Fundamentals of Electrical Engineering
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 06
Basic Laws (Contd.)

So, we will be we are back again, right.

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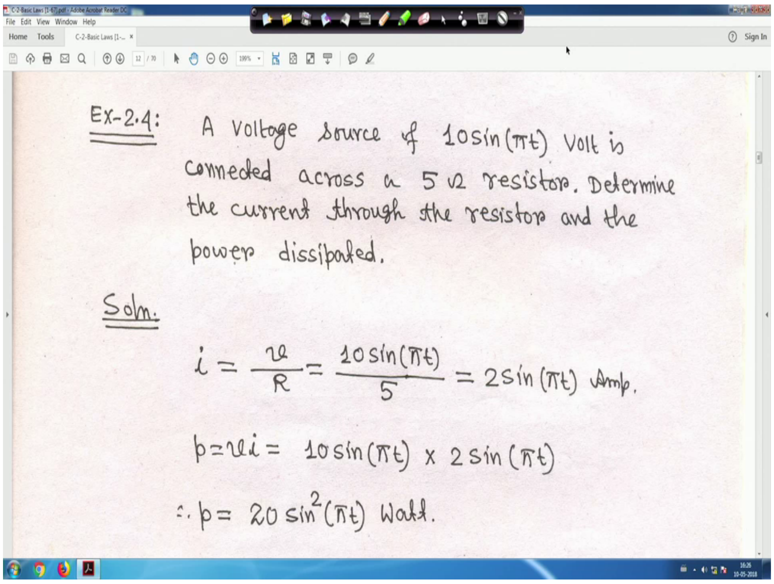

So, particularly now next example we will take it is a, if you see that it is a a voltage source of 10 sin pi t volt, right. Now this time varying voltage for current function, we will see in the your AC ac circuit analysis single phase and 3 phase, but just you just to you know give a some kind of ideas where it write. So, 100 sin pi t, sorry 10 sin pi t volt is connected across a 5-ohm resistor. We have to determine the current through the resistor and the power dissipated.

So, we know i is equal to v by R. So, voltage is given 10 sin pi by t. So, and R is 5 ohm it is given R is 5 ohm it is given, right? So, that is actually 2 sin pi by t ampere it is time function. So, and power is equal to v into i. So, it will be voltage is 10 sin pi t into 2 sin pi t. So, ultimately p is equal to 2 sin square pi t, what is a time function? But in the case of a single phases circuit or 3 phases circuit when we will go for AC circuit analysis at that time we will see this one, right?

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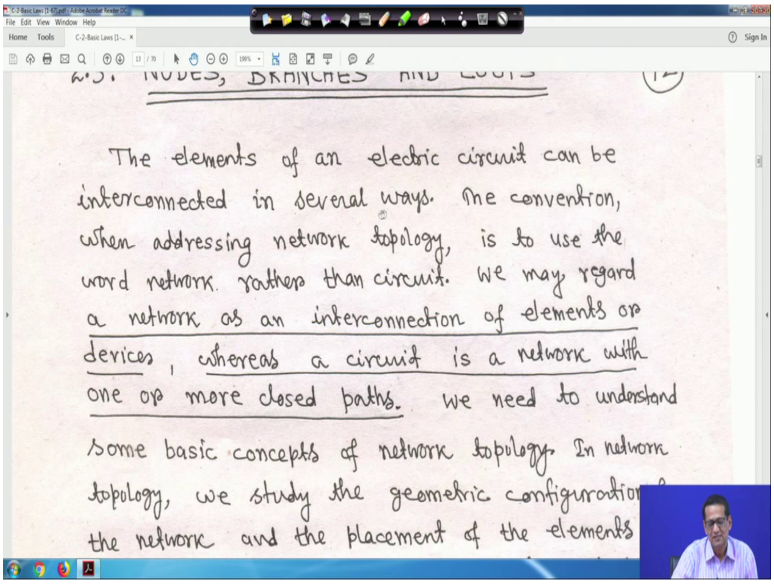

So, next is that nodes branches and the loops, right? This 3 things now we have to try to understand little bit. So, the elements of an electric circuit can be interconnected in several ways. Because we have electrical ele circuit there are may be elements or devices, the convention when an addressing network topology is to use the word network rather than the circuit. So, we may regard a network as an interconnection of elements or devices. Whereas, a circuit is a network with one or more closed path, that I have underlined for you, right?

So, we need to understand some basic concept of network topology. In network topology, we have to study the geo geometric configuration of the network and the placement of the elements in the network. So, these elements include branches nodes and loops.

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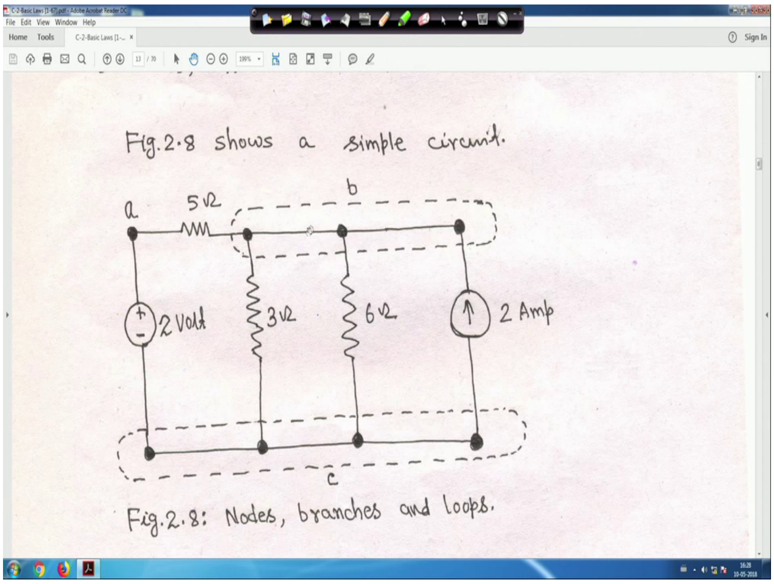

Now, suppose for the purpose of explanation, suppose this is a figure to that is nodes branches and loops we have to find out. Now look all, right of is there, but just see that how thing are. So, if you if you look at this diagram that this one we are what just let me, let me mark it.

So, this one, this point, this point and your this point, these are all 3 points they are connected, you are what you call by wire. So, wire has neglectable negligible resistance, but there is no element electrical element in between these points, right?

So, how to many elements are there? 1 2-volt source, then 5-ohm resistor, 3-ohm resistor 6-ohm resistor and 2 ampere current source. So, there are 5 elements, right electrical elements in this circuit. So, and here also these are all connection of wire and wire has negligible resistance. So, in that case what we can do is that how many branches and you are what you nodes branches and loops are there.

So, gen generally any electrical element it is connected across 2 points or 2 nodes, right. We will come to that across 2 terminal, so that means that is a branch; that means, this voltage is also connected across 2 terminal. So, it is a branch, this 5-ohm register also connected across here and it is a branch. Similarly, 3 ohm also connected across these 2 it is a branch. So, 6 ohm also connected across the terminal it is a branch, and the current source also connected across this it is a branch, right?

So, in this; that means, and this all these 3 nodes this is this all these 3 point they are connected, because what you are call by wire and this 4 4 points, 1, 2, 3, 4 this 4 points also connected by wire, right. So, this can be clubbed together because wire has negligible resistance. So, these 3 point can be clubbed together and these your all 4 points can be clubbed together.

So, that means, node should be here, this is one node a, this all these 3 if you clubbed together it will be that is why it is your, I brought them inside the your dashed your dashed portion this thing this 1, 2, 3. And here also I have your encircle them that all the 4 points together.

So, that means, this is a node one node if you clubbed together all these 3 it will be another node, and if you club all these 4 together it will be another node. So, there will be 3 node so, there will be 3 nodes; that means, your equivalent one if you see this, just hold on, right. If you if you see this equivalent one.

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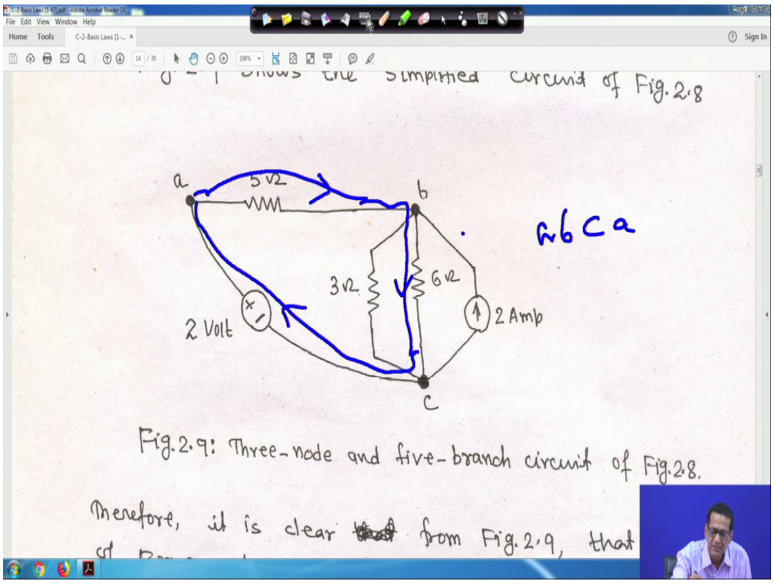

So, this is my equivalent one. Because all the all these 3 nodes clubbed together, all these 3 nodes this all point clubbed together, this 4 also clubbed together because there are wire only. So, finally, it is equivalent one is your what you call this abc there are 3 nodes and 5 branches one voltage source this 5-ohm resistor, this is 3-ohm resistor, this is 6-ohm resistor and this is 2 ampere your current source, right?

