Fundamentals of Electrical Engineering
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Lecture – 25
Circuit Theorems (Contd.) & Capacitors & Inductors

So again we come to another example looked for DC circuit.

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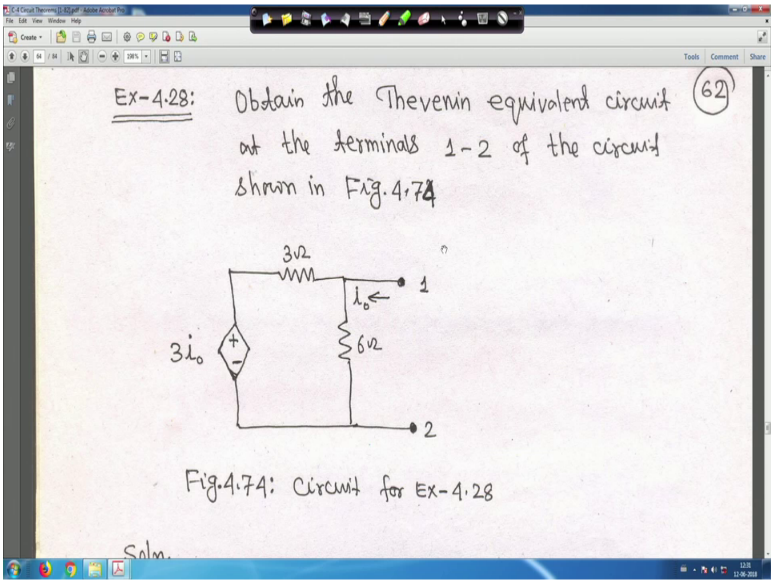

So, many examples giving such that you should not face any problem, if you go through any book I will say that any book you go through you will not get more than this kind of variation in the problem. So, it will very helpful for you, but repeating once again that for AC circuit single phase as well as your 3 phase we cannot give so, many examples because of course, everything is known to you now, only thing is that because it complex number it takes time computational time, here than DC computational will be more than may be 4 times, or even more right. So, that is why so, many examples I am giving for DC circuit varieties of example such that whatever whichever takes be to open you will I believe that, you may not get much more variation than this one ok. Let us come to this example.

So, now question is that here you have to obtain the Thevenin equivalent circuit in terminals 1 2 of the now it is a Thevenin equivalent is given from that you can easily transfer it to Norton. So, one dependent voltage source is there that is 3 i 0 and this is i 0 such dependent voltage dependent voltage source is there; that means, you have to connect a your what you call say voltage source to your a, because without that you cannot get your R Thevenin right.

So, to do this right you have to obtain R Thevenin as well as what you call that are there is no independent source that will see later right. So, only dependent source is there. So, if you go through this right just 1 minute.

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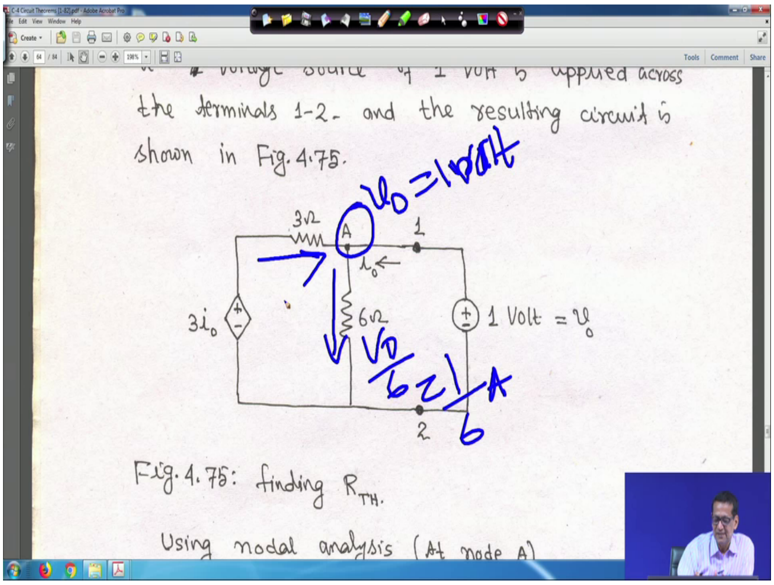

Now, if you apply a voltage source here right so, voltage 1 voltage source suppose V 0 is given right and, this voltage source this voltage source V 0 is given; that means, at this point this voltage source is V 0 actually is equal to 1 volt, because your what you call, because low electrical elements connect here. So, this is V 0 is equal to 1 volt right so, in this case this i 0 current is entering. And you have to what you call and this this current will be V 0 by 6 will be V 0 by 6 right.

So, V 0 is 1 volt so, basically it will become 1 by 6 ampere 1 by 6 ampere right and, if you if you find and if you take this way that what is the current, suppose if I take this way that what is the current entering here like entering here, the way you take or if you take the current leaving this one. So, let me clear it let me clear it; so, let me clear it.

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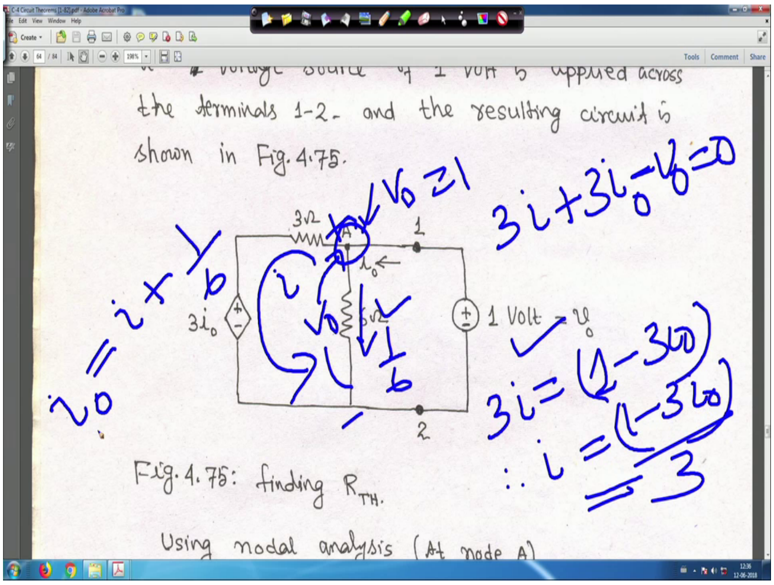

So, current through this current through this is 1 by 6 right. And if we take the current leaving this is node a we have to go for a KCL at this node right and this voltage this voltage is V 0 is equal to 1 volt and V 0 means your this is my V 0 if this is minus, then this is plus right. And if you your what you call move like this, say anticlockwise direction and, this current I take I say, if it is I then it will be 3 i it will be 3 i, then plus terminal it is encountering plus plus 3 i 0 3 i 0, then minus V 0 is equal to 0 and V 0 is equal to 1 volt right; that means, 3 i is equal to V 0 is 1 volt that is 1 minus 3 i 0 right; that means, i is equal to 1 minus 3 i 0 divided by 3 right. So, if you now apply KCL at node a so, i 0 is equal to right, this i right is equal to this i this this is a entering this current is leaving and plus 1 by 6 because this voltage is V 0 by 6, because 6 ohm resistance; so, plus your 1 by 6. So, if you put this expression of i here expression of i here in terms of 1 minus 3 0 by 3 then solve it you will get i 0.

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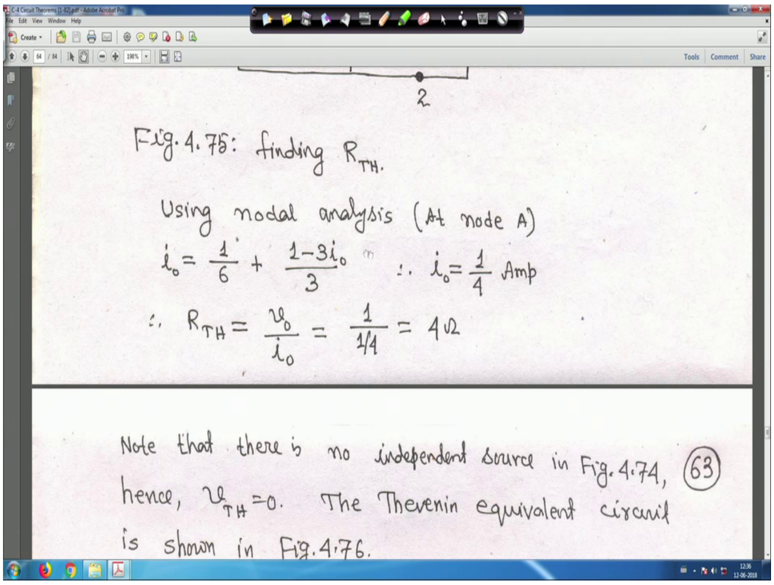

So, let me clear it. So, here it is your what you call that i 0 is equal to 1 by 6 plus 1 minus 3 i 0 by 3. So, i 0 is equal to 1 by 4 ampere right and R Thevenin, then will be V 0 by i 0 V 0 has taken 1 volt right. Therefore, 1 upon 1 by 4, so 4 ohm R Thevenin is equal to 4 ohm. Now, here in this circuit, there is no independent source it is dependent source, there is no independent source. So, if know a V that means, V Thevenin will be 0 because no your what you call independent source is there earlier also you have seen one example. So, V Thevenin will be 0; So, that is why V Thevenin is 0 just this is a Thevenin equivalent circuit just R Thevenin because V Thevenin will be 0, because there is no independent source in the circuit right.

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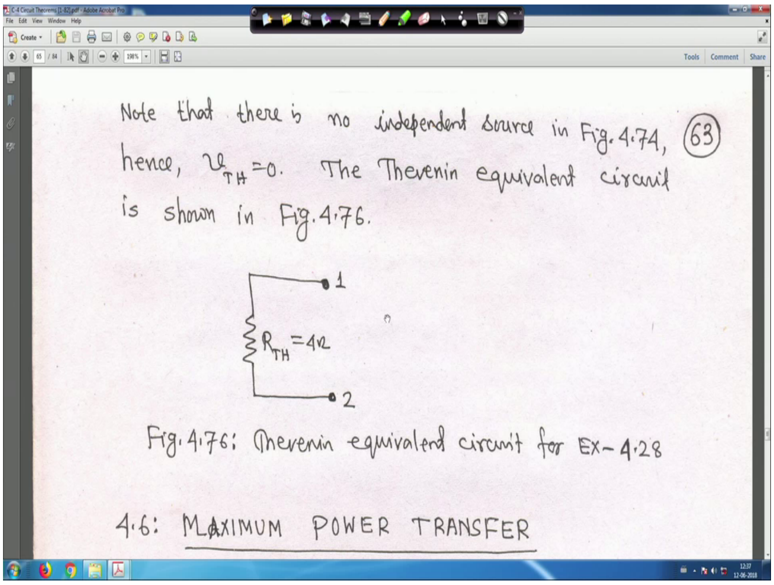

So, with this we have learned Thevenin theorem and Norton theorems.

