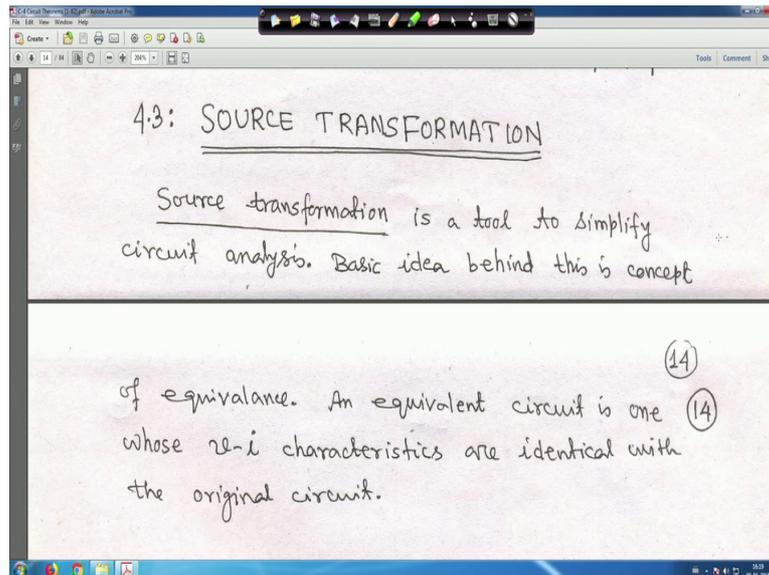


Fundamentals of Electrical Engineering
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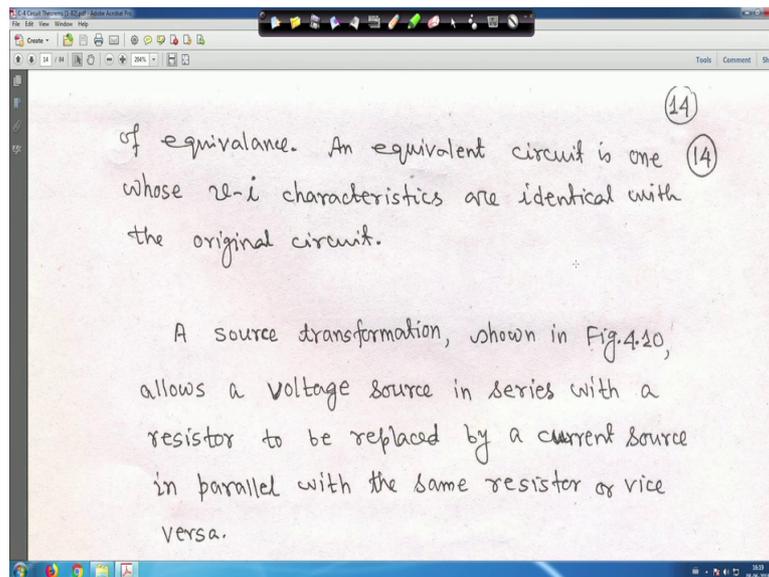
Lecture - 20
Circuit Theorems (Contd.)

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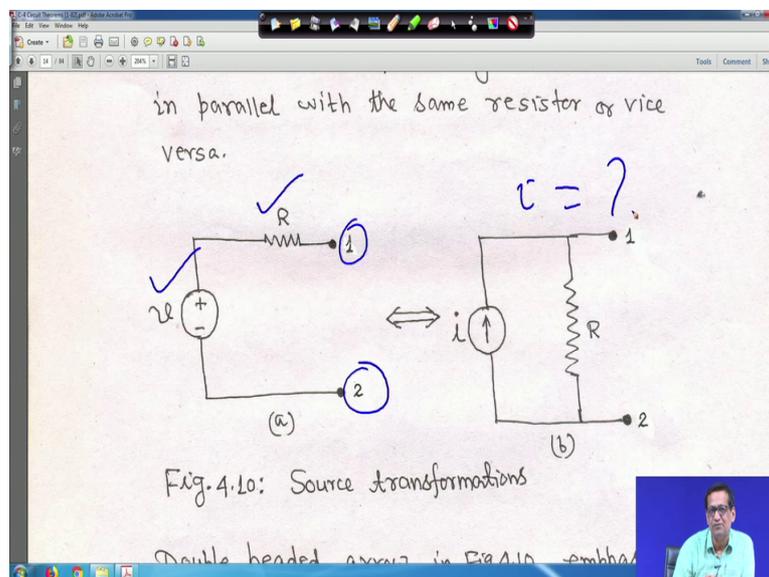
So, so far we have seen that your super position theorem, next we will go for source transformation. Actually this source transformation will your, simplify the circuit analysis; and sometimes it is easy to solve the, you know circuit of computing branch current or voltage or whatsoever. So, things are simple, but we have to try to understand certain things right. So, this is actually basically this is a concept of your, what you call equivalence right.

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And equivalent circuit is one whose $v-i$ characteristic are identical with the original circuit. For example, whatever I have written for example, you consider this source transformation right.

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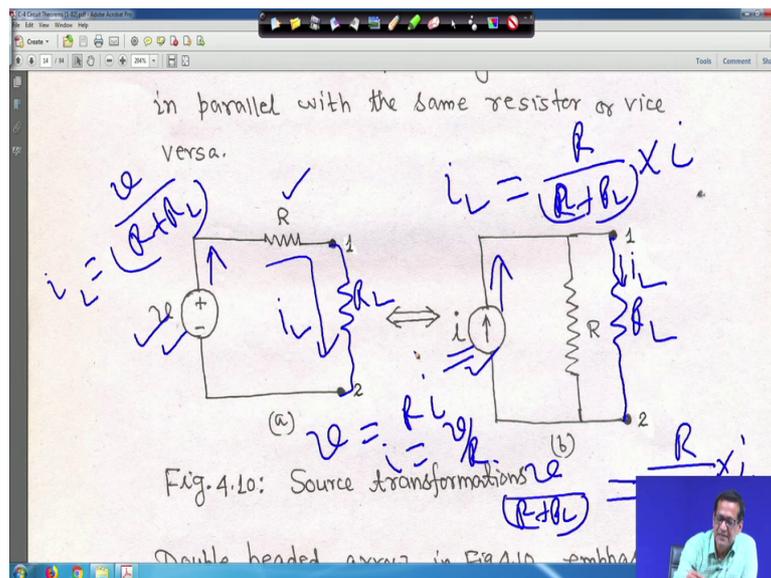


If you look in to the, if you look into the, this circuit that this is your this is voltage source v , and this is the resistance R right, and this is the voltage source v . So, this is actually bilateral I mean either from this circuit you can convert it to your current source or resistance R in parallel or in other way. And terminal 1 and 2 is marked; terminal 1 and 2 is marked. And this

circuit can be equivalent to this one at terminal 1 and 2, but v-i characteristic at terminal one and two has to be same for both the cases right.

Now, before your how we are getting from here to here and what is the your what is the your that vir relationship, what is equal to i, just we will see everything is given at the bottom, but let us see how we can do it.

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For example, for example, suppose first let me clear it. And then suppose, I connect a resistance R_L here suppose this resistance is R_L we call generally R_L means stands for a load resistance. Suppose, current through this current to this is i_L right; that means, same current is flowing through R and R_L because both are in series. So, if you write the expression of i_L , then your i_L is equal to v divided by R plus R_L right. This is the current that is flowing through the resistance R_L , suppose we have connected the resistance R_L .

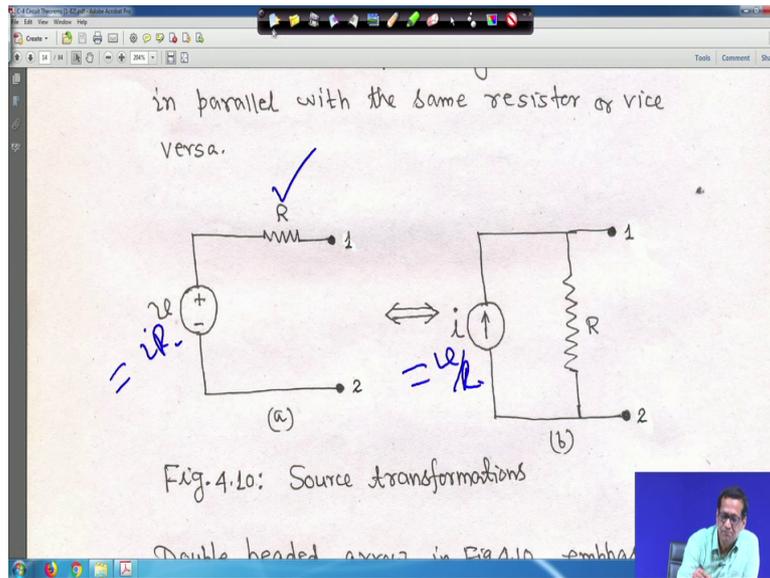
Now, for this circuit also because at terminal one and two, this v-i characteristic of both the circuit has to be same it is I mean the circuits are equivalent to each other. Suppose, if we connect a same load resistance R_L , this is also R_L right, and current flowing through this is say i_L . Here also i_L is flowing here also i_L is flowing, and this current source that is independent current source for the timing we have consider independent voltage source and independent current source.