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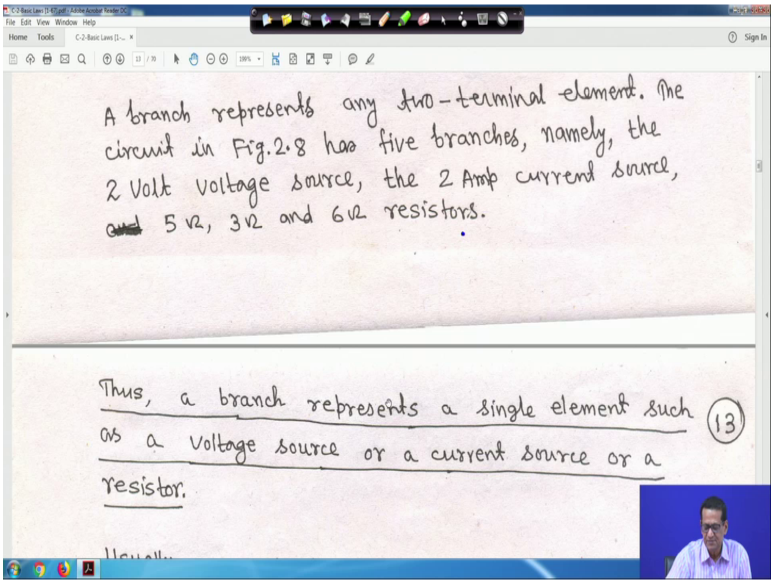

So, therefore, generally your what you call the branch represent a single element that I told you such that voltage source or a current source or a resistor for that in the in the case of this your what you call that DC circuit, right?

So, usudally usually a node is indicated by dot in a circuit, that is your this all dot is indicated your why by this thing, node is indicated by dot, right?

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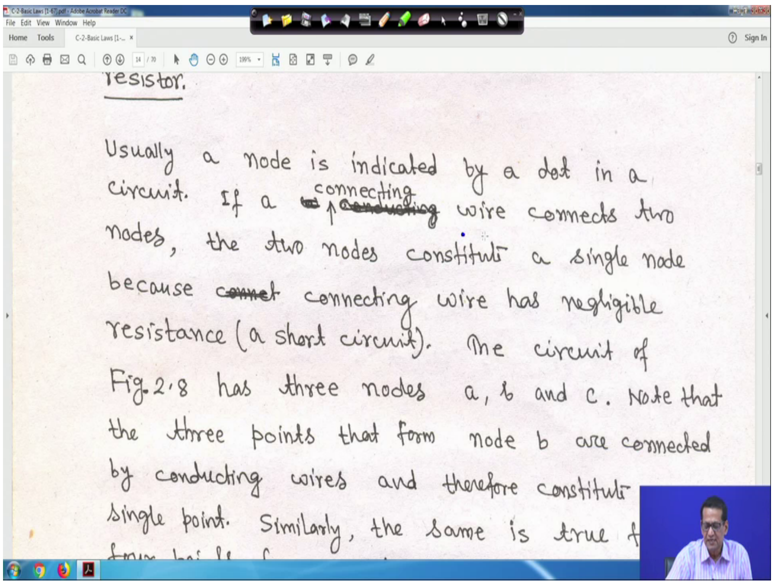

So, so, if a connecting wire that is I told you connects 2 nodes, the 2 nodes constitute a single node because wire has negligible resistance. That is why this has been clubbed together, and all these things have been clubbed together, right?

So, it's so, therefore, we have 3 nodes in the circuit therefore, we have 1, 2, 3 nodes in the circuit and you have 1 2 3 4 5 branches, right. So, this your what you call. So, figure 9 shows the simple this is figure 9.

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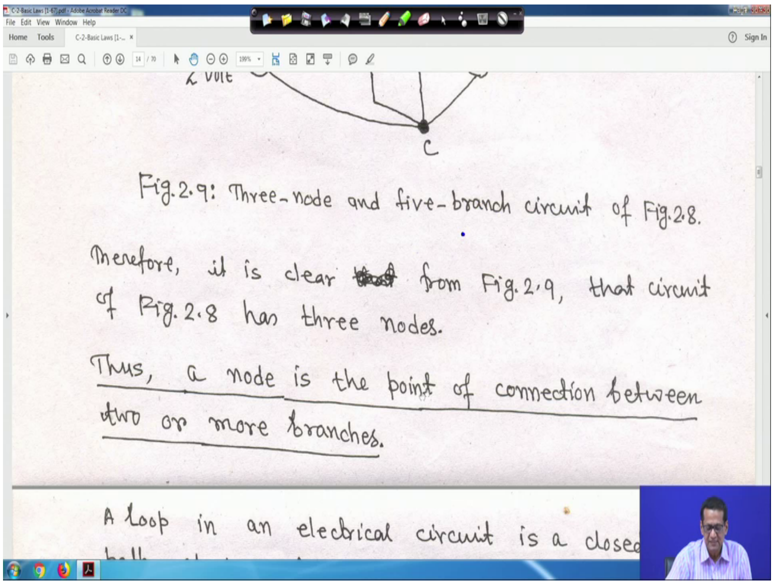

So now question is that means, a node is the point of connections between 2 or more branches. So, if you take this is a node say node b, it is at least 2 or more branches connected here if you take point a 2 at least 2 branches are connected. And if you take here that more than at least 2 or more branches are connected, right? That is that it that is called a node, right. Therefore, a node is the point of connection between 2 or more branches.

Now, now a loop, in the electrical circuit because explacing the ex your before telling this is a loop means. Suppose if you start from here, start from this a point a say, if I take, suppose I am starting from this point a. So, if I move like this, if I move like this and if I move like this a to b say 6-ohm resistor and if I move like this and coming back to a.

So, a b c a so, abca this is a loop, right? If I move like this suppose I moving like this clockwise or anticlockwise? Say I am moving clockwise I am moving clockwise. So, in this case abca it is a loop, right?

So, question is that you have to find out the independent loop. Now what is just 1 minute, let me clear it, right. So, question is that you have to sub if you try to find out that how many how many loops are there in this particular circuit the figure 2.9. This means you will find 6 loops, but 3 of them are independent loop. Now question is that what is your independent loop, right?

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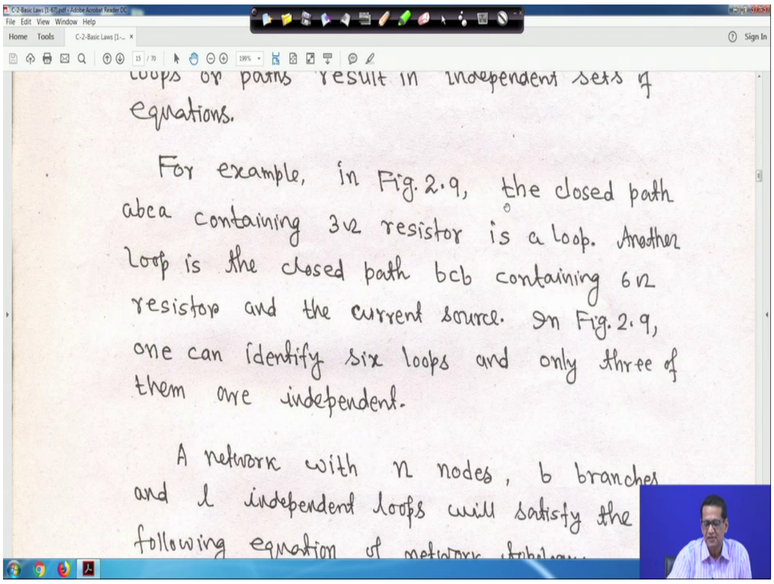

So, that I told you that your what you call that closed path containing 3-ohm resistor is a loop, right abca. Similarly, here you we you can get another you can get another loop, you can get another you are just hold on you can get another loop suppose this is the if you move like this, move like this, move like this and come back here, right? I am moving like this I am coming back like this.

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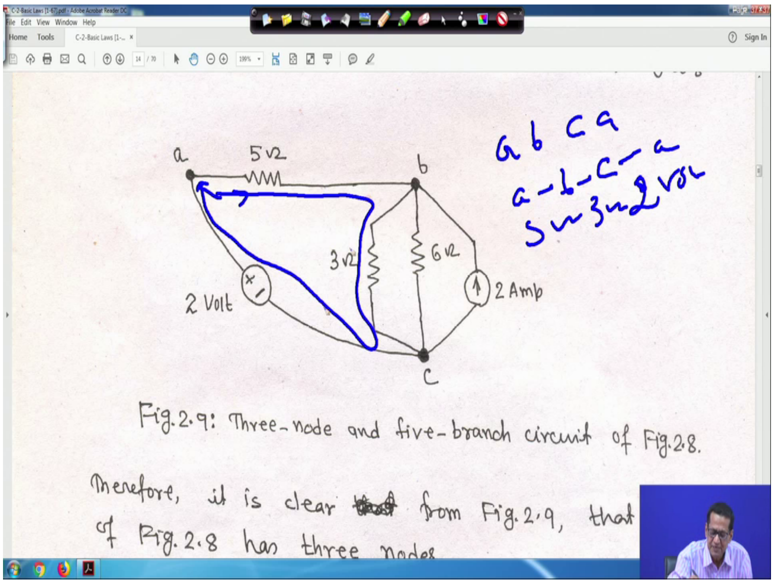

So, this is another loop, it is also this is also a b c a, but you have a to b you have your 5-ohm resistor is there, then b 2 c I mean a I am taking this 3-ohm resistance, then b to c you have 3-ohm resistance, they are going to c to a that is your c to a, that is your 2 volt source, right. So, 5 ohm 3 ohm and 2 volt, this is also this is also a loop, this is also a loop.