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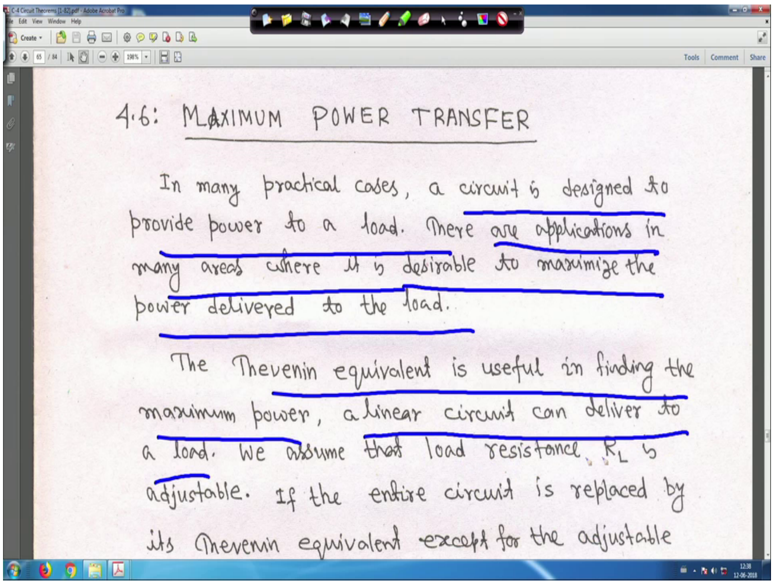

So, basically it is a basically Thevenin's not on transformation, when you go for source transformation. So, whatever over the years my experience shows, that students they face problem for solving problem- your numerical particularly, when they go for Thevenin's theorem are Norton theorem. So, that is why several examples I have taken and this examples will help you a lot to understand this your, what you call this Thevenin's and Norton theorem. Next one is the maximum power transfer right that is maximum power transfer theorem. So, maximum power transfer theorem actually as far as theory is concerned it is very theory is concerned it is very easy.

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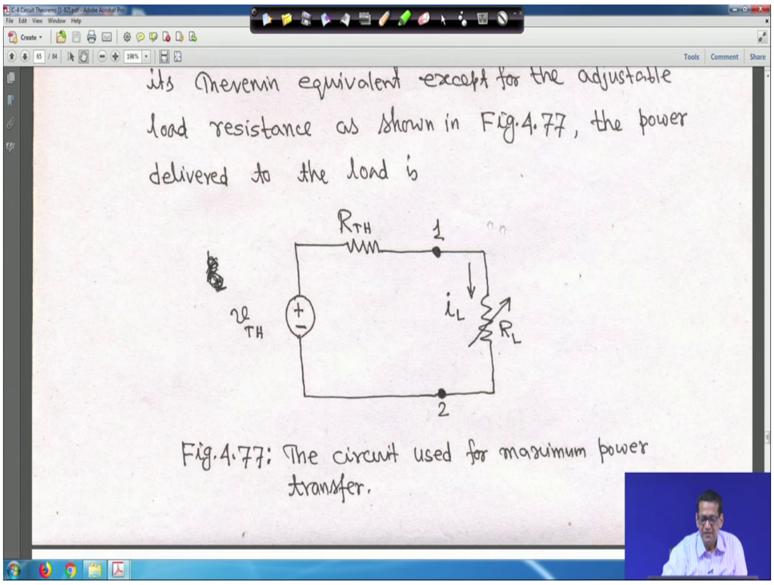

So, the in many practical cases a circuit is designed to provide power to a load, there are applications in many areas, where it is desirable to maximize the power delivered to the load right. So, in this case you will find, you will find that Thevenin equivalent is very useful in finding out the maximum power power right.

So, a linear a linear circuit can deliver to a load right maximum power that is the Thevenin equivalent useful in finding maximum power and a linear site can linear circuit can deliver to a load. So, we assume that load resistance R L is adjustable that is variable right.

So that means, only R L is variable and rest of the circuit, you are fixing it right, it is a fixed thing that is can be represented by V Thevenin and R Thevenin, because you are not changing any parameters in the rest of the circuit apart from R L. So, if it is so then suppose a circuit is given where we have got V Thevenin and R Thevenin right and a load resistance is connected, this symbol is a variable symbol right, then i L is equal to i L is equal to your V Thevenin by R Thevenin plus R L right.

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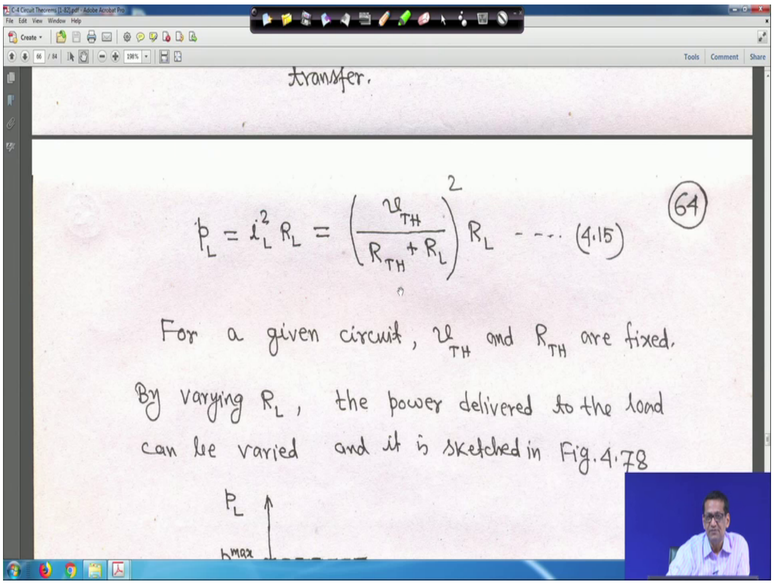

And therefore, your power across the load R L p L is equal to i L square R L. So, i L is equal to from this circuit i L is equal to V Thevenin by R Thevenin plus R L. So, it is i L square R L so, V Thevenin by R Thevenin plus R L whole square into R L right. So, this is the power expression. Now, for a given circuit that V Thevenin and R Thevenin both are fixed right, only R L is variable V Thevenin and R Thevenin is fixed.

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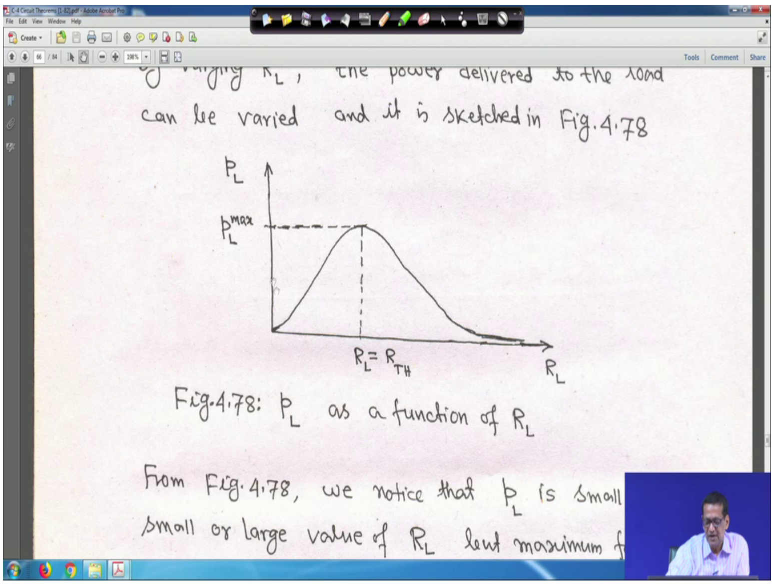

Now, if you plot p L verses your R Thevenin R L, if you plot the plot will be like this right that pl[ot]- it is starting from 0 say. So, plot will be like this so this is the maximum point that is the maximum power transfer right, it will happen when R L will be is equal to R Thevenin and this side is your R L and this side is your p L and this is the p L max this point is the p L max and this is for R L is equal to R Thevenin. So, how we will get R L is equal to R Thevenin that is you here you take your derivative of this your expression with respect to R L right, if you take the derivative with respect to this right.

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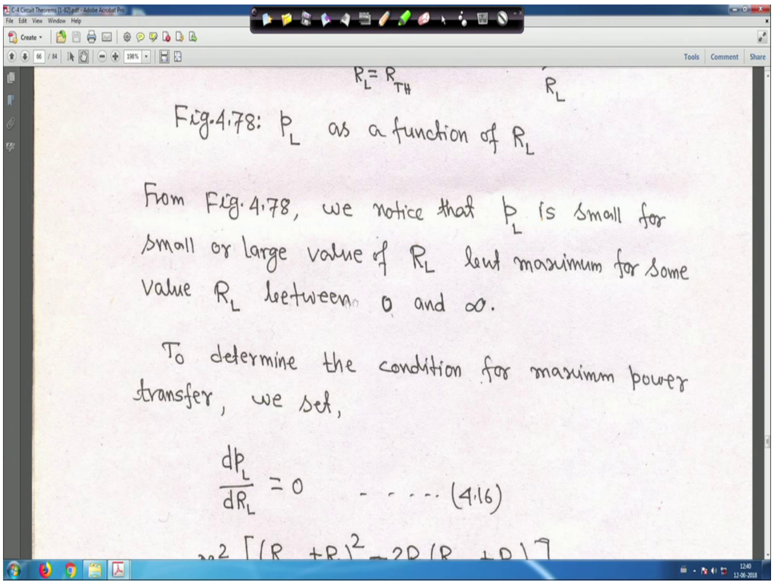

So, R L can vary between 0 and infinity, but if you say d p L upon d R L is equal to 0 this equation number is 16 given. So, if you take the derivative set it to 0 then you will get R L is equal to R Thevenin right.

