Basic Electrical Circuits
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Lecture - 5
Energy and power in elements
(R, C, L, Voltage and Current Sources)

In the previous lecture we looked at control sources. Now, so far we have looked at two terminal elements and also control sources and what we have done is to describe the relationship between voltage and current of these elements. In this lecture, what we look at is the power and energy in these elements. Now, before we get started are there any questions regarding the previous lecture or any of the previous four lectures.

I think now you are able to see the journal as well as the web camera; if someone is not able to see that place please a message in the chat window. I think now you are able to see me. So, if there are any questions regarding the topics we have covered in the previous classes please ask questions you can type into the chat window.

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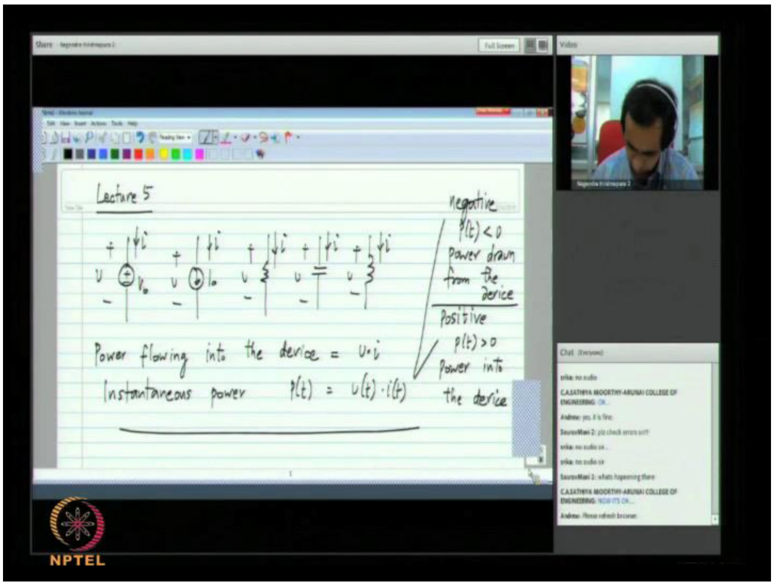

Let us continue with the lecture now. We looked at number of elements the independent sources voltage and current source and also the resistor, capacitor and inductor and each of these is defined by some relationship between voltage across the element and the current through the element. You know what these relations are and in this case I will show all the elements with this passive sign convention that is if v is defined positive on top and negative on the bottom; I goes into the upper terminal the terminal on top.

Now this product v i that is the product of the voltage across the device and the current through a device has some significant and that is nothing, but the power that is going into this device. So, with this sign convention with the passive sign convention v times i with the power this going into this device; now, this either can be constant or changing with time depending on v and i; if v and i v or i is varying it is possible that this power is time varying and in that case it is known as instantaneous power. So, this is what the instantaneous power is and this if it is positive the power is going into the device and if it is negative power is drawn from the device.

On the other hand if it is negative that is p of t is less than zero power drawn from the device. So, this is how the power defined and it is extremely important to follow the passive sign convention that is the appropriate sign source of voltage and current across the elements. Now, what will do is we will look at each of these elements and see what the power is. Because we know that the elements enforce a certain relationship between the voltage and current; that means, certain things were power and we will look at that shortly.

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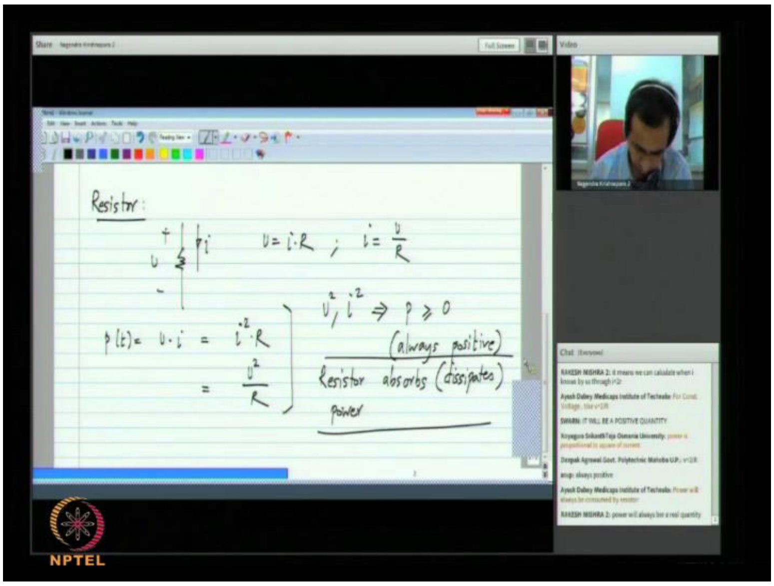

Let us take a resistor. We have some v and some i and you know that v equals i time R, where i is the resistance value. Now, power p of t is v times i now in general it can be dependent on time. Now the resistor does not care if v and i are changing its time at each instant of time the voltage is proportional to current at that instant of time and proportionality constant is the resistance R. So, if I substitute v equals i R from here I will get i square times R; alternatively if I substitute i equals v divided by R. I would get v square divided by R. So, now, I have given this type of relationship please told me what is special about it.

We have v square by R i square by R, so what does it significant. There are number of answers, but I think there probably the question was a little wage my question is please concentrate on the fact that we have i square that is square of some quantity v or v square so, what does that signify. Somebody answered v square and i square need expression implies that p is always positive or it could be zero, but it is never negative. Further, this means that a resistor always absorbs power; you can never get power out of a resistor the resistor always absorbs power and typically also say instead of absorbs dissipates power.

So, in practice if you connect some voltage across a resistor some current will flow and resistor absorbs a power of v square by R and it will go on heating up that is what usually happens in so, happens in practice. The point is that the power is always positive, which means that the resistor absorbs power. So, I think this much is pretty clear.

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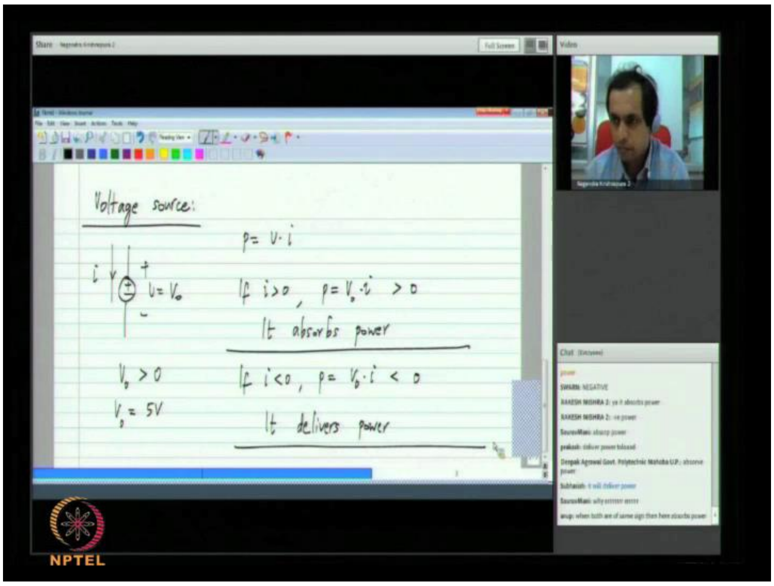

Now, let me take some other elements let me take a voltage source that is I have v equals v naught that is the voltage of the voltage source with this quantity v naught and I have some current through the voltage source. Now, I would like answers from the participants what you think this does will it absorbs power or what is the condition or you say anything about it at all can we make any statements about what the power is going to be in the voltage source. I see a number of answers that some of you say it absorbs power or some of you say it provides power it delivers power.