So, this way you will find just one let me clay let me clear it, right? So, this way in this circuit you may find there are your what you call 6 such loops, but only 3 loops are independent. Just hold on, right

So, all so, question is that that a loop is said to be independent just I am underlining for you.

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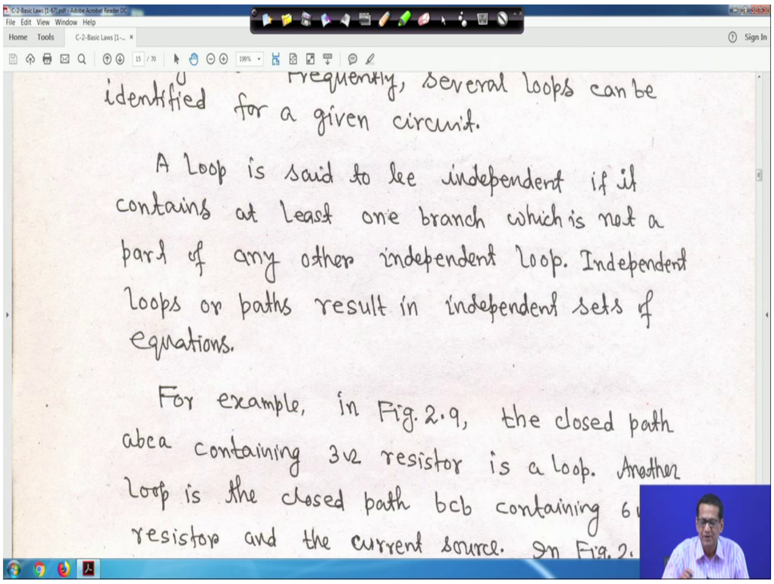

A loop is said to be independent if it content at least one branch which is not a part of any other independent loop; that means, this a loop is said to be independent, right. If it contains at least one branch will be there which is not a part of any other independent your other independent loop at least one branch should be there, which cannot be part of the other independent loop although you will get 6 loops, but only 3 loops will be independent.

So, in this circuit, your just a minute. So, let me clean let me let me clean this one, right? So, in this circuit just hold on; so, in this circuit that I can mark 2 independent loop one is abca that is 5 ohm, 6 ohm and your 2 volt. So, this is one independent loop. Another one I can say abca that is 5 ohm 2 ampere current source and 2 volt.

So, these 2 independent loops I am telling, but one more is there although 6 we will get, that third one is an exercise for you. So, one independent loop I am telling say ab say this one abca. For example, ay 5 ohm, 3 ohm and 2 volt, right. I am I am making it for you, just hold on, right.

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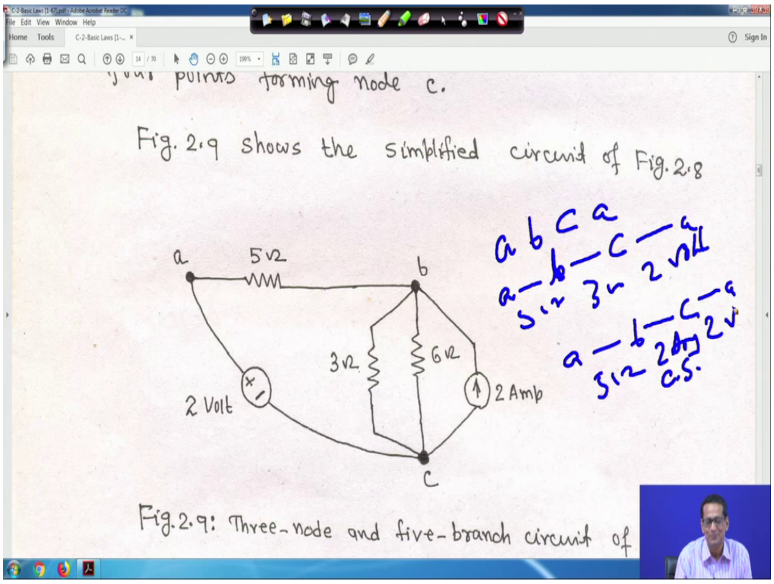

One is say a b c a; that is a to b, if you take a to b a to b this is 5-ohm resistance, then you can take b to c this part, 3-ohm resistance and c to a, this is your 2 volt, right? This is this is one your what you call that one independent loop, another one I can take again abca say a to b; that is 5 ohm, then b to your what you call b to c, there are 2 ampere v current source, right. And then c to a again your what you call there are 2 volt.

So, if you look into that you will find that at least one branch is your what you call not common to others, but one more is there, one more independent loop is there. So, it is an exercise for you to find it out, right. So, let me clean it, right so,; that means, in general. So, here also everything is written the 2 independent loop I have mention here, right? But third one you have to find out, very simple it is slowly you will know, right.

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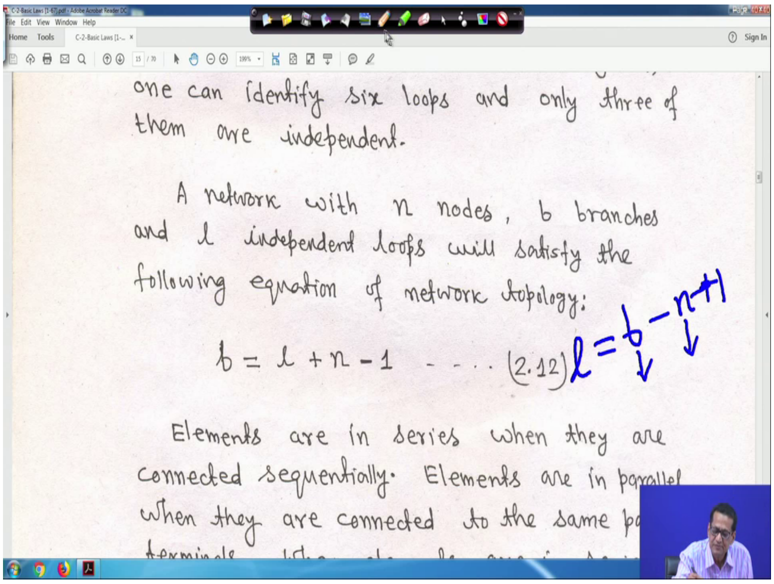

So now in a network, if you have n number of nodes, if you have n number of nodes, and l number of your what you call independent loop and b number of branches, the relationship branch is equal to l plus n minus 1, right? So, this relationship b will be l plus n minus 1; that means, other way if i right here that l is equal to that is your independent loop is equal to it will be b minus n plus from this equation, only from this equation only l is equal to your b minus n plus 1, right?.

This is plus 1, right; that means, if you know the number of branches suppose b is known, then your number of branches are known, then if you if you know the number of nodes, then you can easily find out how many your will be your independent loop.

So, let me clean it, right. So, this is equation 12, it is actually topic 2 chapter 2 so, it is 12 right.

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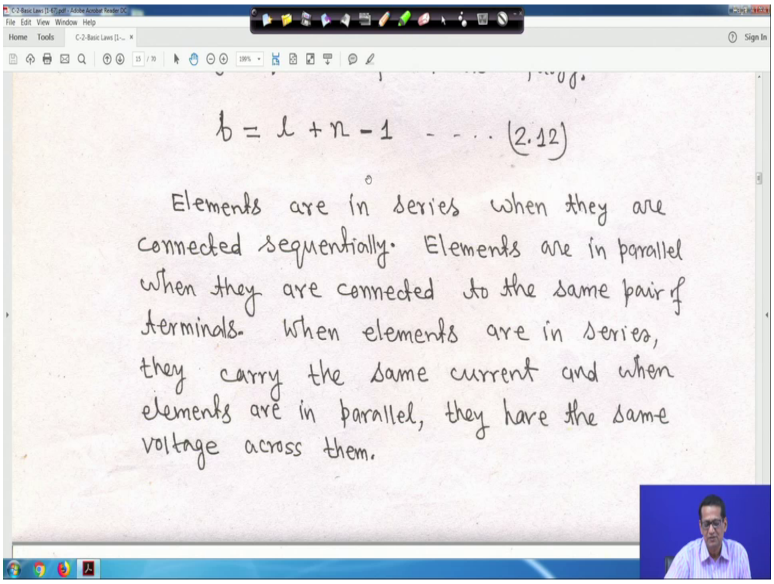

So,; that means, easily you can find out, that your what you call that everything is written here, right. All this things and when elements are connected sequentially; so, there will be series, and when there when I mean when you will say that when that elements are in series means through all the elements that all same current is flowing and when it is in parallel means it is across 2 terminal; that means, across 2 elements the voltage will remain same. So, this is the your what you call this relationship b is equal to l plus n minus 1.

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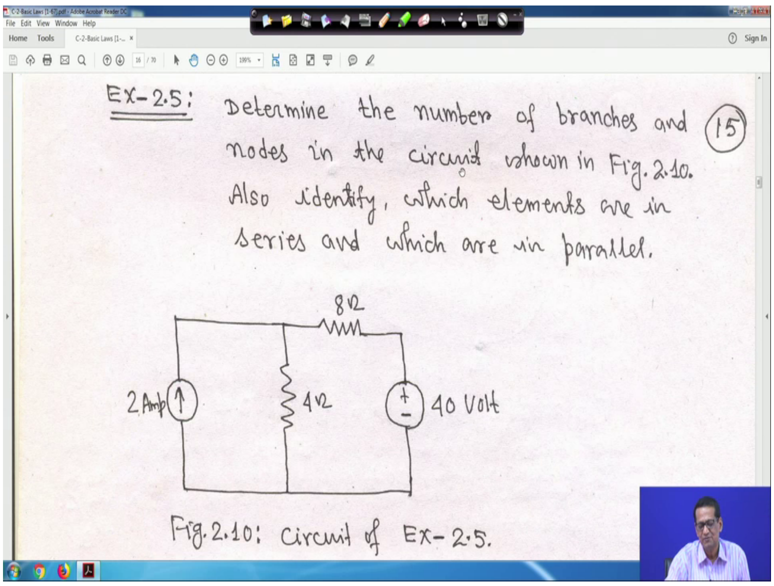

So, for example, so, determine here this is a circuit is given you have to find out that number of branches, and nodes in the circuits shown in figure 2.10, right? And also identify which elements are in series and which are in parallel. So, question is that if you this is a simple problem, you have to find out that your number of your what you call branches and nodes in the circuit, and which elements are in series and which elements are in parallel.

