Fundamentals of Electrical Engineering
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Lecture – 36
First order circuits (Contd.)

So, let us come to your next regarding RL circuits few examples 4 5 examples and with this your first order circuit will stop. I will not give an exercise perhaps except one. So, I will suggest that you open any good book and try to solve some try to solve some problem of your own, and whatever problem had been solved for this course I mean you will not find much difference in others, I mean all varieties of problem have been considered right.

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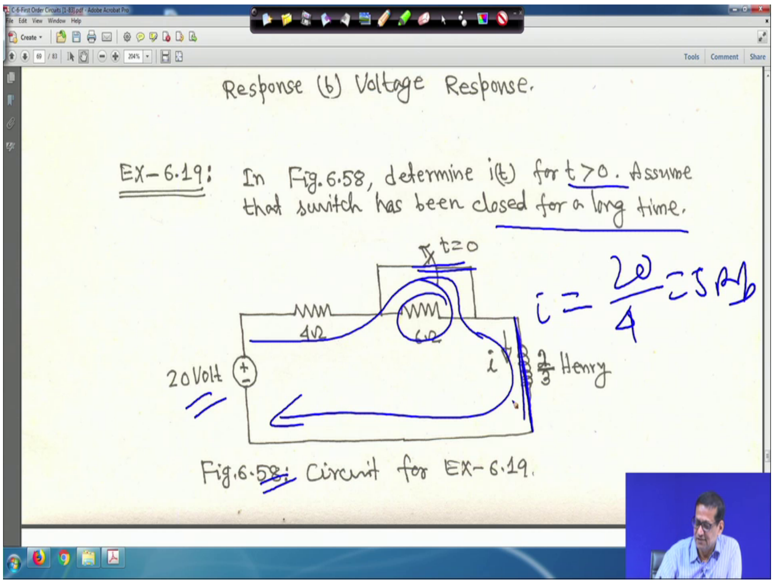

So, let us look into this circuit. So, it is you are given that figure this is figure 58 determine i t for t greater than 0 assume that switch has been closed for a long time. So, this switch was closed for a long time right; that means, this current will flow I mean it is getting a what you call a short circuit path; that means, this current will flow like this, for a long time the switch was closed right. So that means, you assume that if the switch is closed for a long time at that time inductor also will act as a short circuit then what will be the your current initial initial current. So, in that case your what you call say i is equal to it is 20 volt right divided by 4 ohm. So, it is 5 ampere because the switch was closed for a long time.

So, current will flow like this. So, this will be in active because it is a short circuit right and in that case you have to your inductor will behave like a short circuit your. So, your current will be 20 by 4 so, 5 ampere. So, let me clear it. So, if you look into this if you look into this that i 0 minus that is initial inductor current I told you that it will be 5 ampere right. Now, what will happen that your; that means, current through inductor cannot change instantaneously.

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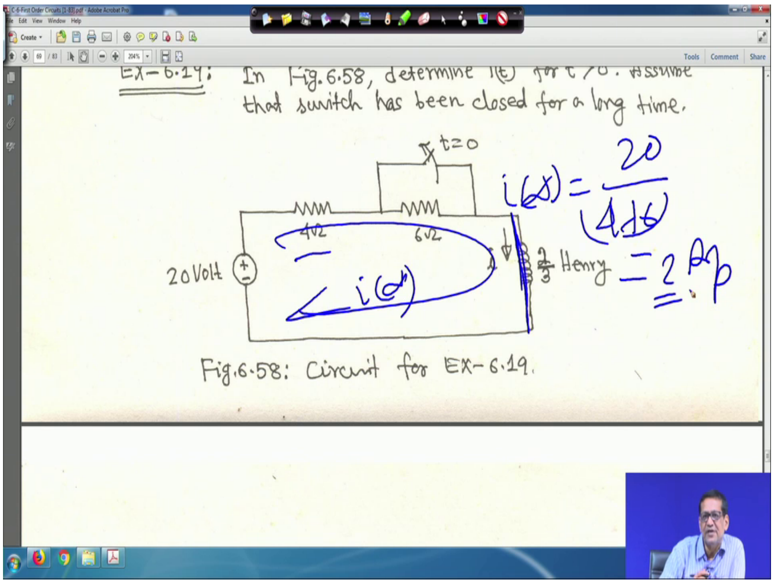

So, when the switch is your what you call when the switch is opened current through the inductor cannot change instantaneously. So, i 0 minus will be is equal to i 0 plus is equal to your 5 ampere. So, i 0 minus is equal to i 0 plus is equal to i 0 is equal to 5 ampere right. Now, second thing is that this switch actually this switch is now opened right, if switch is opened. So, this switch is opened now and at t is equal to 0 and suppose a steady state is reached; that means, switch is open and steady state is reached means inductor again will be short circuit therefore, my i infinity will be is equal to 20 volt and this is open now. So, this is a this is your current will flow like this.

So, this is my and this is my current say i infinity a steady state. So, it will be 20 upon 4 plus 6. So, it will be 2 ampere. So, i infinity will be 2 ampere right. So, let me clear it. So, in the here you will see that your i infinity your is equal to your 2 ampere here it is 2 ampere and if you look into the circuit if you when switch is open and when switch is open.

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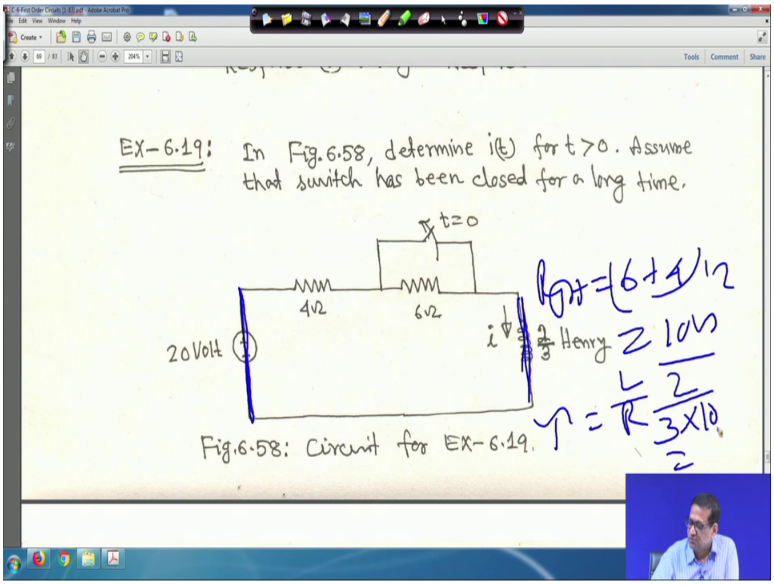

So, this is short circuit. So, what will be the R Thevenin? R Thevenin is simply right you just you just short this is voltage source. So, it will be 6 plus 4 that is ohm that is your 10 ohm.

