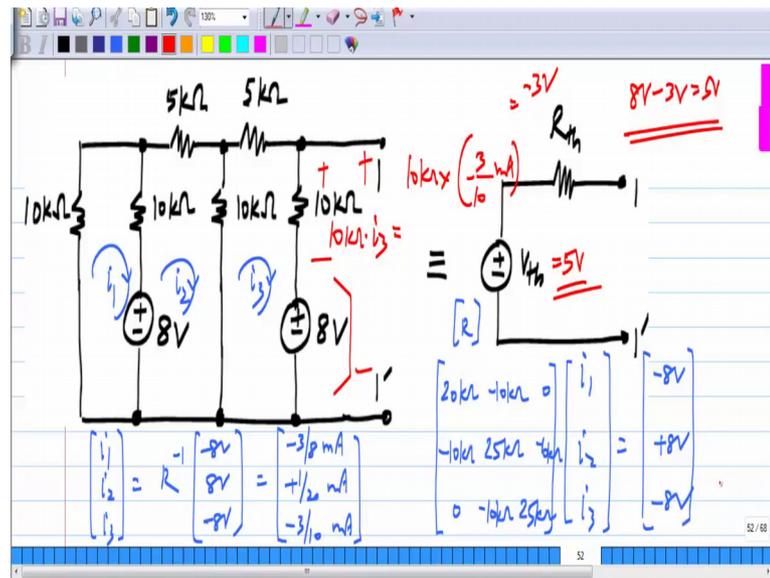


**Basic Electrical Circuits**  
**Dr Nagendra Krishnapura**  
**Department of Electrical Engineering**  
**Indian Institute of Technology Madras**

**Lecture - 82**  
**Solution**

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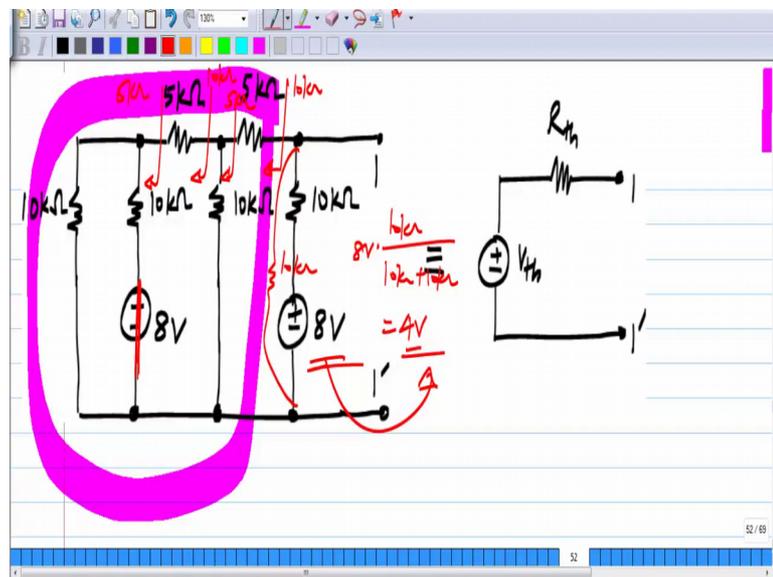
Now, we will discuss the solution to assignment six. The first question asks for the Thevenin's voltage of this circuit between these terminals, and to compute the Thevenin's voltage essentially you should leave these terminals open circuited that is nothing connected to them, and then find the voltage that appear across these terminals. And there are two sources in the circuit; many ways you can do this I will show you a couple of ways. One is to try and use one of the systematic circuit analysis methods like mesh analysis there are three mesh here  $i_1, i_2, i_3$  and it is convenient to use mesh analysis in this case it easiest, in fact, we have only resistors and independent voltage sources.

If we do that then we can write the mesh analysis equations as the resistance matrix times  $i_1, i_2, i_3$  being equal to the source vector. If you go through the first mesh the total resistance is a 20 kilo ohms so that will appear here and the resistance common to mesh 1 and 2 is 10 kilo ohm, so that appears there, and there is nothing common to mesh 1 and 3. Now if we look at the second mesh, we have 25 kilo ohms as the total resistance that appears there and 10 kilo ohm common to meshes 1 and 2, and another 10

kilo ohm common to meshes 2 and 3. And finally, the last mesh the total resistance is again 25 kilo ohm and 10 kilo ohms common to meshes 2 and 3, and nothing common with mesh 1. And in mesh 1, the total voltage raises minus 8 volts, while traversing the mesh in clockwise direction you drop 8 volts, so we have minus 8 volts there. And in the second one while traversing in clockwise direction you go up by 8 volts. So, we have plus 8 volts over there; and for the third mesh, we have again minus 8 volts.

This is the resistance matrix R, and to get the unknown vector, you have to compute R inverse. I assume you can do this; I am not going to show that and multiply that with source vector on the right side, and it turns out you get minus 3 by 8 milliamps plus 1 by 20 milliamps and minus 3 by 10 milliamps. Now what is the voltage, we want to calculate it is this voltage which is the sum of the voltage across 10 kilo ohms and you know that I 3 flowing through this 10 kilo ohms. So, the voltage across this is 10 kilo ohms times I 3, which is 10 kilo ohms times I 3 from here is minus 3 by 10 milliamps which is minus 3 volts. And here we have 8 volts, so the voltage across one, one prime is 8 volts minus 3 volts equals 5 volts. So,  $V_{th}$  equals 5 volts in this case.