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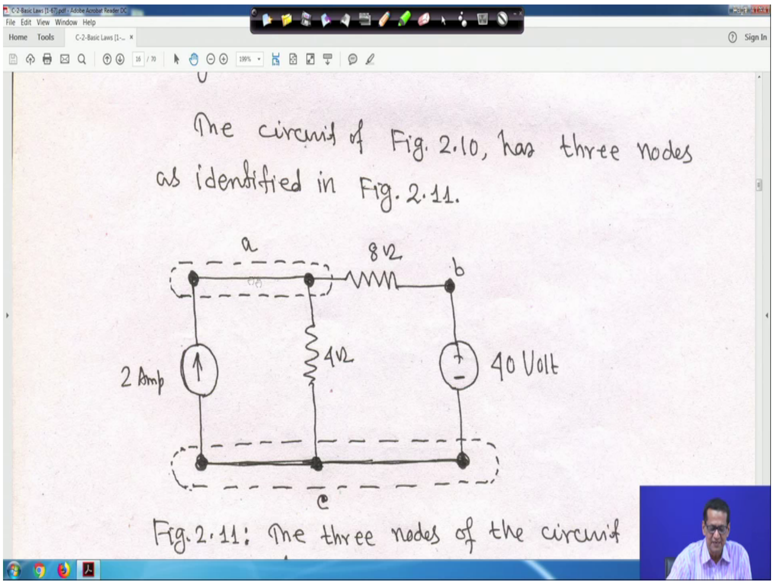

So, if you look into that this part this 3 things, I mean I will go to that that this is actually connected by wire, I mean this 2 point connected by wire. So, nodes we are marking is a by dots. So, this is this is your this is basically a 1 node because it is wire only. So, it clubbed together, and similarly here also 3 points we are marking.

So, they are clubbed together right so, this is a node and this is another one that is your b node, right. This is another one because any electrical elements your connected across 2 point your across 2 terminal means this is a branch. So, this is a branch, and from this means clubbed together. So, a from this b, a to b is another branch because it is a single point, and similarly here to here it is another branch, because it is a to c because all this is a common point. So, a to c, and similarly a to c another 2 ampere current source is there.

So, if you come to the equivalent circuit. So, in clubbed together, then this point is a this is clubbed together. So, this point it is understandable then this 3 points are clubbed together, because they are simple wire only right. So, they are negligible resistance so, we do not consider them in the circuit analysis we neglect them. So, all this things are clubbed together.

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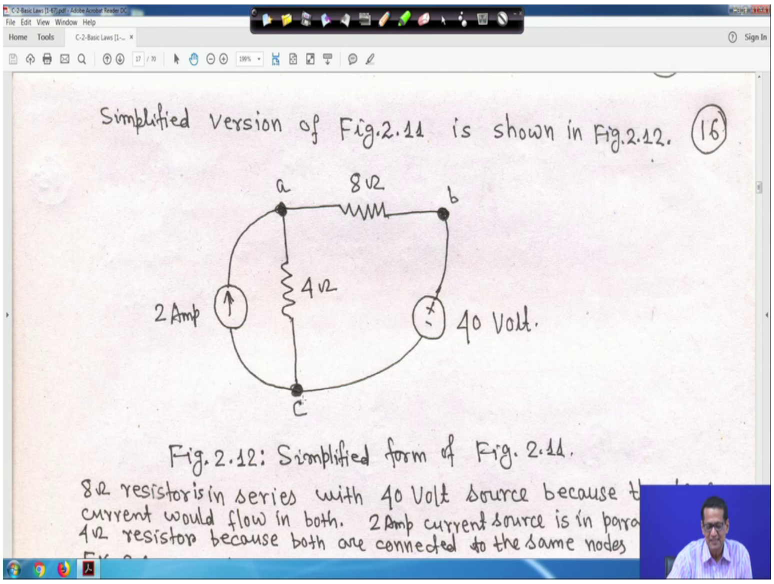

That means this is a point c, and finally, this is a equivalent circuit I mean what exactly we want so, there are there nodes abc. And how many branches are there 1 2 this is a current source, it is connected across a terminal ac, a forum resistance also connected across your ac, right. And 8 ohm resistors connected across ab and this 4 40 volt your voltage source is connected across bc. So, there are 2 ampere source 4 ampere resistor 8 ampere resistor, and 40 volt that voltage source.

There these are the 4 elements and 3 nodes. And series with parallel this current source connected across ab 4 ohm resistor also connected across ab; that means, they are in parallel and this 8 ohm, 8 ohm resistance and this voltage they are connected in series; that means, across ab voltage will remain across ab that 4 across 4 ohm resistance whatever may be the voltage across 2 ampere current source will be the same voltage because that connected across the same terminal so, they are in parallel. And this is same current will flow through 8 ohm as well as 40-volt source, because it is a it is a 48 ohm and 40 volt are in series, this is the idea.

So, from this problem so, from this problem, you first you mark it like this, right. Ah I mean negli we are neglecting wire so, wire resistance cannot be consider in circuit analysis. So, it clubbed together clubbed together, finally, circuit will be like that, and it will easy it will be easy for you to solve the circuit, right?

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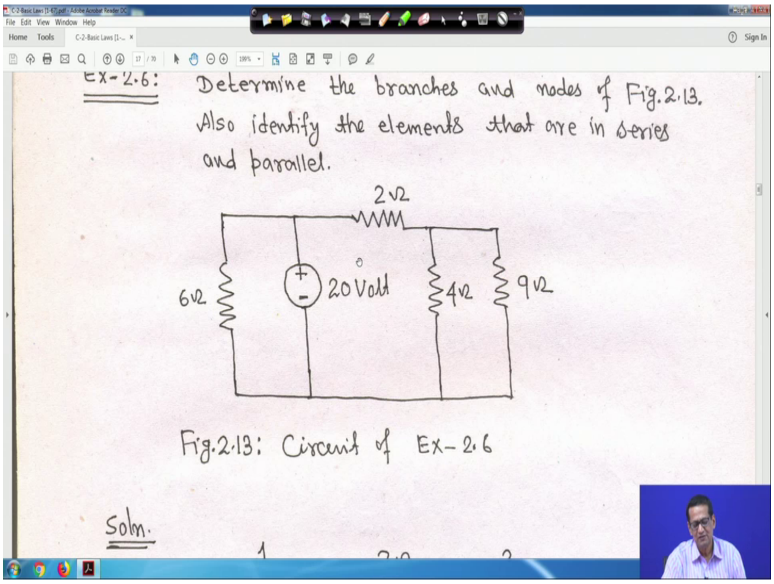

So, this another problem we will take, this is say example 6. So, here also this is another circuit, say determine the branches and nodes of this figure 13, right. For example, to you also identify the element that are in serial or in parallel. So, here also if you look that this point and this point this is wire only. So, and your this can be clubbed together, here also it is wire only this can be clubbed together, right. I mean I mean here it is shown, look this is wire only it can be clubbed together.

So, here and here these 2 points clubbed together. So, mark it by point only node so, this is a node one. And similarly here also if you see this point also can be your these 2 point clubbed together. So, it is also in circle these 2 point clubbed together, and these are all wires 1, 2, 3, 4 this 4 points are clubbed together. This 4 points are clubbed together, right then it will be easy for you to solve the circuit.

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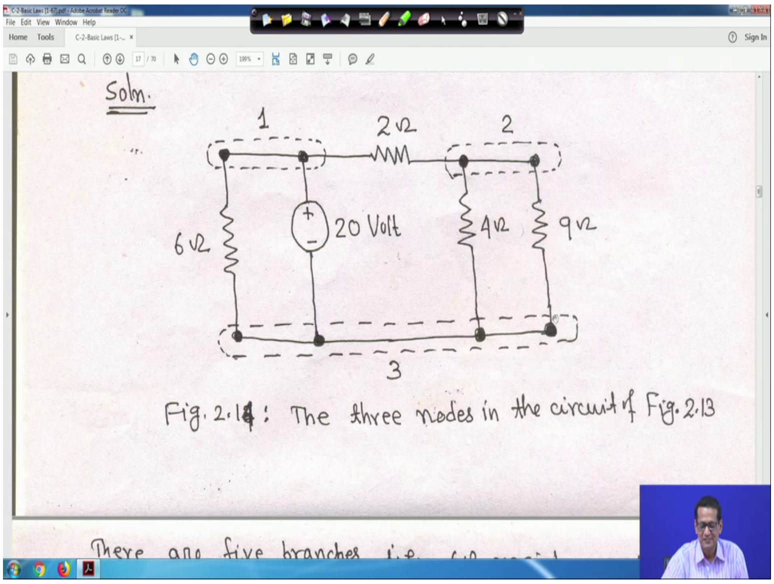

So, in this case what will happen? So, everything is written here everything is written here. So, you have 6 ohm how many electrical branches are there? 6-ohm then 20 volt then 2-ohm resistor then 4-ohm resistor and 9 ohm all together, you have 1 2 1, 2, 3, 4, 5 you have 5 branches, you have 5 branches.