So, on now the fact is that you cannot tell just looking at this it can do either. See the point is p equals v times i now let us assume that the way I have defined it v naught is positive. So, let us say v naught happens to be 5 volts. Now, the proper way of the voltage source is that the current can be anything; it constraints the voltage across it to be v naught, but the current can be anything now if the current is positive a positive current is flowing in the direction shown p is v naught times i and I already said v naught is positive and that will be more than zero.

In this case it absorbs or it delivers power and if i is less than zero that is a current is flowing out of the positive terminal then i is negative and p equals v naught times i will be less than zero; it delivers power. So, if you have a voltage source you cannot say that it is going to definitely absorb power or delivers power depending on the configuration of the circuit; the current will be either going into the positive terminal or coming out of positive terminal. So, depending on these terminals it either absorbs or delivers power.

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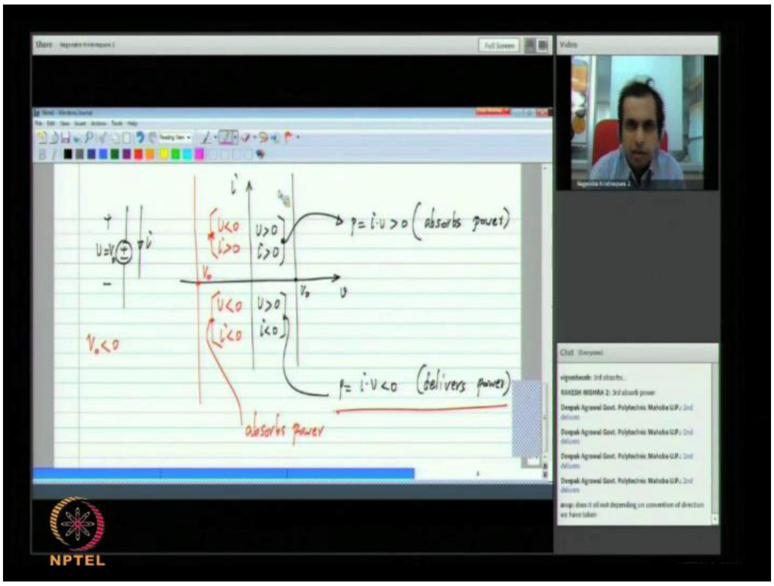

Now, we also know the I-V characteristics of the voltage source; v equals v naught this means that i v and this is the I-V characteristic of a voltage source of value v naught and in this case I have assumed v naught to be positive. Now this axis divides the plane into four quadrants. Now, please tell me in which quadrant the voltage source would absorb the power and where it will deliver power. That is the value of y can be anything right it considers that characteristics of the voltage source is in the first and fourth quadrants. So, if my question is in which quadrant the voltage source should be operating; you know in order to absorb power.

Again, there some answers and this is really simple because in this quadrant the first quadrant v is more than 0 and i is more than 0 so obviously, the product is positive in the first quadrant. In the fourth quadrant v is more than 0, but i is negative so obviously, p is i v which is less than 0. So, this delivers power if it is operating here and this absorbs power. So, if the voltage source is operating in the first quadrant it absorbs power and if it is operating the fourth quadrant it delivers power and what is meant by operating in this quadrant. In the circuit, the current value is happens to be such that it is in the first quadrant. Similarly, when I say in the fourth quadrant current value happens to be such that it is in the fourth quadrant.

There is just another way of putting whatever I said earlier if i is less than 0 it will be in the fourth quadrant. Now, we can also take the course where this v naught happens to be negative. I will show this in here if v naught is negative then the characteristics of a voltage source would be over there now in which quadrant will it be absorbing power and in which quadrant will it be delivering power. Again there are number of answers, but the principle is extremely simple you look at what the signs of v and i are from that you will determine the sign of v times i. In the second quadrant v is smaller than 0, where in voltage is negative and the current is greater than 0.

So, this is the same as this one as far as the i v product is concerned. So, the third quadrant also delivers the power; in the second quadrant it delivers power and in the third quadrant v and i are both negative it absorbs power. So, this is the way it is and you when you may be asked; when you may be asked let us say you have a circuit with number of sources and whether is it absorbing power or dissipating power in a particular condition they have, which see whether in which quadrant it is operating here. Finally, you just have to calculate the product of v and i with appropriate signs and decide whether it is absorbing power or dissipating power.

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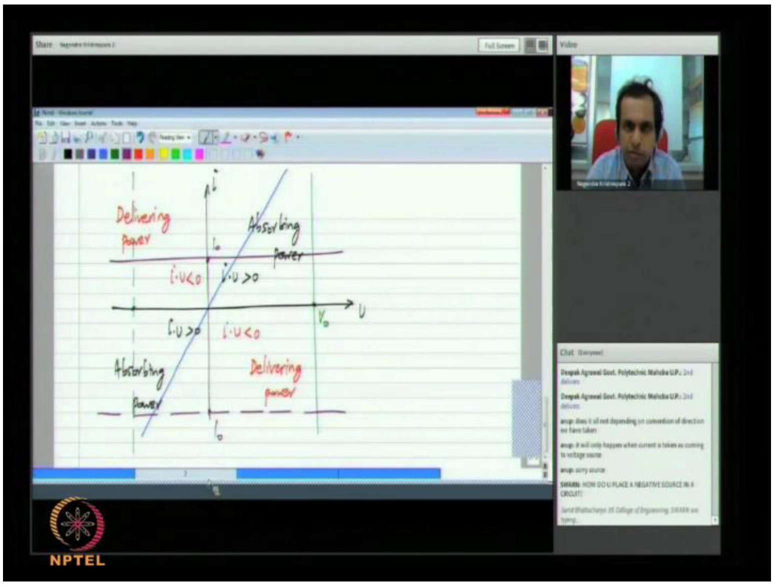

In general, whether it is a voltage source or whatever element it is in the i v plane we know that i times v is positive in the first quadrant and i time v is positive in the third quadrant also. So, the element if it is operating in the first quadrant or the third quadrant it will be absorbing power and if it is operating in the second quadrant or the fourth quadrant i times v will be less than 0 and it will be delivering power. There is a question from Sadiq go ahead hello Sadiq. Now with this we can clearly see what happens with resistor or a voltage source or a current source. Let us say if we have a resistor what would be the characteristics it is a straight line passing through the origin.

