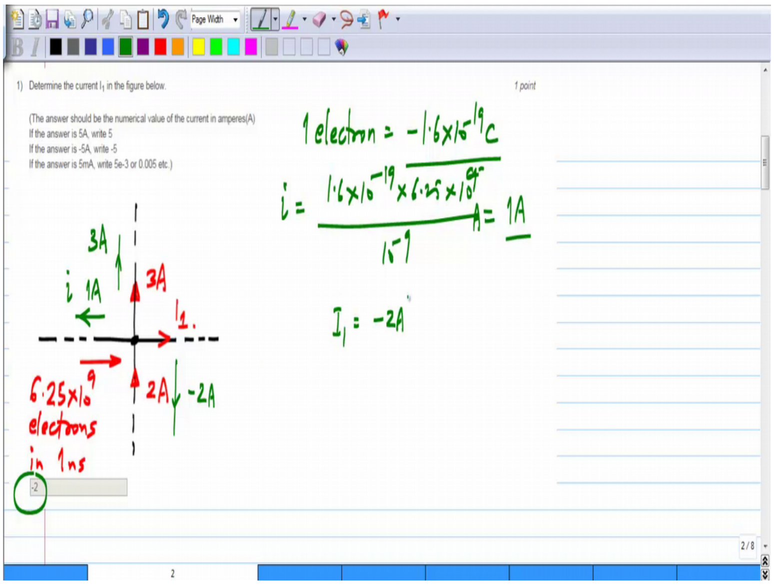
Basic Electrical Circuits
Dr Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology Madras

Lecture - 14
Solution to the Assignment on Units 01 and Units 02

(Refer Slide Time: 00:19)

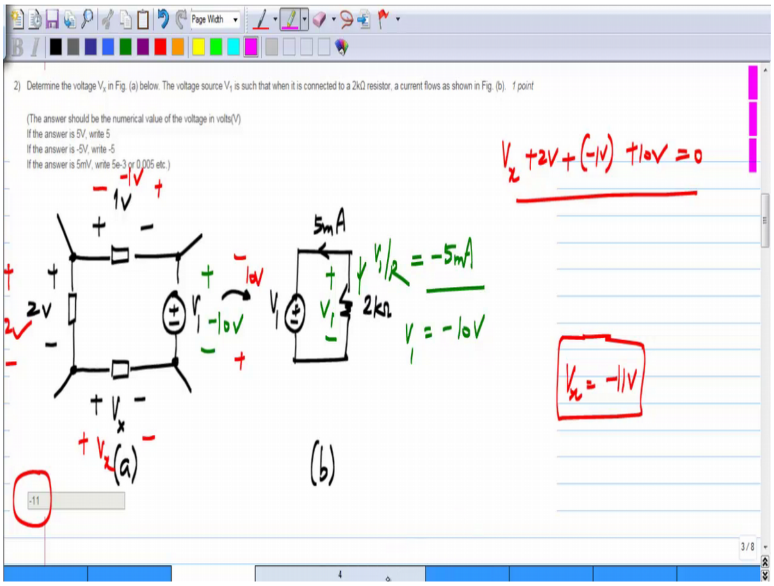


Now, I will discuss the questions posted in the first assignment that is the assignment for units one and two preliminaries of electrical quantities and basic circuit elements. What I will do is I will outline the steps towards the solution, and I will also show the final answer. So, this is the first question out here. So, it says determine I 1, what is shown is node with the four wires connected; now three of the currents are given and you have to find the fourth one and obviously, Kirchhoff's current law is the method to solve this now two of the current given directly this is three amperes flowing outward and this is 2 amperes flowing inward.

So, you have to take all the currents either flowing outwards inwards. Let us say we are take them flowing outwards, so this will be three amperes and this if you represent equivalently as flowing output wards that is minus two amperes. Now this last one its given in terms of number of electrons per unit times, so all you need know is that one electron is minus 1.6 into ten to the minus 19 coulombs . So, when electrons are flowing this way current is actually flowing the other way. So, that current is 1.6 times 10 to the minus 19 times 6.25 times 10 to the 9 divided by 1 nano second which is 10 to the minus

9, which gives us basically 1.6 time 6.25 amperes. This is amperes 1 amperes. So, we have one amperes flowing that way. Remember I did not put the minus sing here because I have already taken I to be in the opposite direction to electron flow. So, now I 1 plus three amperes plus minus 2 amperes plus 1 ampere has to be zero. So, if you solve for this, you will get I 1 to be minus 2 amperes.