So, all these things are written here and how many nodes are there? This if you clubbed together it is one node if you clubbed together node 2 if you club all these together node 3, right. So, this is all together 3 nodes and 5 braches. So, not simplified further here the way, I the way we have made it you can also now make like the previous example circuit you can make this one also, right?

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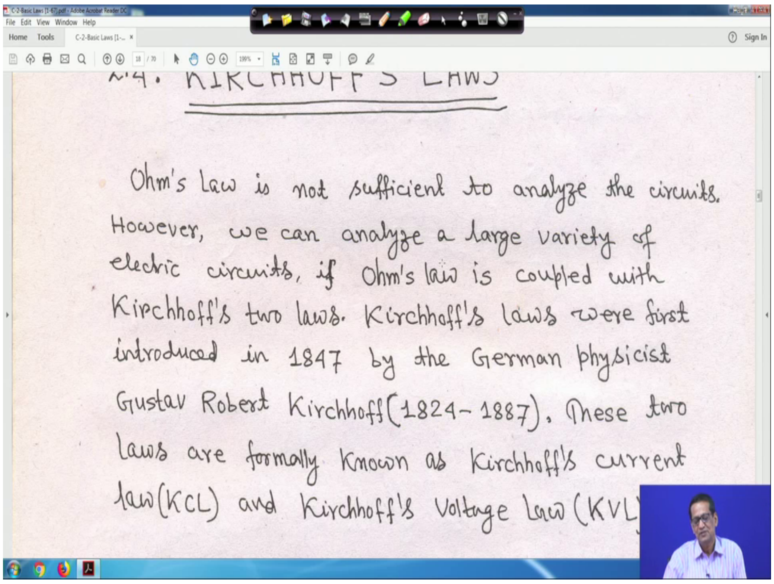

So, next ah so, this is very simple thing this is a understandable for you. Now next is that your what you call Kirchhoff's laws]. Actually he was a germen and a generalist in the pronunciation, whatever I have understood from the people who actually in a this thing. So, actually this c should remain silent in pronunciation, it will be Kirchhoff's laws right. So, c should remain silent. So, anyway so, ohms law actually now we will come to the Kirchhoff's law, there are 2 laws first law and second law, right?

Now, ohms law actually is not sufficient to analyze the circuit; however, we can analyze a large verity of electric circuits if ohms law is coupled with Kirchhoff's 2 laws, right? So, actually Kirchhoff's laws are first introduced in 1847, right? By the germen physician Gustav Robert Kirchhoff live span was 1800 24 to 8 1887. So, these 2 laws are 5 actually formally known as Kirchhoff's current law that is KCL, and Kirchhoff's voltage law that is your KVL. So, Kirchhoff's first law is based on the law of conservation of charge, right?

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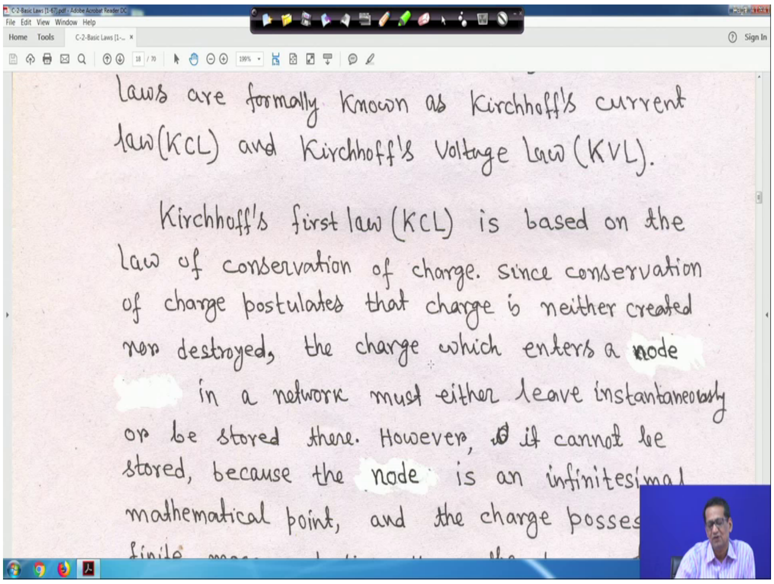

So, this is very simple thing, since I am underline I am let me underline for you, right? Base it is basically it is a conservation of charge. So, since conservations of charge postulate that earlier also we have discuss about this, that the charge is neither created it is neither created nor destroyed. The charge which enters a node charge which enters a node in a network must either leave instantaneously or be stored there, right?

But, however, it cannot be stored because the node is an infinitesimal mathematical point. Because the node is an infinitesimal your mathematical point, right? And the just hold on let me let me d clean this one, right.

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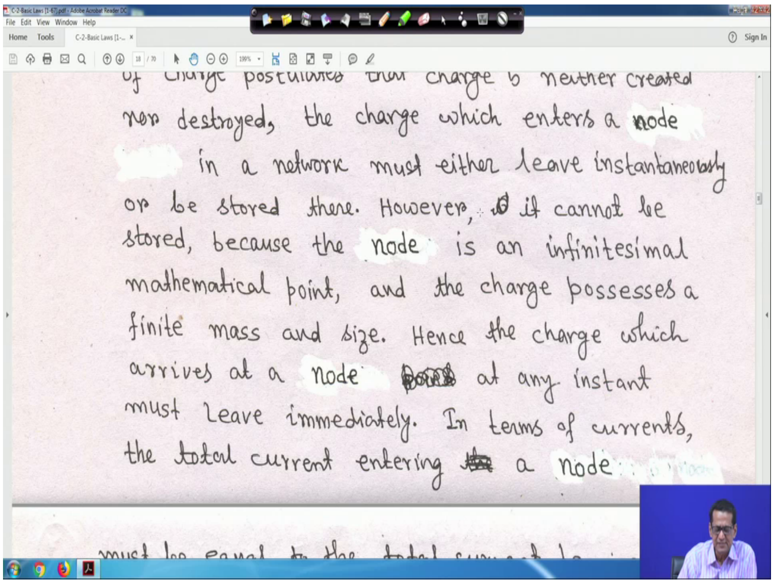

So, charge actually possess a finite mass and size. So, hence the charge which arrives at a node, at any instant must leave immediately, because node actually mathematical point is I mean infinitesimal small very, very small point, right? And there are charge actually possesses a finite mass and size in the charge which arrive at ay node at any instant must leave immediately, right?

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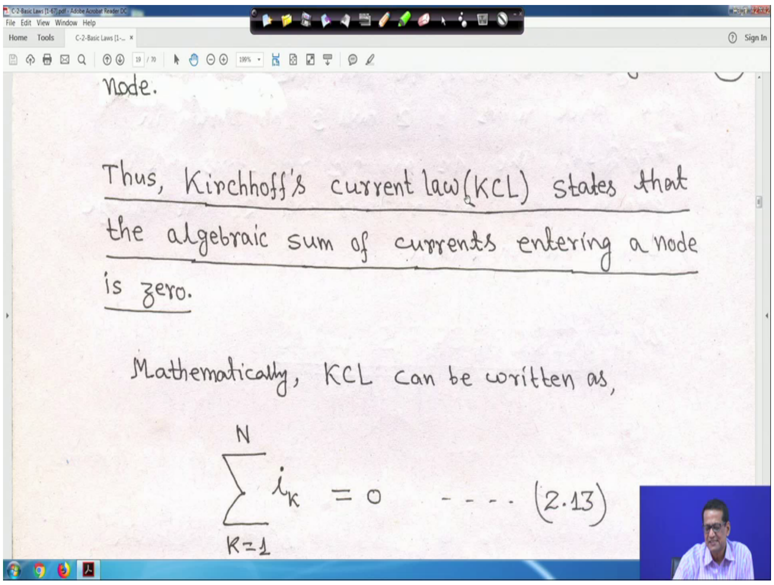

So, in terms of your currents, the total current entering a node must be equal to the total current leaving the node. So, Kirchhoff's first law is coming from the your what you call that your conservation of charge. So, for example, therefore, the KCL that is Kirchhoff's current law states that the algebraic sum of currents entering in a node is equal to 0.

So, mathematically the KCL can be written as say sigma k is equal to 1 to n ik is equal to 0 this is equation 13 this is mathematical. Where n is the number of branches connected to the node, and ik is the kth current entering or leaving the node. Suppose you have you have what particular node suppose there are 5 branches are connected.

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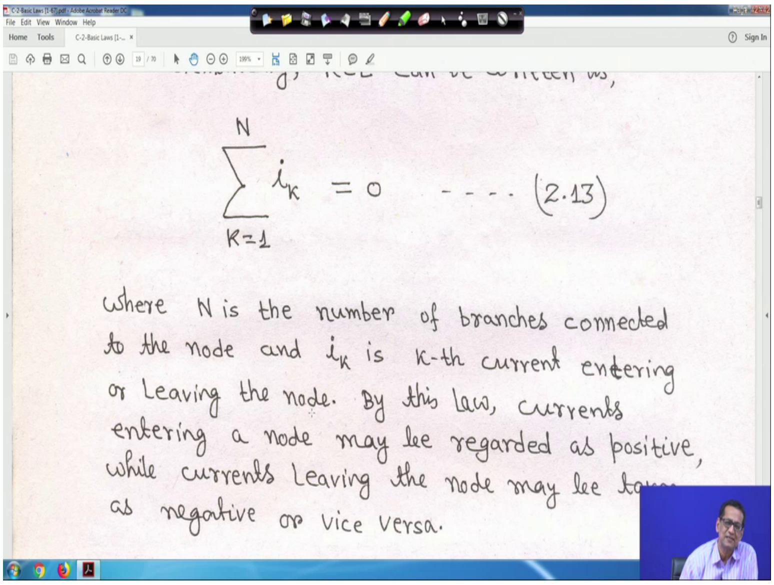

