So, it will be 2 into i then this is plus. So, plus V Thevenin encountering minus terminal plus minus 16 16 volt it is. So, minus sixteen is equal to 0 right. From here, you will get i is equal to 16 minus V Thevenin divided by 2. This is the current i that moving going to this terminal this this node right. So, let me clear it. So, it will be your; that means, in this node you apply K C L.

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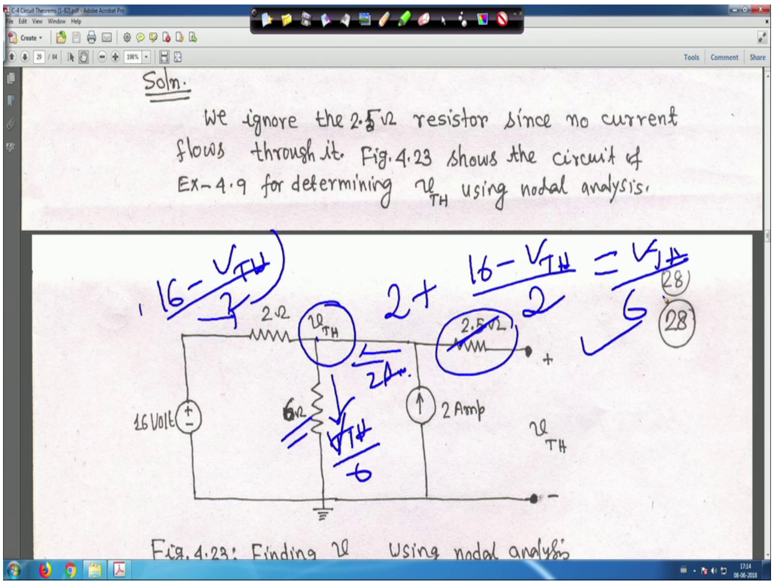

So, current through this, we just saw 16 minus V Thevenin divided by 2; this is the current going and here it is going V Thevenin divided by 6 right, this current resistance 6 ohm and 2 ampere. This is nothing actually this is nothing. So, 2 ampere actually entering here right; it is entering here; that means, this current this is entering, this is entering; that means, 2 plus 16 minus V Thevenin divided by 2 is equal to V Thevenin divided by 6 right. So, the if you solve this, you will get V Thevenin if you solve it. So, let me clear it.

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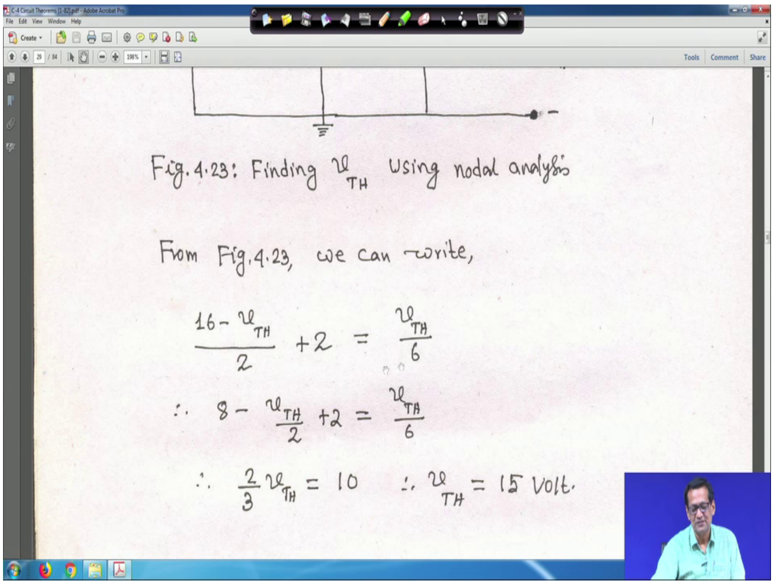

So, this is this is what we have done yet look 16 minus V Thevenin upon 2 plus 2 is equal to V Thevenin upon 6. After solving this, you will get same result, V Thevenin is equal to 15 volt right.