If the then that your then this current flowing through R_L , you can find out that i_L is equal to that is the current division method that is R divided by your R plus R_L into this i . This is the current source i ; this i_L and your what you call this i_L and this i_L both have to be same for equivalent. Here it is v upon R plus R_L ; here it is i_L is equal to the current division R upon R plus R_L into i right. If both are equal, if both are equal, then we can write somewhere I am writing we can write that v upon R plus R_L is equal to your R upon R plus R_L into i right.

So, R plus R_L R plus R_L will be cancelled both sides. So, ultimately it will become v is equal to your R into i right that means this i this i is equal to actually v upon R right. This is that your that means, voltage drop i into R_L and here also i_L into R_L , this has to be same v is equal to your i mean that is that is the idea that is the idea right. So, that means, this is the source transformation that means, from the your if you have a voltage source and resistance R like this, you can convert it into the current source right. And from the same thing, the if it is your i_L it is R , the represent this one that from your bilateral from this current source and this parallel resistance, you can make it v is equal to i R , this is the voltage source and with v this R is in series right. Every all these things are given downwards, but this is for your understanding.

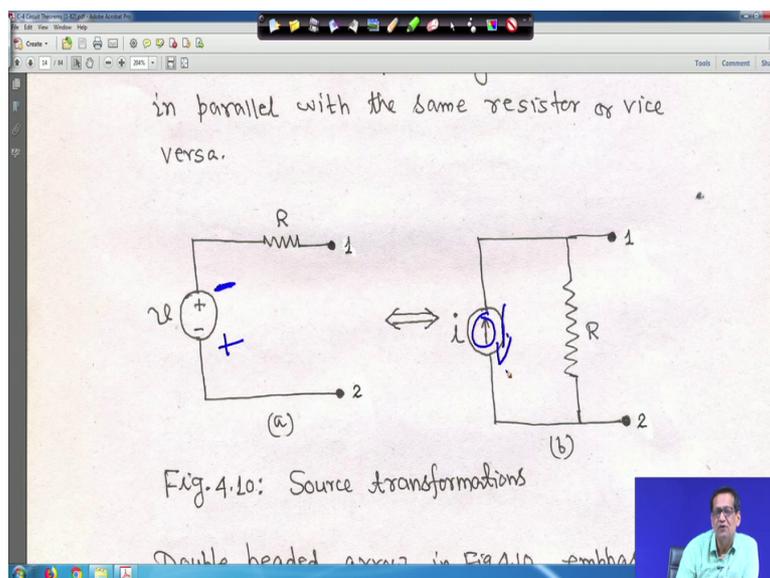
Now, now question is that this is your what you call that and detection of the here your polarity is plus minus. So, current i is showing your plus minus that is current is flowing out from here; here also current is flowing out from here right. So, that is why this when you just let me clear it that means whenever you are going for this transformation that if I go for v and R in your series, then i is equal to here, it will be v upon R right this is v this is R .

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And from this kind of par your current source and this resistance is there in parallel, if you transform this current source to the voltage source, then this v should be is equal to $i r$ this R should be in series vice versa right So, similarly one more thing. So, this is how we do it, but look at the polarity plus minus, so current direction here in the independent current source it is upward right.

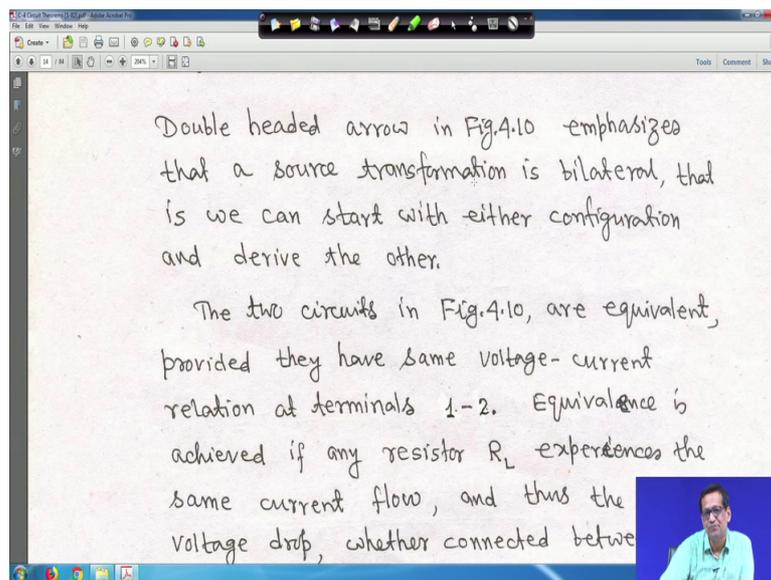
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Now, suppose instead of that suppose if this is my if this terminal for example, if it is minus, if it is plus right, then here also current direction should be downward. So, according to

looking at the polarity that arrow tips should be at the plus. So, current direction should be downward, rest will remain same as it is; rest will remain same as it is right. So, only polarity you have to check. Here if it is plus minus, so plus tip means this arrow one earlier I told you, so it is upward. And if it is if you reverse it, then it will also reverse right so current direction should be in that rest will remain same. So, this is actually source transformation for independent sources. Now, it is true also for dependent sources. So, let me clear this right.

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So, all this, whatever I said whatever I said all this things are written here for your understanding right. And all this whatever I wrote on the blue ink right everything is there, but there here i L there circuit everything I showed how to do it here I have not drawn it, but I showed you the beginning right and these are all same.

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Suppose R_L is connected between nodes 1,2 (15)
in Fig. 4.10(a). Using Ohm's law, the current
in R_L is

$$i_L = \frac{v}{R + R_L} \dots (4.6)$$

Now suppose the same Resistor R_L is connected
between nodes 1,2 in Fig. 4.10(b). We find the
current in R_L is

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current in R_L is

$$i_L = \frac{R}{R + R_L} i \dots (4.7)$$

If the two circuits in Fig. 4.10(a) and Fig. 4.10(b)
are equivalent, these resistor currents must be
the same. Equating the right hand side of
eqns (4.6) and (4.7) and simplifying, we obtain

$$i = \frac{v}{R} \quad \text{or} \quad v = iR \dots$$

Just we will go through step by step everything is written here, but I explain that how that electrical equivalent that i is equal to v upon R or v is equal to iR .

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When eqn.(4.8) is satisfied for the circuits in Fig.4.10, the current i_L is the same for both circuits in the ~~fig~~ Fig.4.10 for all values of R_L . If the current through R_L is the same in both circuits, then the voltage drop across R_L is the same in both circuits, and the circuits are equivalent at nodes 1,2. If the polarity of v is reversed, the orientation of i must be reversed to maintain equi

Now; that means, if] that polarity also I told you this polarity also I told you that if the polarity of v is reverse, the orientation i must be reverse to maintain equivalent that I just told you, the underlined also right. So, let me clear it.