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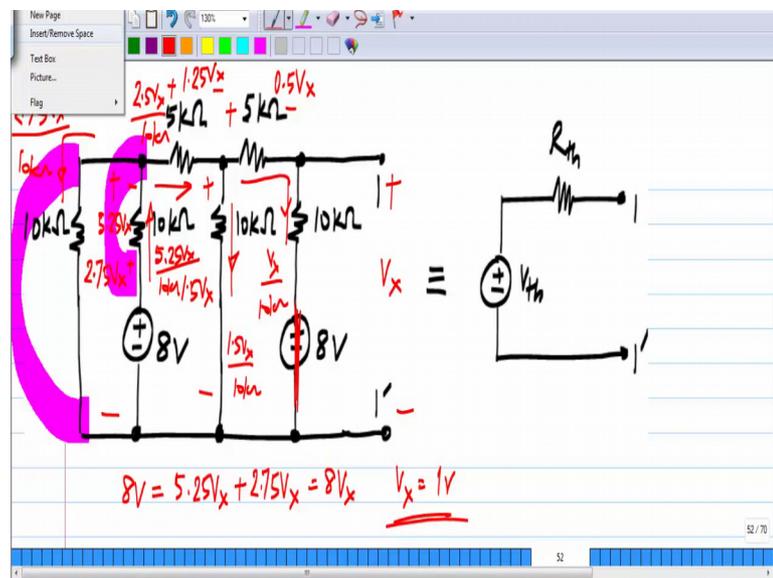


Now, the other ways of doing it, lots of other ways and you can also do it by super position. So, it to do superposition, first let say you set this 8 volts voltage source to 0, so that means that this becomes a short circuit. In fact, this turns out be an easy case to calculate, because if this is a short circuit then we have 10 kilo ohms parallel 10 kilo ohms. So, looking this way we will have 5 kilo ohms. And if you add that to this 5 kilo ohms looking here, we have 10 kilo ohms; if you add that to this 10 kilo ohms looking

this way, you have 5 kilo ohms, you add that to this 5 kilo ohms you will have 10 kilo ohms.

Now, essentially this entire part of it can be replaced by a single resistance of 10 kilo ohms. So, now, you can see that all you have is 8 volt source a 10 kilo ohm resistor and another 10 kilo ohm resistor. So, the contribution of this 8 volt source is 8 volt times 10 kilo ohms by 10 kilo ohm plus 10 kilo ohm, this is the voltage divider equals 4 volts that is a contribution due to only this part. Now we have to calculate the contribution from the other voltage source.

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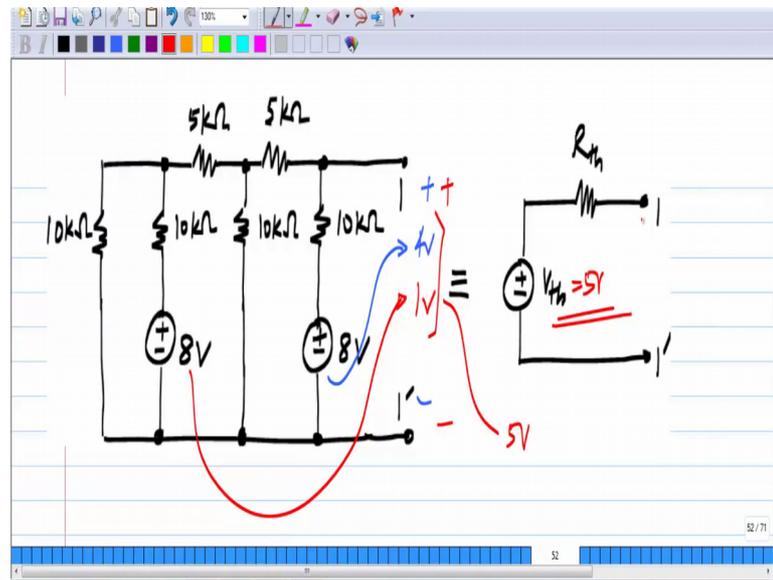


So for that you have to short circuit this, in that case, let us assume that the voltage that appears here is  $V_x$ , then the current here is  $V_x$  by 10 kilo ohms, the same current flows through that. So, the voltage drop across this is  $V_x$  by 10 kilo ohms times 5 kilo ohms, so we have half of  $V_x$  across this. So, the total voltage drop across this one is now  $V_x$  across this plus half  $V_x$  across that, so it is  $1.5 V_x$ . In the current through this is  $1.5 V_x$  divided by 10 kilo ohms. So, the current flowing through this 5 kilo ohm resistor is the sum of this current and that current which is  $1.5 V_x$  plus  $V_x$  by 10 kilo ohms or  $2.5 V_x$  by 10 kilo ohms. Now this current is flowing through 5 kilo ohms, so the voltage drop there is  $2.5 V_x$  by 10 kilo ohms times 5 kilo ohms or  $1.25 V_x$ . And the voltage across here, what is that, that is basically the voltage here  $1.25 V_x$  plus the voltage there, which is  $1.5 V_x$ , so that is  $2.75 V_x$ . So, the current through this is  $2.75 V_x$  by 10 kilo ohms.

Now, the current through this 10 kilo ohm resistor is the sum of this current which is 2.5

$V \times 10$  kilo ohms and this current which is  $2.75 \text{ V} \times 10$  kilo ohms. So, the current through this is  $5.25 \text{ V} \times 10$  kilo ohms in that direction and the voltage drop here is nothing but  $5.25 \text{ V} \times 10$  kilo ohms times  $10$  kilo ohms. So, the voltage drop here is nothing but  $5.25 \text{ V} \times 10$  kilo ohms. So, now, you can choose any of the loops to write KVL around. So, if you chose to write it around this loop, what we have is  $8$  volts will be equal to the drop across this resistor plus that resistor which is  $5.25 \text{ V} \times 10$  plus  $2.75 \text{ V} \times 10$  which is equal to eight times  $V \times 10$ . So,  $V \times 10$  will be just  $1$  volt.