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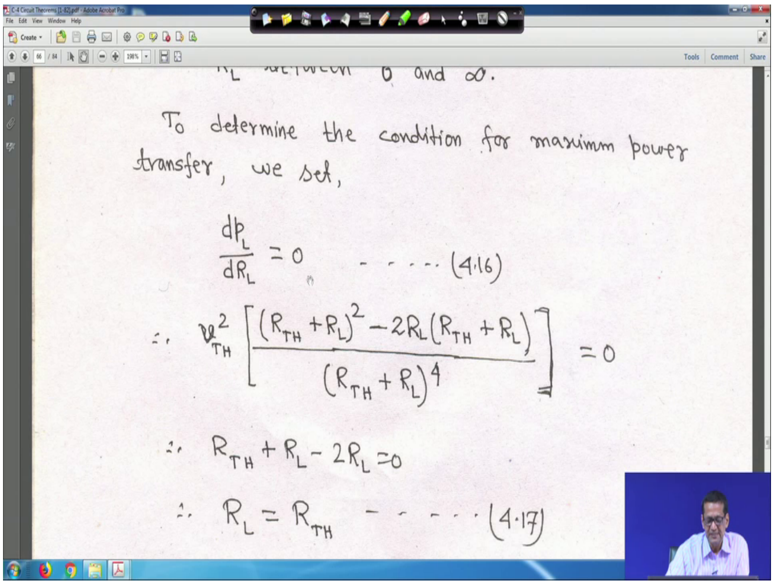

So, maximum power occurs when R L is equal to R Thevenin right.

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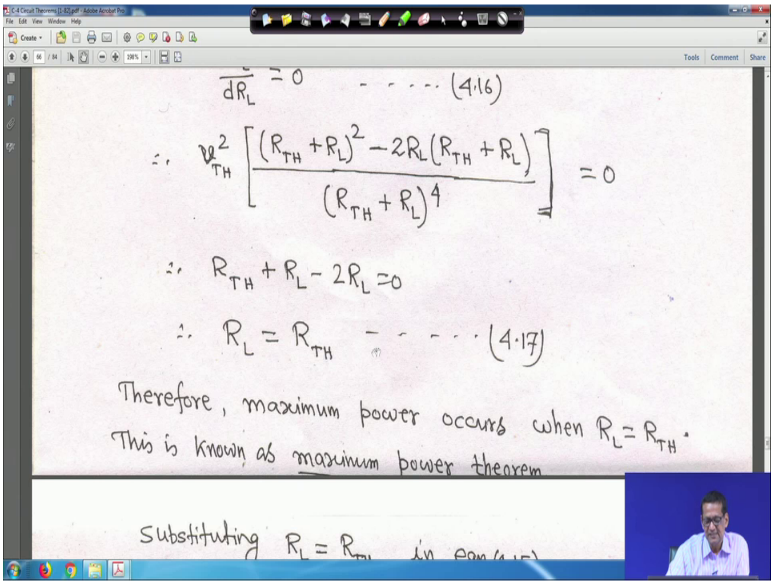

So, if you put R L is equal to R Thevenin in in this equation, now in this equation you put your R L is equal to R Thevenin, if you put R L is equal to R Thevenin in this equation.

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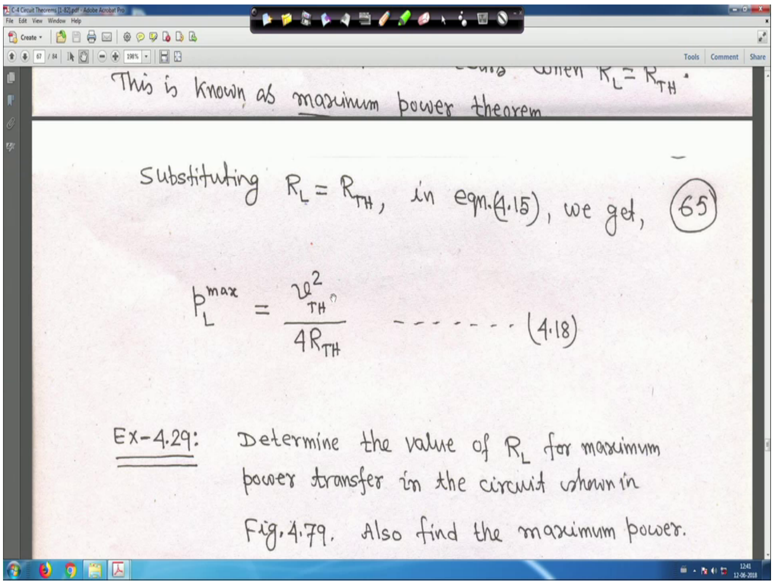

Then you will get you will get p L max is equal to V Thevenin square upon 4 R Thevenin right, this is the this you can this you keep it in your mind that maximum power S equal to V Thevenin square by 4 R Thevenin right. Now, let us take one example.

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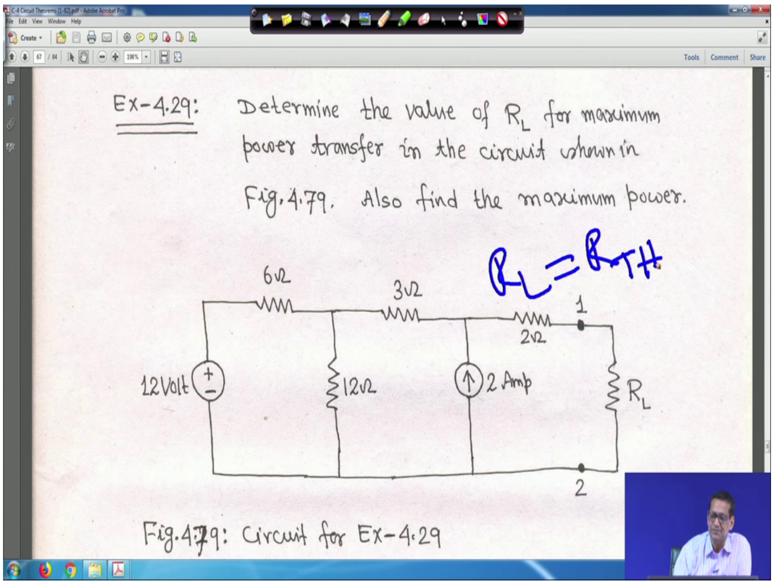

So, determine the value of R L for maximum power transfer, in the circuit shown in figure 79 also find the maximum power. So, first thing is you have to that for maximum power transfer theorem maximum power, that R L will become your R Thevenin that means, you have to obtain for this circuit V Thevenin and R Thevenin right. So, and then you whatever R Thevenin you get for maximum power transfer R L will be is equal to R Thevenin; so, let me clear it. So, to get this open this R L open it R L and we want to find out R L first. So, current source it should be turned off. So, it is open and voltage source is should be turned off. So, it is short right.

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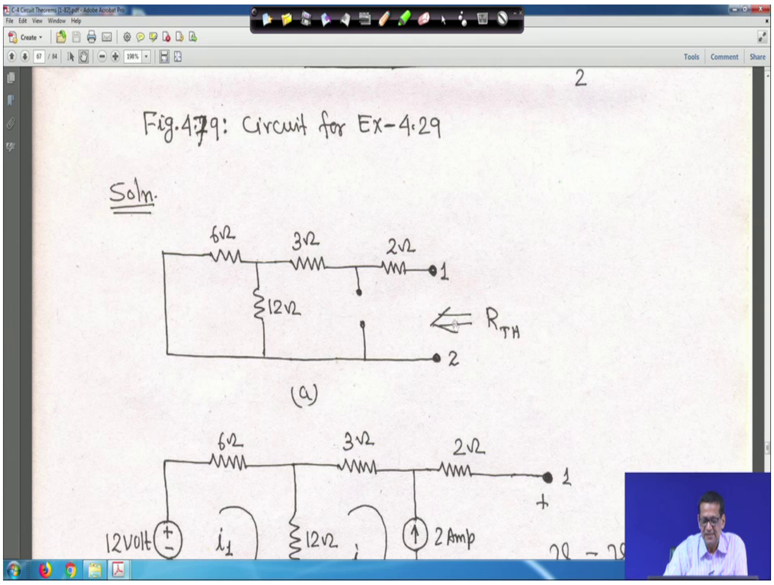

So, in this case if you do so, then you will find 12 ohm and 6 ohm, they are in parallel so; that means, 12 into 6 by 12 plus 6 so, it is 72 by 8 so, 4 ohm with that this 2 ohm and 3 ohm are in series. So, it will be 4 plus 3 plus 2 so, it will be R Thevenin will be 9 ohm right from your memory you can do it.

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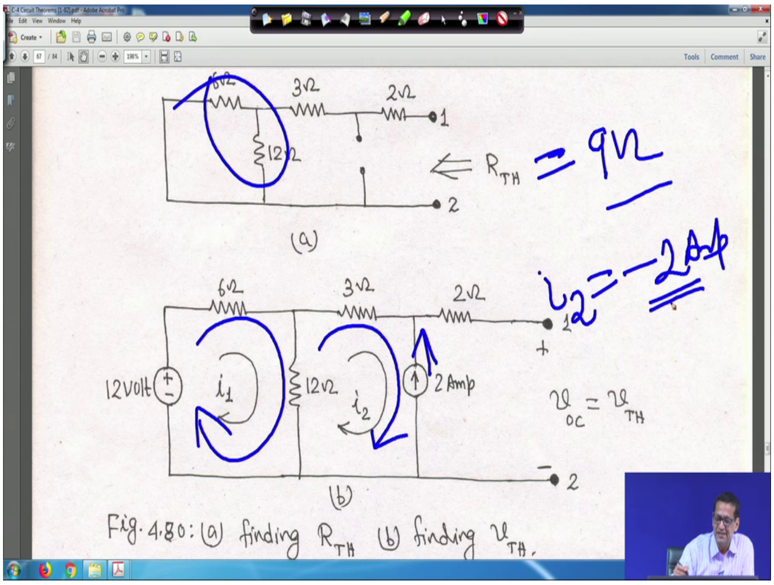

And similarly you have to find out your Thevenin voltage V thevenin. So, it is open circuit. So, here you take 2 mesh i 1 and i 2 the that mesh cu[rrent] mesh current i 1 and i 2 right and you solve this. So, this R Thevenin your R Thevenin directly I told you, it will be your 9 ohm, because this two are in parallel their equivalent will be your 12 into 6 by 12 plus 6 so 4 ohm so, 4 plus 3 plus 2 so it is 9 ohm. and in this case when you take this clockwise a cyclic current i 1 and i 2. So, this current actually going two ampere going upward and we are taking like this. So, your i 2 is equal to will be minus 2 ampere right minus 2 ampere so; that means, i 2 is known. Therefore, you apply your what you call KVL, here in this loop i 2 is known so, if you do so let me so i 2 is minus 2 ampere.