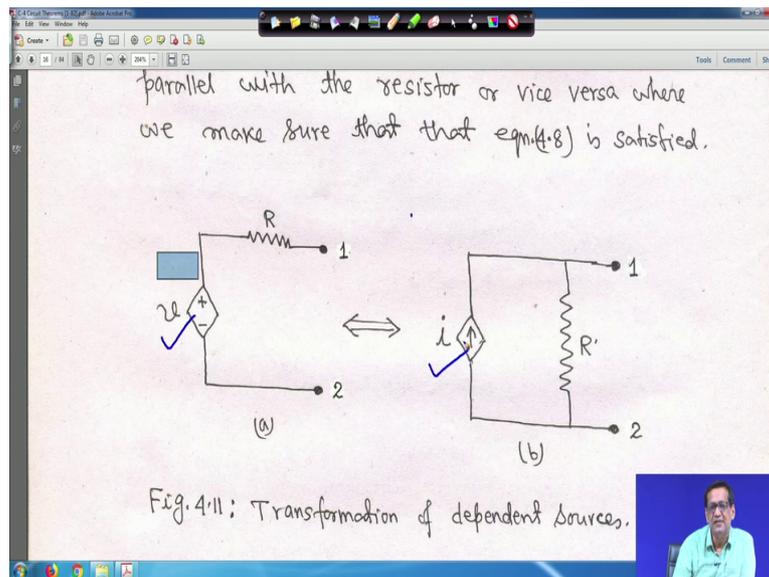
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Source transformation also applies to dependent sources. As shown in Fig.4.11, a dependent voltage source in series with a resistor can be transformed to a dependent current source in parallel with the resistor or vice versa where we make sure that that eqn.(4.8) is satisfied. (16)

The diagram shows two equivalent circuit configurations. On the left, a dependent voltage source v is in series with a resistor R , connected to terminals 1 and 2. On the right, a dependent current source i is in parallel with a resistor R , also connected to terminals 1 and 2. A double-headed arrow indicates the equivalence between the two circuits.

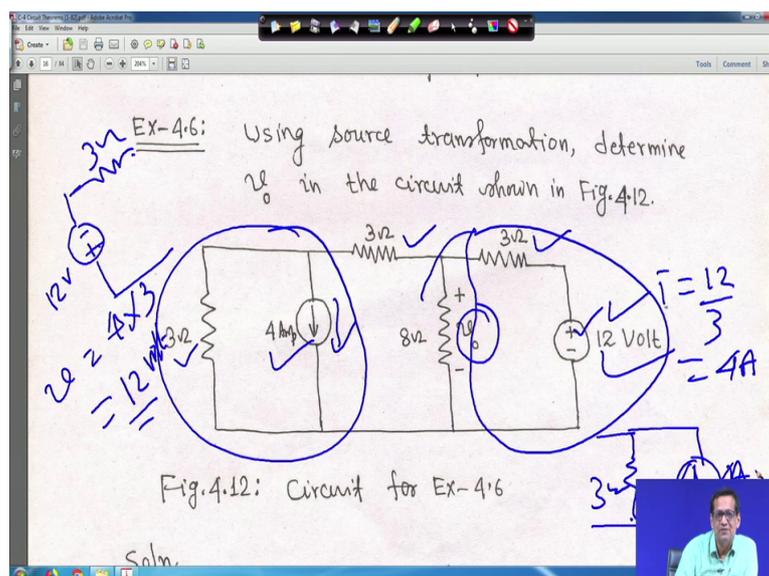
Now source transformation also applied to dependent sources.

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For example if it is a later we will see that where will consider that your numericals for your containing your considering your different type of dependent sources voltage or current. So, if volt if your sorry if your this thing this is the voltage source dependent voltage source right. So, it is also bilateral. So, it will be also your dependent current source later will see this right. So, same way we can same way we can do same way we can transform that in your dependent voltage or current sources.

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Now, consider one example using source transformation you determine v_0 in the circuit for I mean I mean this is your this is your v_0 . So, you have to find out the v_0 in the circuit and so on. And one independent current source is there this is 4 ampere and one independent voltage source is there that is 12 volt right. So, this direction, look at the direction, direction here it is upward right.

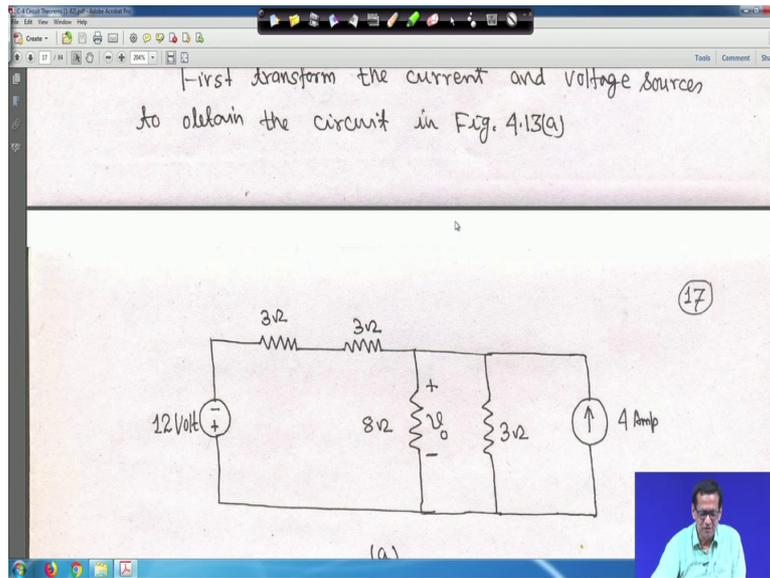
And when you convert this one, I mean this portion, when you convert this one, your this current source and one resistor is there in parallel. If you try to convert it into the your what you call judiciously you have to make it into that your voltage source and resistance in series, the resistance this 3 ohm is in series, then 4 that v is equal to it is 4 into 3 that is your 12 volt, that is 12 volt right.

And this will be the equivalent voltage I mean you are transforming this portion only from your current source to the voltage, but look at this it is downward. So, if I draw it here for this portion, this will be minus, this will be plus right, this will be my 12 volt, and this resistance is in this ohm it will be 3 ohm right this will be 3 ohm. And this 3 ohm and this 3 ohm then both will be in series later we will see the circuit right.

So, similarly here also if you have this 3 ohm and this is 12 ohm 12 volt. Now, if we if we want to convert it to the your suppose for example, this portion, this portion, if you want to convert it into the your current source and the resistance, this 3 ohm will be parallel then to a i is equal to 12 by 3 that is equal to 4 ampere right. And then if you try to if you try to represented by current source, then what will happen these 3 ohm resistance will be in parallel.

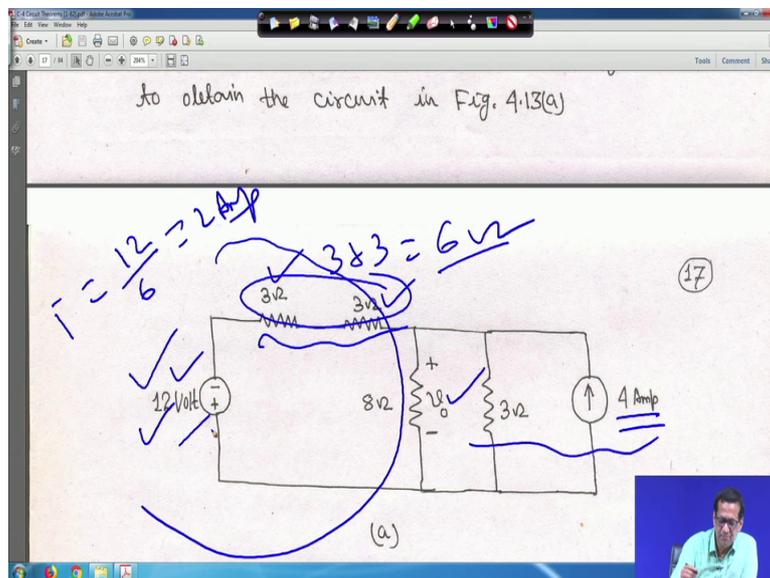
And this will be your current source; arrow is upwards right, and because here plus polarity is here and this will be your 4 ampere right. So, if you do so, then circuit your what you call configuration will change. So, let me so before everything is there at the bottom, but before that I am just trying to explain that how we actually obtained it. So, let me clear it right.

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So, if you go there here look this, first what we have done that this one, we have this portion we have converted to 12 volt I told you.

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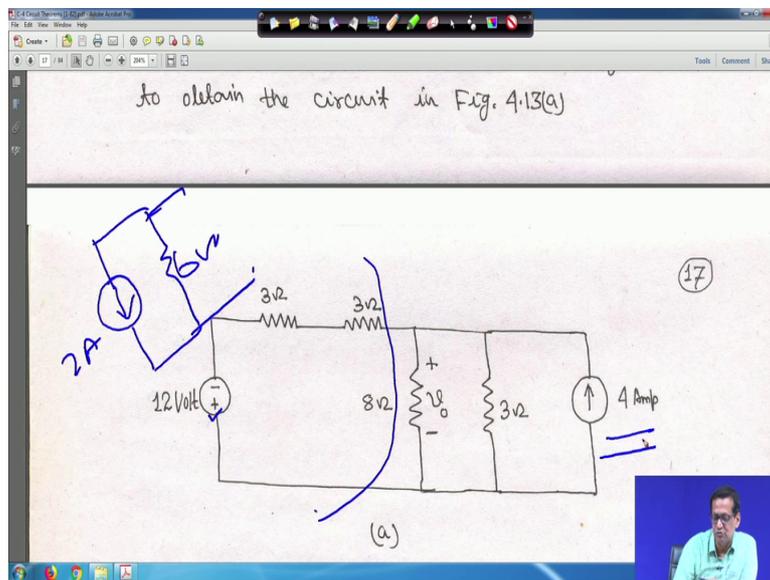


This is 12 volt and I told you the polarity also because current source that is your it is downwards right. And this 3 ohm and this 3 ohm is in series. And similarly this one converted polarity was upward, so it is your arrow is upward, so this is 4 ohm. So, this way this side portion we have converted like this and this side portion we have converted like this right. So,

after this after this our objective is that we have to find out v_0 right next what will happen this 3 this 3 and 3 both are in series. So, 3 plus 3 it will be 6 ohm right.