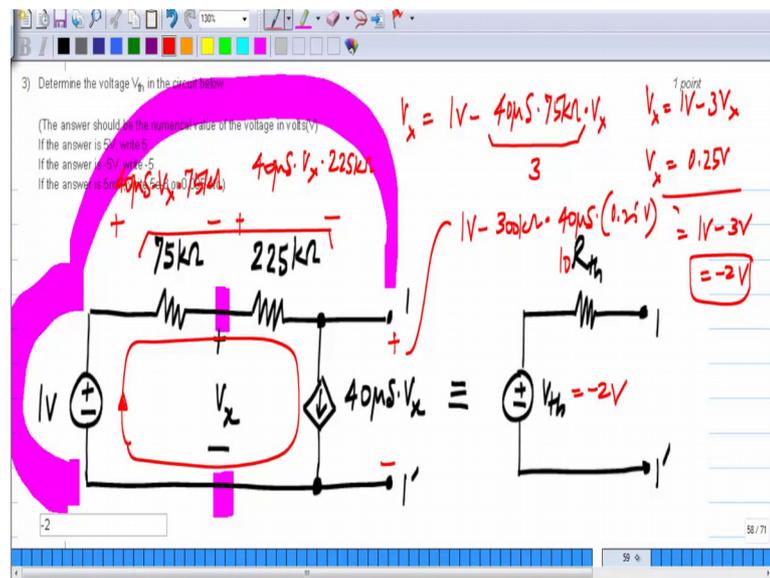
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So, now, what do we have, we calculated that the contribution from this to this is  $1$  volt. The contribution from this to that is  $4$  volts in this polarity both of them are in that polarity. So, the contribution from both put together is  $5$  volts. So,  $V_{th}$  equals  $5$  volts. So, we have calculated with in two different ways - one using superposition another using mesh analysis; and as expected both give the same answer of  $5$  volts. In fact, any problem, I would encourage you to try and solve it in many different ways. So, that you get really comfortable with solving problems.



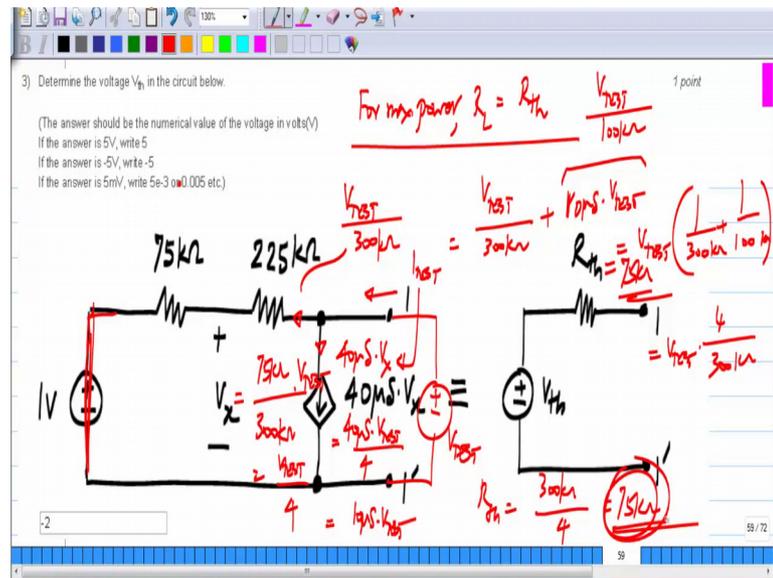
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Now, this again you are asked to find the Thevenin's equivalent, this is a slightly more complicated circuit in the sense that you have a controlled source, but the principles of circuit analysis are exactly the same. First we have a single loop, and the current flowing through this is the same as the current flowing through this controlled current source which is 40 micro Siemens times  $V_x$ . So, across this, we will have 40 micro Siemens times  $V_x$  times 75 kilo ohms, and across this we have 40 micro Siemens times  $V_x$  times 225 kilo ohm. And what is  $V_x$ ,  $V_x$  is voltage between these two which is this voltage 1 volt minus the drop across 75 kilo ohms in this polarity. So,  $V_x$  is given by 1 volt minus 40 micro Siemens times 75 kilo ohms times  $V_x$  and this you know this will be 3. So,  $V_x$  is 1 volt minus 3 times  $V_x$ . So,  $V_x$  turns out to be 0.25 volts.

Now, what we want for the Thevenin's voltage is the voltage between one and one prime here one this is open circuited. So, that is equal to 1 volt minus these entire drop that is 1 volt minus 300 kilo ohms times the current which is 40 micro Siemens times  $V_x$ . So, this voltage turns out to be 1 volt minus 300 kilo ohms which is the sum of these two resistors times the current through them which is 40 micro Siemens times  $V_x$  which is 0.25 volts. So, if you calculate the whole thing you will get this 0.25 times 40 is 10. So, essentially you will get minus 3000 times kilo ohms times micro Siemens basically equaling 1 volt minus 3 volts which is minus 2 volts. So,  $V_{th}$  happens to be minus 2 volts in this case.

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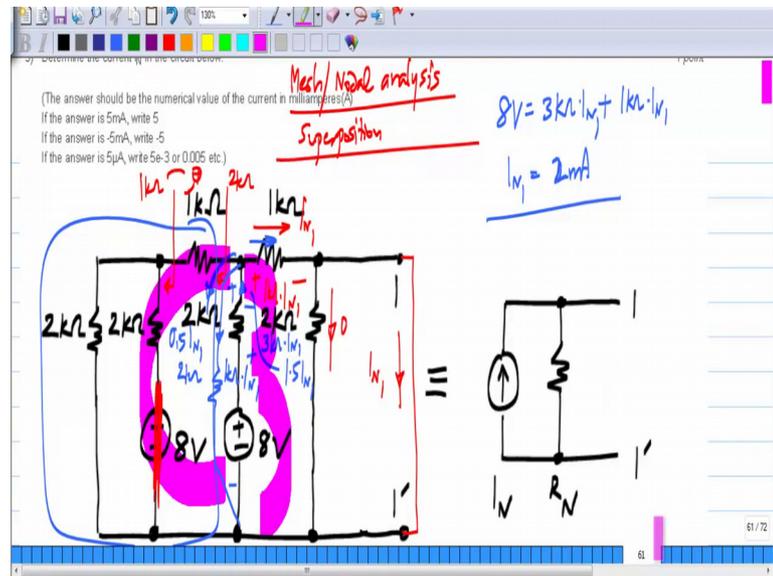
Now, here the question asks that a positive resistance  $R_L$  is connected to the circuit above at 1 1 prime that is a positive resistance  $R_L$  is connected up like this. And what is the value of  $R_L$  such that maximum possible power is dissipated in it that is we have maximum power dissipation in  $R_L$ . We know from maximum power transfer theorem that  $R_L$  must be equal to the Thevenin's resistance. So, this is really an excuse to have a question where you calculate the Thevenin's resistance for maximum power dissipation in  $R_L$   $r_l$  must be equal to  $r_{th}$  which we do not know yet. So, we have to calculate the Thevenin's resistance looking back into the circuit.