So, these straight line characteristics the resistor characteristics would be something like that. So, you see that it is only going through regions which are absorbing power. So, resistors always absorb power exactly the same conclusion varies from the power being either v square by R or i square time R. Now, if you have voltage source if the positive voltage source with the chosen science it can be either here or if it is a negative voltage source it will be over there. It will be one of these two. Now, you can see that its either it could be either absorbing power or delivering power.

Now, similarly if you have a current source a positive current source with the chosen science would be here and it could be either delivering power or absorbing power you have to actually calculate the voltage across the current course to figure out what is doing. Similarly, if I naught is negative if the current source has the negative value then also it can be either delivering it can be either delivering or absorbing power. So, again you have to calculate the voltage across the current source to be able to tell whether it is absorbing power or delivering power.

Again, now it must be pretty clear I get the voltage source in more detail by it must be pretty clear that even the current source can be either absorbing power or delivering power; any questions about this any confusion. Now, there are some questions may be some confusion with the negative source; the negative source basically means that the voltage value is negative that is all you have to do.

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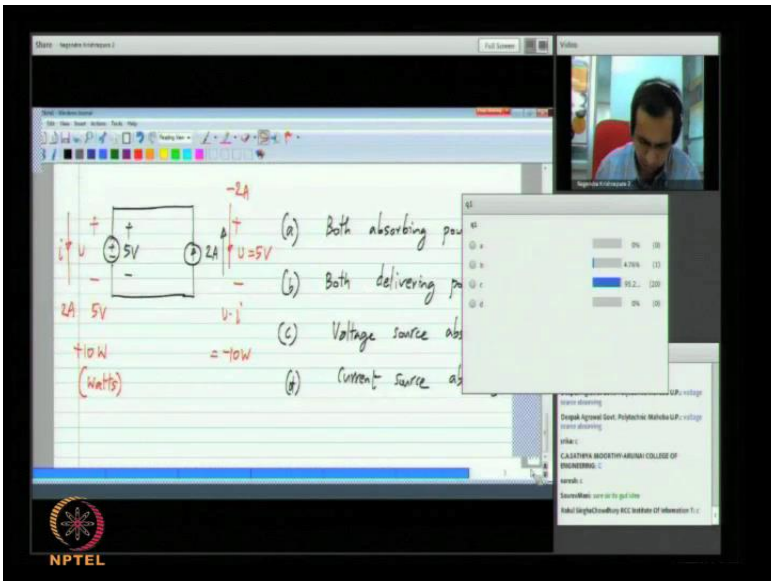

So, just to get some practice let us do a couple of problem, which are very simple what I will do is I will connect. When I write plus minus like this and say 5 volts it means that in this polarity its 5 volts that is the meaning of the simple after voltage source. Similarly, I write 2 ampere like this that means the 2 amperes flowing from bottom to top; now please answer this. Now, we have two sources in the circuit: one is voltage source and one is a current source. Now, let us try this I will draw a pole for the first time you can answer with the pole. Please mark the choices once I announce the pole. Both are absorbing power or both delivering power; the voltage source is absorbing and the current source is delivering power or the current source is absorbing and the voltage source is delivering the power.

So, these are the choices let me try the pole quickly. So, you should be able to see the pole please answer if it is a b c or d. I think those who of you are sitting in front of computer please try to answer the pole and those of you in institution in front of a screen may be you can announce your majority opinion to the mike floor and then they can enter the pole. Please try that the teacher of this we connect, which we can try and use if it is very useful we will do it more often. I think so many of you seeing quick shows and lots of things with SMS voting. So, it should be very comfortable with this type of these are more of answering questions.

I think you can see the participant answers and in fact, it is correct the majority opinion says its c the voltage source is absorbing power and that is the correct answer. In this case answer is quite simple what they do I mean all of you I am not sure and especially in the beginning when you are just telling can you just be systematic and calculate the calculate the power or anything else systematically. Now, for the voltage source if I take v in this direction buzzer convention says i have to be in that direction. Clearly, we see that v is plus 5 volts here by the way I define the voltage source i is 2 amperes; clearly v times i is plus 10 and the product of voltage and current is a 10 watts.

There is something you already become volts and its positive similarly if I take the passive sign convention for the current if I take v like this that is 5 volts this means I will take i in this direction and that is minus 2 amperes; 2 amperes is flowing from bottom to top, which also means its flowing minus 2 amperes is flowing from top to bottom. So, v times i for this is minus 10 watts, so that means that the current source is delivering 10 watts of power, which is going into the voltage source.

Now, clearly its choice is a and b little observed I mean if you have a circuit there is only two sources; it cannot be that both are absorbing power or both are delivering power. Because that violates basic conservation of energy principals; if both are absorbing power then you can ask where is it coming from similarly if everything is delivering power you can ask where is this going. So, it is only two elements it is it is there are only two possibilities for one of them to be delivering power and the other one to be absorbing power in this case the voltage source absorbs power.

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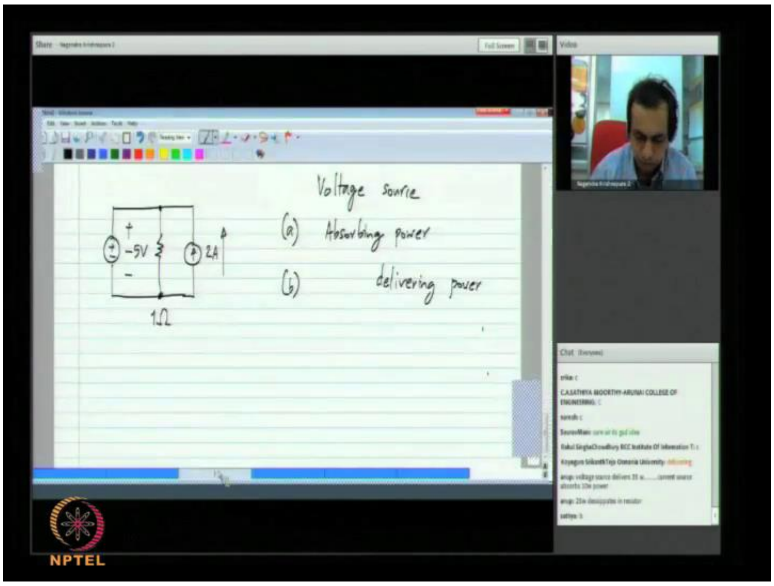

Now, just for little more practice I will give you one more question; I will make this 5 volts that is voltage the meaning of this is that its same as saying its 5 volts in this direction. I have written this plus or minus inside this circle and say minus 5 volts that really means that it is 5 volts in the bottom line plus sign and top is the minus sign. Now, I will introduce just one more complication one that is that I will connect a resistance here, which is 1 ohm. Now, first of all for the voltage source please let me know whether it is absorbing or delivering power.