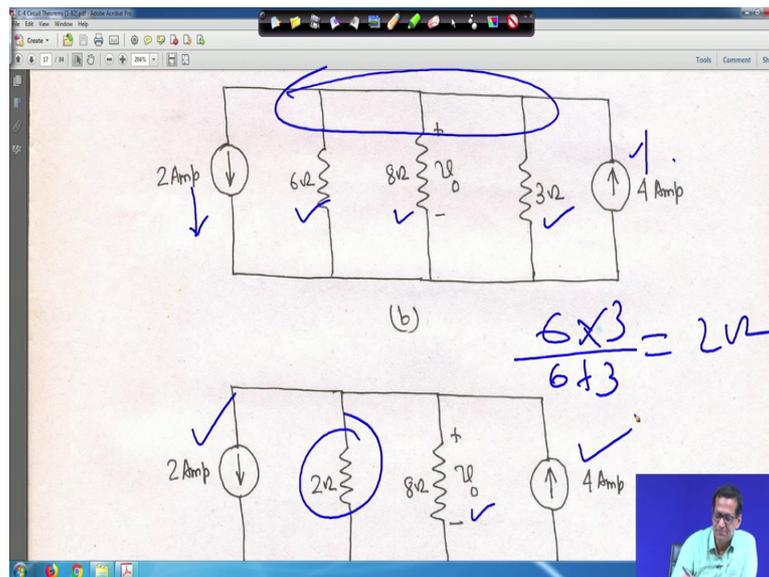
So, now this portion this portion of the circuit this portion of the circuit is 12 volt and this 6 ohm are in series. You convert it to a current source and in parallel you put 6 ohm resistance. If you do so, then current I will be is equal to 12 by 6 is equal to 2 ampere that is 2 ampere right that means that means this portion this portion it will be somewhere I am just I am just clearing it, I am just hold on I am just clearing it.

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Then this portion this portion it can be made it like this. Look plus is here at the bottom right, therefore, this is your 2 ampere; and here this 3 plus 3 6 ohm. So, this 6 ohm will be in parallel right. And after that you connect that circuit has the, whatever way it is given same thing. And this 4 ampere let it be at both the things we converted to a current source right. So, let me clear it.

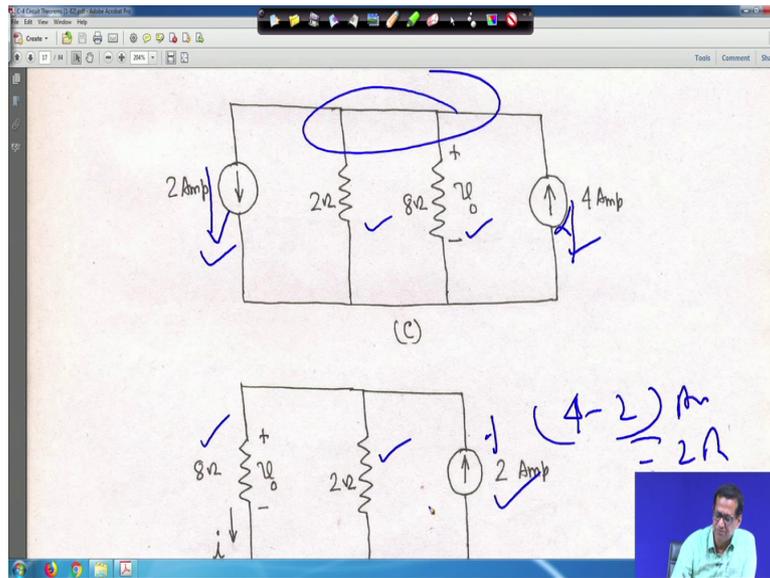
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So, if you go to the next one, then this is your here that is let me go little bit up. So, this is your that 2 ampere downwards and this is 4 ampere your upwards right. So, now, all 3 this all 3 this one, this one, this one, all three are in parallel right. So, because this are this are this is your a common node, no electrical elements are connected here, common node. So, 6 ohm and 3 ohm, they are in parallel, but we have to find out v_0 .

So, we cannot a your eliminate 8 ohm, but 6 and 3, 6, 8, 3 all are in parallel, but take the equivalent of 6 and 3 these two are in parallel. So, this thing is if parallel is 6 into 3 plus divided by 6 plus 3. So, is equal to 2 ohm right. So, this side here, it is 2 ohm that is the parallel of this thing. This 8 ohm is written and this 2 ampere is written and this 4 ampere is written say right, so that means, further simplification then you clear it right.

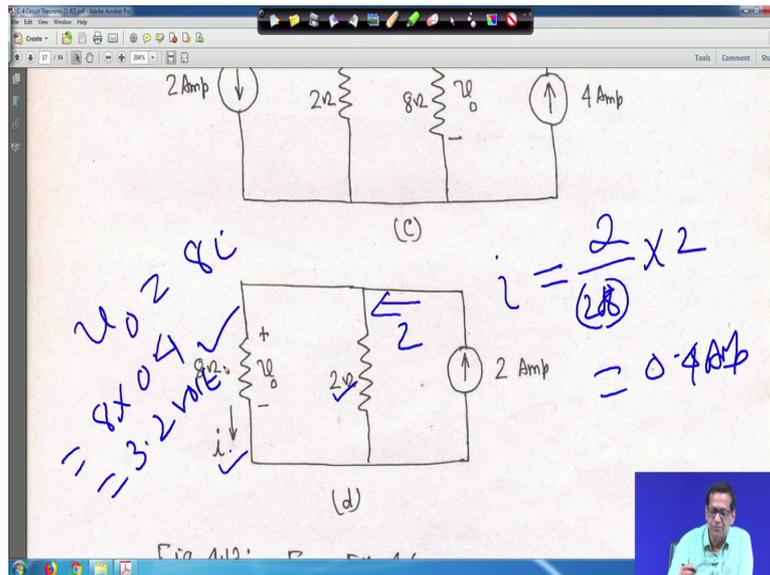
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So, once now once if you so, if you look into this that a this 4 ampere is upward, and 12 ampere 2 ampere is downwards right. And this is a this is your what you call common node all are in parallel; this one, this one, this one, all are in parallel. So, resultant of 4 ampere it is upward and it is downwards.

So, resultant will be 2 ampere upward that is your 4 minus 2 ampere that is is equal to 2 ampere, it is upward right because this is 4 up, this is down. And equivalent is 4 minus 2, 2 ampere because all are in parallel from an intuition you can easily make it. So, this is 2 ampere because of the resultant of this and this is 8 ohm this is 2 ohm after this you go to current division right.

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So, if you go for current division these two ampere current, this is my 2 ampere current right, then what is the what is this i . Now, we have to the current division will find out i is equal to right it is flowing what is the current flowing to 8 ohm resistance it will be 2 right. This 2 divided by 2 plus 8 into 2 that is actually 0.4 ampere right. So, that means, your v_0 is equal to 8 into i because this is 8, this is i , 8 into i . So, is equal to 8 into your 0.4 is equal to 3.2 volt that should be the answer right. So, this is this is how we do it. So, let me clear it.

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Combine 3Ω and 3Ω resistors in series and transforming the 12 volt voltage source in Fig. 4.13(a) gives us Fig. 4.13(b). Now combine 6Ω and 3Ω resistors in parallel to get 2Ω and the equivalent circuit is shown in Fig. 4.13(c). Also combine the 2 Amp and 4 Amp current sources in Fig. 4.13(c) to get equivalent circuit shown in Fig. 4.13(d). 2 Amp current source and the circuit shown in Fig. 4.13(d).