So, how do we do that to calculate the Thevenin's resistance we apply a test voltage here and we short the independent source in the circuit. So, now, we have see that this  $V$  test appears across this combination of 75 kilo ohms and 225 kilo ohms. So, this  $V_x$  is nothing but some voltage divider ratio due to these two resistors times  $V$  test we can easily see that  $V_x$  will be 75 kilo ohms divided by 75 plus 225 which is 300 kilo ohms times  $V$  test or  $V$  test divided by 4 and the current flowing here is 40 micro Siemens times  $V_x$  which is 40 micro Siemens times  $V$  test by four or 10 micro Siemens times  $V$  test the current flowing here is nothing but  $V$  test divided by 300 kilo ohms.

So, the total current flowing here  $I_{test}$  is given by  $V$  test by 300 kilo ohms plus 10 micro Siemens times  $V$  test and this ten micro Siemens times  $V$  test can be written as  $V$  test by 100 kilo ohms. So, the total current equals  $V$  test times 1 by three hundred plus 1 by hundred kilo ohms in the denominator which basically turns out to be  $V$  test times 4 by 400 kilo ohms. So, the resistance looking in here  $r_{th}$  is equal to  $V$  test divided by the

current and if you calculate that you will get 300 kilo ohms by four which is 75 kilo ohms. So, r t h will be 75 kilo ohms of course, the question asked is what should be the value of  $R_L$  connected to this circuit. So, that you dissipate maximum power and answer is 75 kilo ohms.

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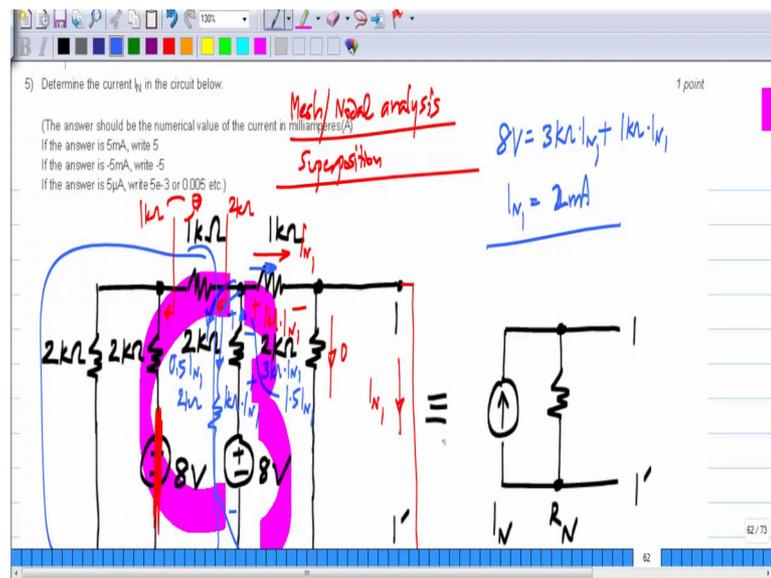
Now, here we have a circuit for which we have to calculate the Norton current. So, again we can take many different approaches. So, you can use any type of analysis mesh or nodal analysis or you can use superposition as well. So, what I will do is do it by superposition, but you can also do it with mesh and nodal analysis and also although you are asked for the Norton equivalent we can always calculate the Thevenin's equivalent first and calculate the Norton current from them I will show the direct method here, but all of those things are possible. So, to calculate the Norton current I have to short this and find the current flowing in that direction. So, let say I call that current  $I_{n1}$ . Now I will calculate it due to the two sources separately. First I will short circuit this voltage source and calculate  $I_{n1}$  due to this 8 volt source, let me call that  $I_{n1}$ , so that  $I_{n1}$ , now that I have short circuited this the voltage drop across this two kilo ohms zero. So, the current through this is zero. So,  $I_{n1}$  will flow that way the voltage drop across that is one kilo ohm times  $I_{n1}$ .

Now, if you look back this way you have 1 kilo ohm because you have 2 kilo ohm parallel 2 kilo ohms and if you look here you have the sum of these two which is 2 kilo ohms. So, this entire network can be replace by a single two kilo ohm resistor and the voltage across that 2 kilo ohm resistor is also this one because this point is short at here

across this you have the same voltage which is one kilo ohms times  $I_n 1$ . So, the current through this 2 kilo ohm resistor is this voltage divided by 2 kilo ohm which is basically half of  $I_n 1$ .

Now, if you look at the current flowing there it is the sum of the current flowing there and there by Kirchoff's current law. So, that current is  $I_n 1$  which is flowing there plus half of  $I_n 1$  which is flowing there. So, that is 1.5 times  $I_n 1$  and finally, the voltage drop across this is this 1.5 times  $I_n 1$  times two kilo ohms which is basically three kilo ohms times  $I_n 1$  now again you can right k V 1 around this loop which includes the voltage source. So, this 8 volts will be equal to drop across this resistor plus drop across that resistor and the appropriate direction. So, 8 volts will be 3 kilo ohms times  $I_n 1$  plus 1 kilo ohm times  $I_n 1$ . So,  $I_n 1$  is nothing but 8 volts divided by 4 kilo ohms which is 2 milli amperes. So, that is the contribution to the Norton current from this 8 volts source.