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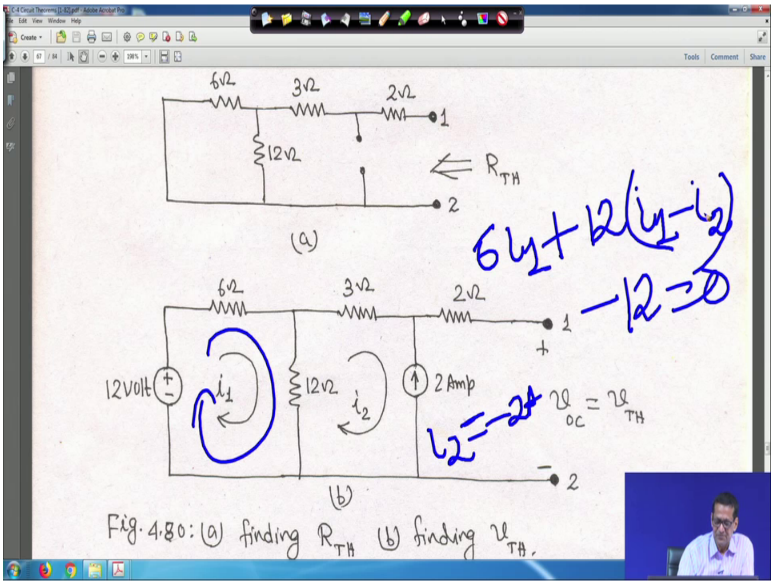

So, I am cleaning it clearing it then again we are writing. So, in that means, in this case it will be your 6 i 1 this 6 i 1 say you write like this 6 i 1 plus 12 into i 1 minus i 2 this one, because we are moving this you are going to this right minus 12 is equal to 0 right. So, and i 2 is equal to I told you that i 2 is equal to your minus 2 ampere. So, here you put i 2 is equal to minus 2 ampere and solve for i 1 so, let me clear it.

After that you apply you find out V o c so, I told you R Thevenin is equal to 9 ohm earlier and i 2 is equal to minus 2 ampere I told you.

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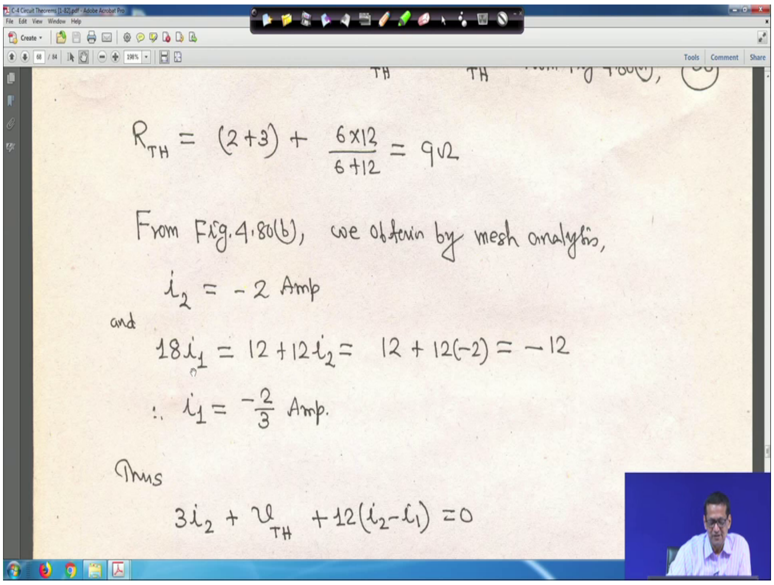

And applying that in that mesh that your whatever you will get i 1 is equal to you will get minus 2 by 3 ampere right that is your i 1 that is in this circuit i 1 is equal to minus 2 by 3 right.

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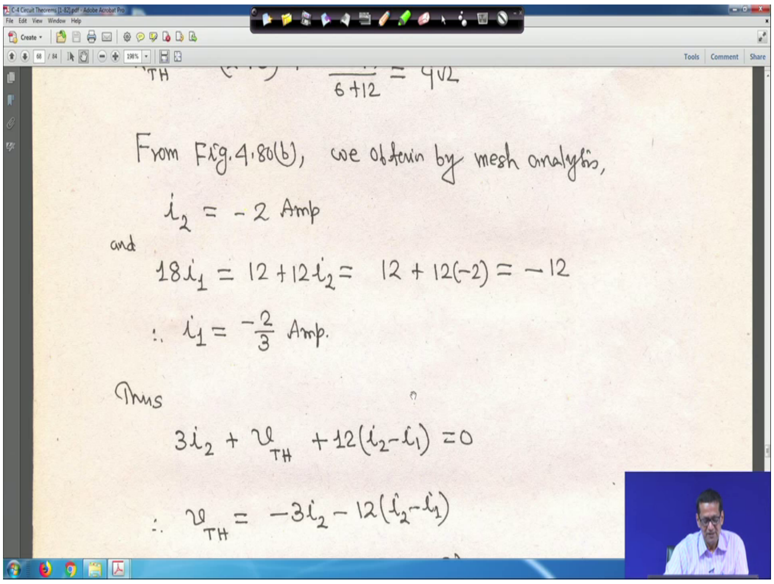

Then what you then you find out your what you call that your V Thevenin right V Thevenin you find out. So, in this case what you can what you the way you want you can find out look, I am making in my way you have many other ways to find out V Thevenin. So, in this case your if you here there is no current here, because it is open right, but you apply KVL like this whatever I have done it here.

So, in this case what will happen this i 2 is if you take like this it is just to a taking like this. So, it will be minus 3 i 2 right, then minus 6 i 1 right because we are taking like this, then your plus 12 minus V oc will be is equal to 0, this way you can write the way you write. Here also if you want here also you can take right I mean if you want let me clear it.

If you want here also to get this here also, you can make it you can take clockwise, or anticlockwise it does not matter. So, in this case it will be what happen it will be minus 3 i 2 plus 12 into your what you call, this we are going this way 12 into i 1 minus i 2 minus V o c is equal to you will get the same result.

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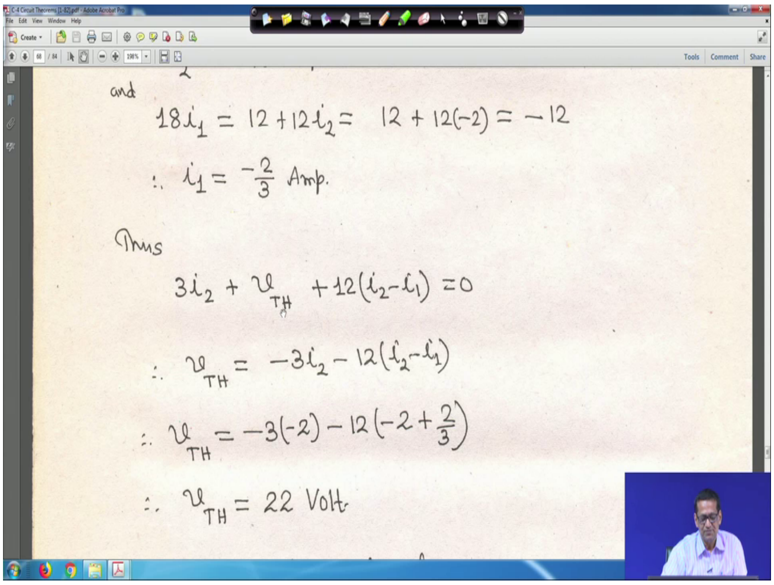

So, as therefore so similar way we are writing this equation for this thing that your 3 i 2 plus V Thevenin plus 12 into i 2 minus i 1 here, your what you call in this case I have gone the way I saw I saw it is your anticlockwise, this equation is written in that your what you call clockwise; that means, if you if you just if you just change the sign, whatever I told it will be minus 3 i 2 it will be minus V Thevenin it will be your it will be if you put like, this it will plus 12 into i 1 minus i 2 is equal to 0.

If you change the sign clockwise and anticlockwise same thing right; so with this you solve V Thevenin is equal to 22 volt therefore, 1 maximum power transfer R L is equal to R thevenin.

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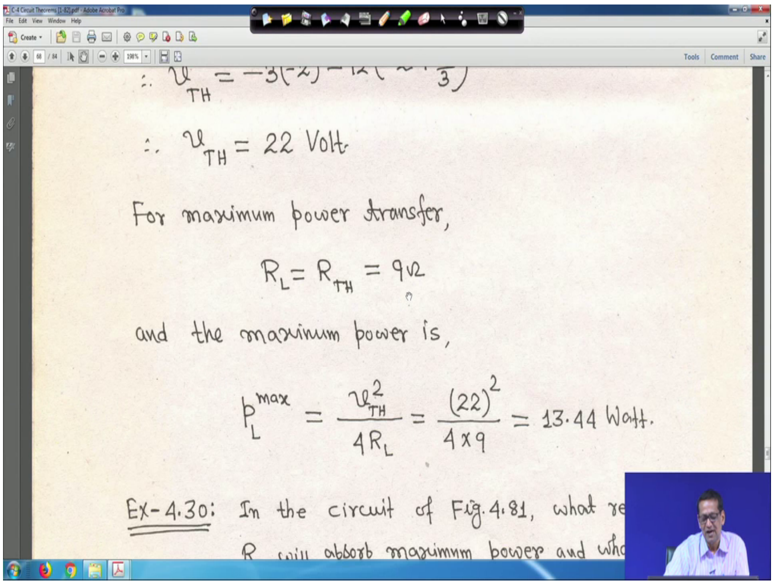

So, this is this one and you know the formula p L max is equal to V Thevenin square by 4 R l. So, 22 square by 4 into 9 so, 13.44 watt this is the p L max right.