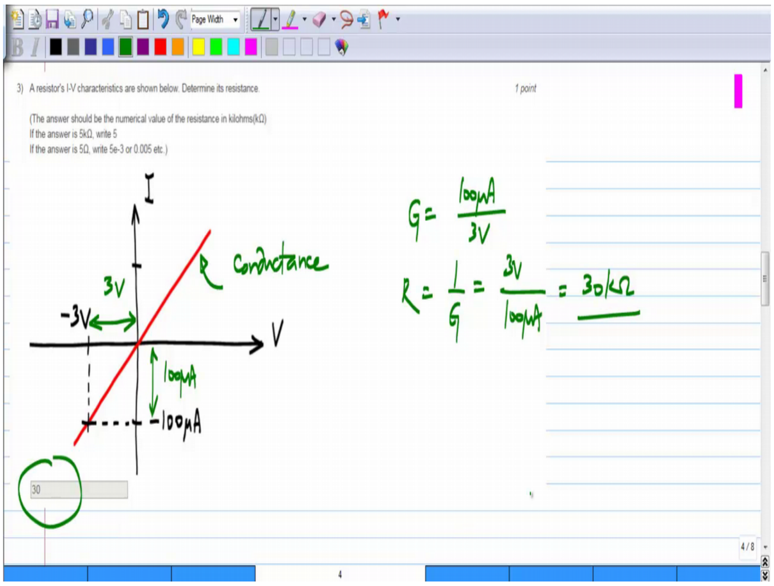
(Refer Slide Time: 02:22)



Here is the second question we are asked to find v x we are given a loop with some voltages already specified and one voltage being unknown. So obviously, Kirchoffs voltage law is the way to solve for this, this voltage V 1, its value is not given directly, but it your are told that if V 1 is applied across 2 kilo ohm resistors 5 amperes flows in this direction. So now we know that if V 1 is applied across the register the current in this direction will be v one divided by R V 1 divided by R is given to be N minus 5 milli amperes . So, what does it say R has given, so V 1 is minus 10 volts. So, in this polarity you have minus 10 volts then all you have to do is to sum up all the voltages in a consistent polarity. So, you take the same kind of polarity it does not matter which way you go. So, let us say we take the same polarity has V x. So, this is v x then I will continue with the same this is given to be two volts and I will continue in the same direction what is given is with this polarity is one volt. So, with the polarity I have marked in red it is minus 1volt. And similarly with this which is consistence with the direction of the loop it is plus 10 volts.

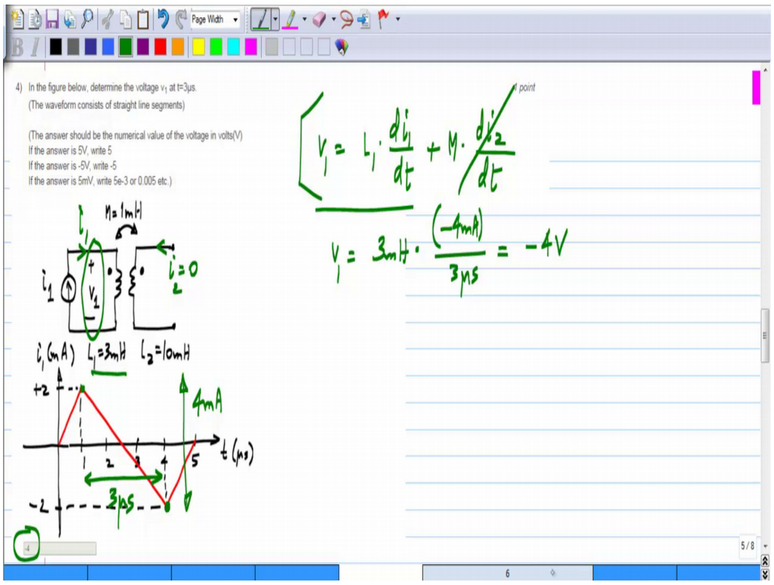
So, now, I sum up everything V x plus 2 volts plus minus 1 volt plus 10 volts to be equal to 0. So, from this we get V x to be minus 11 volts. So, basically all we need to know is volt law will be able to calculate v one and then take the voltages in a consistent direction around the loop I took it. So, that I started with the polarity given for v x and then I continued in that way you could have taken that other way also you would get exactly the same answer. So, polarities are extremely important and please be mindful of them in solving all the problems.