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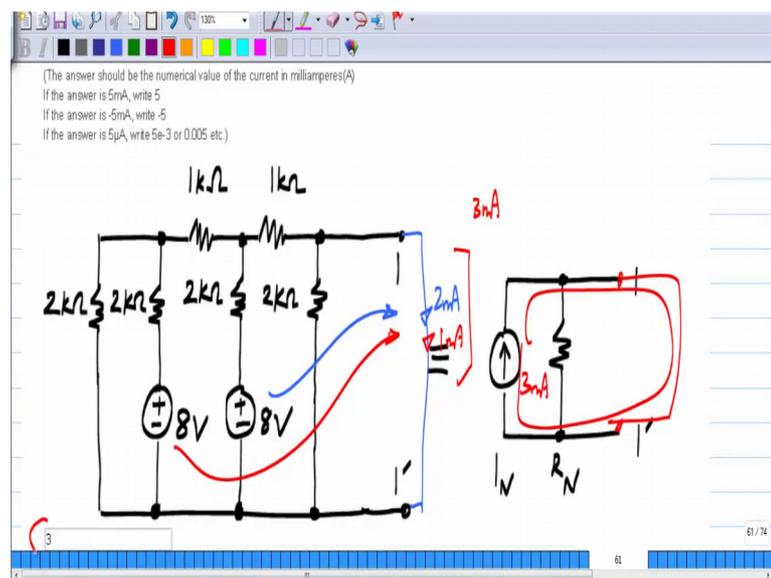
So, now, I have to calculate the other component of superposition by shorting this disabling the second 8 volt source and calculating the contribution to due to that. So, in this case I will call the short circuit current  $I_n 2$  again the current through this two kilo ohms is zero because there is zero volts across it the current through here therefore, is  $I_n 2$  the voltage drop here is one kilo ohm times  $I_n 2$ . Now the voltage drop here is exactly same as the voltage drops there, because this node and that node are shorted and we just have the two kilo ohm resistor. So, across the two kilo ohm resistor also we have one kilo ohm times  $I_n 2$ . So, the current through the two kilo ohm resistor of course, is one kilo ohm times  $I_n 2$  divided by 2 kilo ohm which is half of  $I_n 2$  that is the current over there.

So, the current here is the sum of the current in there and the current in there which is  $I_n/2$  plus half of  $I_n/2$  which is  $1.5 I_n/2$  and the voltage drop across that is  $1.5 I_n/2$  times one kilo ohm which is one point five kilo ohm times  $I_n/2$ .

Finally, the voltage drop here is the sum of this voltage drop and that voltage drop which is point five kilo ohm times  $I_n/2$  here  $1$  kilo ohms times  $I_n/2$  over there. So, that whole thing is  $2.5$  kilo ohms times  $I_n/2$ , because of that the current flowing through that is  $2.5$  kilo ohms times  $I_n/2$  divided by  $2$  kilo ohms which is  $1.25$  times  $I_n/2$ . So, the current flowing over there is the sum of this current and that current which is equal to  $1.5 I_n/2$  plus  $1.25 I_n/2$  which is  $2.75$  times  $I_n/2$ .

So, again we can write Kirchhoff voltage law including this voltage source around some loop. So, that we can solve for the variable  $I_n/2$  this  $8$  volts equals the drop across this two kilo ohms plus the drop across that two kilo ohm. So, the drop across this we already know it is  $2.5$  kilo ohm times  $I_n/2$  the drop across this two kilo ohm in this direction is two kilo ohm times  $2.75 I_n/2$  or which is equal to  $5.5$  kilo ohm times  $I_n/2$ . So, finally, we get the loop equation which is a  $8$  volt equaling  $5.5$  kilo ohms times  $I_n/2$  plus  $2.5$  kilo ohms times  $I_n/2$  which is equal to  $8$  kilo ohms times  $I_n/2$   $I_n/2$  is  $8$  volts divided by  $8$  kilo ohms is one milliamp. Now we had two milli amperes from one of the sources, one milliamp from the other source.

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We had 2 milliamps in this direction from this  $8$  volt source, and  $1$  milliamp in that direction due to that  $8$  volt source. So, put together, they give you a Norton current of  $3$

milliamp. So, when you short this, basically all of these three milliamps flows there, and that the answer you see over there 3, for 3 milliamps.

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6) Determine the current  $I_N$  in the circuit below.

(The answer should be the numerical value of the current in milliamperes(A)  
 If the answer is 5mA, write 5  
 If the answer is -5mA, write -5  
 If the answer is 5μA, write 5e-3 or 0.005 etc.)

Handwritten equations:  
 $I_x = 16I_x + I_N$   
 $I_x = -\frac{1}{15}I_N$   
 $I_N = I_x + 4I_x = 5I_x = 5\left(-\frac{1}{15}\right)I_N = -\frac{1}{3}I_N$   
 $I_N = -3mA$

In the next question, again a Norton current calculation question this time a controlled sources included, but of course, everything can be done with circuit analysis, so you short circuit this. And if you call this current  $I_n$ , we also have this unknown  $I_x$  over there. So, now, the voltage drop across this because this is short circuited is 16 kilo ohms times  $I_x$ . So, the current through this is 16 kilo ohm times  $I_x$  divided by one kilo ohm which is 16 times  $I_x$  the voltage drop across this is the same as that voltage drop which is 16 kilo ohms times  $I_x$ . So, the current through there is 16 kilo ohm times  $I_x$  divided by four kilo ohms which is 4 times  $I_x$ . We also know from a Kirchhoff current law that this  $I_x$  equals this 16  $I_x$  flowing here plus  $I_n$  that is the current flowing here equals the current flowing there plus the current flowing there. So,  $I_x$  will be equal to 16 times  $I_x$  plus  $I_n$ ,  $I_n$  is flowing that way.