The question is in this circuit if the voltage source absorbing power or delivering power. I will broadcast the results now and the majority opinion says that it is the voltage source is delivering the power and that is the correct answer; if you want I will analyze it later and shows you. Now let us make things little more complicated.

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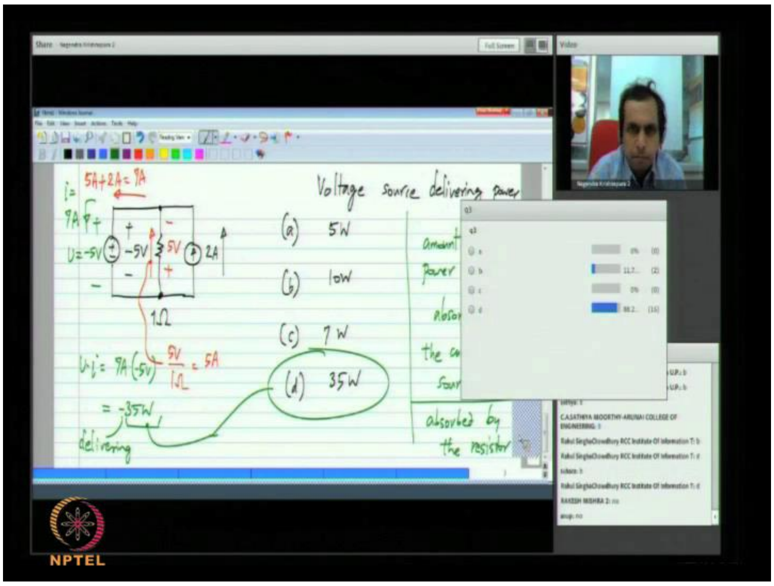

Now, my question to you is the only decided that the voltage source is delivering power and how much is it. So, now we have decided that the voltage source is delivering power, but of course, we are doing engineering; that means that we have to be able to quantitatively calculate things. So, now please mark how much power is it delivering is it 5 watts, 10 watts or 7 watts or 3 watts what is it; the last choice is 35 watts not 3 watts. So, it is delivering power, but how much is it 5 watts, 10 watts, 7 watts, 35 watts or something else I have miss calculated everything. Wait for a couple of more responses before I close.

Now, if we look at the results of the pole may be both b and d that is 10 watts and 35 watts have got more or less same number of votes and I can see more votes for 35 watts coming in I mean this is engineering; although they respond we do not decide things by votes there is only one correct answer here. Let us calculate what is it appears that when you have said 10 watts the answer to the previous question or there were some power of 10 watts in the previous question; when we add only voltage source and current source. Remember in this case we also have an additional component the resistor. So, there is no reason that the answer should be exactly the same as before; it could be coincidently same, but you have to calculate into this.

Now, first of all just to figure out how much power the voltage source is delivering what we need to do is to find out the current for the voltage source. We already know the voltage across the voltage source all we need to do is find is the current across the voltage source. So, there is one more resistor and it is in parallel with the voltage source. So obviously, the voltage across this is 5 volts in this direction or minus 5 in the opposite polarity. So, what does it mean; that means, that the current in the resistor would be 5 ohm divided by 1 ohm equals 5 ampere.

Now, if you clearly see that at this node we have 5 ampere through the resistor and 2 amperes through the current source and the remaining branch to satisfy KCL; you must have 5 amperes plus 2 amperes equals 7 amperes. Now, as far as the voltage source is concerned the voltage with this polarity is minus 5 volts and the current with that polarity with the passive sign convention is 7 amperes. So, v times i is 7 amperes times minus 5 volts, which is minus 35 volts this minus tells you that it is delivering power and this 35 volts is the amount of power that is delivered. So, the correct answer is d.

Now, it is very easy to generate even more problems of this type; we can go on adding resistance and current sources and voltage sources and so, on and you can get some practice yourself. Of course, if you go to the basic book like Headen and Kimberley there are number of problems, but even you can generate these kind of problems yourself. The only thing I say is be very systematic and strictly calculate v time i based on this Kirchhoff’s current law, Kirchhoff’s voltage law and so on and for each element do that properly and you will get the right answer. So, in this itself you can take as an additional excise amount of power delivered or absorbed by the current source or absorbed by the resistor.

You can calculate these things by yourself and may be discuss it on the forum or whatever is convenient for you. Now I hope it is very clear that a resistor always absorbs power a voltage source or a current source can absorb power or it can deliver power depending upon the circuit that connected in. Now, let me ask you another question I have a circuit with a single voltage source and a number of resistors. I have only one voltage source and number of resistors; now can the voltage source be absorbing power.

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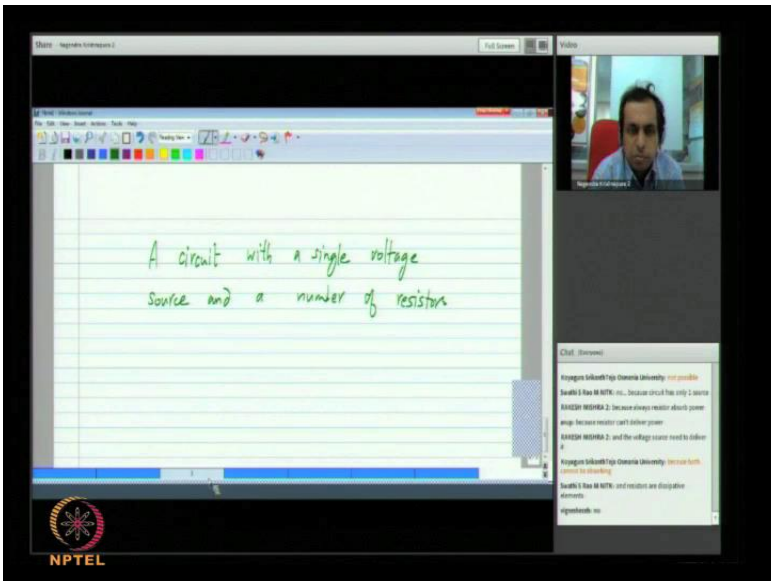

I am talking about a circuit with a single voltage source and number of resistors. You know in general the voltage source could be either absorbing or delivering power. Now, in this case can the voltage source can be absorbing power if so why or if not why not. Clearly, I think all of you are guessed it correctly if you have a single voltage source and all resistors it has to deliver power. You cannot have all the elements in a circuit absorbing power; then the question is from where the power is coming from. So, you have to have at least one source in the circuit which is delivering power. Now, depending on the circuit it could be more than one source, but whatever the circuit you have you the at least one of the independent sources; you have it must be delivering power. So, that part is correct.

