Basic Electrical Circuits
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Lecture – 16

Now, way have looked at a case of having two voltage sources and series, we will now consider all the other elements that we know.

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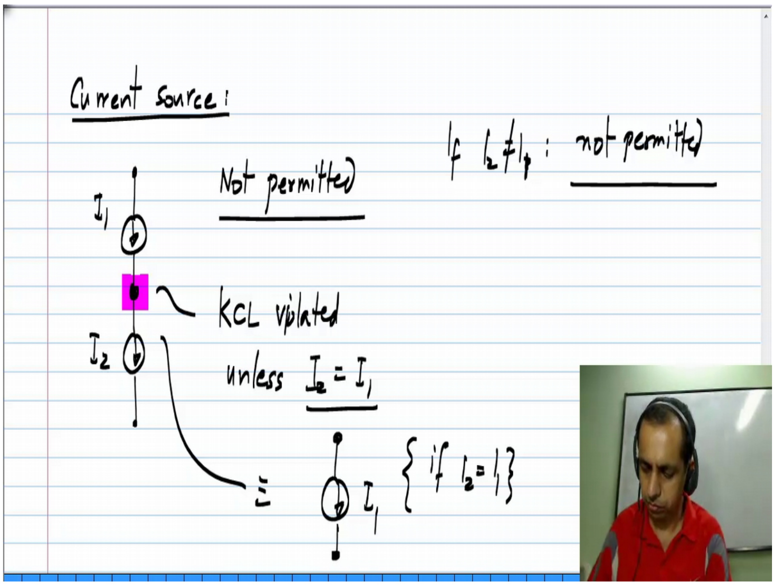
So, the next basic element we know is the current source. Now, we can imagine



connecting current sources like this and let say, they have values I 1 and I 2. We will immediately notice that this connection is not permitted, because Kirchhoff's current law is violated at this node, unless I 2 happens to be exactly equal to I 1. If this is the case, then this whole thing is equivalent to a single current source of value I 1 and if I 2 is not equal to I 1, then this connection is not permitted. So, what this means is that, if you have two unequal current sources, you cannot connect them in series, because such a connection necessarily violates Kirchhoff's current law.

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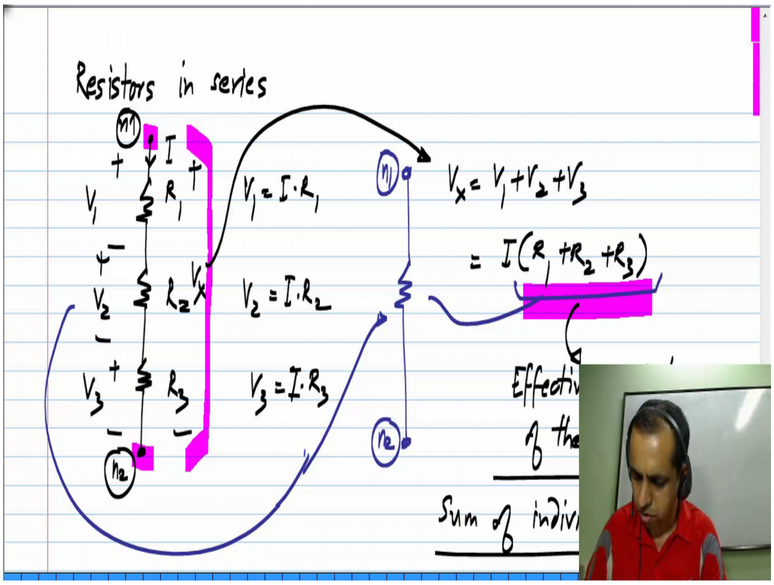

So, next we look at resistors in series. So, I will take a number of resistors just for illustration, let me put down three of them. Now, what we want to know is, what is the effective behavior between the upper and lower terminals. So, for that let me mark the voltages across each resistor and the current through each resistor and we know that, the same current flows through all the resistors, because of the series connection and so I will call that current I.

So, by ohms law we know that V 1 is I times R 1, V 2 is I times R 2 and V 3 is I times R 3 and the total voltage between these two, if I call that V x from our earlier discussion we know that it is the sum of individual voltages. So, V x is v 1 plus V 2 plus V 3 which is I times R 1 plus R 2 plus R 3; that is the relationship between the voltage across the series combination and the current through the series combination. So, one thing you notice immediately is that, this is the proportionality relationship as well, the voltage is proportional to the current and the proportionality constant happens to be R 1 plus R 2 plus R 3. So, that is the effective resistance of the series combination.

