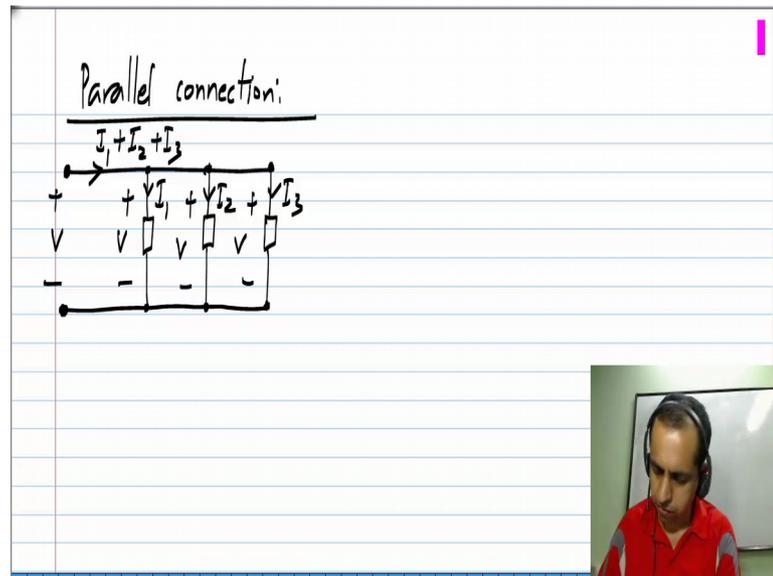


Basic Electrical Circuits
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Lecture - 17
Elements in Parallel

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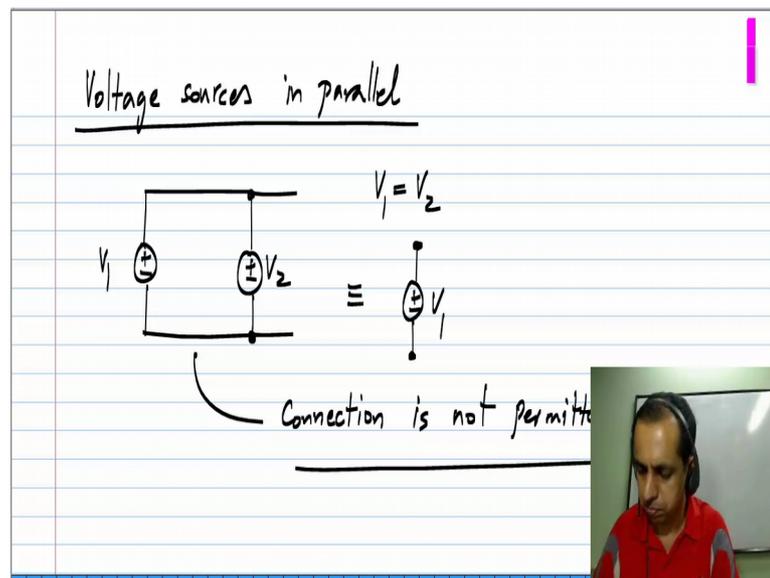
We have looked at series connection of two terminal elements where the same current flows through all the elements and the total voltage across the combination is the sum of the voltages. We will now look at the parallel connection of two terminal elements, which can be thought of as a counter part of series connection with the roles of voltage and currents interchange.

When we have a number of two terminal elements parallel connection implies that you connect one terminal of all the elements together and another terminal of the all the elements also together to a different node, and these two nodes form the terminals of the effective parallel combination. So, I can put any number of this in parallel. Now what is this do, you can look at the voltages across these elements, if you form a loop here involving the first two elements, you will easily see that V_1 equals to V_2 and these two elements V_2 equals V_3 and so on, that is because they are connected between the same two terminals. So, parallel combination has the property that the voltage across all the elements is exactly the same.

Let me call this current I_1 this one I_2 and this one I_3 and clearly you see that the total

current this voltage is be the total current flowing into the parallel combination as I_1 plus I_2 plus I_3 . So, now you can see that this is the exact counter of part of the series combination, here the voltage across all the elements is exactly the same, and current of the parallel combination is the sum of individual element currents. So, with these, we can quickly go through all the elements again and see what there parallel combination behaves like. So, again the reason to do this is though these are rather elementary is to gain some confidence that you can reason out everything from first principles.