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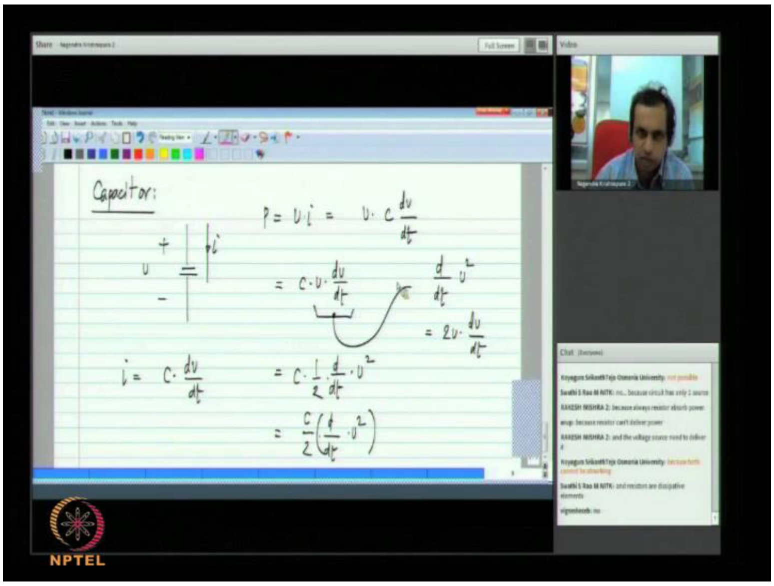

Now, I discussed a voltage sources current sources and resistors; let us move on to what happens in inductance and capacitance. Again, you know the I-V relationship for the capacitor the capacitor current is c times dv by dt and the instantaneous power p is v times I, which is v times c dv by dt. Now, this itself looks a little complicated and we cannot tell whether its absorbing power at some instant or delivering power; either is possible depending on if p and dv by dt both positive its absorbing power. Similarly, p and dv by dt are both negative it is absorbing power or if p and dv by dt have opposite signs it is delivering power.

So, all of these things are possible. Now it is more interesting to look at slightly different quantity; let me rearrange this first this is c times v times dv by dt. Now from basic calculation you know that if you have if you try to differentiate v square what you will get is 2 v times dv by dt time derivative of v square is 2 v times dv by dt and we have something like that over here. So, you have v times dv by dt basically so, what we have is c times half of d by dt of v square. I will say c by 2 d by dt of v square. So, the instantaneous power that is going into a capacitor turns out v directly proportional to the time derivative of v square and this itself either positive or negative.

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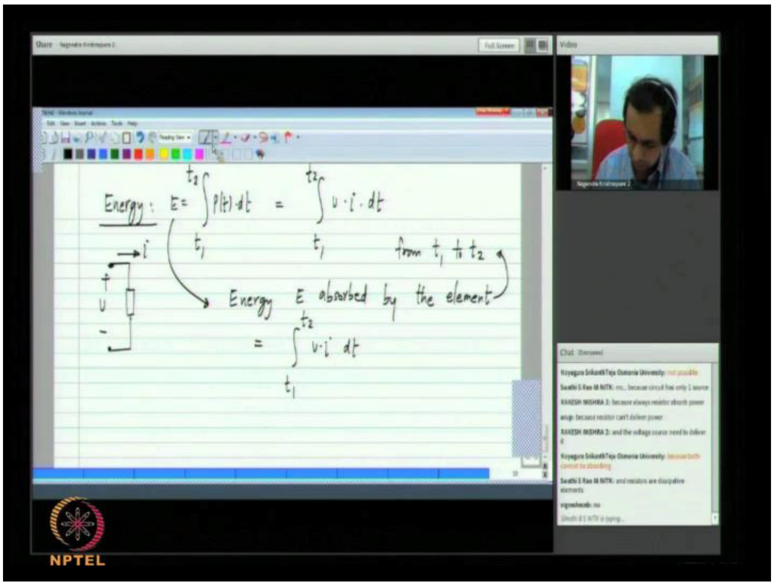

Now relative quantity into power is what is known as energy and what is energy? Energy is nothing but the integral of power over time. So, let us say you take definite integral from t 1 to t 2 and you have some element v with across it and for it they know that power itself is v times i. So, the energy E that is absorbed by the element; energy E that is absorbed by the element is given by the integral of v i dt and when I put some limits here t 1 to t 2; this means that energy E absorbed by the element over a time from t 1 to t 2 so, that is what we meant here. So, energy E and depending on how long you wait the different amounts of energy will be absorbed it is an integral quantity.

So, you have to specify the time over which the energy is absorbed and that is equal to the integral of v time i dt. Now with this reference we can look at what happens in a capacitor; we solve that this power c by 2 d by dt v square.

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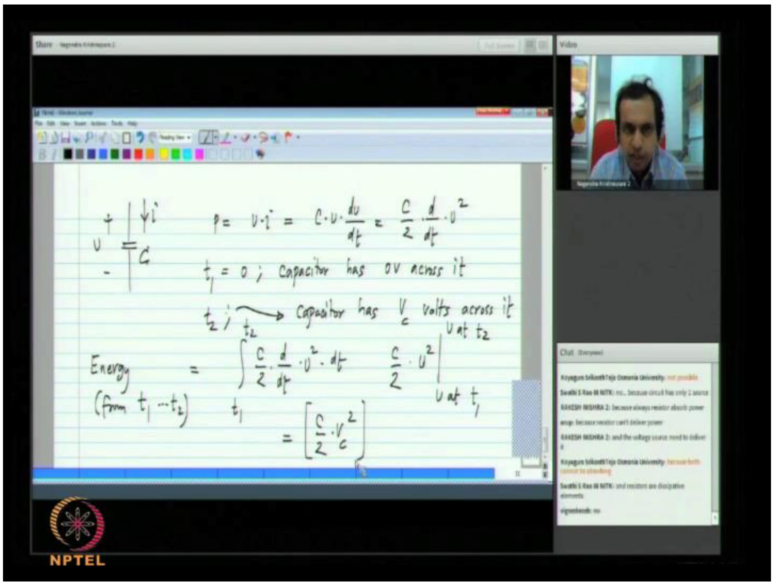

Let me write the capacitor again v i and this is the capacitor c and power, which is v times i can be written as c times v times dv by dt, which is c by 2 time derivative of v square. Now, let me integrate this and I will also chose t 1 to be 0 and I will assume that the capacitor as 0 volts across it; this is just starting point. I start from a capacitor that has 0 volts and then v and i are related in some way they are related by i equals c dv by dt may be vary v or i vary i it does not matter. But they vary in some way and finally, I reach a certain time t 2. So, the energy absorbed by the capacitor from t 1 to t 2 is nothing, but integral of c by 2 d by dt v square dt from t 1 to t 2.