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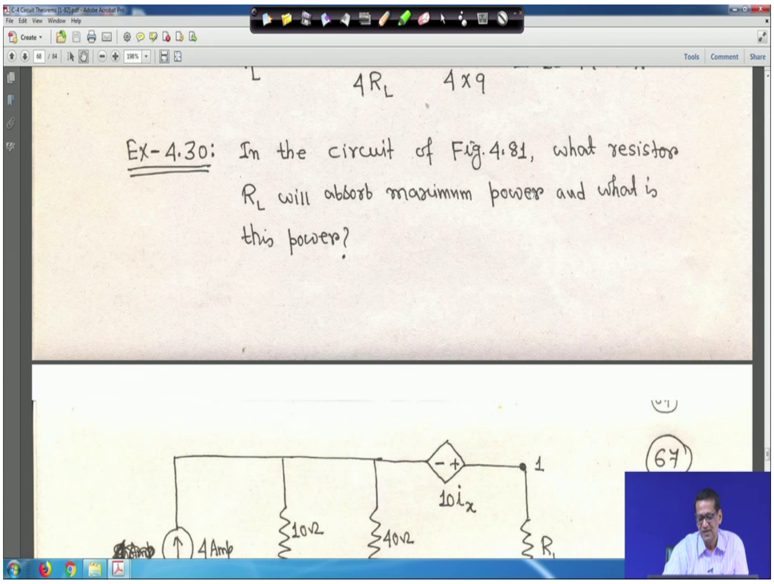

So, in the circuit of figure 81 what resistor R L will absorb maximum power and what is the power.

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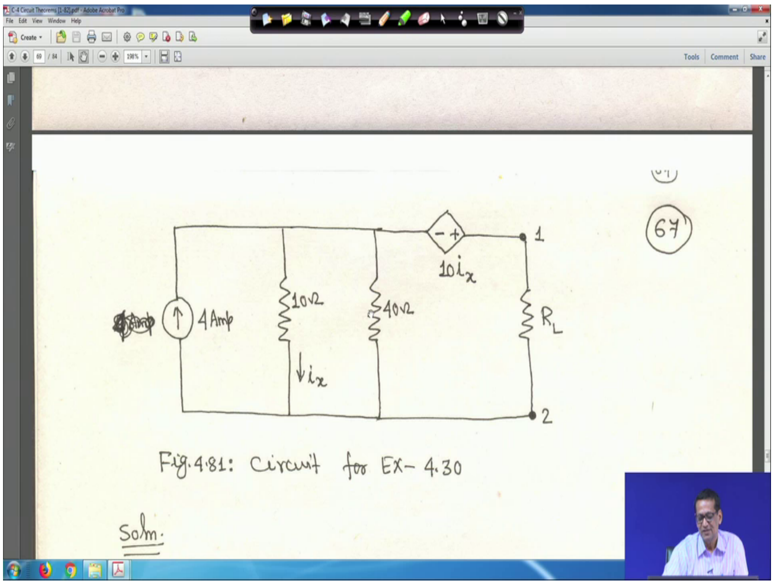

So, here also same thing we have to find out your V Thevenin and R Thevenin one dependent voltage source is there this is i x, current is here is i x this this i x is here right.

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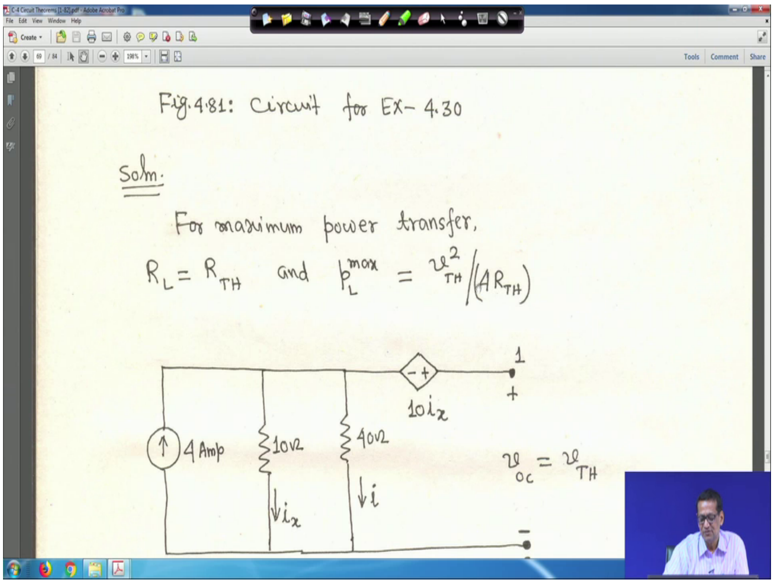

So, in that case what will happen for maximum power transfer you know p L max is equal to V Thevenin square by 4 R Thevenin right.

So, here it is open circuit V o c is open circuit and as soon as it is open circuit one thing is there and you just i kept it i x as it is i so, with the previous i x i it will change, but just i did not do it just it is understandable right. So, this is for V o c is equal to V Thevenin you can get this is this is your what you call that your 4 ampere current, that is the independent current source and this is 10 ohm and this is 4 ohm right.

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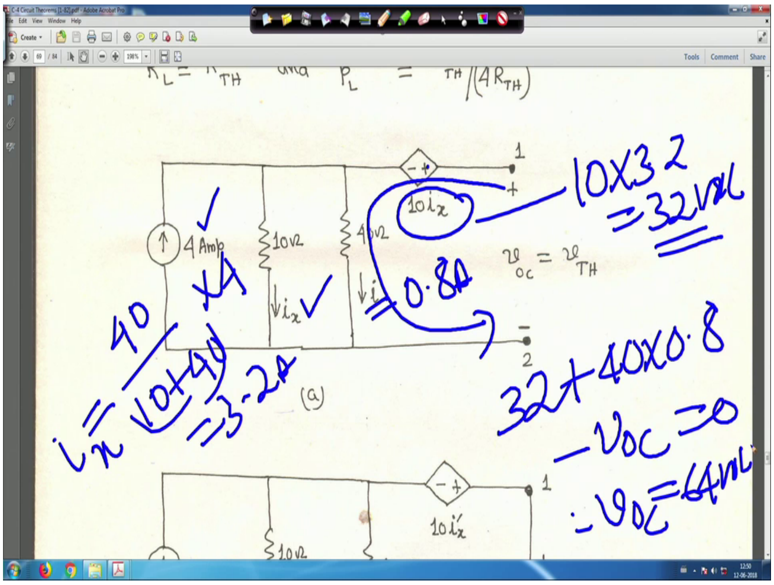

So, you can you have to find out what is the current through, this your this i x right. So, here it is i x is equal to it is a current division right. So, it will be 40 divided by 10 plus 40 into this 4 ampere; this 4 ampere current right. So, basically it will be your 3.2 ampere. So, i x will be is equal to 3.2 ampere. So, this is my 3.2 ampere current right.

So, if this is 3.2 ampere current, because our interest is and i is equal to if it is 3.2. So, this i is equal to 4 minus 3.2 directly, you will get it will be 0.8 ampere this is my i right. So, there is my point 8 ampere that means, this is 10 i x i x is equal to 3.2; that means, this 10 i x will be 10 into 3.2 right that is your 32 volt that is your 32 volt right. So, and this current is 0.8 ampere.

Now to get V o c to get V o c suppose I can apply KVL here itself here, I can apply k your k this thing your KVL here itself. So, in that case it will be plus 10 i x 10 i x is equal to 30 volt right 32 volt rather. So, because 10 i x we got thirty volt plus terminal is encountering first directly writing that 32 right and, this 0.8 ampere this current is flowing through this your your what you call that 40 into 0.8. So, plus 40 into 0.8 right, then minus terminal encountering first, then minus V o c is equal to 0 hope I have not missed any term. Therefore, my V o c is equal to 64 volt right so, let me clear it.

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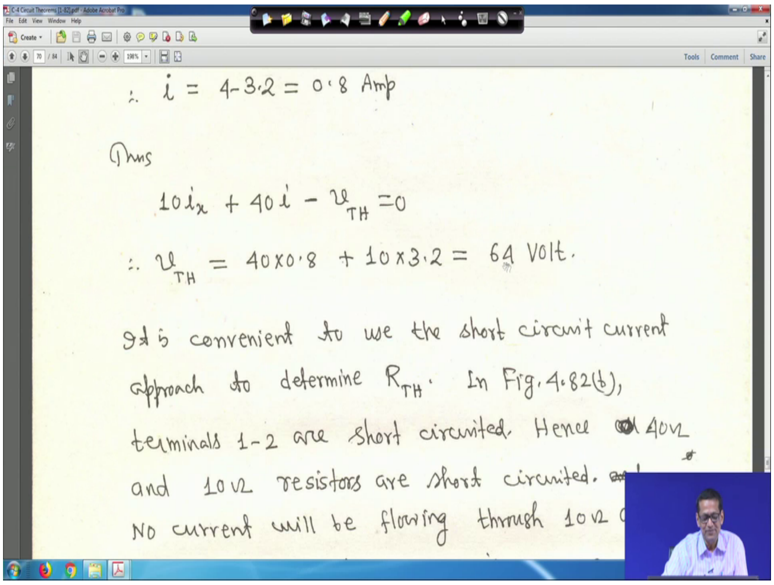

So, if you look into this before going to that that my V Thevenin here you got 64 volt right. So, the way I told you that how to do it now question is now, similarly for Norton also just to give you a favor this Norton means we have short circuit right, nothing has been told in the problem, but just to give a favor that just we as soon as you have short circuit this,

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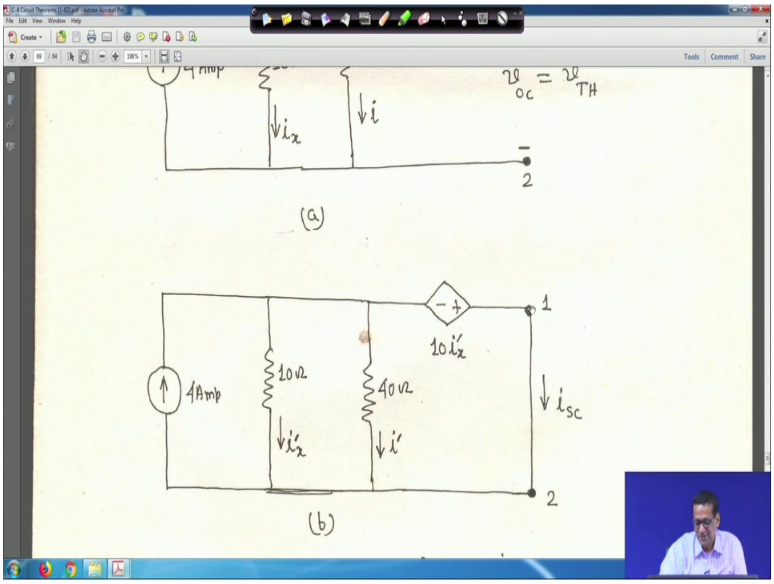

This is my i x dash and your what you call and this is 10 ohm and this is 40 ohm right and this is my your what you call this is a dependent voltage source.