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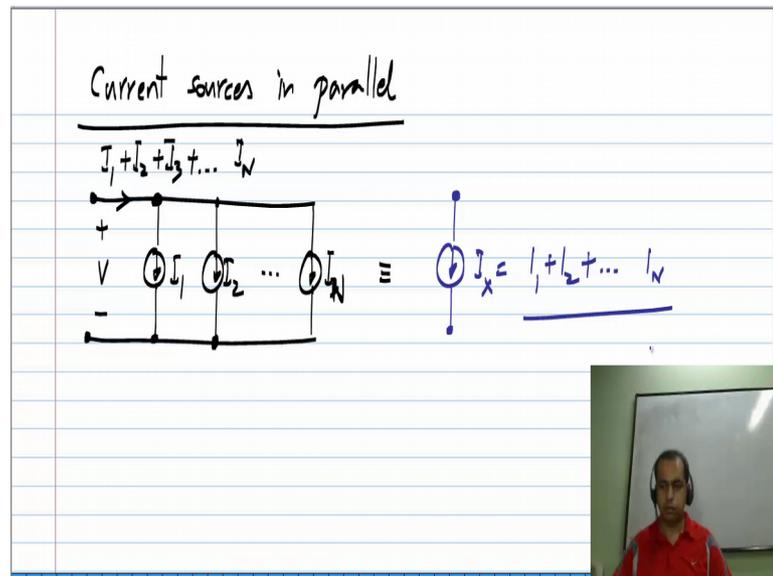


Lets me first look at voltage sources in parallel, so I have two ideal voltage sources V_1 and V_2 ; I connect them in parallel. Now I form a loop and apply Kirchhoff's voltage law, it tells me that V_1 has to be equal to V_2 . So, what it really means is that this connection is not permitted if V_1 and V_2 are different from each other; and if V_1 happens to be equal to V_2 , the whole thing equals a single voltage source of value V_1 . So, just like a series connection of currents sources is not permitted in general parallel connection of voltage sources is not permitted in general. So, it will be permitted only if the two voltage sources are identical; and in that case, the result is trivial, the result is also same voltage source. Now one thing I have to caution here is that do not get confuse between this and connecting two batteries in parallel, you can always say I can buy two batteries 1.5 volts and 9 volts, and connect them in parallel using two wires what is stopping me what you mean by it is not permitted.

Now, here we have talking about ideal voltage sources. If you do have ideal voltage sources, this connection is not permitted. Now the things with batteries is that its

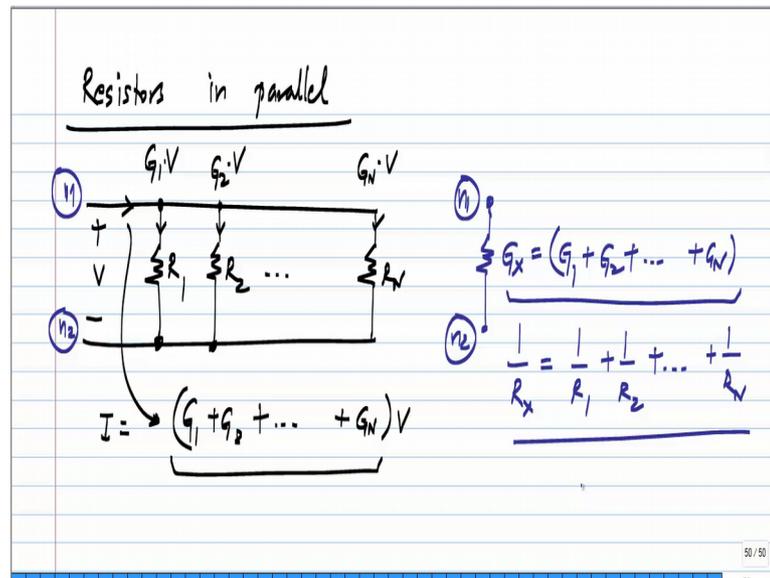
approximate voltage source; it is not an ideal voltage source it has some resistance in series. So, those things can be connected in parallel with each other. What happens is that large current flow and then that will reduce the life of the batteries, but when it comes to ideal voltage sources connecting them like this will violate Kirchhoff's voltage law and consequentially is not permitted.

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Now we look at current sources in parallel. So, let say we have these two terminals and I have a number of current sources I_1, I_2, I_3 and so on all the way to let say I_N ; I have N current sources in parallel. So, the same voltage appears across all of them, but that is not relevant, because voltage across the current source has no influence on current through it and trivial application of Kirchhoff's current law shows that the current flowing here is I_1 plus I_2 plus I_3 all the way to I_N . So, parallel connection of current sources is equivalent to a single current source I_x whose value is sum of individual current sources. So, this is the counter part of voltage sources in series.