So, all these things have been explained and solved. You just go through what I told right. So, everything is written for you just you go through it that how you solve. So, slowly and slowly come down.

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shown in Fig. 4.13(d).

From Fig. 4.13(d),

$$i = \frac{2}{(2+8)} \times 2 = 0.4 \text{ Amp}$$

$$\therefore v_o = 8i = 8 \times 0.4 = \underline{\underline{3.2 \text{ Volt}}}$$

EX-4.7: Using source transformation, determine i_x in the circuit shown in Fig. 4.14

So, this is your I told you that this is your answer that 3.2 volt I told I solved it everything for you everything is written here. So, you can easily make out that how things are. When you will go through this video at that time you can make it, but everything I have explained right.

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EX-4.7: Using source transformation, determine i_x in the circuit shown in Fig. 4.14

$v = 2i_x$

$$i = \frac{v}{5} = \frac{2i_x}{5}$$

$$i_x = 0.4 i_x$$

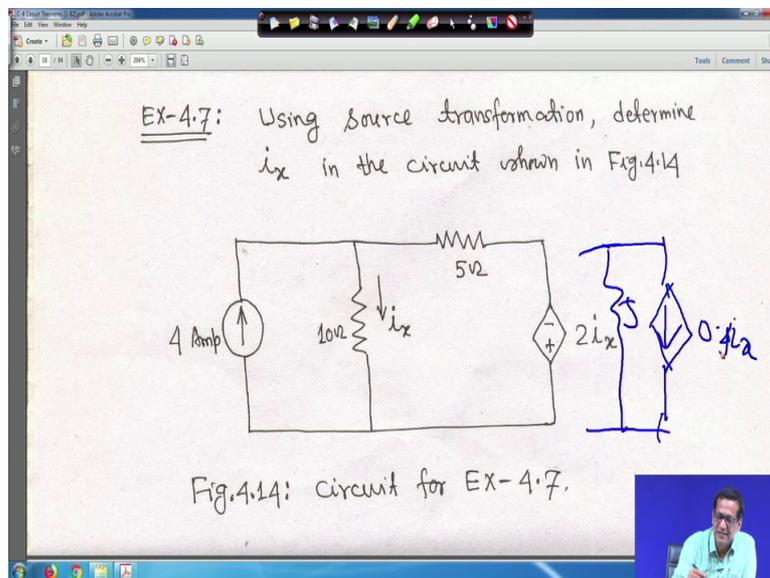
Fig. 4.14: circuit for EX-4.7.

So, take another one. So, now, using source transformation determine i_x in the circuit your shown in figure this 14 that is it is chapter topic 4. So, this thing one dependent your what you call voltage source is voltage source is there. So, dependent voltage source is there. And this is your 4 ampere your independent current source. And you have to find out what is i_x that is the thing you have to find it out.

Now, question is that this dependent voltage source and 5 ohm, they are in your what you call your these two, these two, this 5 ohm and these two are in series. So, if try to convert it to the your what you call dependent current source, same transformation same philosophy here right. So, if you if you do so, this is for example, this is dependent your voltage source. So, if it is your $2 i_x$ right, v is equal to said to polarity look here is a bottom right plus right.

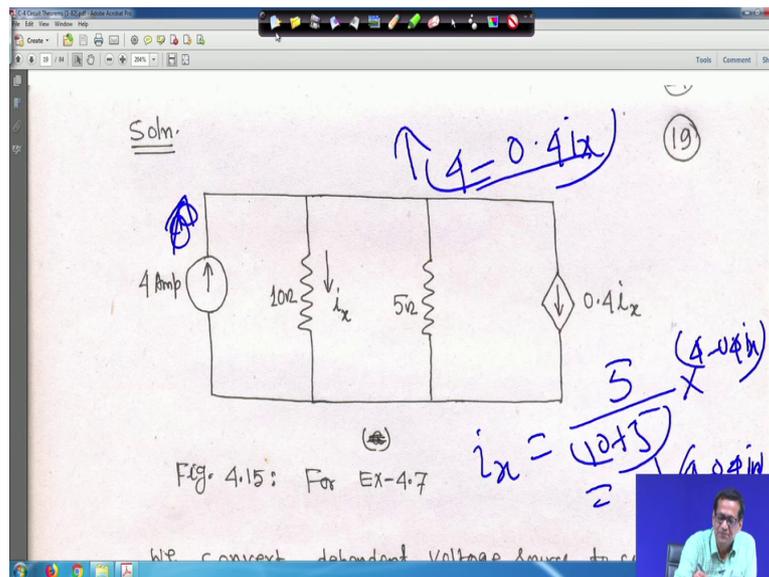
And if v is equal to $2 i_x$, then i suppose if i want to convert it to a dependent your current source then i will be is equal to your v divided by this 5, because 5 ohm is there and v is equal to your $2 i_x$ divided by 5 is equal to $0.4 i_x$ right. So, dependent voltage source will be converted to dependent current source right. So, it is $0.4 i_x$.

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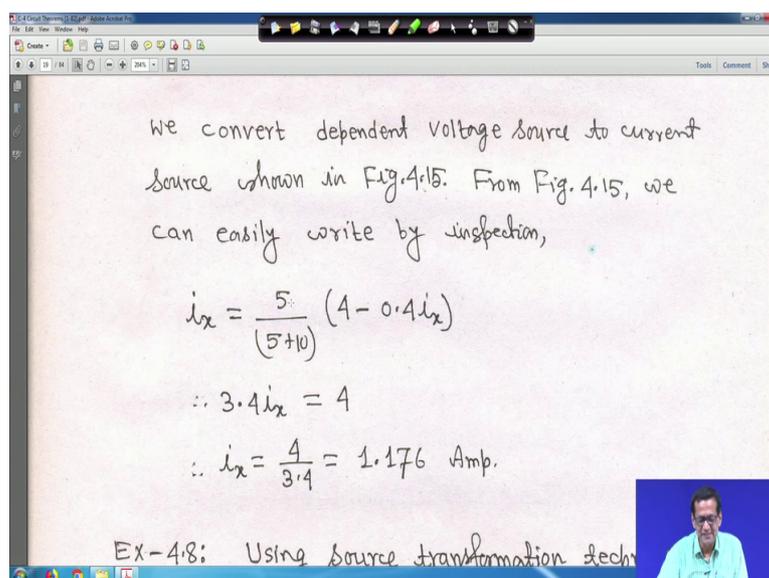
Now, if you try to rep represent that one let me clear it right let me clear it; that means, because plus is here. So, arrow tip will be downward right, so it will be your $0.4 i_x$. And with this 5 ohm resistance will be in parallel 5 ohm resistance will be in rest you connect with this right, rest you connect with this. So, this is actually how we can convert it same philosophy dependent or independent same philosophy. So, let me clear it.

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So, so if you if you go to the equivalent one then circuit is becoming like this, this circuit is becoming like this I told you that this arrow this arrow will be downward. Look at the polarity and $0.4 i_x$ and i_x 5 ohm this is 10 ohm, this is 5 ohm, and you have to find out the current through this right basically 10 ohm and 5 ohm both are in parallel right. But we will go for current division and this is 4 ampere.

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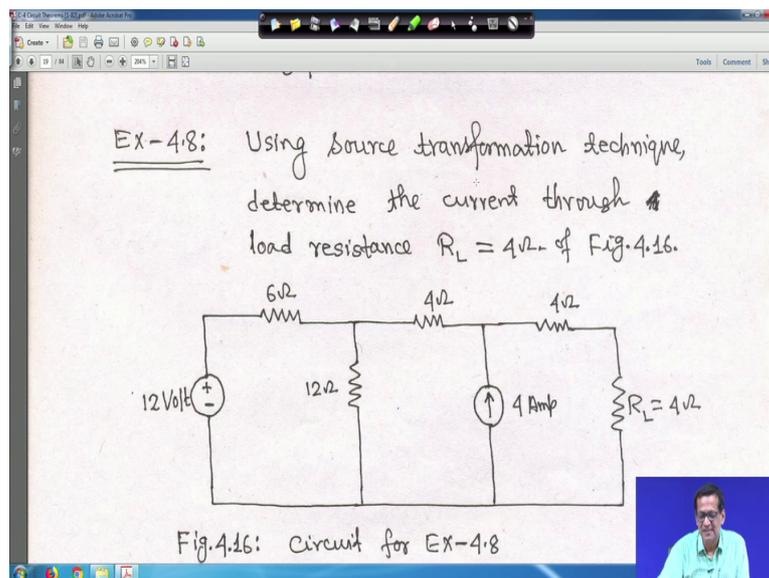
Now, if you if you now move go for current division right, if you look if you look into your this thing what we have made we have made i_x is equal to 5 by 5 plus 10 , 4 minus $0.4 i_x$

what is how it is coming. This is this one actually this is upward this is your downward. So, if you make it resultant of it, it will be actually your 4 somewhere I am writing here it is 4 minus $0.4 i_x$ right.