So, current entering or leaving a node the algebraic sum is equal to 0

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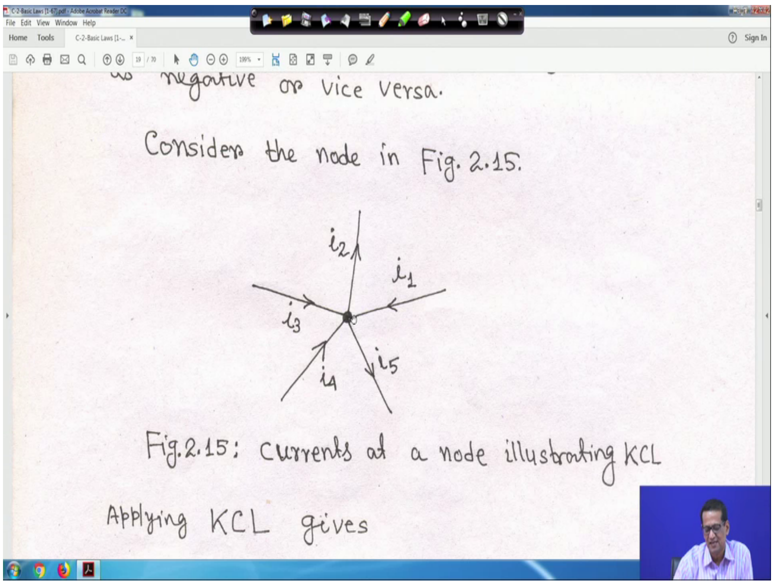

So, for example, if you take this if you take this your what you call this diagram. So, in this case only one node is there if you see how many incoming current. Look i 3 and i 4 are i 1 i 1 i 3 i 4 this is incoming current, and i 2 and i 5 are outgoing current.

Therefore, if you apply KCL this the KCL at this node, that is Kirchhoff's first law current law, if you apply at this point then applying KCL it gives a because algebraic sum, your what you call of the current meeting at this node is 0, right. Therefore, if you apply say see if you take that i 1 i 3 all incoming current is your positive sign then i 1 then minus i 2 because it is outgoing I 1 minus i 2 it is incoming then plus i 3 it is incoming plus i 4, and it is your it is your outgoing minus i 5 is equal to 0.

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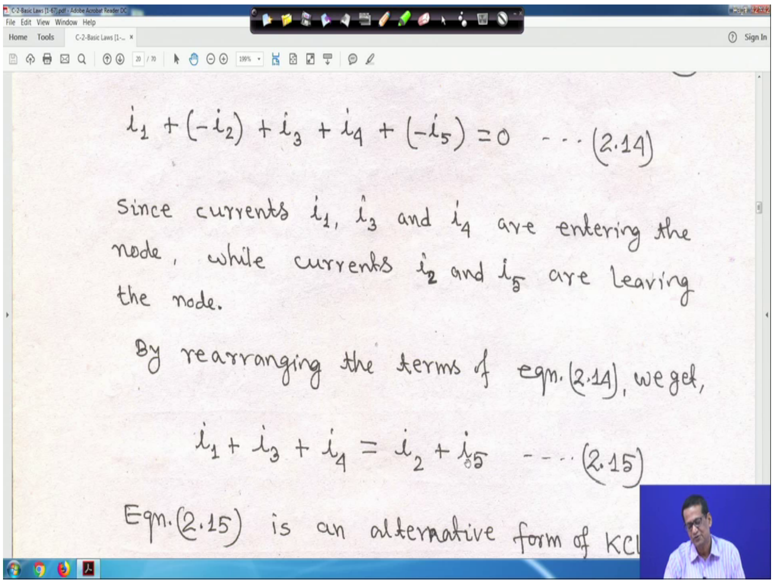

That means if you look i 1 then I am algebraic sum that is why if you plus, then in bracket, I am writing minus i 2 plus i 3 plus i 4. Because these 2 are i 3 and i 4 are incoming current and i 5 is outgoing current. So, plus in bracket minus i 5 is equal to 0.

Since currents i 1 i 3 i 4 are entering the node or while currents i 2 and i 5 are leaving the node. In other way you can write if you rearrange this that incoming current I 1 plus i 3 plus i 4 is equal to outgoing current i 2 plus i 5 this is equation 5; that means, that any node in summation sum of the incoming current is equal to the sum of the outgoing current, that is k your KCL.

Therefore this is an alternative one, but same thing, but it is easiest one right. So, it is clear that sum of the current entering a node is equal to the sum of the current leaving the node, right?

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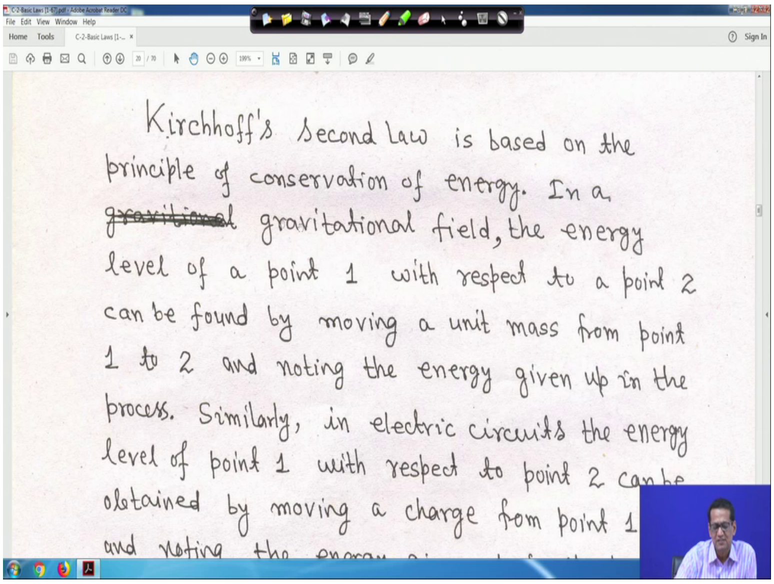

Then Kirchhoff's second law actually is based on the principle of conservation of energy. First one was conservation of charge second one is the principle of conservation of energy.

Suppose in a gravitational field the energy level of a point with respect to point 2 can be found by moving a unit mass from point 1 to 2, and that the energy given up in the process, right. Yes, that is that is from the physics, now similarly in an electric circuit the energy level at of point 1 with respect to point 2, I am just underlining for you, right?

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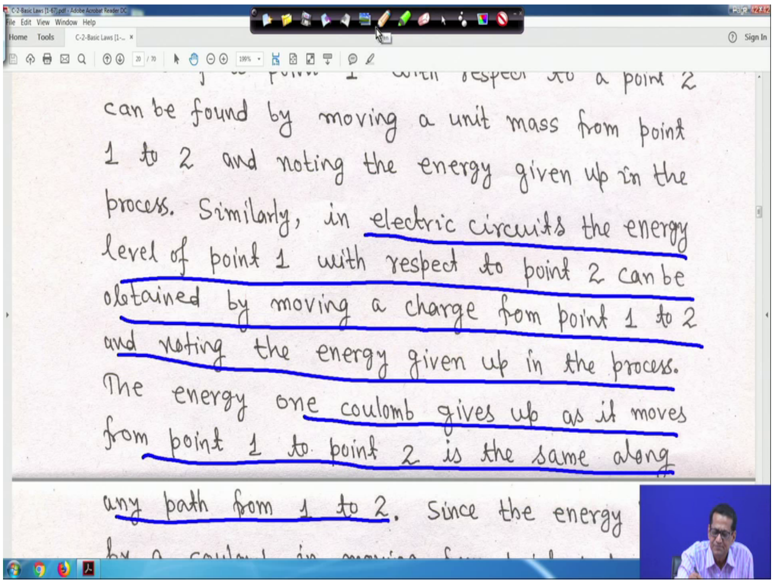

Similarly, in electric circuit the energy level of point 1 with respect to point 2 can be obtained by moving a charge from point 1 to 2, and noting that the energy given up in the process, right. So, the energy one that is energy actually that one due to one coulomb charge gives up as it moves from point 1 to point 2.

That is gives up as it moves from point 1 to point 2 as in the same as the same along any path from the one to 2 it is, whatever we have take, right, so that means, you are take your taking a coulomb charge from point 1 to say I noting that what is the energy given up.

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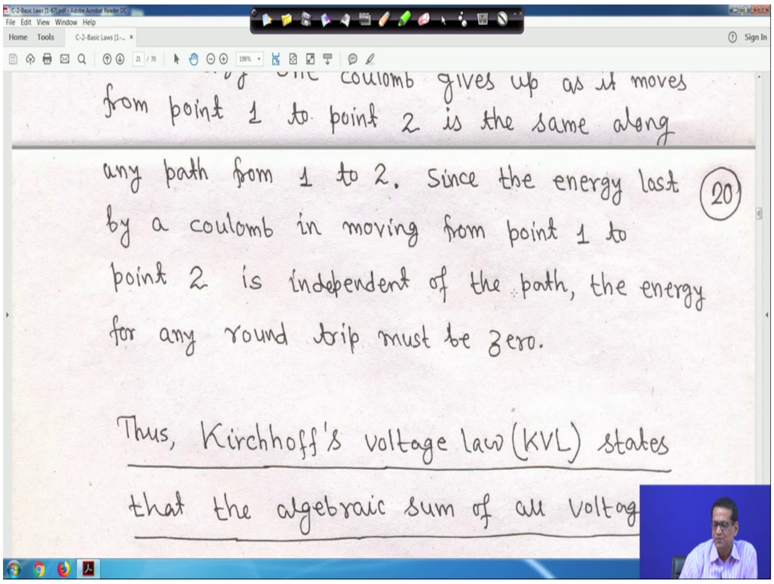

So, let me clean this so, since the energy lost by coulomb charge, right. In moving from again I marking for you, since the energy lost by coulomb in moving from point 1 to point 2 is independent of the path. So, the energy for any round trip must be equal to 0, right. This is actually a problem conservation of energy.