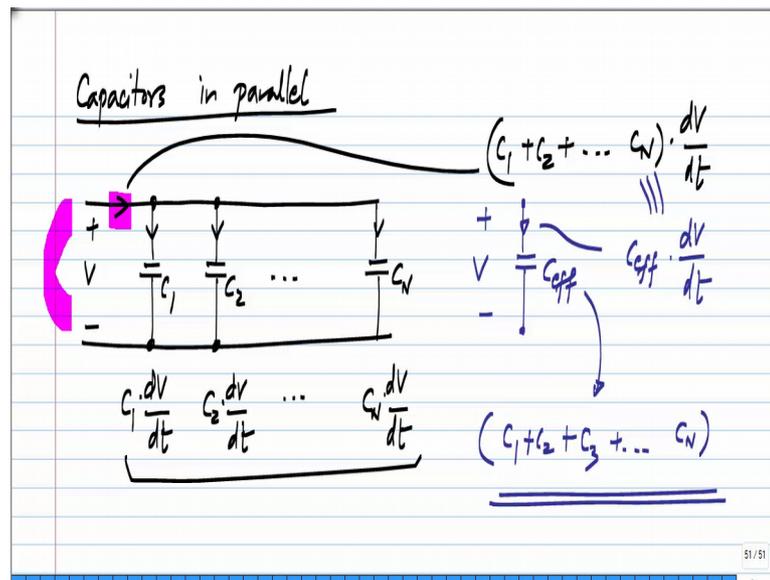
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Now, I consider resistors in parallel. So, again we have two terminals across which let say we have voltage V , and we have a number of resistors R_1, R_2 all the way to R_N . Now the current through each of them is given by ohms law; and for this particular case, it is more convenient to use the conductance form, I will write this current as G_1 times V , where G_1 is the conductance, this current as G_2 times V and so on. And finally, this is G_N times V . And the current here is; obviously, the sum of all of these, which is G_1 plus G_2 all the way to G_N times V . So, this is the current I is some number times the voltage. So, you see that this is the same relationship that would exist in a single resistor; this proportionality would be the conductance of that single resistor. So, because of this proportional relationship between I and V , we know that parallel combination resistors also behaves exactly like a resistors, whose effective conductance is given by G_1 plus G_2 all the way to G_N .

So, I if call this terminals n_1 and n_2 between n_1 and n_2 , it looks like a resistor, and you can calculate the conductance like this. If you prepare to use the resistance form, the reciprocal of the effective resistance is given by sum of reciprocals of individual resistances. This is the form that is probably familiar to all of you, but many times it is easier to use conductance in analysis than resistances.

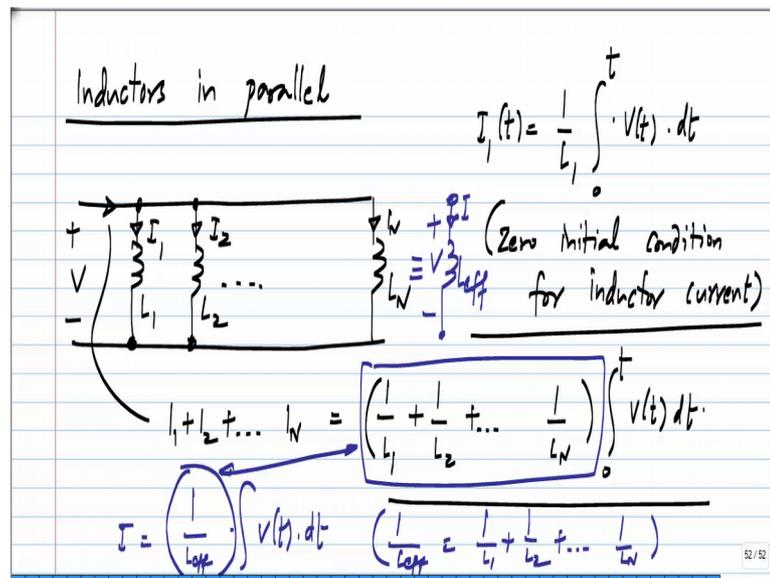
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Now, we consider capacitors in parallel. So, you have two terminals across, which we have voltage V , and we have C_1, C_2 all the way to C_N . And we can write the expression for the currents and individual capacitors, we know that the current through capacitors C_1 in that direction is C_1 times derivative of V , current through capacitors C_N in that direction is C_N times derivative of V . I did not say explicitly by now I think you are used to the idea that when you have parallel connection of capacitors voltage across all of them to the same and is equal to V . And finally, the current through this is C_N times derivative of V . So, the total current coming out of here is the sum of all of these things which is simply the sum of capacitors times the time derivative of V .

Again you see that the relationship between the voltage here, and current there, looks exactly like that of a capacitor that is if you had some capacitor C_{eff} and voltage V across it current through would be C_{eff} times derivative of V . We see that these two are the same form; clearly it is saying that the effective value of capacitance is C_1 plus C_2 plus C_3 and so on. So, parallel combination of capacitors acts like a single capacitor, whose value is the sum of individual capacitors.

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Now, we consider a number of a inductors in parallel L_1, L_2, L_N , and all of them has same voltage V across them. I will mark the current I_1, I_2, I_N . Now we know from previous discussion that the current I_1 and time t equals $1/L_1$ integral 0 to t of voltage across inductor. And this is assuming zero initial condition for the inductor current. So, the total current which is I_1 plus I_2 plus I_N equals $1/L_1$ plus $1/L_2$ all the way to $1/L_N$ integral of 0 to t V of t dt . So, now we see that this is exactly the same relationship we would had; if we had a inductor, whose values equal $L_{\text{effective}}$ then voltage and the current would be related by I equals $1/L_{\text{effective}}$ integral of V over time. So, clearly the reciprocal of effective inductance equals the sum of reciprocals of individual inductance $1/L_{\text{effective}}$ equals $1/L_1$ plus $1/L_2$ plus $1/L_n$. And this is similar to having resistors in parallel; if you write out the expression in terms of resistors, we saw that we got a similar form.