Let us say the time t 2 capacitor has certain v c volts across it. Now, you can see that this time derivative operator and integral cancel each other. You will be left with c by 2 times v square with the value of voltage at t 1 to earlier voltage at t 2 and this is given by c by 2 v c square. So, what this means is that the capacitor if you charge it up to a voltage v c v have energy it has all its energy. So, v have an energy c by 2 times v c square across it. Also just like the power in resistor is always positive the energy in the capacitor is always positive v c itself could be either negative or positive, but the capacitor would have stored some energy.

Any questions about this part of it; what I did was try to find out what power dissipated in a capacitor was it comes out as some not all dissipated power absorbed by a capacitor is; it comes out is derivative of something. Now energy which is the integral of power comes out as c half the v c square half of capacitance styles the square of the voltage and that is always positive. So, if you charge a capacitor from let us say discharged place from 0 volts to a voltage v c it could have absorbed the energy or source energy of c v c square. Any questions about this; how you derived it or any sticky points.

So, now, I also started from t 1 equals to 0, where capacitor has 0 volt across it and nothing is stored in it no charge no peace no energy. I took it all the way to a voltage v c and it has in energy c by 2 v c square stored across it. So, from this we can say that now the important thing is how exactly the voltage changed it went from 0 to v c in whatever manner, but finally, the energy is stored in the capacitor is half c v square. So, the energy in the capacitor does not dependent on how you reached that voltage, but it is dependent only on the voltage across the capacitor.

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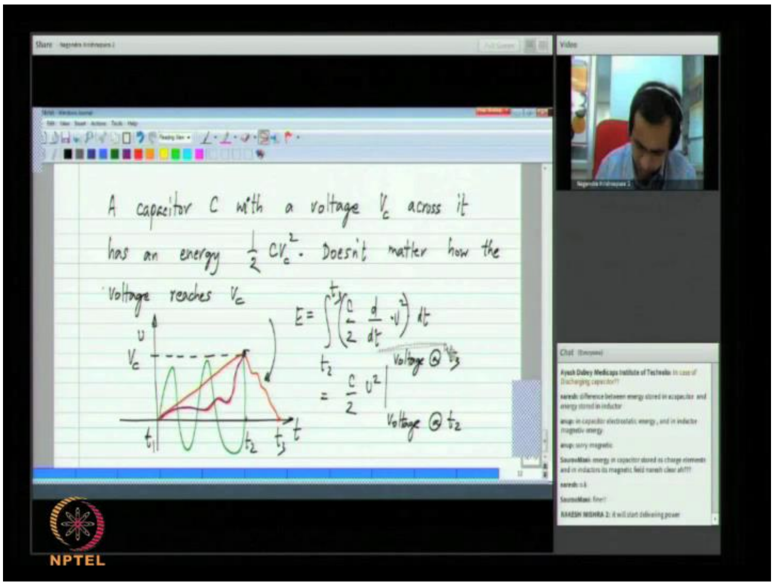

It does not matter what is meant is let us say i brought the voltage across the capacitor v as a function of time t and let us say this is the voltage v c. Now, I could have reached it as a straight line like way reached it in some strange way like this. Now, I could do even wilder stuff and go there. So, I have shown that initially at 0; that means, its energy and everything is 0. Finally, I reach a voltage at v c so; that means, that once I reach here I would have totally absorb the energy of half the v c square and that is stored in the capacitor. Now, there is a question on what happens when you discharge a capacitor.

So, let us say again. So, I call this time as t 1 and I call this t 2 where it is at v c and let us say it goes to 0 from here and I will show some arbitrary wave form it will go to 0 at a time t 3. So, if you look at what happening during this time integral from t 2 to t 3 c by 2 integral of that whole thing. This is the energy absorbed by the capacitor during this time. But what do we get? Again the integral and the time derivative cancel each other and at the end of it c by 2 v square with the voltage at t 2 and the voltage at t 3.

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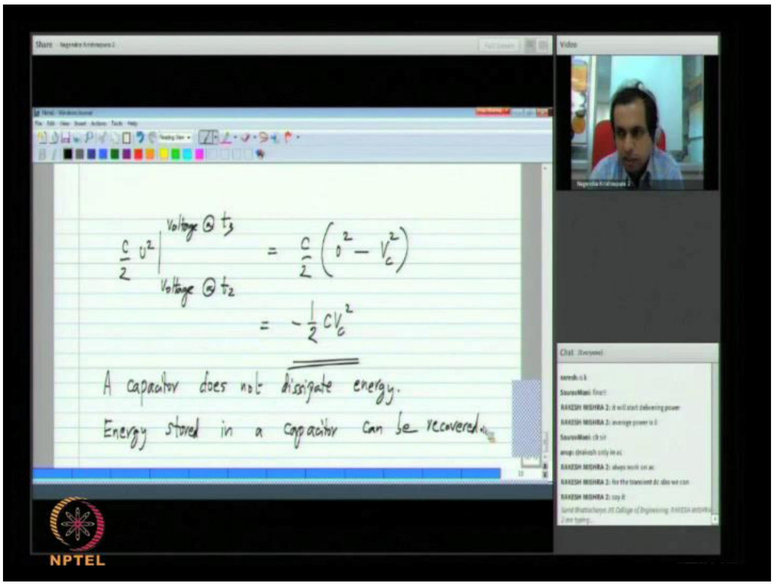

Now what is this going to be it will be c by 2 and voltage at t 3 is 0 because at least 0 volts minus voltage at t 2 is v c. So, here minus half c v c square what it meant is it is negative; that means, that the capacitor gave out energy. So, if it is positive the capacitor absorbs energy and if it is negative the capacitor delivered energy. So, if you charge a capacitor to v c it could have saved energy of half c v square and now if you discharge it back to 0 it gives back its energy.

So, a capacitor does not dissipate energy whereas resistor you charge it to some voltage it draws some energy from the source and then you discharge it back to zero; it gives back all the energy to the source. So, a capacitor does not dissipate any energy, but it can store energy I hope that is clear. So that means, that the energy is stored in a capacitor can be recovered you can use it and it is one of the important uses of a capacitor it store energy in it and then it can also get the stored energy.