So, R Thevenin is equal to 10 ohm and tau the time constant will be L upon R right. So, it will be 2 by 3 into 10 right. So, 1 by 115 second that is your tau. So, let me clear it. So, if you look into that everything had been made it here if you look into that tau is equal to L upon R Thevenin; so, 1 upon 15 second. Now we know this i t is equal to i infinity plus i 0 minus i infinity e to the power minus t by tau. So, i infinity is equal to 2 i 0 we have computed 5, i infinity again 2 and e to the power minus 15 t. So, it will be i t is equal to 2 plus 3 e to the power minus 15 t ampere right.

So, this is simple problem right similarly if you determine here determine i t for all the values of time in the circuit. All the values of time means 40 less than 0, 40 greater than 0 this is the meaning and look here it is 5 volt is there and here only 5 u t that is one step volt step input is also there for 5 u t volt right and this is 0.2 ohm this is 0.6 ohm and this is 0.3 Henry right.

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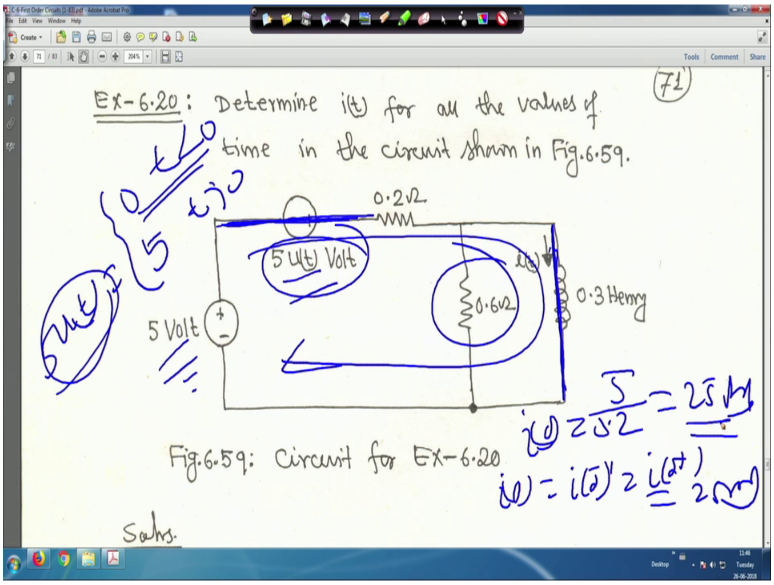

So, one thing is there that this is this 5 volt is connected, but this is 5 u t right. So, this is 5 u t means this is you know that 5 u t means it is 0 for t less than 0, and it is 5 for t greater than 0 because u t is 0 for t less than 0 and u t is 1 for t greater than 0 right.

So, in this case suppose for t less than 0 suppose for t less than 0 that means, this voltage source which actually it is 0. So, in that in that case for if it is for t less than 0, then this will be you make it like a circuit will be like this because this voltage this voltage will be 0. So, make the circuit like this right like short right. And this 5 volt is there and in that case what will happen and if circuit remains for a, I mean if it is like this then at steady state, the inductor will act as a short circuit right. So, inductor will act as a short circuit.

So, at that time what will happen your initial current this current direction is taken like this; that means it is like this; that means, it is like this because it is short. So, this 0.6 ohm is not effective nothing will go through this. So, current through 0.6 ohm resistance is 0 right. So, in that case your this initial current that i 0 is equal to your i 0 minus is equal to i 0 plus whatsoever is equal to it will become 5 by 0.2. So, it will be 25 ampere right so; that means, my i 0 is equal to i 0 minus is equal to i 0 plus is equal to 25 ampere right. So, this is because of this step input this for t less than 0 right. So, this is 25 ampere now let me clear it. So, next solution is there later right.

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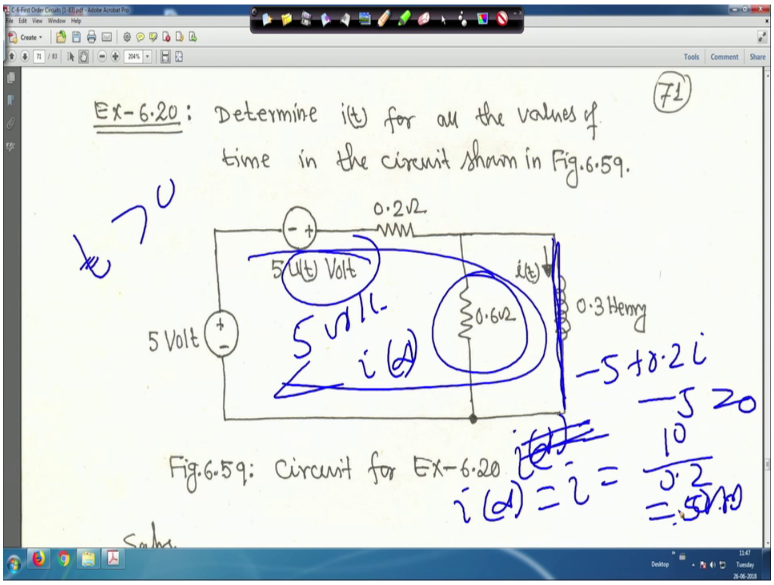

So, now question is that for. Now, for t greater than 0 at that time this 5 volt source will be there right. So, at that time it is 5 volt and if t greater than 0 means u t is 1. So, this 5 volt is there right and if you think that your circuit at that time your, what you call that your circuit is in your steady state right.

Then again your then again it will act as your what you call as short circuit at t greater than 0 and assume that it is reached to a steady state, a steady state condition right in that case also that it is short nothing will be flowing through this because this is a short circuit path. So, current will flow like this current will flow like this. So, in that case your i infinity the steady state value right it will be 5 if you apply KVL here you look I am rather I am writing for you. So, if you apply KVL in this there, it will be minus 5 plus 0.2 into i again minus 5 is equal to 0.

Therefore my i is equal to your 10 divided by 0.2 that is your 50 ampere. Actually this current is basically i infinity. So, this current this is actually i infinity is equal to i. So, it is 50 ampere I infinity. So, i 0 is equal to 25 ampere and i infinity is equal to your 15 your 50 ampere right. So, steady state value let me clear it now to get that your what you call to get that your R Thevenin.