So,  $I_x$  is nothing but minus 1 by 15 times  $I_n$ . And if you write Kirchhoff current law here with this one milliamp source, we get one milliamp to be equal to  $I_x$  flowing that way plus four  $I_x$  that way  $I_x$  plus 4 times  $I_x$  which is basically five times  $I_x$  and  $I_x$  is nothing but minus 1 by 15  $I_n$ . So, this will be five times minus 1 by 15 times  $I_n$  or minus 1 by three times  $I_n$ . So,  $I_n$  would be minus 3 times 1 milliamps or minus 3 milli amperes, so  $I_n$  in this case, minus 3 milliamps. So, again just very easy circuit analysis systematically done will give you the Norton current or Thevenin's voltage or whatever it is you want to calculate.

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$I_x = 16I_x + I_W$   
 $I_x = -\frac{1}{15}I_W$   
 $I_W = I_x + 4I_x = 5I_x = 5\left(-\frac{1}{15}\right)I_W = -\frac{1}{3}I_W$   
 $I_W = -3mA$   
 $R_L = R_N$

Again this question which is for finding out the Norton resistance, but forced as a maximum power question a positive resistance  $R_L$  is connected to the circuit above at 1 1 prime that is instead of the short circuit we connect a positive resistor  $R_L$ . And you are ask to find  $R_L$  such that the power in  $R_L$  is maximum. We know that the power in  $R_L$  is maximum, when its value equals the Thevenin's or Norton resistance of the source to which it is connected. So,  $R_L$  has to be equal to  $R_N$ .

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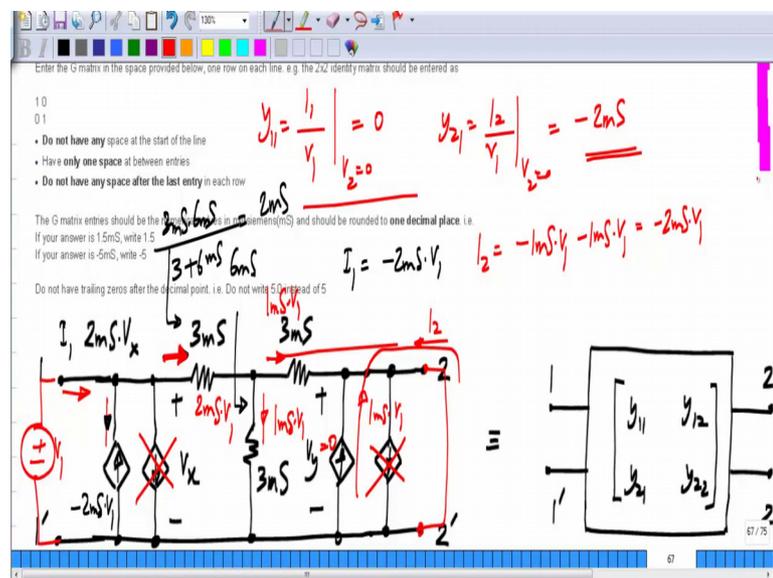
$V_{NST} = -16k\Omega \cdot I_x - 4k\Omega \cdot I_x = -20k\Omega \cdot I_x$   
 $I_{NST} = -4I_x - I_x = -5I_x = -5 \cdot \frac{V_{NST}}{-20k\Omega} = \frac{V_{NST}}{4k\Omega}$   
 $R_N = 4k\Omega$

Now, we have to compute  $R_N$  to compute  $R_N$  while computing  $R_N$  this becomes an open circuit. So, we have only this part of it. So, this is an open circuit which means that no current flows over there and we can apply a voltage or a current source let say I apply

a test voltage source. So, I set that zero current flows here because this is an open circuit for Norton resistance calculation, we have opened that and if this is a  $I_x$  it has to be flowing that way. So, the voltage drop in this direction is minus 4 kilo ohms times  $I_x$  because  $I_x$  is flowing upwards the same voltage drop appears across the one kilo ohm resistor. So, the current flowing here is minus 4 kilo ohm times  $I_x$  divided by 1 kilo ohm which is minus 4 times  $I_x$ .

Now, we know that  $V_{test}$  is the sum of this voltage drop which is 16 kilo ohm. Now we know that  $V_{test}$  is the sum of this voltage drop in this polarity plus that voltage drop this voltage drop here is minus 16 kilo ohms times  $I_x$  because of the polarity of this controlled source and the voltage drop between there and there is minus 4 kilo ohms times  $I_x$ . So, the whole thing is minus 20 kilo ohms times  $I_x$ . We also know that  $I_{test}$  which flows this way is the sum of this current and that current. So, the current flowing this way is minus 4 times  $I_x$  current flowing this way is minus  $I_x$ . So,  $I_{test}$  is minus four  $I_x$  minus  $I_x$  is minus 5  $I_x$  and  $I_x$  itself, we can get from here the first equation to be  $V_{test}$  divided by minus 20 kilo ohms or  $V_{test}$  divided by 4 kilo ohms. So,  $V_{test}$  by  $I_{test}$  which is the Norton resistance is 4 kilo ohms.