I mean direction will be upward not putting here this direction of this one will be upward. And this current this current is divided into 10 ohm and 5 ohm, therefore, a current division method your i_x will be is equal to your 5 divided by 10 plus 5 right into your 4 minus $0.4 i_x$ right. So, basically it is one-third because 5 by 15 then 4 minus $0.4 i_x$ after that you solve for i_x . So, we have to from your intuition you have to make it that how to solve this circuit. So, let me clear it.

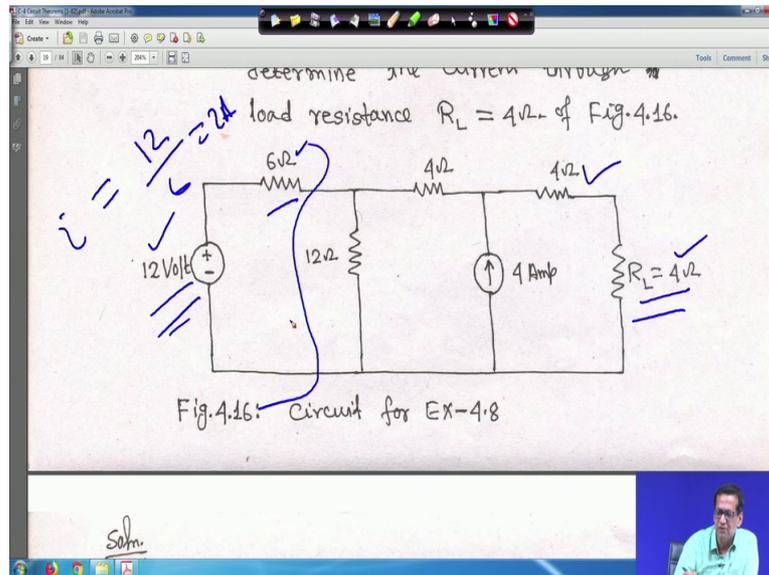
So, if we go to this one, so it is given that we know after solving this one, you are getting your what you call i_x is equal to 1.176 ampere things are easy. Just you have to from your intuition you can solve it that how to do it right. Next one let me clear it.

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Next one using source transformation technique, determine the current through load resistance R_L is equal to 4 ohm in this figure 16 right.

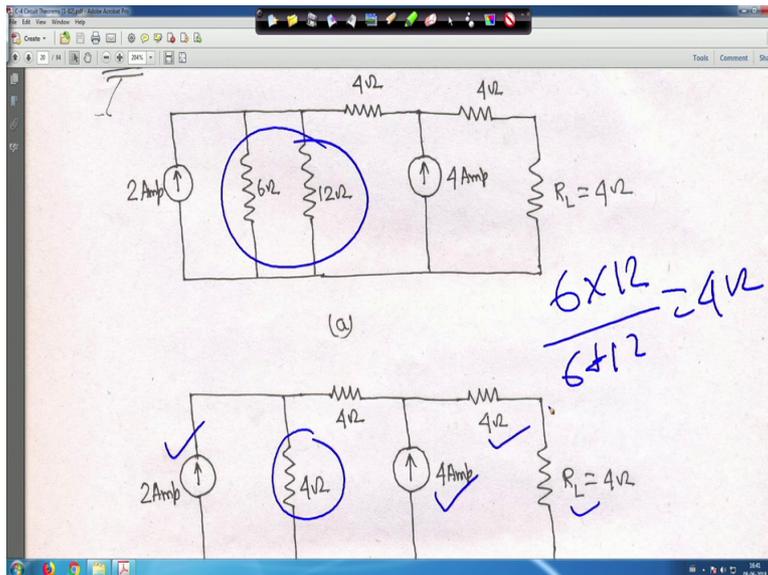
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So, you have to find out your you have to find out your current through this 4 ohm resistance. All the 4 and this 4 and this 4, both are in series, so effective will be 8 ohm, but you cannot you cannot remove this 4 ohm because you have to find out the current through this load resistance 4 ohm right. So, this one this, this side if you look into that this is 12 volt source and polarity is plus minus this is plus this is minus 6 ohm.

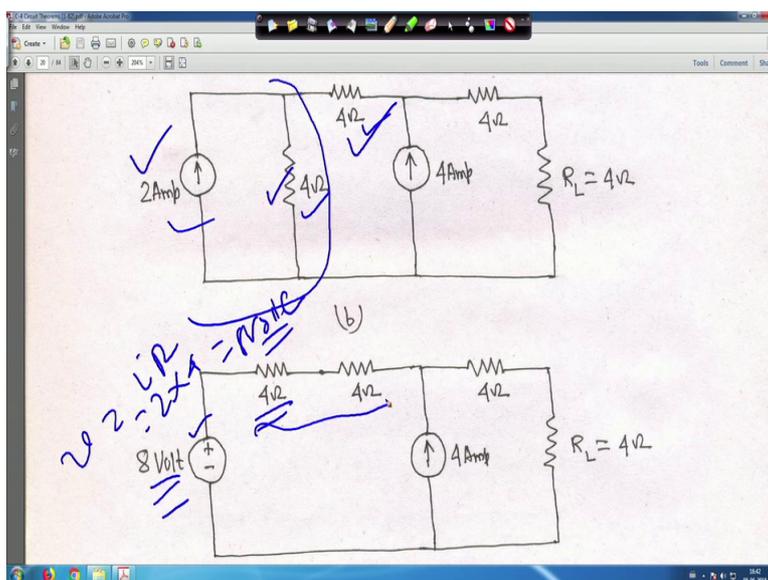
So, if you want to convert it to a current source right, only this portion, if you convert it to a current source and a resistance parallel 6 ohm parallel to it, therefore, i is equal to your 12 by 6 this 12 by 6 is equal to 2 ampere your arrow direction of the independent current source will be upward right. And at that time this 6 ohm will be in parallel to this 12 ohm and with this 12 ohm right. So, if you convert this one to a this portion to a current source and a 6 ohm in parallel then look how the circuit will look like right.

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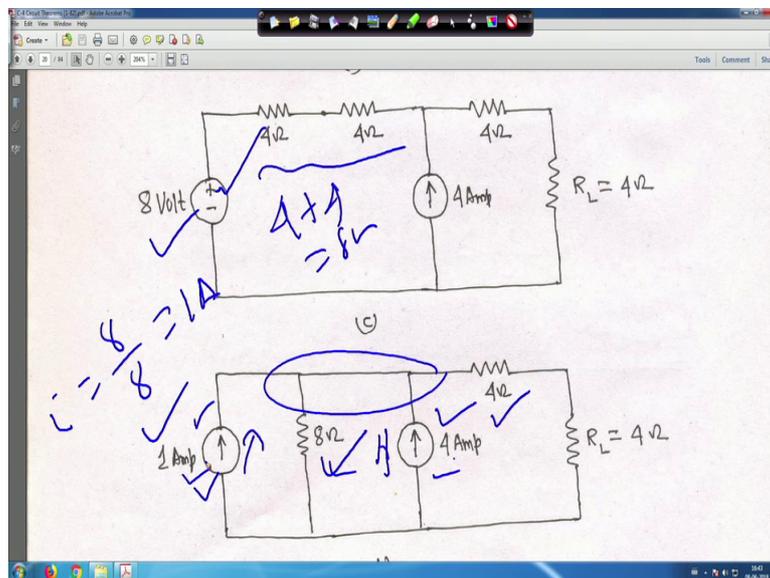
If you do so, look these two ampere, and this is your what you call this is your 6 ohm right, this 12 after this transformation. This 12 ohm is there and this 4 ohm and this 4 ohm, this one is there as it is right. Now, once you have done this then this 6 ohm and 12 ohm both are in parallel. So, you find out that equivalent that is 6 into 12 divided by 6 plus 12 that is actually is equal to 4 ohm right 12 into 6 your 72 divided by 18, so 4 ohm. So, that means, that means, this 4 ohm is here equivalent of this 4 ohm is here and this is 2 ampere and this is 4 ampere right, both are upward R. R_L and 4 ohm this things are as it is right. So, let me clear it right.