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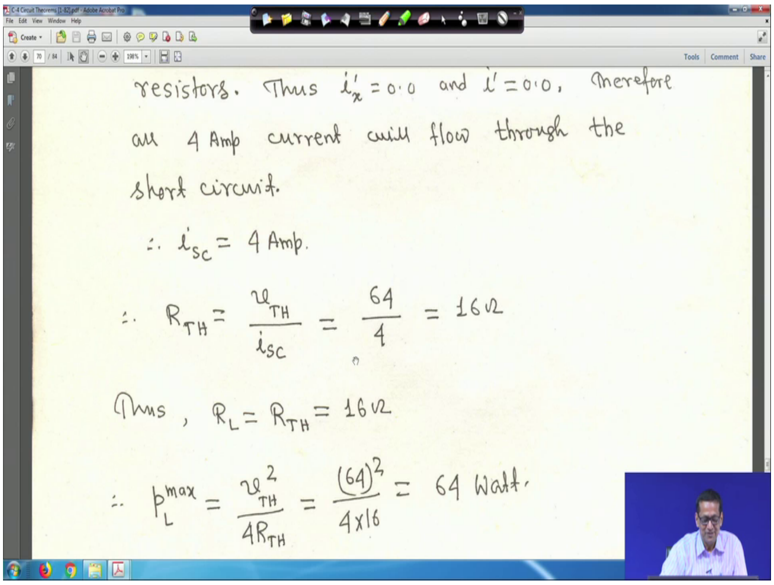

So, whenever you apply this your this Norton, then your you have to find out that here it is given i x is equal to you got ampere.Nnow how we are getting it right. So, question is that your this is shorted this is shorted. So, you have to find out that this as this part is shorted. So, basically what will be and this is your i x your i x i x dash right.

So, and this is shorted so first thing is you have to see that how this current division are right. So, if you if you look into your this thing that this 10 ohm and 40 ohm, they are in parallel and earlier we have and this is your dependent voltage source i x i x dash right. So, in this case what is the i x dash same as before it will be i x dash will be your 3 point your what you call that your 3.2; 3.2 ampere. And current through i dash will be your what you call same as before 0.8 ampere.

Now, question is that what is your i s c because this is a short circuit path. So, as it is a short circuit path so, what will be my i s c; so that is the thing. So, question is that as soon as this this your as soon as it is getting a just 1 minute as soon as it is getting a your short circuit path this is short circuit path. So, this 4 ampere current actually directly you will go through this your short circuit your path, because in this case it will be ineffective it will be ineffective and in this at the same case your i, if it is ineffective means this i x dash will be 0 and i dash will be 0. So, there will be nothing here and i s c will be simply your 4 ampere.

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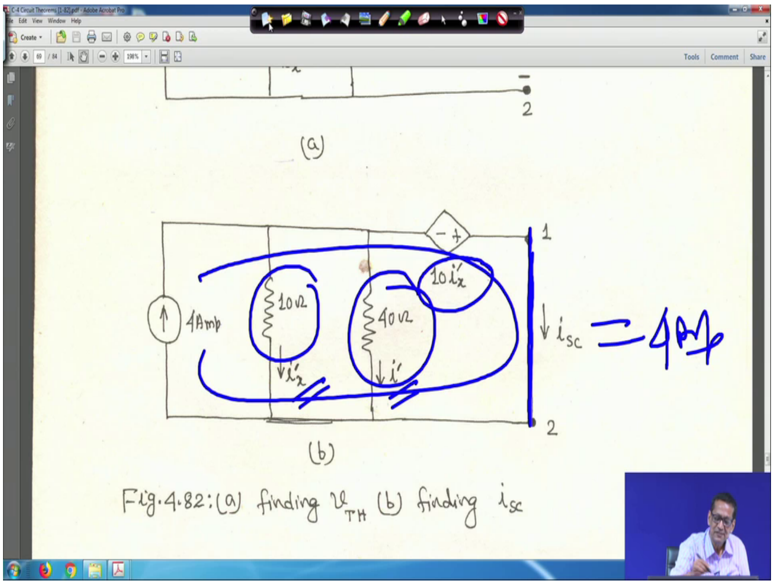

So, if generally any source any current flow through the short circuit, it will not go to any your what you call any other electrical element. So, this is your basically i x dash will be 0. So, nothing there is nothing able here and all this 4 ampere will be flowing like this it will be in a short circuit loop right. So, i s c will be 4 ampere so, that is why that is why if you come to this right, so all this things are written here, for you just go through it right i x dash is equal to 0 i dash is equal to 0 every everything is written

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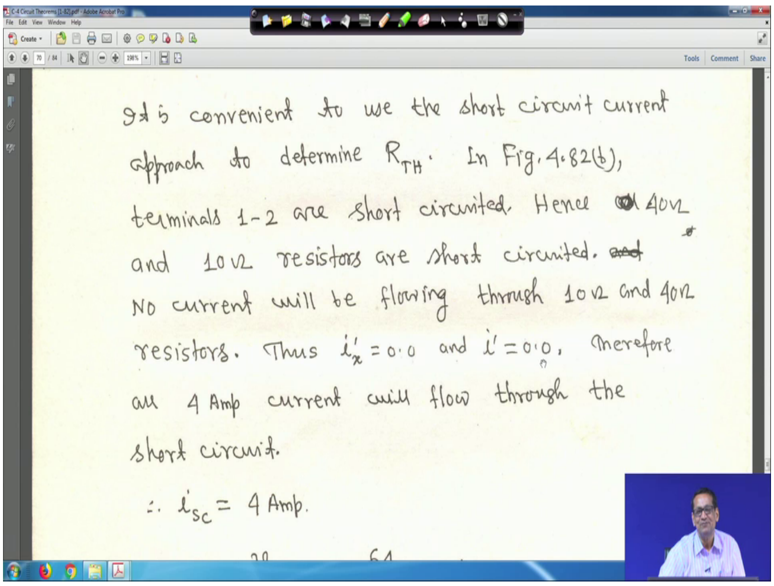

. And only only thing is that when it is not short circuit right at the time current division will be there, but which I told. But when short circuit is there they it will not follow anything and everything is here all write up is here for you just go through, it whatever I told right. And therefore, i s c will be 4 ampere. Therefore, R Thevenin will be V Thevenin by i s c it is 64 by 4 it will be sixteen ohm. Therefore, for maximum power transfer R L is equal to R Thevenin is equal to your 16 ohm and p L max V Thevenin square by 4 R thevenin; so 64 watt right.

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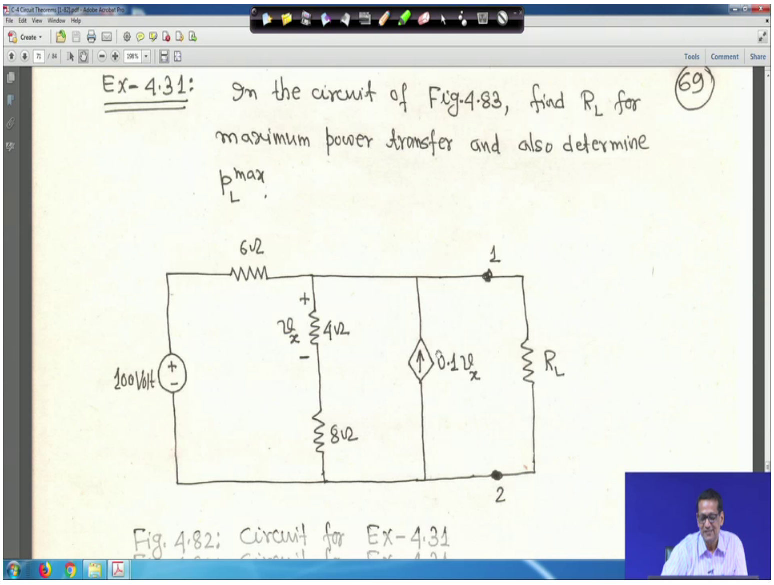

So, this is the answer so, look the and this is probably the last example of this chapter that in the circuit find R L and maximum power transfer also determine p L max. So, here I will not explain much. So, many we have explained 30 examples for video course right, I mean it is it is it is very lengthy procedure right. So, here 0.1 V x is here here V x is there right and you have to find out R L and R L is equal so, I sorry you have to find out maximum power. So, R L is equal to R Thevenin; so V o c is equal to V Thevenin.

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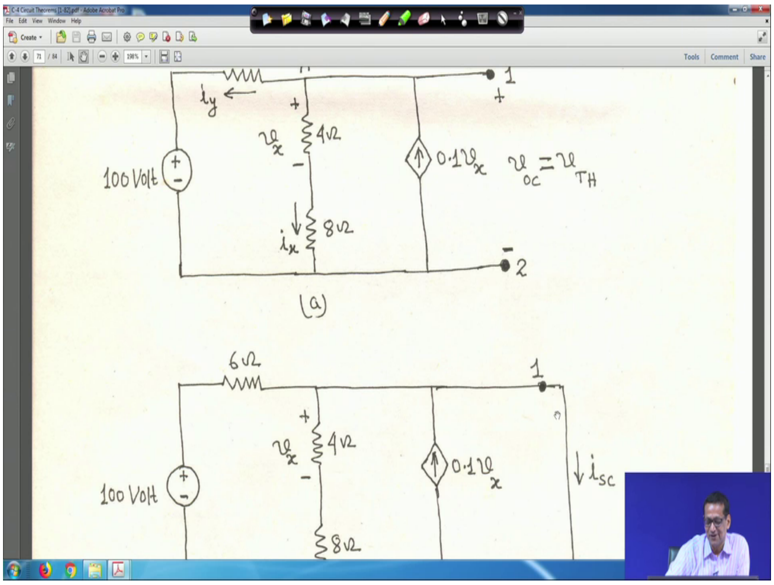

So, all all this i y direction is given i x is given V x is given and this is node a here we will apply KCL also right. And this is your short circuit Norton also shown that this is short circuit. This is for Thevenin it is open circuit for Norton, it is short circuit just to show you give you a favor of Thevenin and Norton. And then your then looking at looking at this two circuit right look at this is for V Thevenin and, this is for V Norton then everything is explained to you right.