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So the value of  $R_L$  to be connected equals  $R_N$  equals four kilo ohms. Now the last question is about two port parameters or y parameters, and you have to determine the y parameters of this circuit all y parameters. And from the definition of a y parameters as short circuit parameters, you will be able to easily calculate them we know that  $y_{11}$  is  $I_1$  by  $V_1$  with  $V_2$  being zero or port two short circuited. So, now if port two short

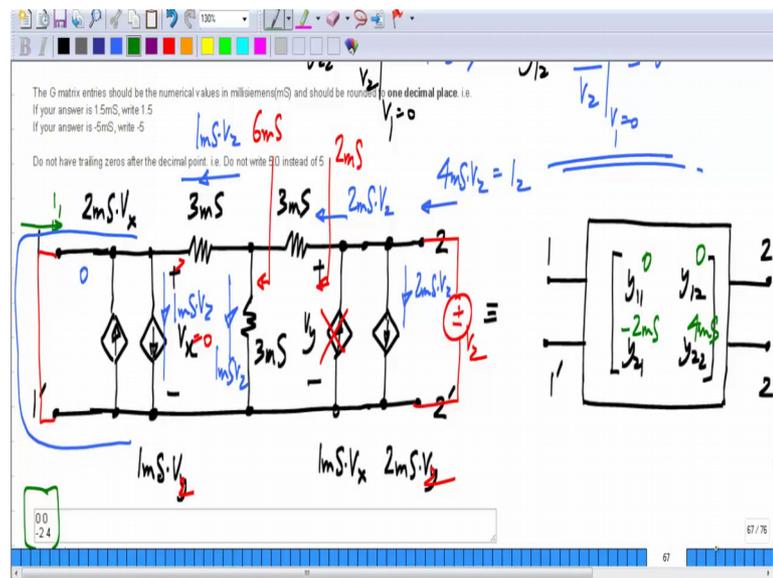
circuited this  $V_y$  is zero  $V_y$  will be zero; that means, that this current source goes away one milli Siemens times  $V_y$  is zero, it is an open circuit in this two milli Siemens times  $V_y$  this is also zero, it is an open circuit. So, now,  $V_x$  is nothing but this  $V_1$ . So, if you calculate the total current over there what you get is this current plus that current.

So, now, you can calculate, you can do the regular circuit analysis and calculate stuff. So, here in this direction we will have minus 2 milli Siemens times  $V_1$ , because upwards it is two milli Siemens times  $V_x$  and  $V_x$  is a same as  $V_1$ . So, down wards it is minus two milli Siemens times  $V_1$  and if I call this current  $I_1$ . So,  $I_1$  will be minus two milli Siemens times  $V_1$  plus the current flowing through that. So, if you look at that first of all this three milli Siemens and this three milli Siemens are in parallel because the short circuit combines them and you have them in parallel.

So, looking this way what you have is a six milli Siemens resistance you have this controlled source also so, but the current of this controlled source flows through the short circuit because it is terminated by a short circuit. So, the conductance looking here is the series combination of this 3 milli Siemens and 6 milli Siemens. So, that is given by looking this way you will have 3 milli Siemens times 6 milli Siemens by three plus six milli Siemens which is basically two milli Siemens. So, the current that flows here is 2 milli Siemens times  $V_1$ . So, interestingly if you look at  $I_1$ , it is minus two milli Siemens times  $V_1$  flowing here plus 2 milli Siemens times  $V_1$  flowing there. So,  $I_1$  is actually 0 when port two short circuited  $I_1$  is 0. And we actually get  $y_{11}$  to be 0. And we can calculate  $y_{21}$  from the same picture by computing  $I_2$ , we know that  $y_{21}$  is  $I_2$  by  $V_1$  and of the same condition  $V_2$  being zero or port two short circuited.

What is  $I_2$ , first of all we know that the current that is flowing here is two milli Siemens times  $V_1$  and that is splits into two parts. So, these are two equal parallel conductance remember because of the short circuit they are in parallel. So, this two milli Siemens times  $V_1$  splits into two equal part as one milli Siemens times  $V_1$  and 1 milli Siemens times  $V_1$  and also there is the current through this controlled source which is 1 milli Siemens times  $V_x$  or 1 milli Siemens times  $V_1$  and these two add up and flow as  $I_2$ . So,  $I_2$  will be minus 1 milli Siemens times  $V_1$  minus 1 milli Siemens times  $V_1$  minus 2 milli Siemens times  $V_1$ , so this  $I_2$  by  $V_1$  is nothing but minus 2 milli Siemens so that is the procedure to calculate this.

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Now, we can calculate the other two parameters. So,  $y_{22}$  is  $I_2$  by  $V_2$  with port one short circuited. So, I will short circuit port one and apply  $V_2$  and I short circuit port one  $V_x$  equal zero. So, this becomes an open circuit and that becomes an open circuit  $V_y$  equals  $V_2$ . So, this is  $V_2$  and this is also one milli Siemens times  $V_2$ . So, again we do the convention of circuit analysis. So these three milli Siemens and these three milli Siemens are in parallel, because of the short circuit and the current through this controlled source goes into the short circuit which is across it the short circuit is placed across the contribution current source.

So, this one milli Siemens times  $V_2$  flows entirely through the short circuit there is also some more current here which can go in that way. So, looking this way we have parallel combination of two three milli three milli Siemens conductance, which is 6 milli Siemens and looking here we have 6 milli Siemens in series with 3 milli Siemens, we worked out earlier that this will correspond to 2 milli Siemens of conductance. So, now, the current flowing in this is  $V_2$  times the conductance across the these two which is two milli Siemens so that is two milli Siemens times  $V_2$  current flowing here is also two milli Siemens times  $V_2$  because of the controlled source.

So, the total current flowing that way is four milli Siemens times  $V_2$  and this is nothing but  $I_2$ . So,  $y_{22}$  which is  $I_2$  by  $V_2$  is four milli Siemens now we are still to calculate  $y_{12}$  which is basically the current flowing in port one that is you have to calculate  $I_1$  in the same circuit with port one short circuited. So, that again we can do quite easily we already determined that two milli Siemens times  $V_2$  flows there and that divides equally

between this three milli Siemens conductance and that three milli Siemens conductance. So, it goes us one milli Siemens times V 2 and one milli Siemens times V 2.

If you absorb this controlled source is draw in one milli Siemens times V 2. So, the actual current that flows this way in this path is zero because this one milli Siemens times V 2 goes into that and that is zero. So, y 1 2 which is I on by V 2 with V 1 being zero or port one short circuited is zero. So, the y matrix of this circuit is zero zero and minus two milli Siemens and four milli Siemens and that is what is given over there. So, by systematically analyzing circuit you can determine the two port parameter of any circuit.