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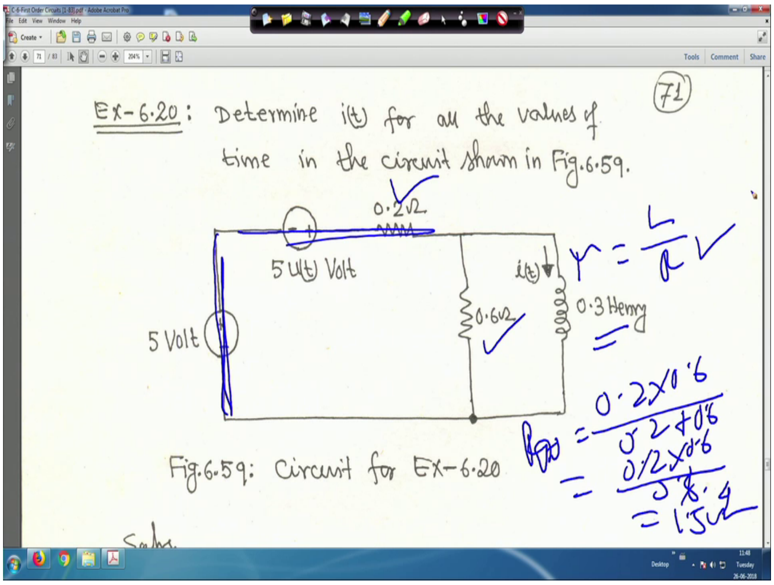

So, this source should be short and this source should be short. So, 0.2 ohm and 0.6 ohm are in parallel. So, R Thevenin will be is equal to 0.2 into 0.6 divided by 0.2 plus 0.6 right. So, it will be 0.2 into 0.6 divided by 0.8, right. So, it will be your 0.4. So, I think it will be 1.5 ohm right. So, and here the tau is is equal to L upon R you l is 0.3 Henry. So, you can easily compute tau. So, all this calculations how has been made I showed you. So, now, come to this solution. So, in this case R Thevenin is for coming around 0.15 ohm right whatever it is and this is tau is equal to L by R Thevenin coming 2 second.

And by definition 5 u t is equal 0 for I told you it is less than 0 and it is 5 for t greater than 0. So, i 0 minus I told you it is 25 ampere i 0 is equal to i 0 plus is equal to i 0 minus 25 ampere because at the time of switching current to inductor cannot change instantaneously right and for t greater than 0 i infinity I told you it will be 50 ampere I showed you right. Now, we know from this for t greater than 0 we know that i t is equal to i infinity plus i 0 minus i infinity e to the power minus t by tau right.

So, you substitute all these values you will get i t is equal to 50 minus 25 e to the power minus 0.5 t ampere. So, t greater than 0 therefore, for all the time means it is i t is equal to 25 ampere the initial value, for t less than 0 and this is for t greater than 0 50 minus 25 e to the power minus 0.5 t ampere that is for t greater than 0 or simply you can put it in a like this, i t is equal to 25 right plus 25 minus e to the power minus 0.5 t u t. Actually this one your this 2 have been this 2 have been your what you call have been your combined together right. So, that is why u t is made therefore, i t is equal to once again I am writing note that for t less than 0 u t is equal to 0 and for t greater than 0 u t is equal to 1 right. So, this hope you have understood this right now next take another one, this is a, this problem is little bit interesting.

So, in figure 60 right I will show you, the switch has been in position a for a long time right and at t is equal to 0 it is thrown to position b, determine you have to determine a that is i t for t greater than 0, then b v 0 minus then v 0 plus and di by dt 0 plus right all these things we have to determine. So, this switch has been in the position a for a long time and at t equal to 0, it is thrown to position b; that means, in this problem switch was at position a for long time; that means, circuit has reached steady state right, circuit has reached.

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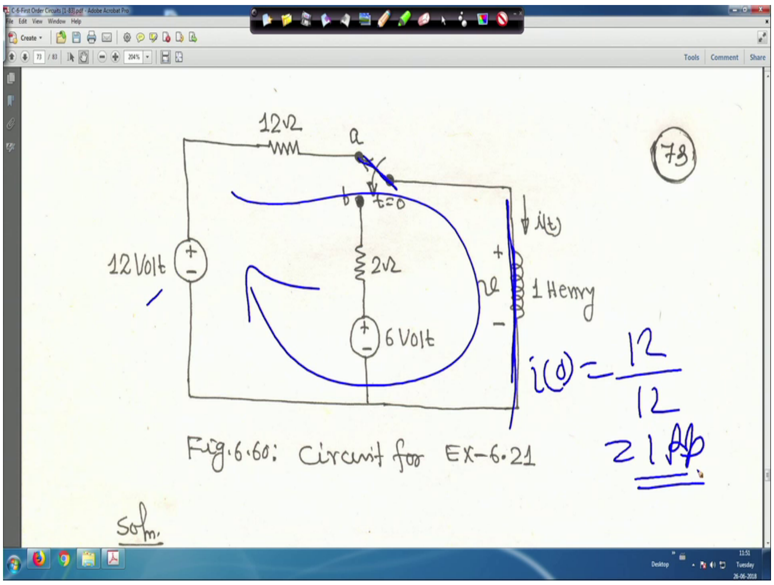

Suppose this one it was positioned like this for a long time, at that time inductor is behaving like a short circuit right and current through this that initial current that is i 0, it will be 12 volt and if you apply KVL here if you apply KVL here like this, it will be 12 by 12 volt by 12 ohm is equal to 1 ampere right. So, this is your i 0 is equal to i 0 minus is equal to i 0 plus that is your 1 ampere right. Now, at t is equal to 0, the switch has been thrown it here right.

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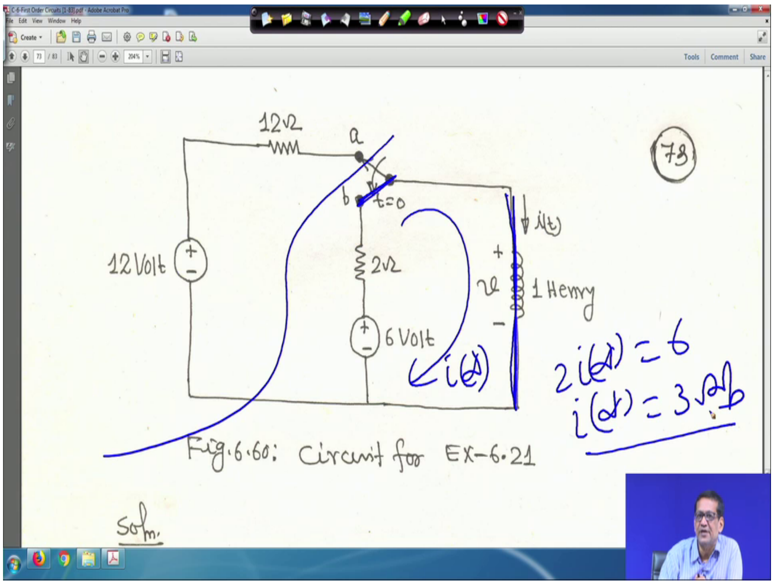

So, this part is isolated switch has been thrown it here. So, at that time also you have to find out what is my what is your i infinity say first. And i infinity means suppose t greater than 0 suppose it has reached to a steady state. So, again it is short circuit, at that time current flowing through this is i infinity that is the steady state value right. So, in that case it is 2 into i infinity is equal to 6. So, i infinity is equal to 3 ampere right. So, i 0 is equal to 1 ampere and i infinity is equal to 3 ampere right and where and let me clear it right. So, this is your this is your i 0 minus is equal to 1 ampere I told you i 0 is equal to i 0 minus is equal to i 0 plus that is 1 ampere and at t is equal to 0 switch is in position b right.