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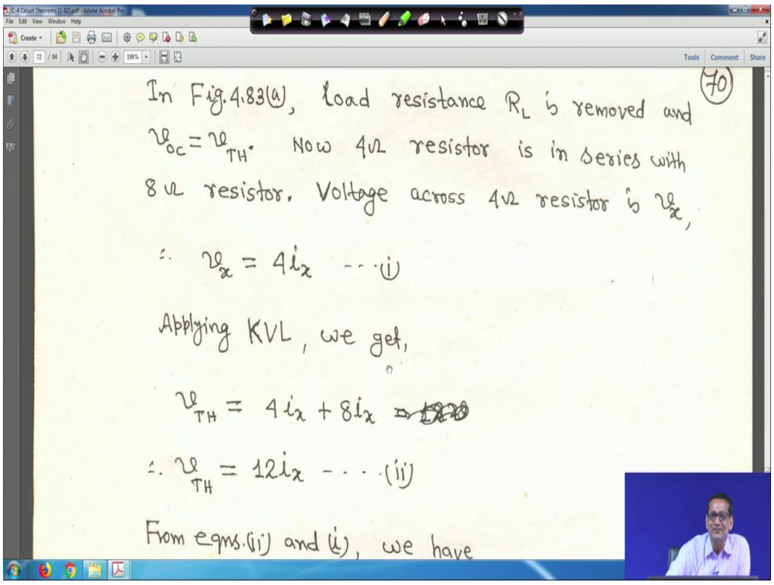

And please go through it I am not explaining this this is a last one all are written in detail all are written in detail and, everything is understandable to you now right, because time time it is taking long time.

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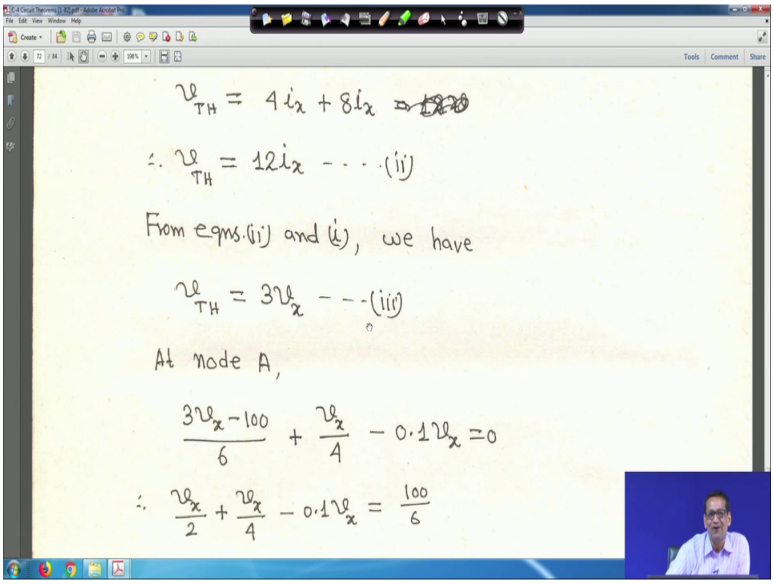

And it that I told you at node a you please apply your KCL and solve it, you will get V x is equal to 25.64 volt, then V Thevenin automatically will become 3 V x if you look at the problem.

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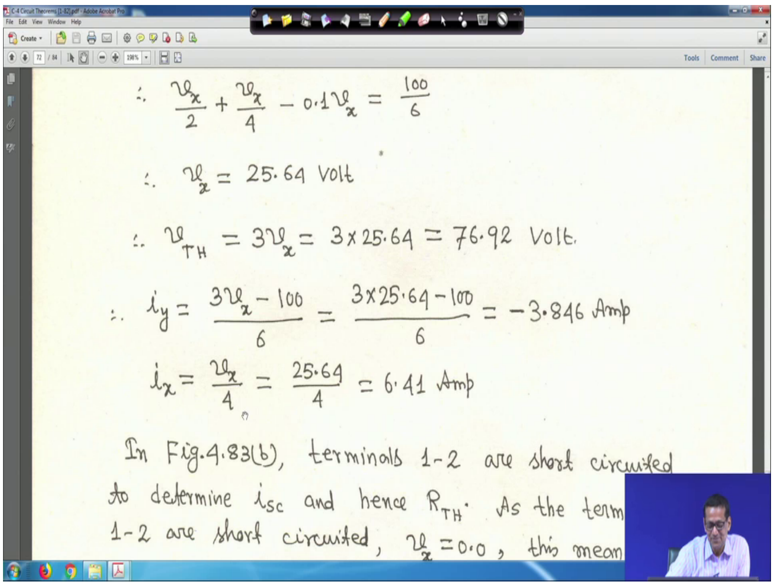

So, it will be 76.92 volt and i x V x upon 46.4 ampere and i y is minus 3.846 ampere right. So, with this if you your as the terminals 1 2 short circuited V x is 0, this means your 4 plus 12 ohm that is 4 plus 12 ohm is equal to it is actually that is 12 is equal to it is just 1 minute, it is your V x is 0.

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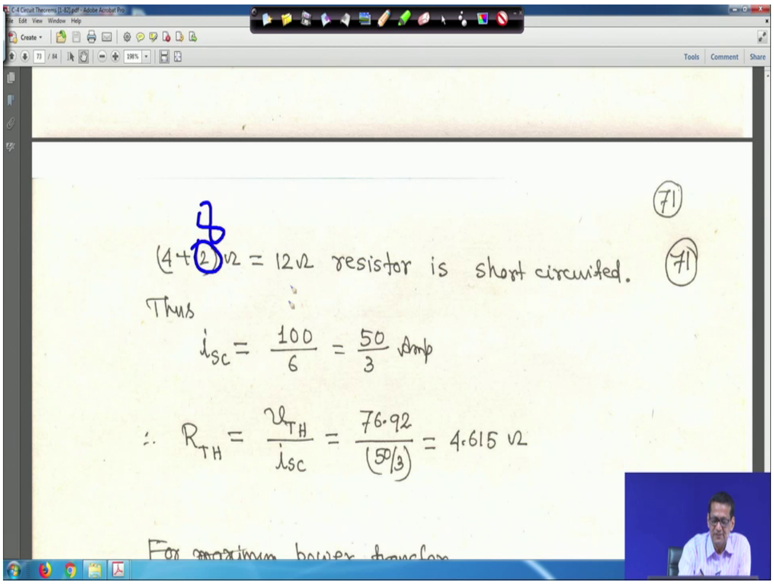

So, it is actually here look at the circuit your V x is 0 it is actually 1 my one writing error is here actually it is 8 right. So, it will be 12 it is a writing error. So, this will be 12 so, let me clear it and R Thevenin will become your this V Thevenin by i s c; this is 8 right is equal to 12 so, 4.615 ohm.

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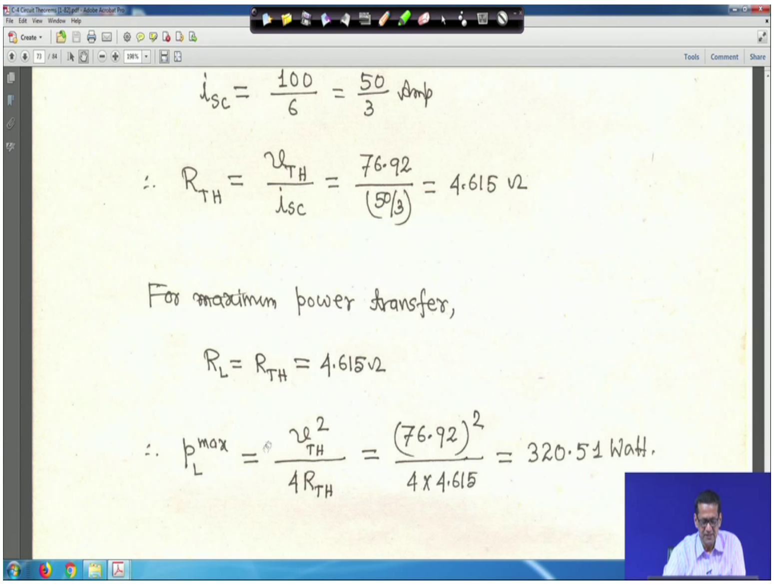

So, not much to explain for this because many things we have done. So, and for maximum power transfer p L max V Thevenin square by 4 R thevenin; so, 76.9 square by 4 into R Thevenin that is 4.615 320.51 watt.

So, total 31 or 30 31 problems we have made it. So, not giving you an exercise I have many problems here for exercise so, not giving that. So, all varieties of problem have been solved for you even when telling you so, many thing sometimes you know I have to also every problem, before giving you the solution every time as if I am also solving for you right. Hope this will be very helpful for you.

So, with that next so, with that circuit theorem chapter is over. So, next we will got to your what you call that your capacitors and inductors.

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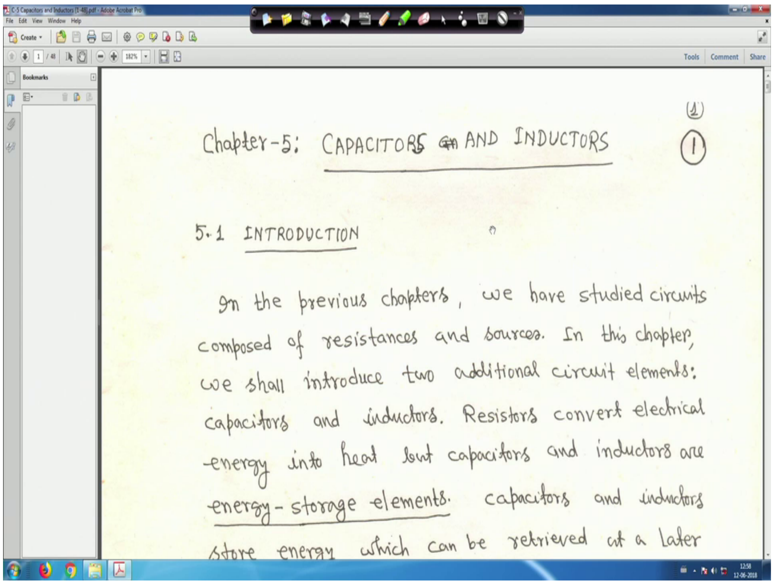

So, the because we have to study DC transient and we have to learn about capacitors and inductors so, before going to this just one just one and two things again I would like to tell that practice]take any book and practice a lot because, when you will do the when assignment will be given. So, based on that only lecture this video lecture notes only and, if you find I have made any error or any mistake right you do not hesitate to mail me, or put a question in that your what you call in the forum will reply or will try to reply all this your what you call all your questions right.