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9) Determine the y-parameters of the circuit below. 2 points

Enter the G matrix in the space provided below, one row on each line. e.g. the 2x2 identity matrix should be entered as

```
1 0
0 1
```

- Do not have any space at the start of the line
- Have only one space at between entries
- Do not have any space after the last entry in each row

The G matrix entries should be the numerical values in microsiemens(μS) and should be rounded to one decimal place. i.e. If your answer is 1.5μS, write 1.5 If your answer is -5μS, write -5 Do not have trailing zeros after the decimal. Do not write 5.0 instead of 5

The circuit diagram shows a two-port network with a dependent current source  $2I_x$  and resistors of  $5k\Omega$ ,  $5k\Omega$ ,  $15k\Omega$ , and  $15k\Omega$ . The dependent current source  $2I_x$  is controlled by the current  $I_x$  through the  $5k\Omega$  resistor. The dependent current source  $2V_1$  is controlled by the voltage  $V_1$  across the  $15k\Omega$  resistor. The output port is short-circuited.

Handwritten equations:

$$I_1 = \frac{V_1}{75k\Omega} - \frac{2V_1}{15k\Omega} = 0$$

$$y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0} = 0$$

$$I_2 = -\left(\frac{V_1}{15k\Omega} + \frac{2V_1}{15k\Omega}\right) = -\frac{V_1}{5k\Omega}$$

$$y_{21} = \frac{I_2}{V_1} \Big|_{V_2=0} = -\frac{1}{5k\Omega} = -200\mu S$$

The next problem is to you find y parameters of this two port and it as a resistors and controlled sources, but of course, we can find the y parameters in the usual way for two of the parameter. We short the second port and apply a voltage to the first port then we find the currents I 1 and I 2. Now because this is shorted this 5 kilo ohm and this 5 kilo ohm they appear in parallel. So, looking here we see a 2.5 kilo ohm resistance and looking here we see five plus 2.5 which is 7.5 kilo ohms. So, the current that goes here is V 1 divided by the total resistance, which is 7.5 kilo ohms and because these two a equal resistors V 1 by 15 kilo ohms flows this way and V 1 by 15 kilo ohms flows that way and we also know that now we have this two times I x and I x is flowing down wards it is V 1 by 15 kilo ohms. So, here we have two times V 1 by 15 kilo ohms flowing that way and here again we have two times I x flowing upwards which is 2 times V 1 by 15 kilo ohms.

So, first of all  $I_1$  is this current minus this current which is flowing upwards by applying KCL at this node. So,  $I_1$  is  $V_1$  by 7.5 kilo ohms minus  $2 V_1$  by 15 kilo ohms which we will easily recognize to be zero. So,  $y_{11}$  which is  $I_1$  by  $V_1$  with the second port short circuited is 0 and  $I_2$  is the negative sum of this current and that current, so  $I_2$  is minus  $V_1$  by 15 kilo ohm plus  $2 V_1$  by 15 kilo ohms or basically minus  $V_1$  divided by 5 kilo ohms. So,  $y_{21}$  which is  $I_2$  by  $V_1$  with the second port short circuited is basically this coefficient which is minus 1 by 5 kilo ohms or minus two hundred micro Siemens.

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The slide shows a circuit diagram and handwritten calculations for finding the y-parameters of a two-port network. The circuit consists of a 5kΩ resistor in series with a parallel combination of a 5kΩ resistor and a dependent current source  $2I_x$ . This is followed by another 5kΩ resistor in series with a parallel combination of a 5kΩ resistor and a dependent current source  $2I_x$ . The output port is short-circuited. Handwritten calculations show the determination of  $y_{12}$  and  $y_{22}$  by setting  $V_1 = 0$  and  $V_2 = 1$ .

Handwritten calculations:

$$y_{12} = \frac{I_1}{V_2} \Big|_{V_1=0} = -\frac{1}{5k\Omega} = -200\mu S$$

$$y_{22} = \frac{I_2}{V_2} \Big|_{V_1=0} = 0$$

The resulting admittance matrix is:

$$[y] = \begin{bmatrix} 0 & -200\mu S \\ -200\mu S & 0 \end{bmatrix}$$

Now, the two other parameters can be found in a similar way this is  $V_2$  and we short circuit port one. First of all from just the symmetry of the network, the network looks the same looking from port one and looking from port two we should expect that  $y_{11}$  is the same as  $y_{22}$  and  $y_{21}$  is the same as  $y_{12}$ , but we will calculate it and verify that anyhow. So, if apply  $V_2$  here again because this is short circuited this 5 kilo ohm and that 5 kilo ohm appear in parallel. So, looking this way we have 2.5 kilo ohms and looking here we have 5 plus 2.5 or 7.5 kilo ohms. So, now, this current here is  $V_2$  divided by 7.5 kilo ohms and half of that goes here half of that goes there each part is  $V_2$  by 15 kilo ohms.

In these current sources controlled current sources, we have two times  $I_x$  which is  $2 V_2$  by 15 kilo ohms. We can see that this current and that current are the same, so  $I_2$  equal 0. This controlled current source is two times  $I_x$  which is also two times  $V_2$  by 15 kilo ohms. So, the current here will be the sum of these two which is three times  $V_2$  by 15 kilo ohms or  $V_2$  by 5 kilo ohms. Now  $I_1$  should be measured in this direction. So, what

we have as a result is that  $y_{12}$  which is  $I_1$  by  $V_2$  with port one shorted will be minus 1 by 5 kilo ohms; and  $y_{22}$  which is  $I_2$  by  $V_2$  with port one shorted is 0, and this minus 1 by 5 kilo ohm is nothing but minus 200 micro Siemens. So, the answer finally is that these diagonal elements happened to be zero in this particular case and  $y_{12}$  and  $y_{21}$  are both 200 micro Siemens.