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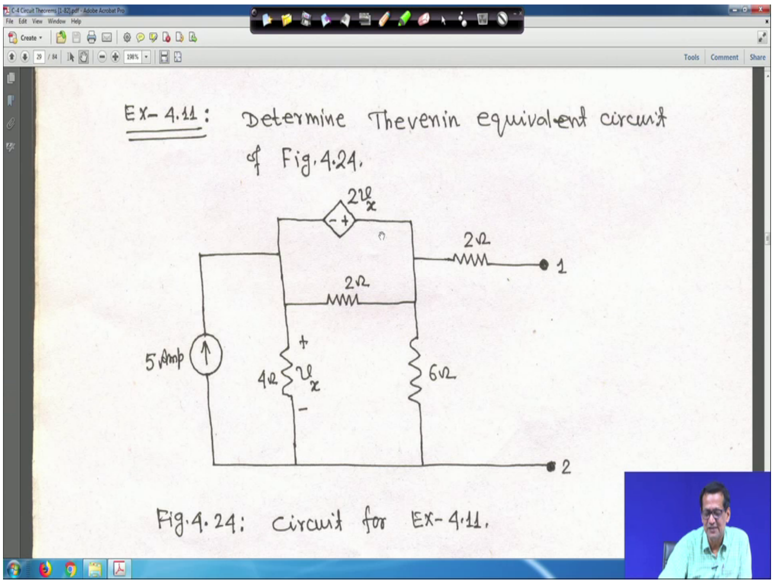

So, next another one is determine Thevenin equivalent circuit of this figure. Here. what dependent voltage source is there, one independent current source is there right. So, what you have to do is, this this is a dependent voltage source and this is a dependent voltage source this is V x and V x is here V x is here across voltage drop across 4-ohm resistance right and this is a terminal 1 2. We have to find out the Thevenin equivalent circuit; that is your V Thevenin and your R Thevenin right and one independent current source is there.

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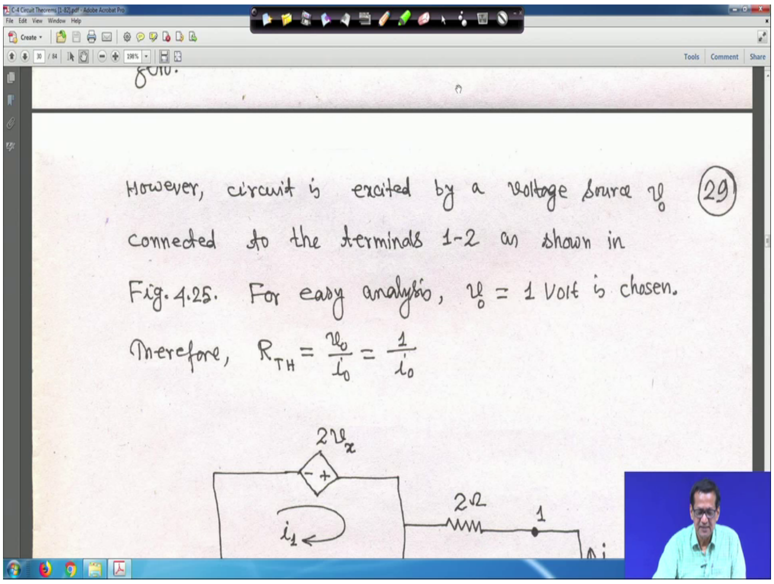

So, let me clear it. So, here if you go to this that it is look here, you have a dependent voltage source right. So, when you try to find out R Thevenin, this independent current source should be turned off right; independent current source should be turned off. It should not be there, but it put across 1 and 2 either you current a current source, whatever ampere you want value and or a voltage source right and then you have to get R Thevenin. So, let me clear this.

So, if you come to this, it is a dependent source right. So, if you come to this look this your this current source is switched off. It is not there; 5 ampere should not be there. It should be turned off. It is open right, but input what we have done is we have connected a voltage source V 0 is equal to 1 volt 1 2 3 4.

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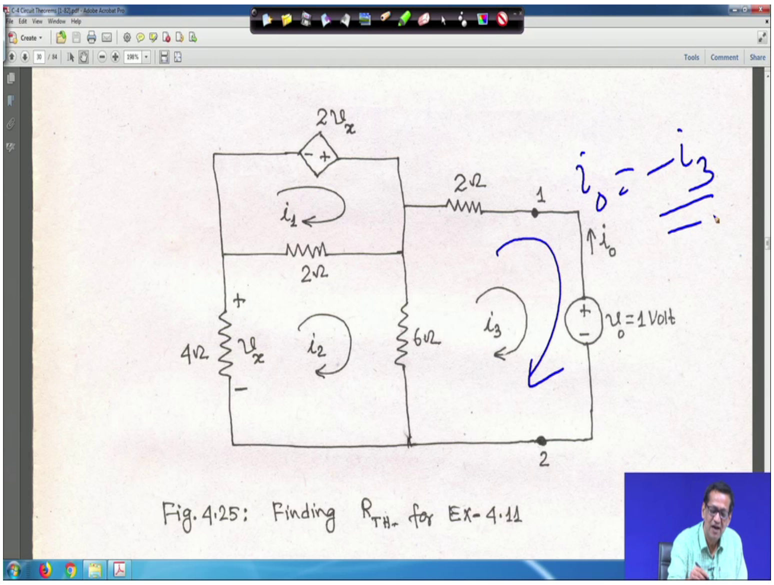

Whatever you want, it does not matter. Some numerical value you do and you have solve this circuit to get the R Thevenin; that means, whenever dependent source is coming that numericals becoming little bit complicated, but easiest way to do it right.