And because this is purely your see your nearly 75 to 80 percent of this course is basically electric circuit theory and find out all the good books are given in that your I have mentioned in that your what you call, in that course itself and just find out any book and try to solve many problems. Because this course is mainly for problems right and you have to you have to give you have to try different type of problems and understanding is starting from the basic concept, you try to see how things are right. And if you find I am made any calculation error, or anywhere you just please let me know.I have I will rectify myself right do not hesitate your to mail me, or put the question in the forum we will answer right.

So, next you come to the capacitor and inductors. So, in the previous chapters many places I have written that in the book, but book was never written right. So, please read that word book is a chapter. So, in the previous chapter, we have studied circuits that is composed of resistance your resistances and sources. So, for we have studied resistance and you are dependent or you are independent voltage, or current sources that is all. Now, we have now in this chapter we will see introduce two additional circuit element that is capacitors and inductors.

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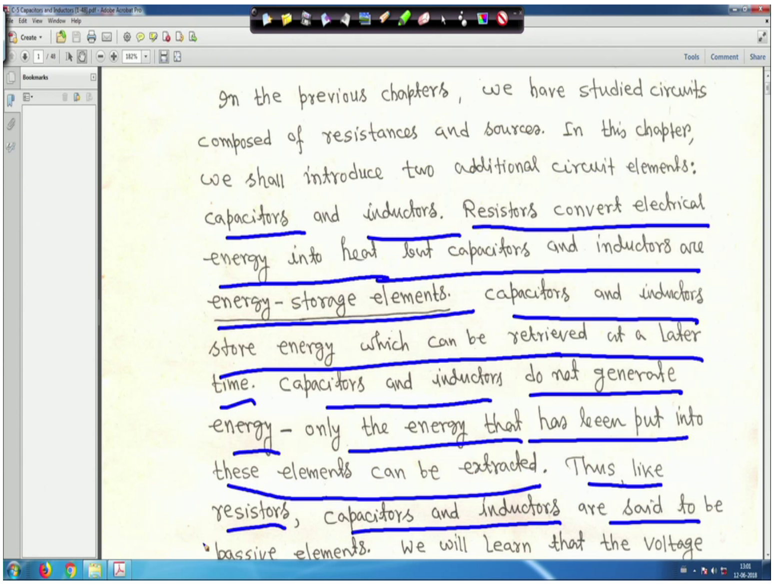

So, just because after this we will study that your first order circuit, because capacitor inductors, we have to learn and AC circuit of course. So, in this chapter we shall introduce that two additional circuit elements that is your capacitors and inductors right. So, resistors convert your current your convert electrical energy into heat, but capacitors and inductors are energy storage elements right.

They you can store energy in them, but they cannot store energy. So, that is why they are passive elements right. So, capacitors and inductors store energy which can be retrieved at a later time. So, capacitors and inductors do not generate energy only the energy that has been put into these elements and can be extracted right. Therefore, thus like capacitor resistor capacitors and inductors are said to be your passive element right.

So, capacitor inductors also passive elements because, they of their own they cannot generate energy you can store their energy in capacitor, or inductor you can retrieve also; that means, other way sometimes we tell that they have memory like because they can store energy right.

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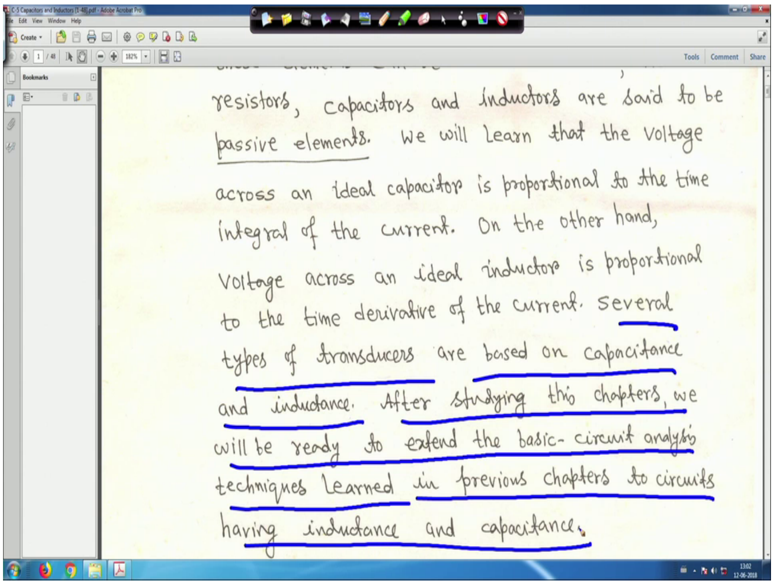

So, that is why your these are passive elements right. So, what that we will learn that the voltage across the ideal capacitor is proportional to the time integral of the current, this you have learn also from your high secondary physics. On the other hand voltage across the ideal inductor is proportional to the derivative of the current this also you have learned from your high secondary physics electricity chapter right.

So, several types of let me clear it. So, several types of transducers are based on capacitance and inductance. After studying this chapters, we will be ready to extend the basic circuit analysis technique, you all learned in previous chapter to circuit having inductance and capacitance. So, let me clear it.

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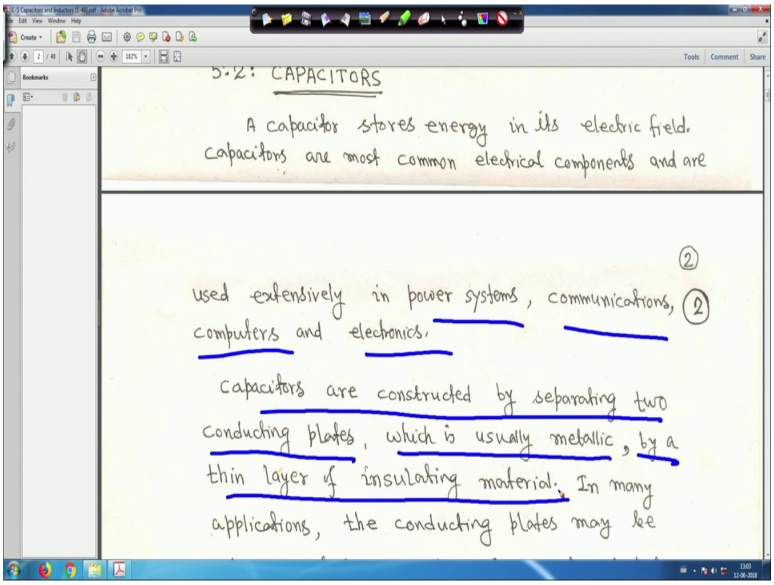

So, so that means, that is a capacitors a capacitors stores energy in its electric field right. So, capacitors are most common electrical component and are used extensively in your power system, communication computers and electronics. So, basically capacitors are constructed by separating two conducting plates which is usually metallic by a thin layer of insulating material right. So, let me clear it; some ideas I am giving right such that we will have some ideas about this by a thin layer of insulating materials right.

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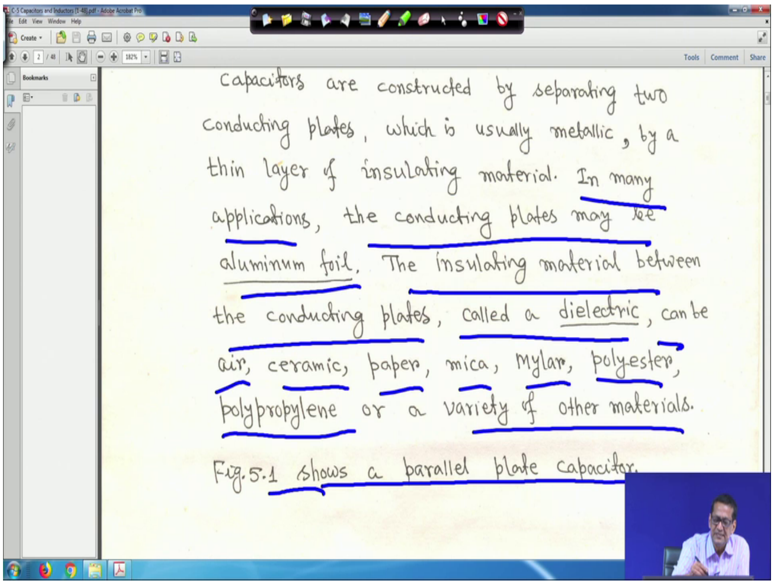

In many applications the conducting plates may be aluminum foil right the that conducting plates may be aluminum foil and the insulating material between the conducting plates, we called a dielectric right. It can be air, ceramic, paper, mica, Mylar, polyester, or polypropylene, or a variety of other materials right. So, this is actually you have a two plate conducting plate and between you have dielectric we call insulating material right. So, figure 1we will set chapter 5 so, 5.1; so figure 1 so is a parallel plate capacitor so, go to this.

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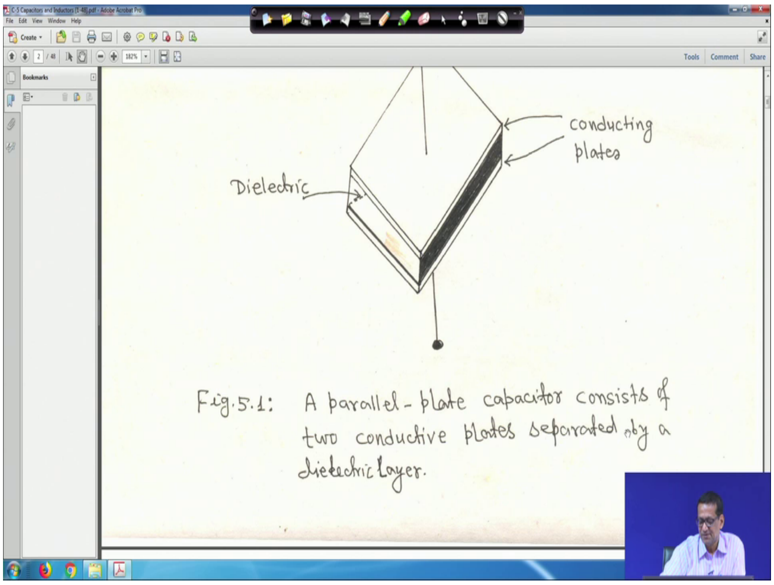

So, this is a parallel plate capacitor simple diagram, I have drawn it by hand only right. So, this is dielectric and this upper and lower two conducting plates and in between this is your what you call in between, this is dielectric right any book you will get this diagram right. So, parallel plate capacitor consists of two conducting plates separated by dielectric layer right.

So, thank you very much we will be back again.