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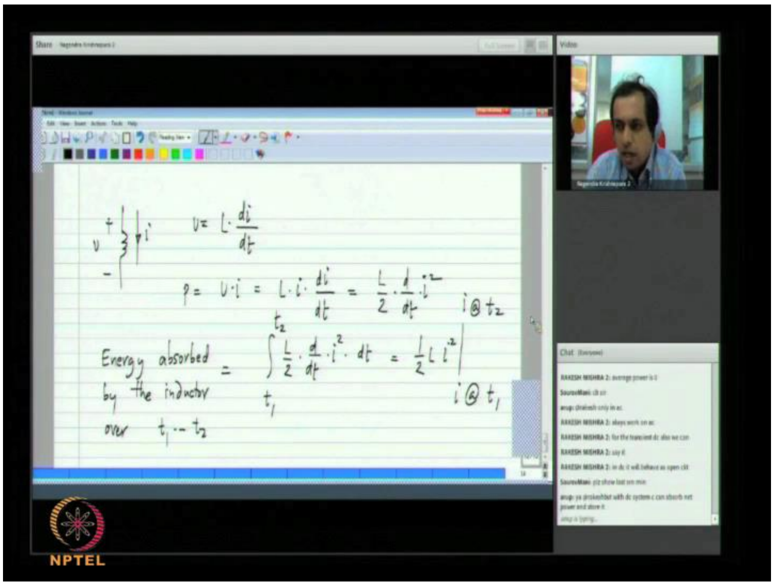

Now, let us take an example of an inductor it is very similar to that of the capacitor v and i; now you know that the voltage is proportional to the time derivative of current. So, the power is v times i, which is L times i times di by dt and this itself can either positive or negative and use the useful way to write this as L by 2 d by dt i square. Again, this it is not an interesting quantity as the energy; energy absorbed by the inductor equals and a derivation t 1 to t 2 equals the integral from t 1 to t 2 over l by 2 d by dt of i square with respect to time. So, again this will be half L and i square; this will be the value of i at t 1 and value of i at t 2.

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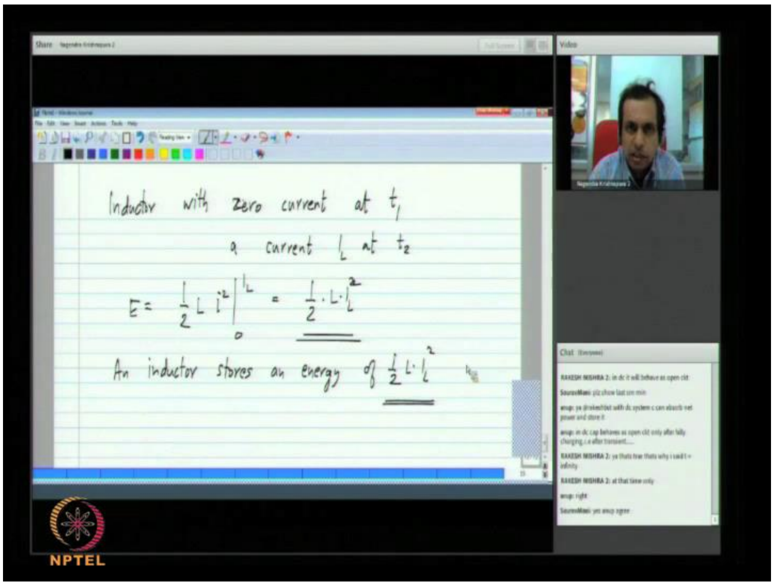

So, if you start from an inductor that is that has zero current in it and goes to the current of I L at t 2. The energy absorbed would be half L i square from 0 to I L, which basically gives you half L I L square. Now, this means that an inductor stores energy of half L I L square that is half of inductance time per square of the current through the inductor just similar logic that we had employed earlier. We can show that by discharging from some current I L to zero current to can recover all of the energy.

So, the inductor also does not dissipate any energy and it stores energy of half L I L square it also does not depend on how we reach I L; you could reach it gradually; you could reach it abruptly and you could go back and forth using positive and negative values and reach that. So, as long as you have the current I L it will have energy stored which is half of L I L square in the inductor any questions about this.

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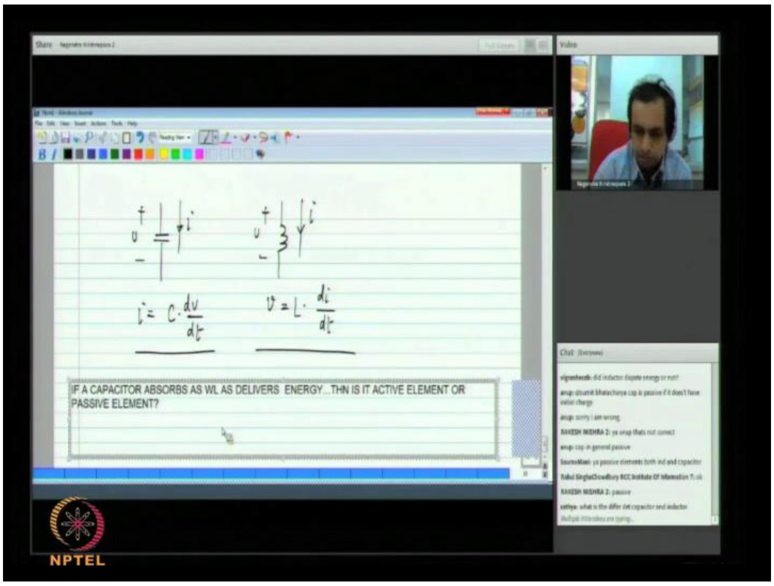

There is one question, which is basically asked what a difference between an inductor and a capacitor is. Now I mean i and v relationships are different for a capacitor here we have voltage v across it and a current i through it i c times dv by dt and in an inductor if you have a voltage across it and the current through it i is L di by dt. So, as far as circuits as far as the terminal characteristics are concerned it is like the roles of current and voltage have reversed in a capacitor the current is the time derivative of voltage in inductor I made a mistake here; this should be v the voltage is the time derivative of current. So, that all we have it and physically of course, there is a difference a capacitor stores energy in the form of electric fields and an inductor stores energy in the form of magnetic fields.

On other words another way of saying it is a capacitor stores voltage and inductor stores flux linkage; inductor stores current inductor stores a current. Now, there is another interesting question, which is that if a capacitor behaves as if a capacitor can absorb power and also deliver power it is an active element or a passive element. So, this was the question. Now, again I would probably turn this back on participant and ask what would you think is capacitor an active element or a passive element and anyways the same question can apply to the inductor. Now, it is true that a capacitor can deliver power, but deliver energy but the point is I still consider it a passive element; it can only deliver the energy, which is stored in it.

So, start from a capacitor, which is discharged now it cannot deliver any energy it can absorb some energy and then give it back. That is a very useful mode of operation for a capacitor or an inductor you can use that to store energy; sometimes what happens is there many cases in which circuit needs a lot of energy at some particular instants. So, what you do is you arrange the circuits such that capacitors is charged up and it stores energy and during those instants of very high energy demand it can give out energy, but we still consider it a passive energy element because you first have supply energy to it and then take it out. I hope that is clear.