So, what does it mean? It means that this entire combination is equivalent to between the two ends a single resistor, if I mark the two ends let me call them perhaps terminals n 1 and n 2. So, between n 1 and n 2 I have a single resistor, whose value is given by this volt. So, the effective resistance of a series combination of resistors is the sum of individual resistances. Now, again this is probably a result that every one of you is familiar with, if I gave you a series combination of resistors and asked you for the total resistance, you would immediately come back with some formula.

But, the reason I spend so much time on this is that, even such elementary results you should know the reasoning behind them. So, once you get used to doing something like this; that is, every result that you know you have a reasoning behind them and that is to say, you have a way to prove the result. Once you have that as the concept become more and more complicated, you will still be able to prove all of them and really get a mastery over the concepts.

The reason to do this is that as the problems get more and more complicated, you should still be able to prove every step of it and connect everything, every new result to something that you know some basic concept that you know from earlier.

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From this, it is … e whole things simply is equiv… …ces.

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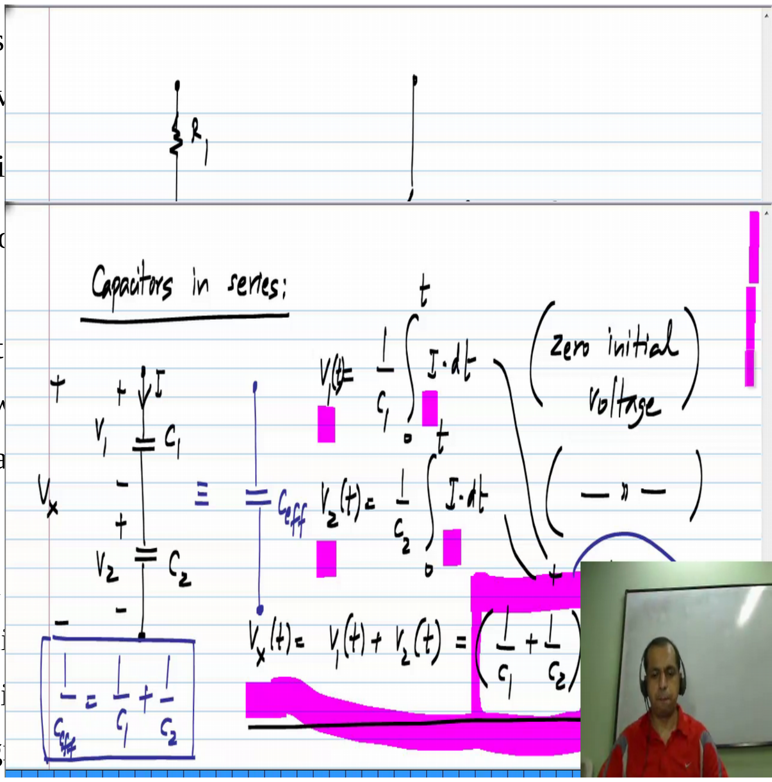

The next we lo… …rs in the usual way C 1 and … will mark the individual volt… integral of the current and I w… will also here assume 0 initia… …ning a 0 initial voltage across …

Now, if I look … obviously, it is the sum of indi… V x which is V 1 plus V 2 is gi… over C 1 plus 1 over C 2 integ… …d I looks very similar to between V 1 and I or V 2 and I. in other words, this relationship also the relationship between V x and I also looks like some capacitor and this proportionality constant we have in front of the integral is the reciprocal of the effective capacitance.

So, the nature of this relationship says that the whole things is equivalent to some capacitor C effective and the proportionality constant tells you how much that is, this constant in front of it should have been 1 over C effective and that is equal to 1 over C 1 plus 1 over C 2, so this gives you the value of the effective capacitance. Now, you can extend this to more than two capacitors, so if you have N capacitor in series, the reciprocal of the effective capacitance will be the sum of reciprocals of individual capacitances.