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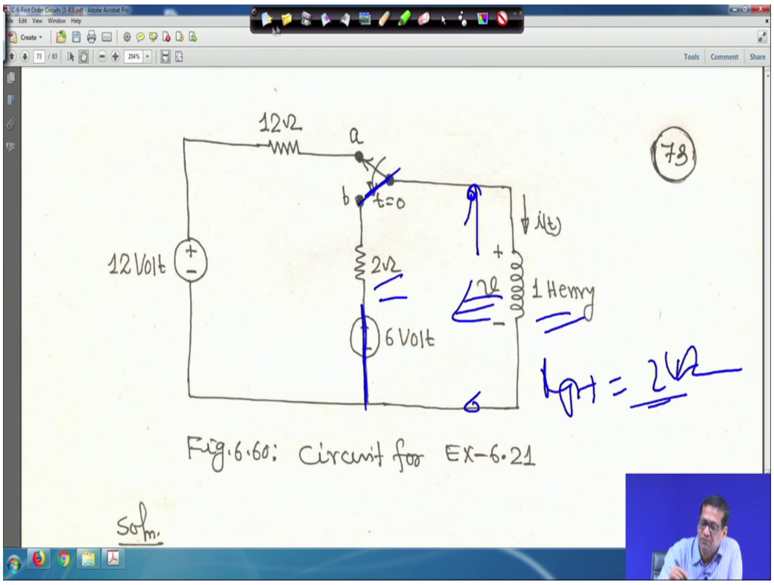

So, in this case when switch is in position b when switch here when switch is in position b. So, it is very simple R Thevenin is equal to 2 ohm; because this from this 2 point you are looking to get that R Thevenin and at that time you are making this voltage source short. So, basically it will be 2 ohm. So, R Thevenin is equal to 2 ohm right and L is given 1 Henry so, you can easily compute your time constant right. So, in this case your tau is equal to L by R Thevenin. So, L is 1 Henry and R Thevenin 2 ohm. So, 0.5 second and i infinity I showed you that it is 3 ampere how to get it this 3 ampere right.

So, because switch is in position b and the circuit reached the steady state. Now, for t greater than 0 we know that i t is equal to i infinity plus i 0 minus i infinity e to the power minus t by tau. So, you substitute all these value i infinity i 0 and tau, you will get i t is equal to 3 plus 1 minus 3 e to the power minus 2 t or you can simply write 3 minus 2 into e to the power minus 2 t ampere right. So, that is for t greater than 0. Now, second thing, when switch was in position a under steady state condition inductors act as a short circuit right. So, in this case your because from there you can easily find out right.

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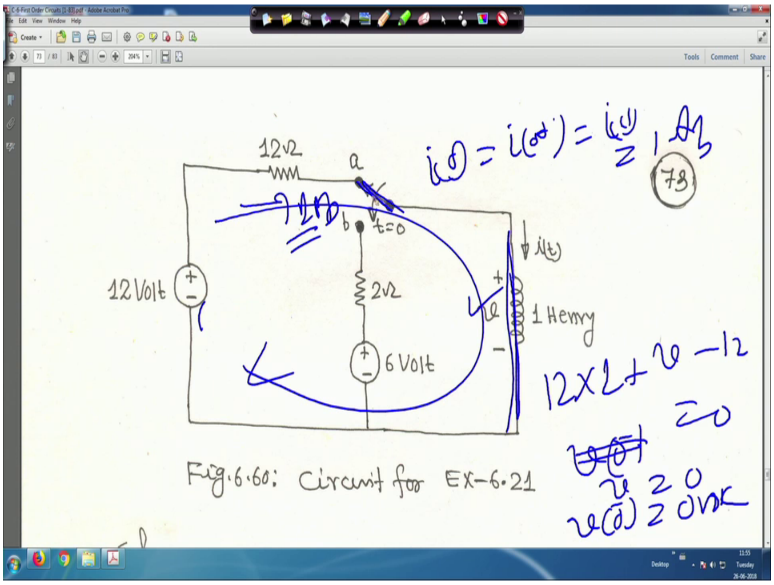

Because here, I mean when switch was in position a; so inductor is behaving across a short circuit and this is the voltage across the inductor. So and current through this is one ampere this is your i 0 i 0 minus is equal to i 0 plus right is equal to i 0 is equal to one ampere that you have seen.

So, if you apply KVL like this because inductor is acting as short circuit. So, it is 12 into 1 because current flowing through this is 1 right plus v minus 12 this minus 12 is encountering minus is equal to 0. That means my v 0 minus it actually it will be first let me write down, it will be v is equal to 0 which is nothing, but v 0 minus is equal to 0 volt. Because at that times this circuit this your switch was in position a for long time. So, it is v 0 minus is equal to 0 volt right. So, let me clear it. So, that is why your v 0 minus is equal to 0 volt, now at t is equal to 0 when switch 1 switch was placed in position b we apply KVL.

So, when switch is in position b I will look into this circuit when switch is in position b at the here at the position b. So, you apply KVL at that time say it is suppose that current is equal to your i or what you call i 0 your i 0 minus is equal to i 0 plus right. So, here you apply KVL in this loop you apply KVL right. So, if you do so, you will get this one your 2 i 0 plus plus v 0 plus minus 6 is equal to 0. Just in that loop you please apply and take I is equal to i 0 plus because at the time of switching current cannot change so, inductor instantaneously. So, you will get 2 i 0 plus v 0 plus minus 6 one I mean this one right.