(Refer Slide Time: 04:52)



Here is the third problem extremely simple, what you have told is that I-V characteristics the where register are given. And you have to find the resistance basically you know that I-V characteristics are a straight line, and the slop of this line corresponds to the conductance. And of course, this is passing to the origin otherwise it would not be a resistor then one other point is given when the voltage is minus 3 volts, the current is minus 100 micro ampere to calculate the slop of this it is extremely easy. So, this distance is three volts and the corresponding vertical distances hundred micro amperes. So, the conductance which is the slop is 100 micro amperes dived with 3 volts and the resistance which is the inverse of that is 3 volts by hundred micro amperes equals 30 kilo ohms so that is what is given here.

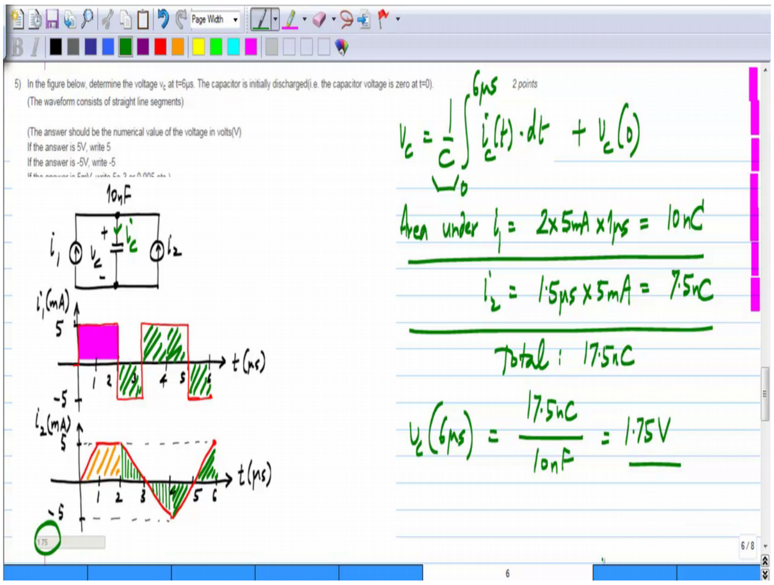
(Refer Slide Time: 06:01)



The next question the mutual inductor is given some current is given to the first pointing the second pointing is left open so; that means, that the current here is zero. Now you are asked to calculate V one at a particular time and some shape is given to I 1 consisting of straight line segments. So, you can of course, solve for this systematically you know that the voltage across one of the coil of an inductor is L 1, the self inductance of the coil times time derivative of I 1 which is I 1 that is the current flowing through the first coil plus mutual inductance times the current through the second coil I 2 is to be given zero over there. So, this entire term becomes 0. All you have is really a single coil if you open circuit one of the coil of a mutual inductor, it is basically a single coil corresponding to the other one, so then L 1 is given.

So, all you have to do is to find the slop and slop of a straight line can be found very easily over a period of three a micro second that is one micro second to four micro second the current changes by four milli amperes. So, L 1 times dI 1 by dt is 3 milli Henry times the change in current has minus 4 milli amps because it starts from plus two and then go goes to minus 2. So, it is minus 2 milli amps divided by 3 micro seconds . So, this corresponds to minus four volts, so V 1 in this direction you know the dot convention and the polarity for v one and so on. I did not discuss that, but based on that I have written this and v one turns out to be minus four volts many cases you would have got either negative signs where there should not being and so on. So, please go back check every step to make sure that you have taken the correct signs for every voltage in current at every steps.

(Refer Slide Time: 08:27)