So, you have 3 you are 3 loops. We have taken 3 mesh. We have taken it is one this is one, this is one loop, this is 2 and all this things you please apply K V L and solve it. Probably, I have not solve it for you. Only I give you the final answer. So, you write down K V L for mesh 1 K V L for mesh 2 and K V L for mesh 3 and accordingly and V 0 is equal to you take 1 volt and after that, you will solve for i 0 right.

So, if you do; so, if you do; so, you will get i 0 is equal to 1 6 ampere. This is I am leaving up to you. You please solve it and also you find out what is V x value an a exercise for you and you solve it. To save the time, some cases I made it like this. Particularly, for A C circuit, single phase, 3 phase, I have to give everything; then, I will to be the solution solution. You please do it of your own.

So, here also, you please right your all K V L equation and solve for i 0. Here, actually only one thing is here. Only one thing is here i 3 we have taken like this and i 0 is your what you call upward, it is going downward; that means, your i 0 is equal to minus i 3 right. That is, all clear it.

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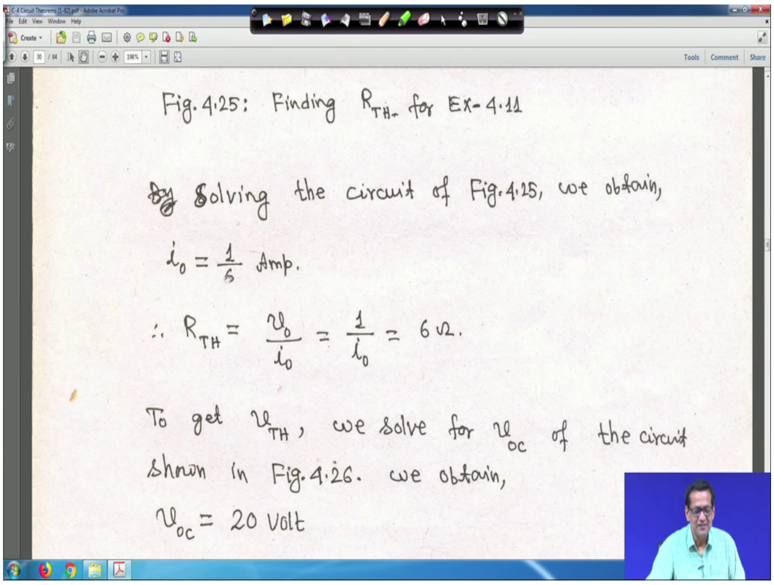

So, in this case, you will get i 0 is equal to 1 upon 6 ampere and R Thevenin is equal to V 0 i 0 V 0. We have taken 1 volt and i 0 is equal to 6. It will be 6. You take any value it is a linear circuit V 0 1 volt 2 volt does not matter. So, you will get this one.

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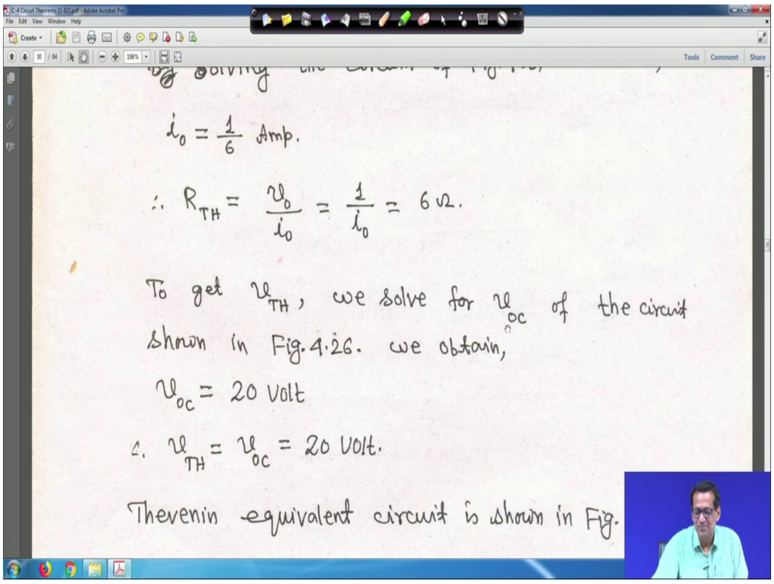

Similarly, to get Thevenin's, so you solve for V oc of the circuit shown in figure your this thing right. So, when you are and answer is 20 volt, here also you please solve. When you are obtaining that V o c, you please that V Thevenin voltage, you please solve this circuit you please solve this circuit right.