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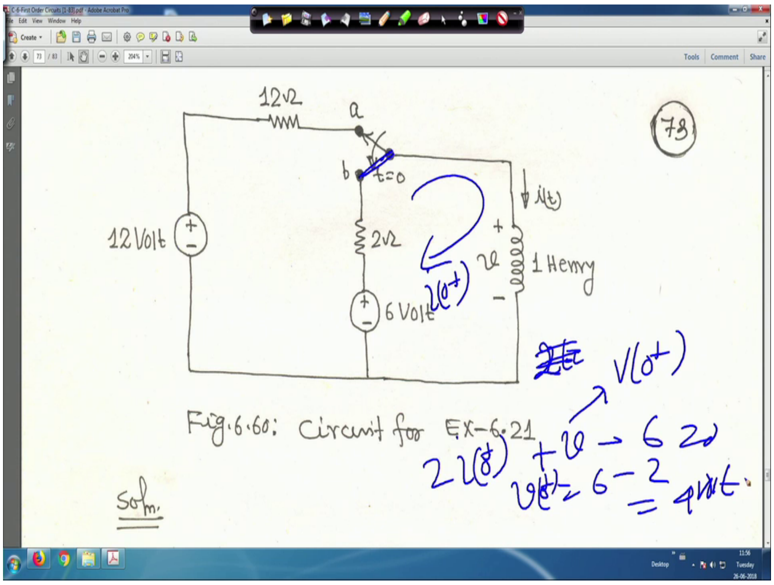

So, if switch is in position if switch is in position this one, at the just at the time of switching the current flowing through this is i 0 plus right. So, it will be if you move like this, it will be 2 into here I am writing it will be 2 then i then 0 plus right plus v minus 6 is equal to 0, but i 0 plus is equal to 1. So, v will be is equal to your actually it will be v 0 plus right v is equal to v 0 plus, it will be 6 minus 2 is equal to 4 volt right. So, let me clear it.

So here, your this is your v 0 plus is equal to 4 volt and we also know generally we know v is equal to L into di by dt. So, as v 0 plus is 4 volt we known. So, we can write L into di dt 0 plus is equal to v 0 plus is this has been asked. So, di dt 0 plus has been asked to find out. So, di dt 0 plus will be v L 0 plus v L v 0 plus upon L. So, L is 1 Henry and v 0 plus is 4 volt. So, it will be 4 ampere per second right. So, little bit understanding is required. Now, next is this problem, listen this particular the switching that DC transient the switching thing, only thing is that you are we are all understanding has be very clear then only you one can easily solve it, in no time you can solve it, but just one has to see that how things are happening. Now in this figure the switch has been open for a long time; that means, this switch actually was open for a long time and your what you call and if the switch is closed at t is equal to 0 determine i t.

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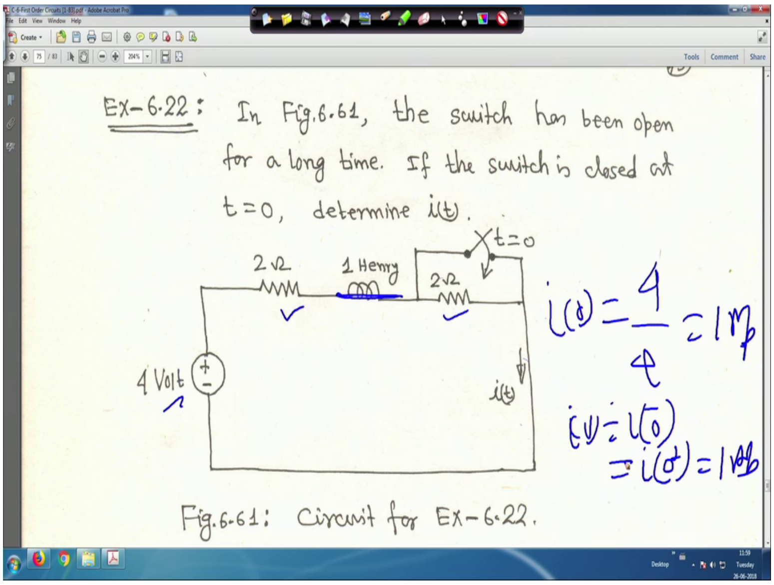

So, this switch was open for a long time means, that inductor is behaving like a short circuit right. And, it was opened for a long time that one you find out what is your i 0; and i 0 is equal to at the time of switching i 0 is equal to i 0 minus and at the time of switching i 0 plus it will not change right.

So, in that case in that case if you apply if you try to find out i 0, it will be 4 divided by 2 ohm and 2 ohm because it was open for a long time. So, it will be 4 upon 4 is equal to 1 ampere right this is 1 ampere now. So, this is i 0 and i 0 is equal to just before switching i 0 minus is equal to just after switching i 0 plus is equal to 1 ampere, because current through the inductor cannot change instantaneously. Now, let me clear it, now this switch is closed; this switch is closed right.

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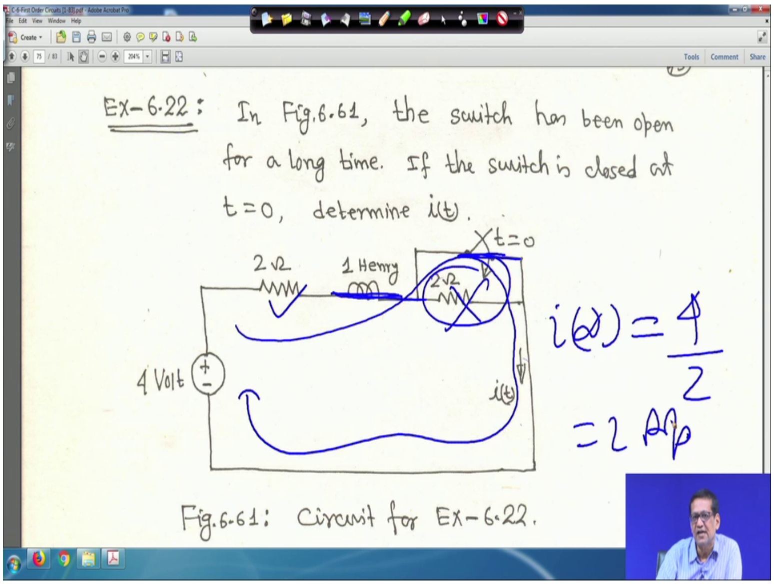

That means this switch is closed now. So, in that case this is inactive right it is short it is shorted. So, and suppose and circuit has reached to a steady state so, the inductor acting as a short circuit right. So, you make it like this therefore, my i infinity will be is equal to your 4 divided by 2 because only 2 ohm resistance is active, because current path will be like this, it will be like this right. So, this is not there because it is short circuited. So, it will be 2 ampere, that is my steady state value that i infinity right.