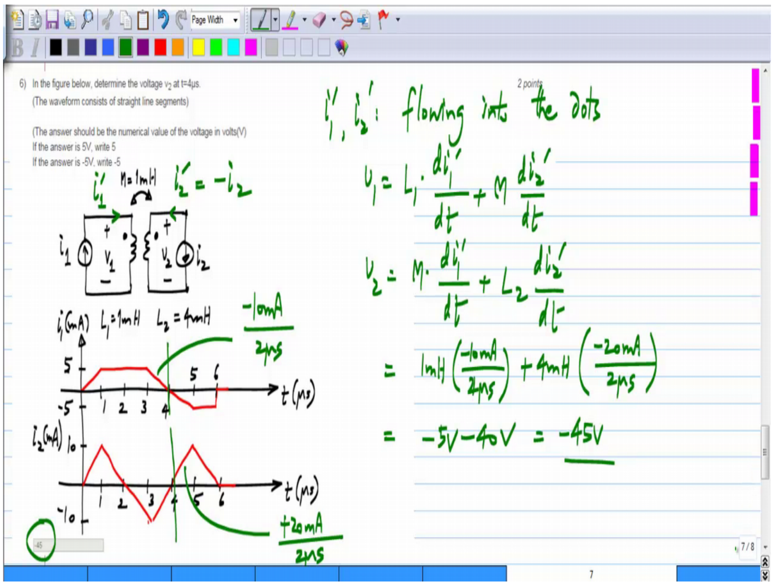


This is the fifth question we have a capacitor and you are asked to find the voltage across the capacitor at some time. So, you have to use the equation governing the current voltage of the capacitor. You know that the capacitor voltage is 1 over c integral of I of d d t from zero to as certain time let us say t 1. In this particular case that is 6 microseconds and to that you have to add the voltage of the capacitor that t equal to zero. The statement of the question says you have to find v c at t equals six micro second so that is why I have six micro second as the upper limit and V c of zero is zero because of its capacity is initially discharges the way from consist of straight line segment that basically means that you can calculate the slops very easily what is it that you have to find you have to find the integral of the current flowing through the capacitor by the way let me denote this has to v I c just to avoid confusion you to find I c in this direction and integrated to find v c with this polarity and I see by Kirchhoff's current law it is just I 1 plus I 2.

So, what I have to do is find the area under I 1 plus I 2 and integration is a linear operation. So, I can find the area under I 1 up to six micro seconds and area under I 2 up to six micro seconds and add the two together. So, now, what is the are under I 1 we have basically in this positive part we have five milli amps times two micro seconds and here we have minus five milli amps times one micro second similarly this positive area is plus five milli amps times two micro seconds and finally, this negative area is minus five milli amps times one micro seconds. So, if you calculate the total area you will get two times five milli amperes times one micro second.

So, you can imagine let me erase all this. So, this negative area cancel this that one and this negative area cancels that one. So, you will left with only this much. So, this is ten milli amperes times micro seconds which is basically 10 nano coulombs be careful of all the units while carrying out this integration and so on. Similarly the area under I 2 can be calculated we notice that this positive area cancels this negative area similarly this negative area cancels that positive area. So, what I am left with is this part of it and I can easily calculate that area to be area under I 2 you have to calculate all the rate of six micro seconds some of the areas have canceled out and left with it orange part. And that gives me basically 1.5, I have 1.5 because I have one micro second here and here I do not have the full rectangle I have only the triangle. So, it is 1.5 micro second times 5 milli amps which is 7.5 nano coulombs. So, the total area is 17.5 nano coulombs and have to divided by the capacitance. So, V c at six micro seconds will be seventeen point five nano coulombs by ten nano farad which is 1.75 volts.

(Refer Slide Time: 13:07)



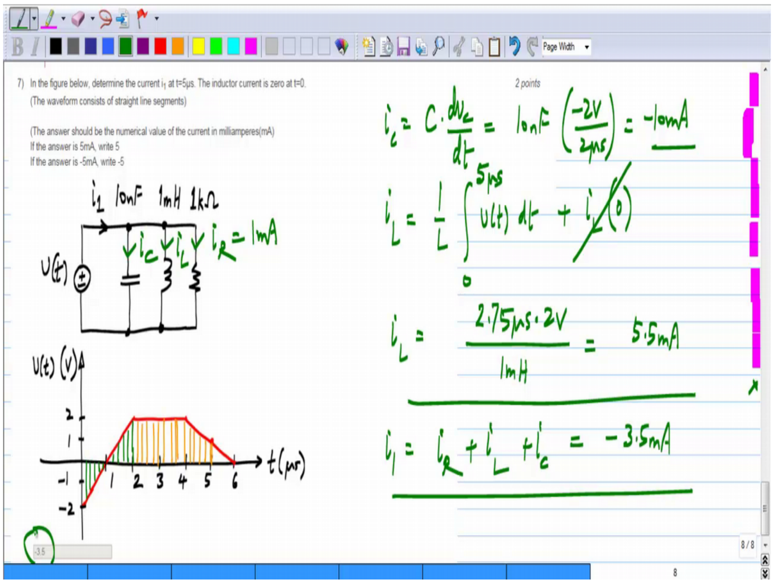
Then we come to the sixth problem in this case we have a mutual inductor, but currents are being driven into both coils. So, now, let me denote the currents with proper polarities I will choose both coil currents is flowing into the dots let me call this I 1 prime and this is I 2 prime . So, remember I 1 prime and I 2 prime have chosen them to be flowing into the dots then by convention of mutual inductance I know that V one with the dot being positive it is L 1 dI L prime by dt plus m dI 2 prime d t. And similarly v two with the dot being positive is m d I 1 prime by d t plus L 2 d I 2 prime by dt. And do not get confused with the symbols I 1 and I 2 used for this you have to take the currents going into the dot, and calculate the voltages with the dot defined as positive for the voltage. And we also to find V 2 at the equals four micro seconds and your given I 1 prime and I 2 prime effectively I 2 prime is nothing but minus I 2 and I 1 prime is simply I 1.