Now, the Kirchhoff's just a minute let me clean it, right? So, just hold on let me let me let me clean it. Therefore, this second law the Kirchhoff's voltage law that is KVL we call states that the algebraic sum of all voltages around a closed path or loop is equal to 0, right.

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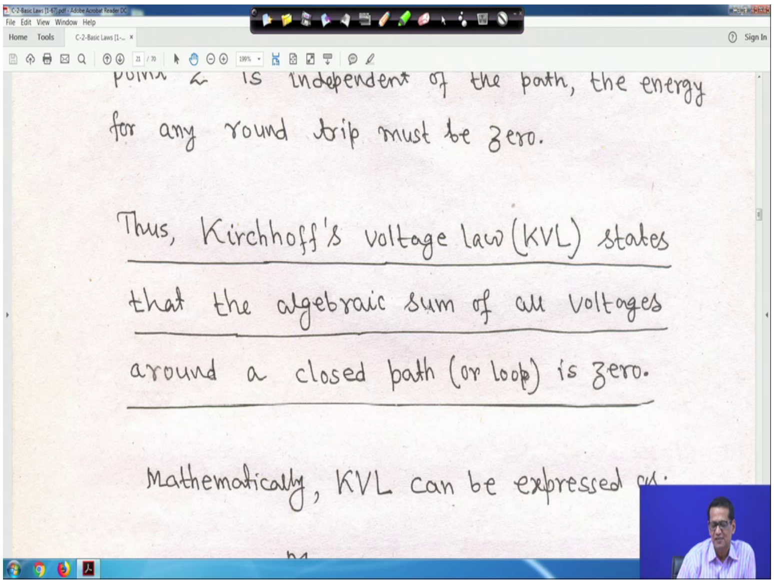

This is KCL first one was first law was KCL, right. And second one is a Kirchhoff's voltage law that is KVL. It is states that the algebraic sum of the voltage around a closed path is equal to 0.

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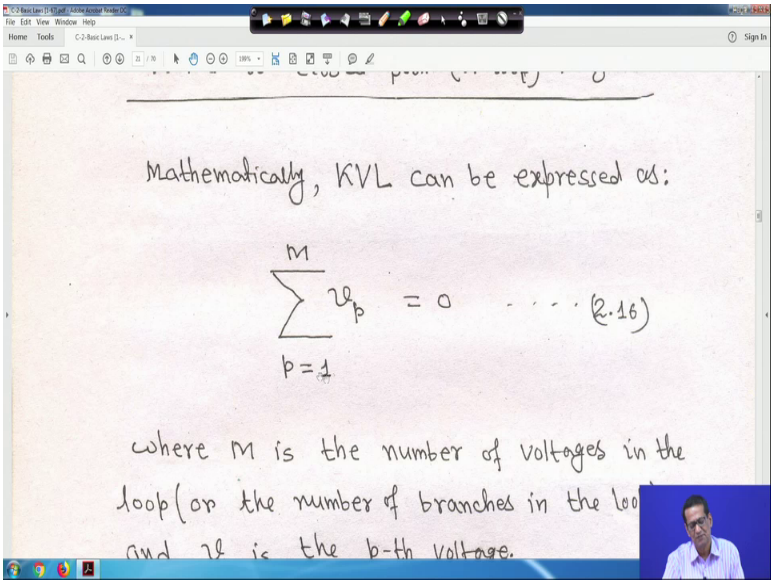

Now, mathematically the KVL can be expressed as a sigma p is equal to 1 to M so, vp is equal to 0. Where m is the number of voltages in the loop later we will know, right. Or the number of branches in the loop, right and vp is the pth voltage.

Now, if you look for the purpose of explanation of the KVL if you look into this circuit.

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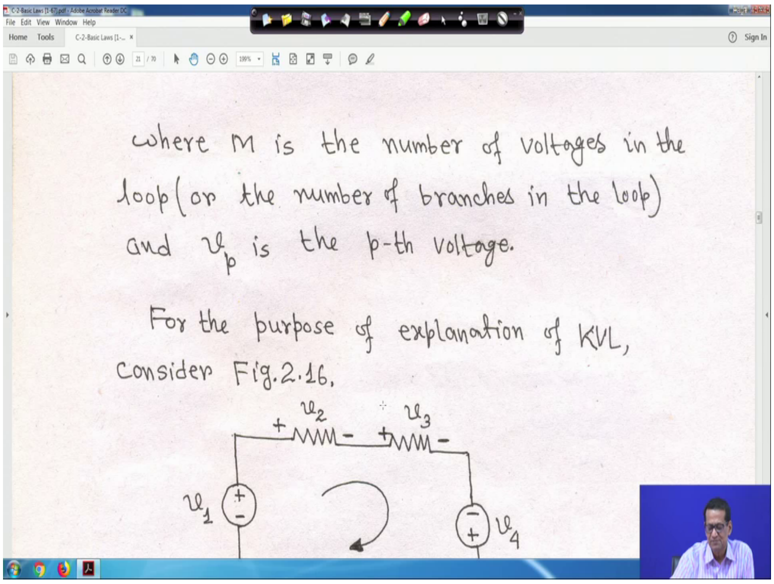

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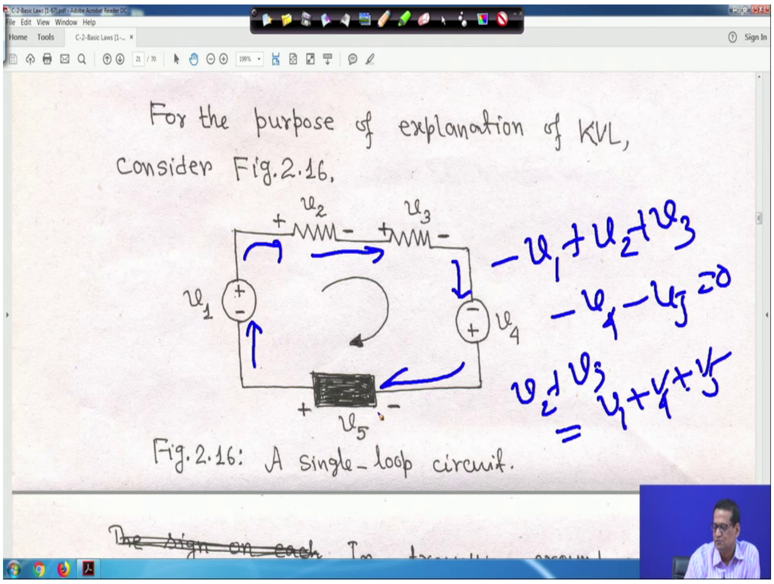

So, here what we will do? We will follow certain convention. So, write up is there, but suppose this is a circuit this is a voltage source which is plus minus, it is a your what you call plus minus polarity is shown, and this resistor also plus minus polarity is shown here also resistor. Plus, minus polarity is shown and this is also v 4 plus minus polarity shown, but we have to follow certain your what you call certain convention.

Now, in this case whenever that your current this we have to follow certain convention. So, arbitrarily we have marked plus minus plus minus whatever voltage. So, polarity you know mark it resistor also arbitrarily you marked it does not matter ultimately when you solve using your ohms law and your Kirchhoff's first law and second law we will get the same solution.

So, in this case arbitrarily you mark then what you do ah? Then what you do when current entering into the positive terminal suppose this current is suppose this is that a current is you have taken the direction in the anticlockwise, sorry clockwise direction and this is the this is, suppose this way you suppose we are moving it or moving it or moving it clockwise, this is actually we are taken that we are moving from the clockwise.

So, as soon as you move from the clockwise we will see which terminal you are first encountering. So, as you are from the clockwise so, first were encountering the negative sign. So, it should be minus v 1, now as we are moving like this clockwise encountering for the plus terminal. We have taken arbitrary say, right so, these things you have plus v 2, then again when you are coming entering with the you are think considering this one. So, these same we are moving clockwise so, encountering the plus terminal first. It will be plus v 3.

Then when your moving clockwise so, encountering the minus sign so, minus v 4, right. And then when you are coming to here clockwise, this way I am shown, but for your understanding I will making the path. So, minus this is actually minus v 5 is equal to 0. So, minus v 1 plus v 2 plus v 3 minus v 4 minus v 5 is equal to 0, otherwise v 2 plus v 3 is equal to your v your v 1 plus v 4 plus v 5, right?.

This is the thing, because we have mark polarity, but you move if you are moving clockwise see first which term which polarity you are encountering first the voltage case if you move like this plus minus. So, minus v 1 here it is plus v 2 encountering plus v 3 minus v 4 then your minus v 5 is equal to 0, right?

So, let me now clean this one, right? So, the same thing I have written here.

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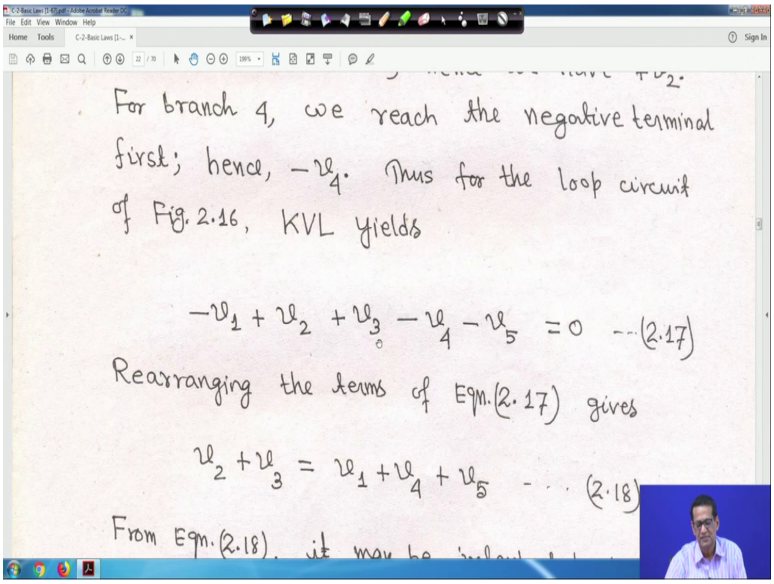

For you all these item is there, but same thing that minus v 1 plus v 2 plus v 3 or whatever written here.