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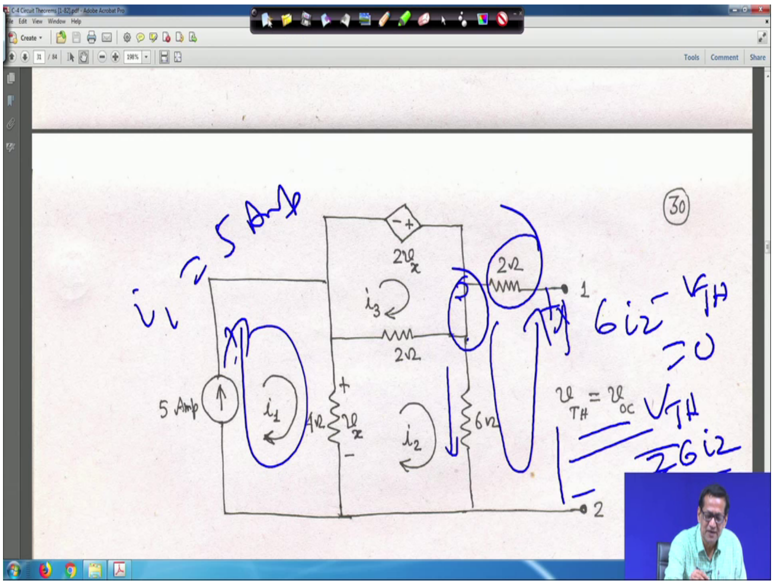

So, here this current is taken like this; this is also upward. So, i 1 is equal to 5 ampere right. So, the way the way I have told you that nodal analysis, may you please solve it. After after solving this, you find out V Thevenin. V Thevenin means, this is plus and this is your minus as usual and after this and it is open circuit.

So, no current no current is flowing through this 2-ohm resistance; that means, that means, if you apply your what you call how to find out V Thevenin; that means, this terminal is same; this and this is same right. So, that means, V Thevenin will be if you apply your K V L like this, it will be current i 2 is going like this, it will be 6 i 2 minus V Thevenin is equal to 0that means, V Thevenin is equal to 6 i 2 right is equal to 6 i 2. So, solution is given. So, please solve this one here. Solution is given that V o c is equal to 20 volt; that is, V Thevenin is equal to V oc means, V Thevenin right,; 20 volt. So, Thevenin equivalent shown in figure; so, this is you please solve it right. I am giving you this thing. So, this is actually your Thevenin equivalent circuit that is your 20 volt and 6 ohm and this is the terminal 1 right.

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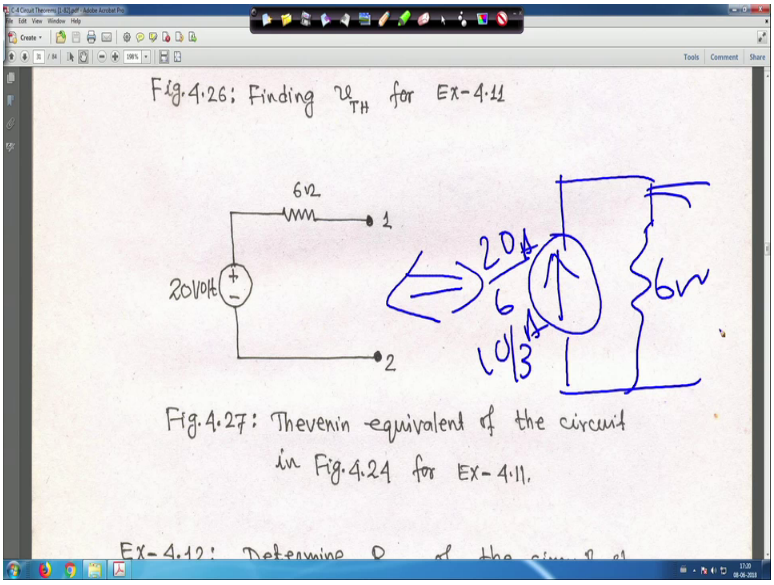

And, another thing is, if this one you want to suppose, convert it to your current source right, that actually this one if you transform into current source, so, plus look at the terminal. So, this is your, this will be your 20 by 6 ampere right. If you want to convert it to current source, later we will see. This much and this will be your 6-ohm resistance. So, it will be 10 by 3 ampere right. So, if you this Thevenin equivalent if it is converted to the your what you call a current source and 6 ohm will be in parallel right with this.

Thank you very much. We will be back again.