So, all I have to do is calculate these derivatives and also I have to do it at t equals four micro seconds that is at this instant. So, now, I have to calculate the slop of this part of the straight line I find that the slop of I 1 is it is changing from plus five milli amps to minus five milli amps over an interval of two micro seconds. So, minus ten milli amps by two micro second is the slop of y one and I 2 is increasing from minus ten milli amps to plus ten milli amps over a period of two micro seconds. So, the slop of this is plus 20 milli amps it changes by twenty milli amps over a period of two micro seconds and L 2 and m are given. So, it is quite easy.

So, I have to m which is 1 milli Henry times the rate of change of I 1 prime which is minus 10 milli amps by 2 micro second plus L 2 which is 4 milli Henry times this is remember this plus twenty milli amps by two micro second is rate of change of I 2 and I 2 prime as minus I two. So, the rate of change of I 2 prime is the negative of this. So, I will again get a negative number here minus twenty milli amps by 2 microseconds. And if I add up these two, I will get minus 5 volt from this and minus 40 volt from that which gives me minus 45 volts.

So, again it is the matter of a using I-V characteristic of the mutual inductor with the correct sign convention. So, you keep the sign convention in mind otherwise you will get all kinds of wrong results this case there are two terms. So, if you make mistake in a sign for both of them it is actually good at least you will get the magnitude, but the negative answer, but you make a mistake in sign from one of them you will get some confusing answer which looks difference in both sign and magnitude from the actual answer . So, please be very, very meticulous about the signs of voltages and currents.

(Refer Slide Time: 17:20)



Here is the last problem you will find this current I 1 at equal 5 microseconds. Now we have a voltage v connected to a capacitor and inductor and a resistor. Now it is clear that the same voltage V appears across all of them just by Kirchhoff's voltage law. So, voltage here is v of t volt of there is v of t and the volt of there is V of t. So, now, what I do to find this current I 1, I have to calculate the current through the resistor current through the inductor and current through the capacitor and sum them all up. So, I have I r I l and I c and the way form of v is given here. So, let us calculate all three currents and add them up and also you are supposed to it at equal five micro seconds the easiest to calculate is I R. So, t equals to five micro seconds v is one volt and r is one kilo. So, I r simply equals to V by R, which is 1 milli amperes.

Now next i c will be c times the time derivative of V c which is 10 nano farad and the time derivative of v which is basically the slop of this part of the line it falls by two volts over two micro seconds. So, the slope is minus two volts by two micro second which receive minus 10 milli amperes. And finally, you have to calculate l and l. So, this is I c and I l is one over l integral under voltage curve from zero to five micro seconds plus the value of the inductor is zero which is given to be zero so that goes away. So, what I have to do is to find the area under this curve up to 5 micro seconds. So, I see that this negative area handles with that you have to find the area up to this part. So, that is the area that you have to find the signing up the rectangle and triangle which make up this odd shape polygon you will see that the area of that is 2.75 micro seconds times 2 volts that is the area and I have to divide that by the inductions which is one milli Henry to get the total current to be 5.5 milli amps and this I 1 is nothing but the sum of I r I l and I c which comes out to be minus 3.5.

So, to summarize what you have to do to solve this assignment first of all you have to be familiar with Kirchhoff's current law and voltage law and you have take the quantities in each in a consistence direction. For instance for Kirchhoff's current law you take all currents flowing outwards from a note similarly for Kirchhoff's voltage law you mark all the voltages around the loop in the same direction if some voltages are given in the opposite direction. So, you neglect the value and take it in your direction in this way it has to be always systematic and secondly you need to know all element I-V characteristics also with the current polarity of voltages and current. So, most of this is basically keeping track of all the right polarities of voltages and currents and because you are given some way forms in places you have to calculate the slops of this way forms or areas under the way forms.