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So, now, what we have what we have what you can do is this current this current source and these two, you convert to a convert it to a voltage source and series they put 4 ohm in series right. Therefore, v is equal to your $i R$, so this is 2 ampere and this is 4 ampere. So, 2 into 4 that is your 8 volt right, this is your 8 volt. So, here it is 8 volt and direction is upward. So, this is your plus minus and that means this volt 8 volt and this 4 ohm, these two are in series. Along with that this 4 ohm resistance was there, so 4 and 4 both are in series. And this is 4 ampere this part of the circuit keeps it as it is right. So, after transformation, so that means, these two 4 plus 4, this is 8 ohm right, they are in series. So, let me clear it.

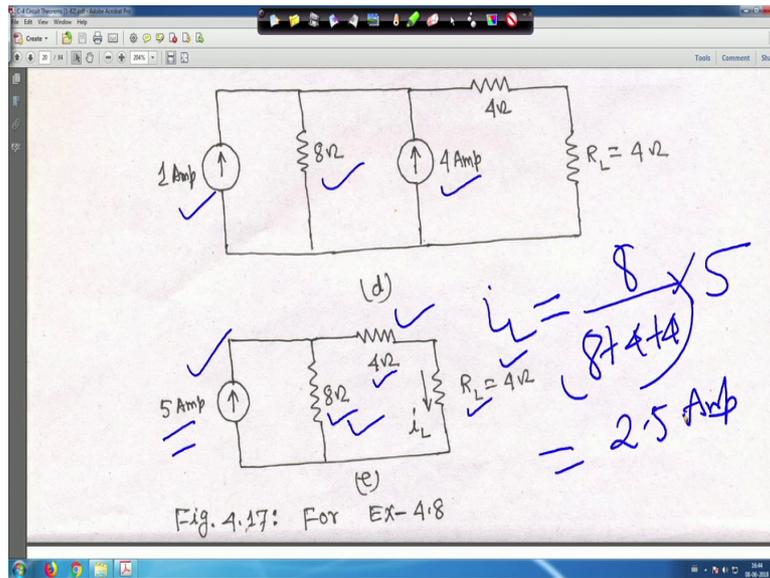
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So, next is next is what we have done that this 4 this 4 and 4, 8. So, 4 plus 4 it is 8 ohm and 8 volt source is there. So, transform into a current source, so i will be is equal to 8 by 8 is equal to 1 ampere. So, this is 1 ampere. Arrow is here if plus is here, so arrow is upward, so this 8 ohm is in your what you call is in parallel with this current source. And this 4 ampere and this 4 as usual it is there right.

The that means, if you look into that this 4 ampere is upward and this 1 ampere is also upward, and this your what you call this all this things this one, this one, this one and this 4 plus 4, it is basically 8 ohm, but all this things are in parallel. If you look 1 ampere 8 ohm, 4 ampere this 4 plus 4 8 ohm all are in parallel. So, if you take the resultant of this 4 a this independent current source 4 ampere upward this one ampere. So, resultant will be your 5 ampere right; resultant will be 5 ampere upward. So, let me clear this.

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So, that means, 5 ampere is here 5 ampere is here your here it is 5 ampere because 4 and plus 1 both are upwards. So, 5 ampere is here. And this 8 ohm is here. And this 4 ohm 4 ohm is there. So, from the current division method basically, this is also 8 ohm, this is also 4 plus 4 both are in series 8 ohm. So, actually current flowing to this is 2.5 ampere this is 5 by 2. So, current division method if I make it i_L is equal to it is 8 divided by 8 plus 4 plus 4, because these two are in series. So, 4 plus 4 into this current 5 ampere it is 5 right. So, it so it will become 2.5 ampere right so, that is the answer the current flowing through this. So, let me clear it.

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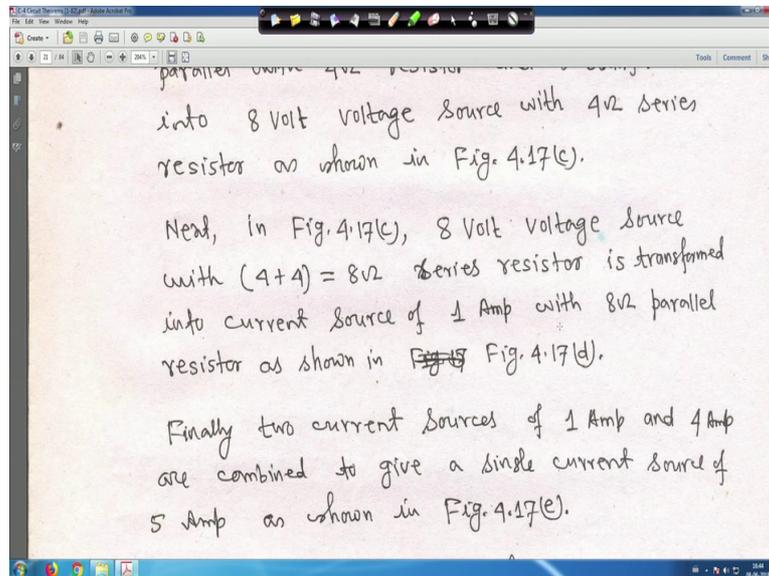
The 12 Volt voltage source with 6Ω series resistor is converted to a current source and in parallel with 6Ω resistor - as shown in Fig. 4.17(e)

6Ω and 12Ω resistors of Fig. 4.17(e) are in parallel and their equivalent is $6 \times 12 / (6+12) = 4\Omega$ as shown in Fig. 4.17(b).

In Fig. 4.17(b), 2 Amp current source is in parallel with 4Ω resistor and is transformed into 8 Volt voltage source with 4Ω series

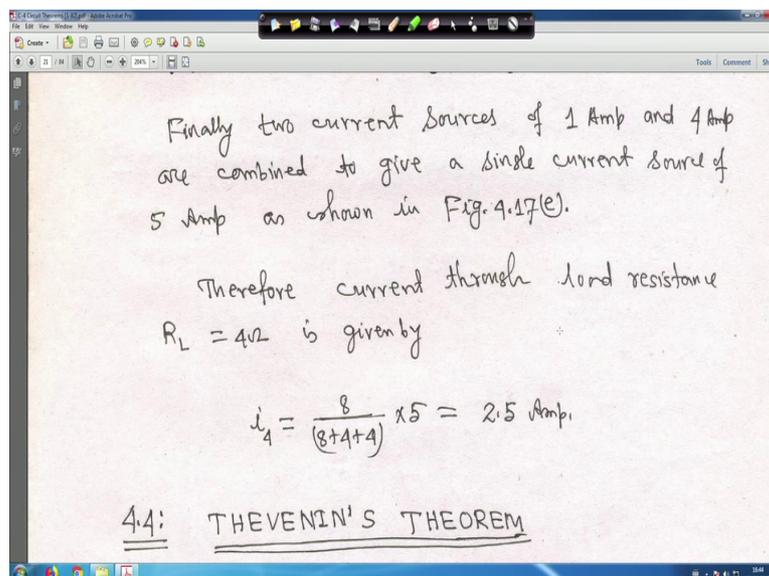
So, all these things are explained here. I told you everything all right of is there. So, you will when you will go through this video lecture, if you have any difficult, you can go through my right up, but everything I explained how to solve it right.

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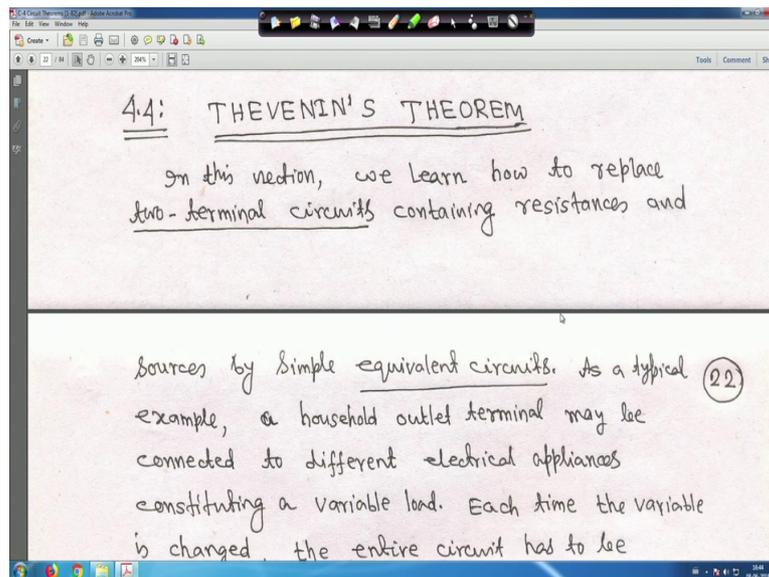
So, all these things are explained right, finally 2.5 ampere.