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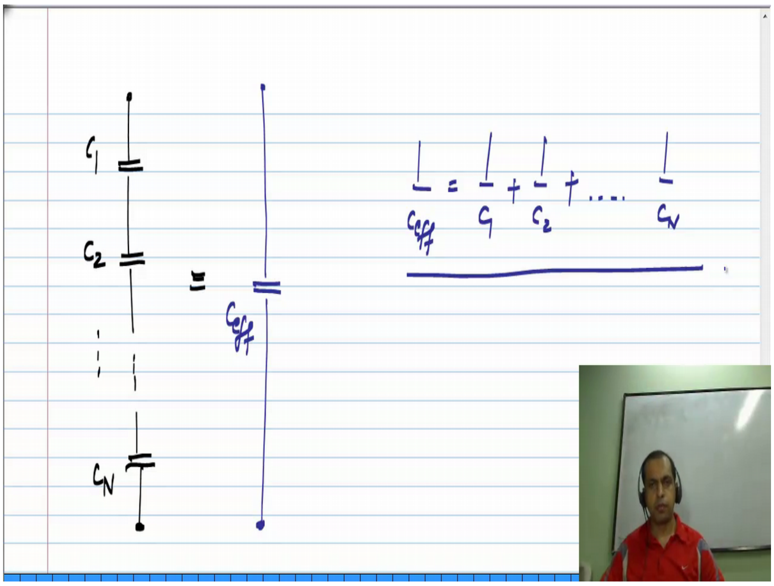

Next we will look at inductor in series.

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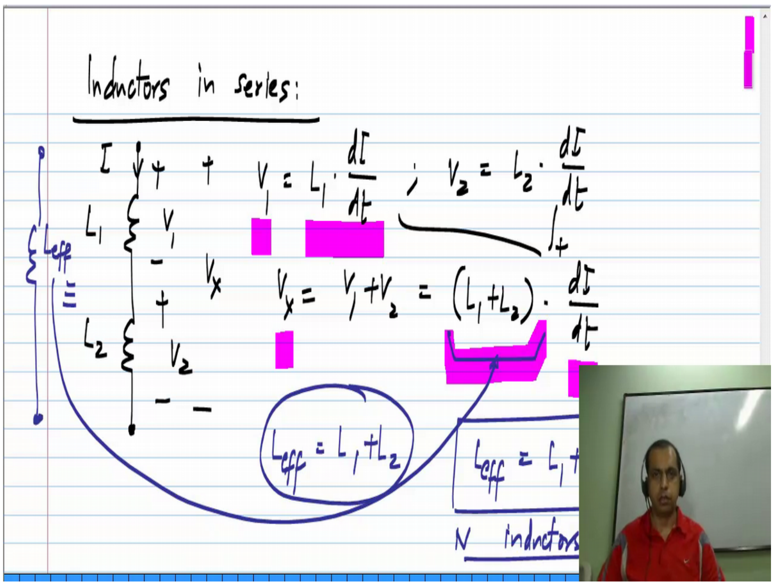

Let me start with two inductors L 1 and L 2 and mark the individual voltages V 1 and V 2 and the current through the series combination which is I. We know that V 1 is L 1 times the time derivative of I and V 2 is L 2 times the time derivative of I in this total voltage V x is V 1 plus V 2, which if you sum these two you will see that it is L 1 plus L 2 times the time derivative of I.

So, again the relationship between this V x and the current I looks exactly similar to that of a single inductor. The only different thing is the proportionality constant in front of the time derivative of the current. So, clearly from the nature of this relationship we deduce that the series combination is equivalent to an inductor and the value of the inductor let me label at L effective is given by the sum of individual inductors and I won't draw a separate picture for this, you have seen this couple of times before.

If I have n inductor in series, the combination is equivalent to a single inductor whose value is L 1 plus L 2 plus L N, this is for N inductors in series. Now, these are all elementary results what I want to emphasize is that we start from the basics that is KCL or KVL. Here, in case of series combination Kirchhoff's current law tell us that the same current flows through all the elements, Kirchhoff's voltage law tell us that the voltage across the ends of the combination equals the sum of individual voltages. Then we combine these consequences from Kirchhoff's current law and Kirchhoff's voltage law with the I V relationship for each elements and deduce the nature of the series combination. So, in all the cases we have seen, so far we of course, taken series combination of identical elements, the series combination also looks like the same element and the value is modified in some way.