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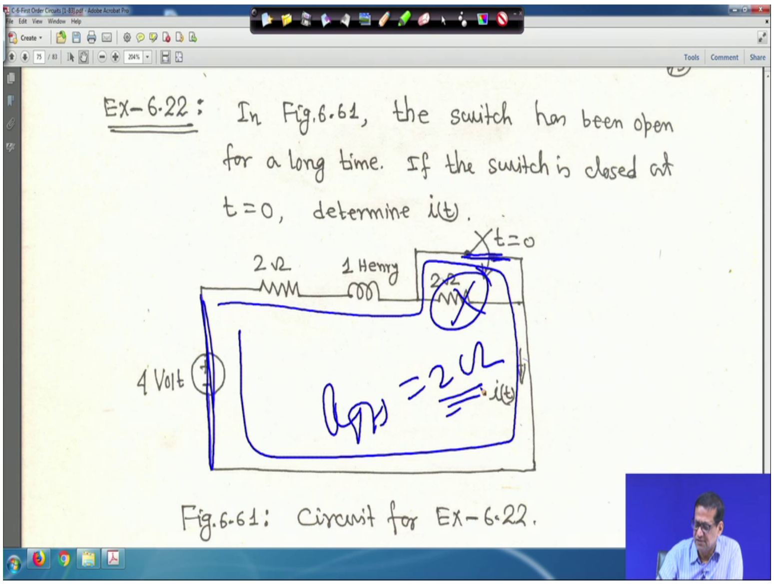

So, let me clear it and as switch is closed as this is closed and if you your what you call. So, circuit path is like this that this is the closed circuit therefore, my R Thevenin this is also you can short it for getting R Thevenin is equal to 2 ohm. It will not come because after switch closing the switch this is becoming inactive right it is shorted. So, it will be 2 ohm that is your R Thevenin right and you can find out tau is equal to L by R time constant. So, everything I said here right though i 0 minus it is 4 ampere, R Thevenin is equal to 2 ohm I told you. So, tau is equal to L by R Thevenin l is 1 Henry. So, half second and t tends to infinity that is i infinity I told you it is 2 ampere.

And for t greater than 0 we know this one that i t is equal to i infinity plus i 0 minus i infinity e to the power minus t by tau. If you substitute all the values i infinity i 0 and tau you will get i t is equal to 2 minus e to the power minus 2 t ampere right. Now, if you want i t for all t then i t is equal to one ampere for t less than 0 because i 0 minus is equal to 1 ampere and it will be 2 minus e to the power minus 2 t ampere for t greater than 0 right. Therefore, we can write this equation that i t is equal to 2 minus e to the power minus 2 t is equal to we can write like this 1 plus 1 minus e to the power minus 2 t u t right.

So, this is your i infinity and this is your this thing sorry this 1 plus 1 minus e to the power minus 2 t right. So, this way you can this way you can write your what you call when u t is equal to 0 that is t less than 0 it is 1 ampere right and when u t t greater than 0 u t is equal to 1. So, it will be it is 1 plus 1 e to the power minus e to the power minus 2 t so, 2 minus e to the power minus 2 t right. So, this way you can write. So, that is why I writing note that for t less than 0 u t is equal to 0 and for t greater than 0 u t is equal to 1 right. So, this is hope this problem is understandable to you right.

So, in now in another thing is that in figure this thing at t is equal to 0. So, figure I will show you that switch S 1 is closed for and 4 second later switch S 2 is closed determine i t calculate i for t is equal to 2 second and t is equal to 5 second right. So, at t is equal to 0 switch S 1 is closed and 4 second later S 2 is closed. So, this is the circuit. So, at t is equal to 0 that your at is equal to 0 this switch S 1 is closed right and at t is equal to and 4 seconds later this S 2 will be closed right.

So, at that time S 1 and S 2 after 4 second both will remain closed forever right. So, let me clear it. So, at I mean when this your what you call that this initially this switch this was also open and this was also open so; that means, this voltage source has no effect this voltage source has no effect right. So, if you look into this just hold on, if you look into this right. So, initially that your as this is open this is open.

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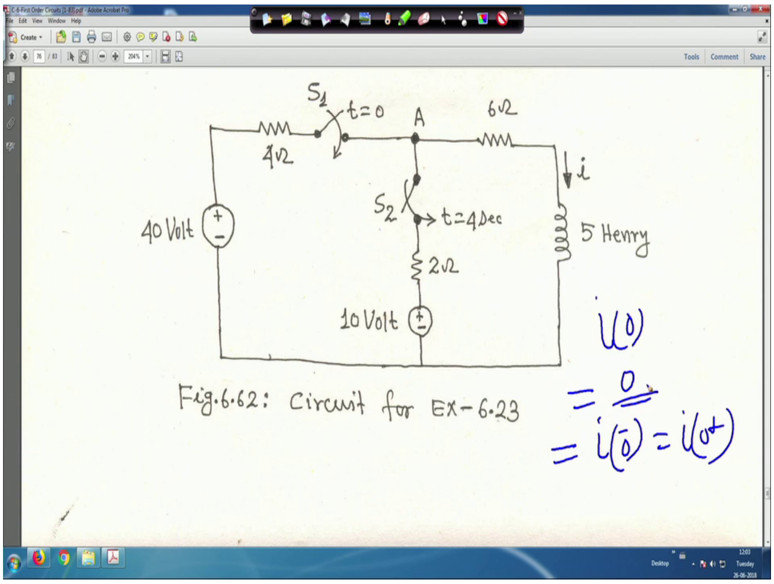

So, initially this i 0 is equal to your 0 that is is equal to i 0 minus is equal to i 0 plus right. So, this is 0 because this was open and this is open now this now this S 1 this one is closed all, this is open right, but this also open S 2, S 2 will be closed 4 second later.

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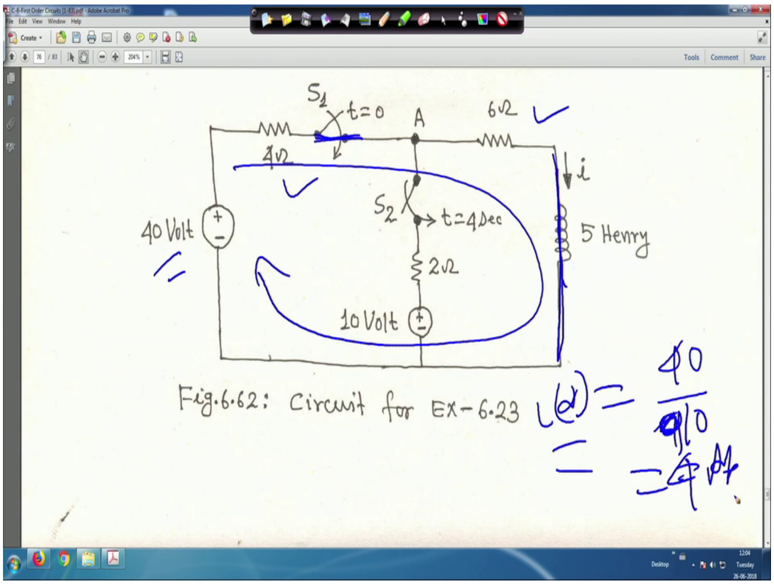

So, this is closed and; that means, this is the path right, this is the path this is open.