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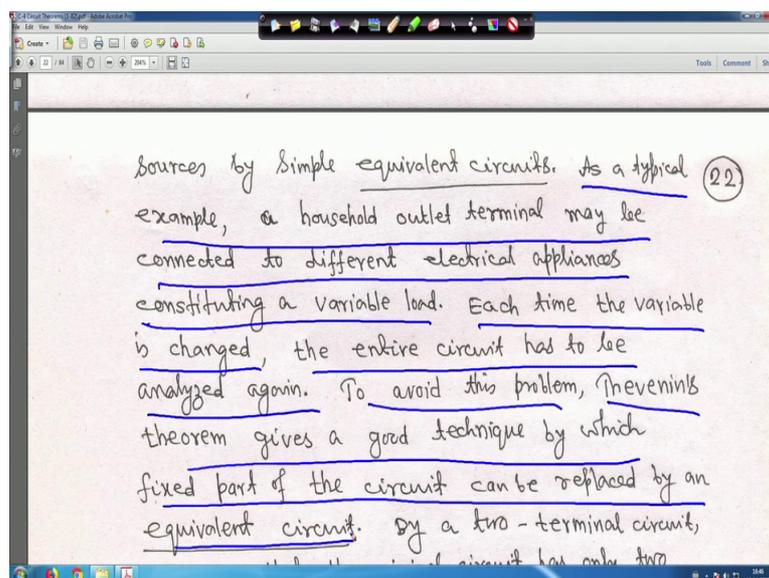
So, after this after source transformation we have learned, next another important thing that you learn that is your Thevenin's theorem right.

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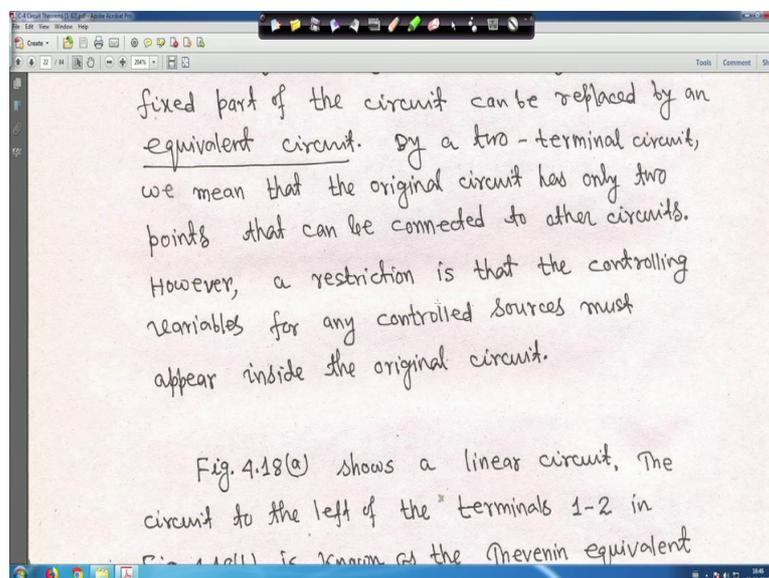
So, in this section, we will learn how to replace two terminal circuit containing resistances and sources by simply equivalent circuit that you have learned. As a typical example for that your simply equi suppose you have a last circuit, but your interest is to find out the current particular branch. And if that branch your what you call and if the branch resistance is variable say but rest of the circuit is unchanged, then the rest of the circuit we can find out to an equivalent your what you call voltage called Thevenin voltage and equivalent resistance called Thevenin resistance. So, how will do this right?

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Suppose, for example, for example, say as a typical your what you call as a typical example the house hold outlet terminal connected to different electrical appliances constituting a variable load. Each time the variable is change right, the entire circuit has to be analyzed again I mean if you take a last circuit and one particular branch say R is changing. So, whatever we have studied till now again and again you have to solve the whole circuit right. So, this is very much your cumbersome, and it is time consuming process. So, to a avoid this problem Thevenin's theorem gives a good technique by which fixed part of the circuit can be replaced by an equivalent circuit right. So, this is your what you call that Thevenin's theorem. So, what it states?

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Now, next is that your by two terminal circuit we mean that the original circuit has only two point that can be connected to other circuits right. However, restriction is there in the controlling variables for any controlled sources must appear inside the original circuit. So, here Thevenin's initially when first time those who are studying first time for them just you have to be very care full that how you do it and how you can get it right.

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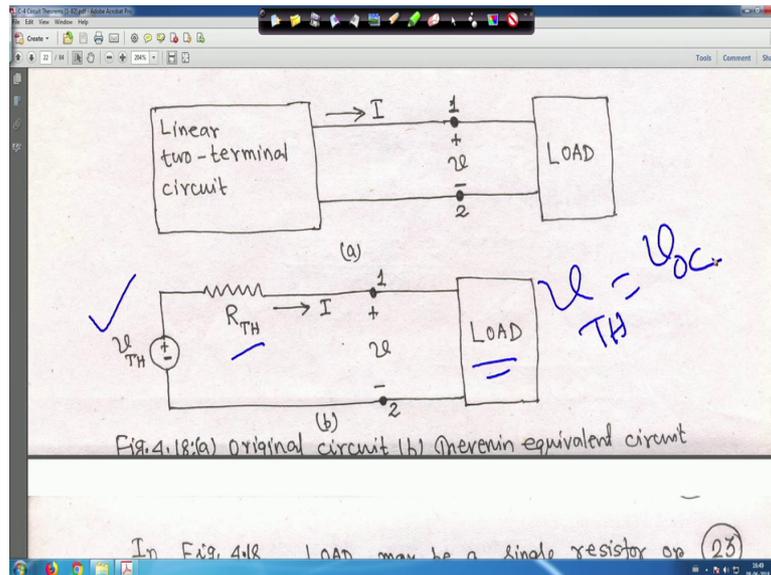
Fig. 4.18(a) shows a linear circuit. The circuit to the left of the terminals 1-2 in Fig. 4.18(b) is known as the Thevenin equivalent circuit. It was developed by M. Leon Thevenin (1857-1926) in 1883, by a French telegraph engineer.

The diagram shows a box labeled "Linear two-terminal circuit" on the left, connected to a "LOAD" on the right. The terminals are labeled 1 and 2. The current flowing through the load is labeled I . The load is represented by a rectangle with a downward-pointing arrow and the word "LOAD" inside. The terminals are marked with a plus sign at terminal 1 and a minus sign at terminal 2. There are checkmarks next to the terminal labels. A small inset video of a man in a green shirt is visible in the bottom right corner of the slide.

So, for example, suppose this figure this thing it shows a linear circuit that is circuit to the your what you call left of this terminal this side this side left of the terminal this 1 2, this is terminal 1 and 2 in figure your what you call is known as this is a figure, this linear circuit is given two terminal circuit. And this Thevenin equivalent at bottom it is there. So, it was developed by M. Leon Thevenin. His life span was 1857 to 1926. And in 1883, he was a French telegraph engineer. So, 1883, he give this concept when he was 26 years of age right.

So, that is your this is an equivalent suppose terminal 1 and 2 some load is there. And linear 2 terminal circuit this is a this is a big circuit to the left of this one, but some terminal 1 and 2 is there. And some load is connected and these may be variable load I mean suppose this load is changing if every time this load resistance is changing then whole circuit you have to solve right. So, but Thevenin's theorem suggests that if you if you just rest of the circuit, if you can bring it to an equivalent two terminal circuit, then after that you connect this one you can easily find out what is the current flowing through this load resistance R right. So, let me clear it.

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So, its Thevenin's equivalent says that this circuit that this voltage that v_{Thevenin} and R_{Thevenin} right. So, this is my v_{Thevenin} that equivalent one this is my v_{Thevenin} and R_{Thevenin} with that you connect this load in series with that. Load resistance whatever it is right and this is called v_{Thevenin} ; sometimes it is called open circuit voltage also v_{oc} later we will see sometime v_{Thevenin} we call v_{oc} right. So, that is your what you call the Thevenin your voltage that that you have to learn how to obtain and R_{Thevenin} . When ac circuit will come at that time instead of R_{Thevenin} , it will be z_{Thevenin} that there we will see the impedance part right. And current i is same this current i is same. So, this is that Thevenin equivalent circuit, but how to do it.

Thank you very much, we will be back again.