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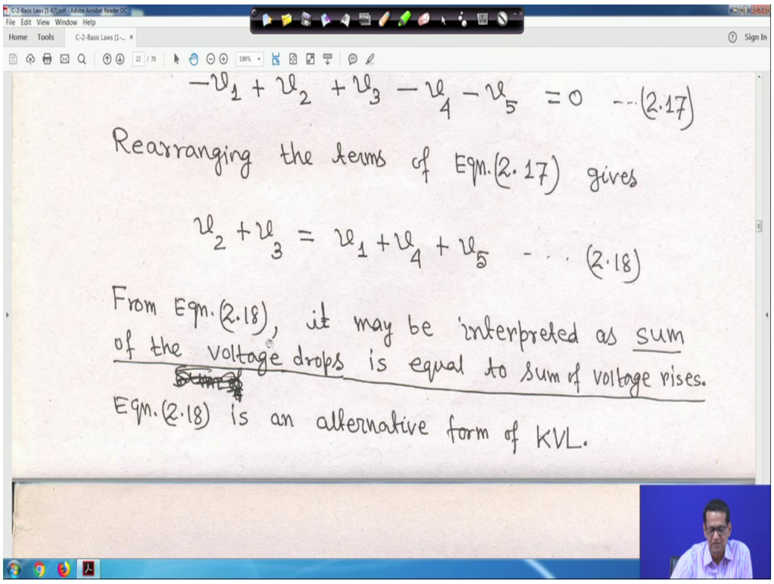

This is equals to 17 or rearranging the term v 2 plus v 3 is equal to v 1 plus v 4 plus v 5. That is equation your 18, may be interpreted as sum of the voltage drop is equal to the sum of the voltage rises, right. So, this is that means, sum of the your what you call voltage drops, that is v 2 plus v 3, right. That is v 2 v 3, there will be voltage drop across the resistor, right. As far this thing and this is an electrical element. So, it is not a resistor may be something else, right. Is equal to your sum of the voltage rise whatever polarity we have taken this is voltage drop another thing voltage rise.

So, this one so, may be interpreted as sum of the voltage drop is equal to the sum of the voltage rises. So, it is an alternative form of the KVL, that is the Kirchhoff's second law. So, note that if you had travelled counterclockwise, the result will have the same, right suppose if you if you move we have moved clockwise, you can move anticlockwise also result will be same, just I am showing for your under the way want suppose same circuit also.

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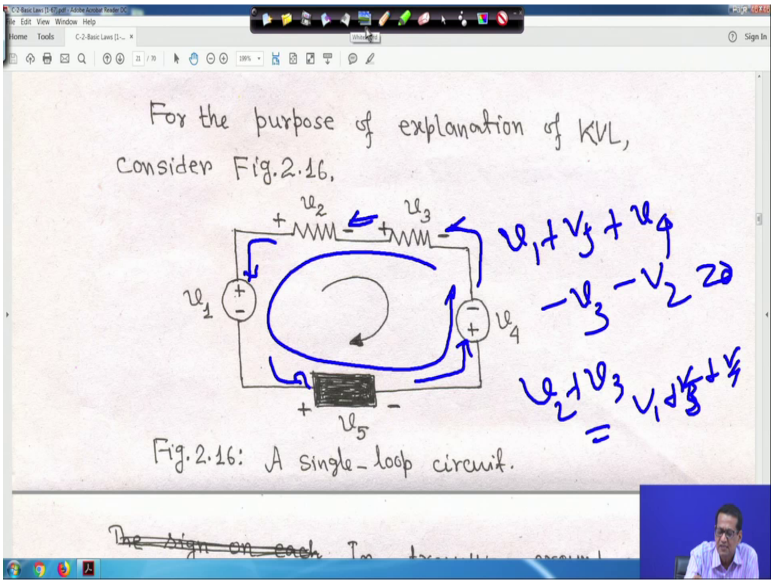

If you move this is clockwise, if you move anticlockwise like this, if you move anticlockwise like this. So, I am moving it so, anticlockwise if I move. So, this is ultimately we will get same thing this is v 1, right. You move like this is plus v 5 because it is encountering plus terminal here also plus terminal first, this is also encountering plus terminal because we are moving like this we are moving like this. So, this will be your plus v 4, then we are moving like this encountering minus sign first. So, minus v 3 and here also encountering minus sign first minus v 2 is equal to 0.

That means your same thing you got v 2 plus v 3 is equal to v 1 plus sorry v 5 plus v 4 whatever we got so, let me clean it. So, clockwise or anticlockwise does not matter you will get the same equations identical thing, right?

So, your what you call anticlockwise I not shown here, but I told you the same thing v 2 plus v 3 is equal to v 1 plus v 4 plus v 5, right.

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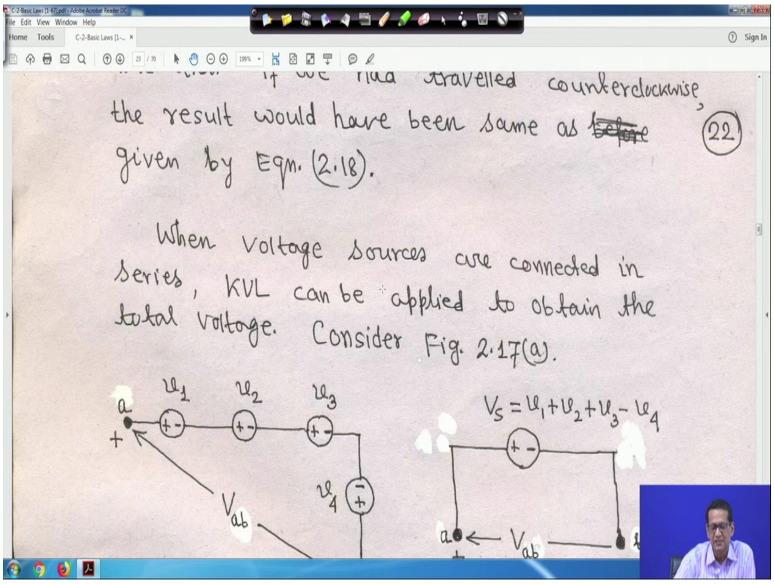

So, suppose if you take another one, suppose this figure 2.17 voltage sources in series and equivalent circuit.

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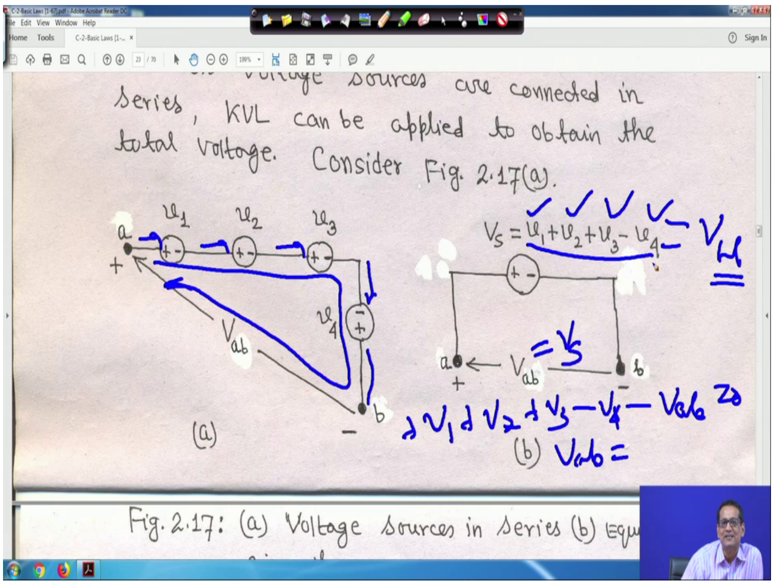

Suppose if we take that this particular your circuit that we have 3 voltage sources, right. V 1 v 2 v 3 and this is another is there one more is there this is v 4.

Now, if you add the va your what you call that total voltage sources, if you move clockwise what isoever, and this is the your this is your voltage vab. If you move clockwise say clockwise, anticlockwise it does not matter you will get same thing suppose if you move like this, just hold on just hold on, if you move like this suppose I moving clockwise like this I am moving clockwise like this.

So, what will happen? If you look into that the plus as soon as clockwise moving it is plus v 1, right. Then again plus v 2 because it is clockwise, this is also clockwise, I am moving clockwise, this is plus v 3 this is v 2 plus v 3, then clockwise this is minus v 4 because minus sign encountering first minus v 4 then here also vab is there, but I moving clockwise. So, encountering minus terminal paths.

So, minus your vab is equal to 0; that means, vab is equal to your this v 1 what is written here then plus v 2 then plus v 3 and that is your v ab right. So, vab is equal to this one vab is equal actually this is vab and vs is shows actually it is a supplied voltage so, vab actually is equals to vs.

So, this way we can wait now if you apply here also your clockwise that your KVL, it will be your vs minus vab is equal to 0. So, vab is equal to vs is equal to vab. So, that is vab is equal to v 1 plus v 2 plus v 3 minus v 4. I think everything is understandable to you ah.

Thank you very much we will be back again.