So, this branch has no effect right and suppose this your this at steady state the inductor is acting as a your short circuit right. So, in this case if it is so, then what will be then what will be the your what you call that your steady state current that is infinity for when is S 1 closed i infinity. So, i infinity will be this is 4 ohm and 6 ohm result 10 ohm are in series and this is a 40 volt. So, it will be 40 by 4 that is your 40 by 10 rather sorry let me let met this is this is 10 is equal to 4 ampere.

So, i infinity is equal to 4 ampere right that is your an initial value of i 0 is equal to 0 and i infinity is equal to 4 ampere. Now, here let me clear it now here if you try to find out that what will be the time constant, this is your this is closed this is open right and your to get the your R Thevenin for this case, but this is open S 2 remains open R Thevenin voltage source should be shorted right.

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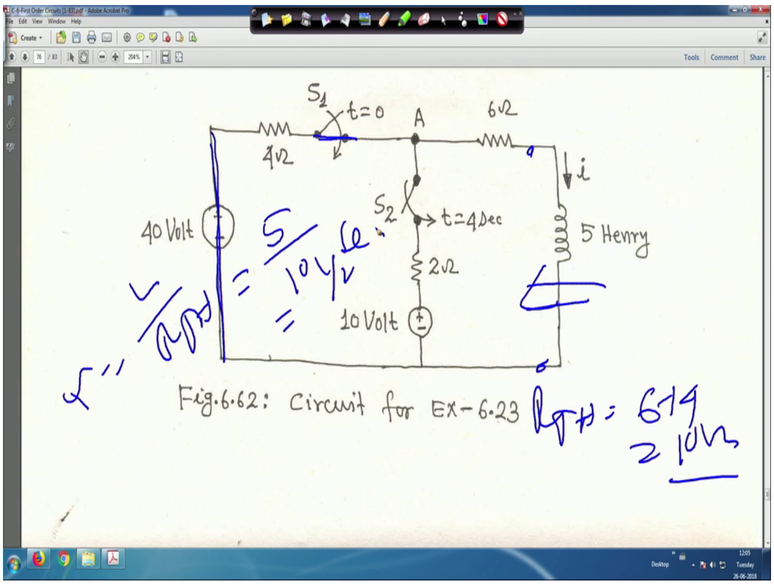

And R Thevenin will be is equal to we are looking from this terminal you are looking from this terminal, this is open it will be 6 plus 4 is equal to 10 ohm this is R Thevenin and tau is equal to L by R Thevenin right.

L is equal to 5 Henry and it is your 10 ohm is equal to half second is equal to half second right. So, with this with this everything I say it right with this i infinity 4 R Thevenin 10 ohm tau is half second and we knew this formula, i t is equal to i infinity plus i 0 minus i infinity e to the power t by tau. Put all these values you will get i t is equal to 4 into 1 minus e the power minus 2 t ampere that is in between 0 and 4 second because switch S 1 is closed right, now for t greater than 4 second.

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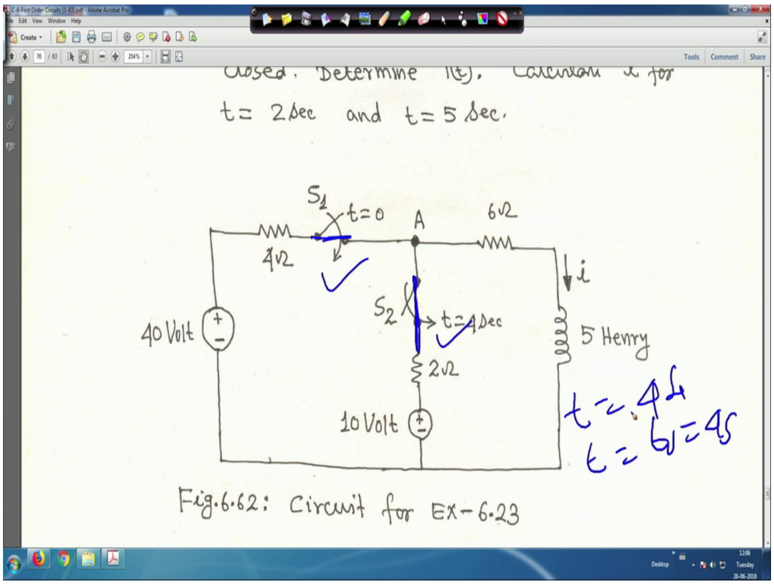

Now, at t greater than 4 second this is closed this is closed and this is also closed; that means, we will assume these 2 switches are closed forever right. So, I mean this is also closed this is also closed at t is equal to 4 second this is closed the these 2 switches are closed forever right. So, in that case again you have to find out your what you call i infinity and your initial value at t is equal to 4 second that is at t is equal to t 0 is equal to 4 second you have to find out what is the initial condition and at steady state what is the final condition, and then you have to find out the expression for t greater than equal to 4. So, in this case I hope you will understand this right when both switches are closed right.

So, S 2 is closed this means S 1 and S 2 are closed forever right. So, sudden closing of S 2 does not affect the inductor current, because the current cannot change abruptly through the inductor. Thus the initial current is at t is equal to 4 you put at t is equal to 4 in this expression here i t is equal to 4, 1 minus e to the power minus 2 t here you put at t is equal to 4 because the switch S 2 is closed. When you will solve this problem know all this problem when you will see this, first you will draw the circuit on your notebook after that you see what is happening right.

When you are reading, when you read this video lecture for all the time you will see that first you draw the circuit on your note book and then you will try to solve of your own people looking into the solution and what I am telling right. So, you put t is equal to here 4 second. So, you will find that i 4 is equal to i 4 minus is equal to i 4 plus right approximately 4 ampere. Because 1 minus e to the power minus 8 e to the power minus 8 is too small; so, approximately 4 second that is t is equal to 4. Now, let v be the voltage at node A. So, in this case now suppose steady state is reached this one steady state is reached. So, this is closed this is closed and this is your node a, this v means your v infinity right the steady state value at that time this one it is short circuited right.

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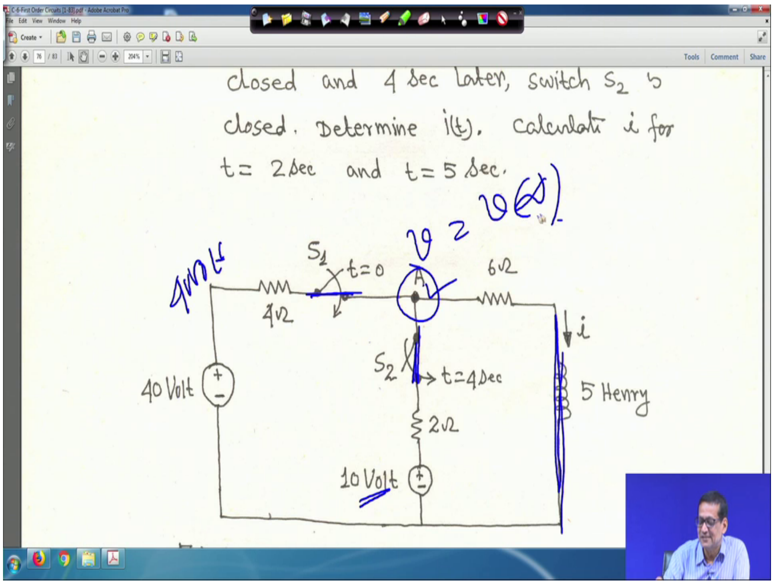

So, at that time you apply your what you call KVL this voltage is v volt 40 volt right because this 40 volt and here it is your 10 volt is there right and this v infinity means this is the your what you call this voltage across your this is short so, 6 ohm your resister. So, here nodal analysis we have already studied. So, directly I am writing this equation right as this your what you call this applying your KCL at node A, v is equal to nothing, but v infinity. So, in this case you please you when you apply that that your your KVL that is of 40 minus v plus 10 minus v by 2 is equal to v by 6 v is nothing, but v infinity right. So, let me tell you once again.

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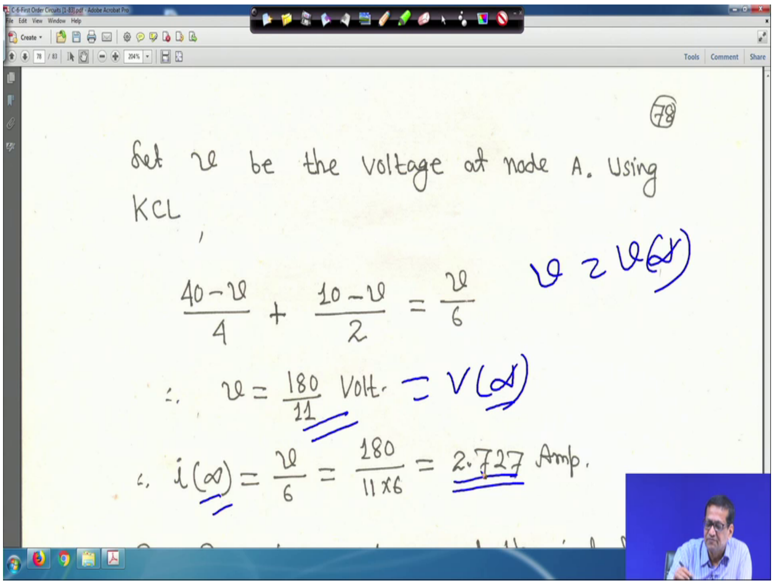

This v is nothing, but v infinity the steady state, when inductor is acting as a short circuit right. So, if you solve this v actually this is v infinity. So, it is 180 upon 11 volt right. So, in this case i infinity will be v by 6 because across that 6 ohm resistance your voltage your voltage this nodal analysis we got this v infinity.

So, it will be v your v by 6, that is 180 upon 11 into 6 because v infinity is equal to 180 upon 11. I did not write v infinity, but it is understandable that is your 2.727 ampere right. So, let me clear it. So, the Thevenin resistance at the inductor terminal is if you look into that very simple it will be 6 plus 4 into 2 upon 4 plus 2. I need not go back to the circuit you draw the circuit on your note book and just you can you will get it; it will be 22 upon 3 ohm. So, tau will be l L upon R Thevenin. So, 5 upon 22 by 3 is equal to 15 by 22 second that is tau. So, from equation 75, we know this no because it was t is equal to not 0 t is equal t is equal to t 0 that is 4 second.

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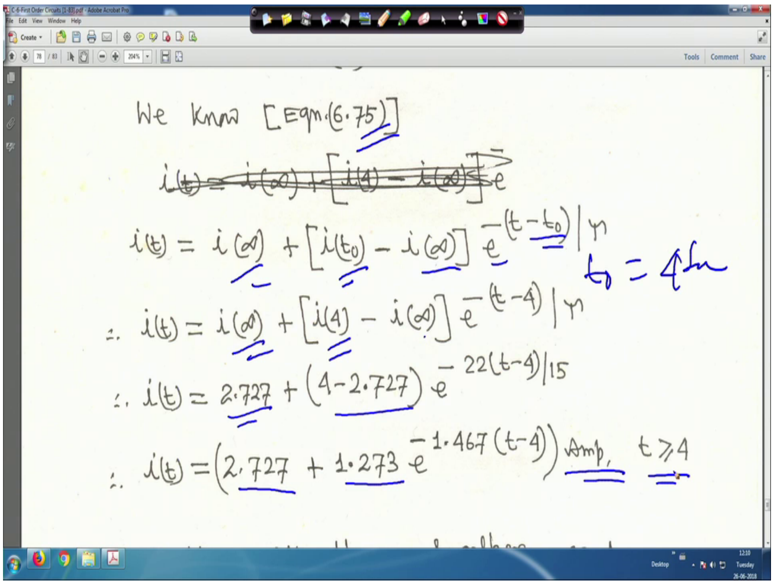

So, that is why your from equation 75 it is i infinity then i t 0 minus i infinity e to the power minus t minus t 0. So, it is basically i infinity i t 0 means t 0 is equal to 4 second. So, t i 4 minus i infinity t 0 is equal to actually it is 4 second because S 2 was closed after 4 second. So, if you put all these value i infinity i 4 i infinity and t your tau value. So, you will get i t is equal to 2.727 then 4 minus 2.727 then e to the power minus 22 by 15 into t minus 4.

So, i t will becoming your 2.727 plus 1.273 e to the power minus one 0.467, but t minus 4 this ampere for t greater than equal to 4 right. Let me this thing. So, putting all this together we have that i t is equal to 0 for t less than equal to 0 that we have got initial value of i 0 and 4 1minus e to the power minus 2 t for in between your t greater than equal to 0 less than equal to 4. And for t greater than equal to 4 this one you got it because 2 switches were there, and it has been asked to find out at t is equal to 2 second what is the value of i. So, i 2 that is at t is equal to 2.

So, 4 1minus e to the power minus 4 it is 3.93 ampere and it has asked also at t your 0.5 seconds. So, it will be 2.77 plus 1.273. So, 1 minus 4.67 is equal to 3.02 ampere; with this we will close that first order DC circuit as many as 20, 3 problems have been solved different type of problems, with this I believe all the parts of the DC portions have been covered.

So, from the next if you all next lecture we will go to that single phase AC circuit; and DC circuit we have solved several problems I mean I mean several problems for all 6 chapters, but in AC circuits as complex number will be involved and because of that we will restrict the number of numericals maybe 7, 8, 9, 10 per each chapter or may less because complex number involved, but I will, but any good book when you will follow you will solve the problems. So, we will see that single phase AC circuit from the next visual lecture so.

Thank you very much.