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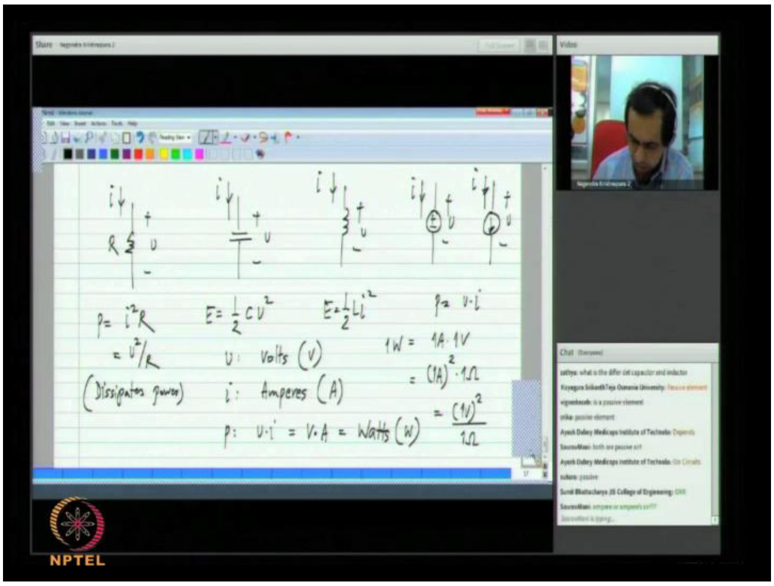

Now, before I go further let be clear about few things resistor be i the power is i square R or v square by R always dissipates power and a capacitor and a inductor the energy is half c v square in a capacitor and half L i square in an inductor, where i is the current at that instant. You see that the instantaneous power in a resistor will be the instantaneous voltage square divided by r our instantaneous current square by R. Now, the instantaneous energy stored in a capacitor is the voltage at that instant square time half c it leads instantaneous stored in an inductor is the instantaneous current i time half L and we also said that the voltage and the current source either absorb or deliver power.

So, the power is v times i and you can also find out the energy can integrate the power over some time to see how much energy has been delivered by the voltage source or the current source for a given period. Now, we know that the voltage v is measured in volts and with the symbol positive v and the current i is measured in amperes the symbol is upper case capital A; now the power which is v time i which is volts ampere is measured in is denoted by the units of watts is measured in units of watts denoted by W. So, 1 watt equals 1 ampere times 1 volt and also equals 1 ampere square times 1 ohm from this formula. We just show that used to a different ways of arriving at a units of watts and it also equals to 1 volt square divided by 1 ohm.

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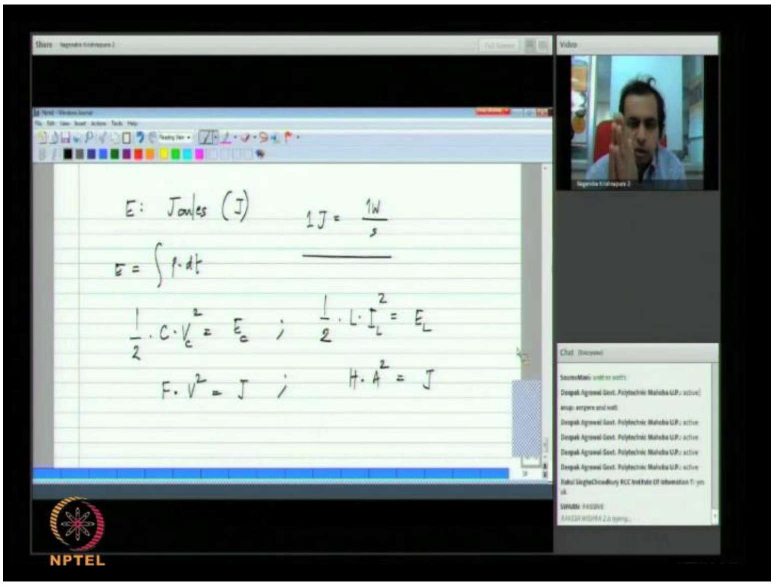

The energy E is measured in joules denoted by J; now we know that the energy is the time integral of power; so, 1 joule equals 1 watt per second. So, I think these are the mostly you are familiar with these things. This part I am just refreshing you merely and also we know that clearly the dimensions have to be consistent. So, half c v square is the energy in a capacitor. So, if you multiply pirates by the volt square you will get units of joules. Similarly, half L I L square is the energy stored in an inductor and if you multiply henries the units for inductor with ampere square you get joules again.

So, whenever you do any calculations please do it completely in units; there is not much point giving answers like the current is like it one does not make any sense it has some units. So, it has current of 1 amp or 1 mili amp and so on. Similarly the energy could be joule or pico joule or a nano joule or whatever it may be everything has to be specified with everything has to be specified with proper units.

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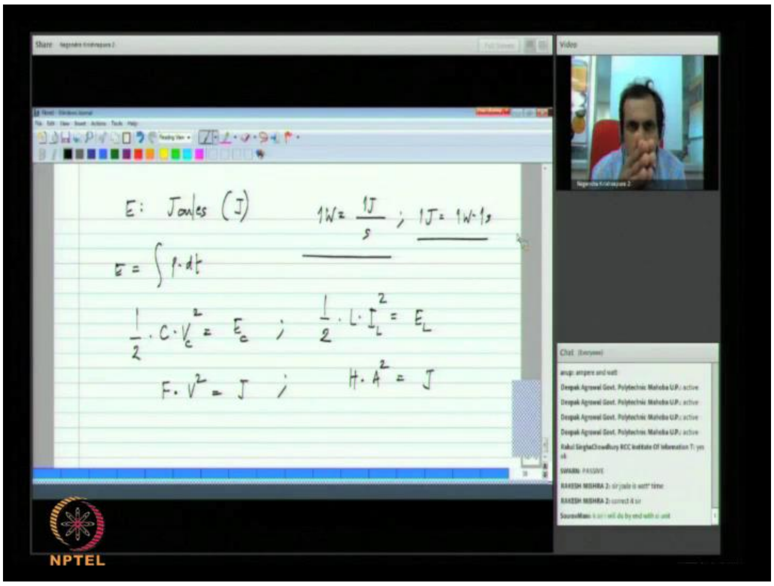

Now here appears I have made a mistake here the power of rate of change of energy. So, 1 volt is 1 joule per 1 second or 1 joule is 1 watt times 1 second, this means that if you deliver 1 joule of energy in 1 second the average power is 1 watt. Alternatively, let us say you have a resistor and it is dissipated 1 watt and if you wait for 1 second it would have dissipated 1 joule of energy.

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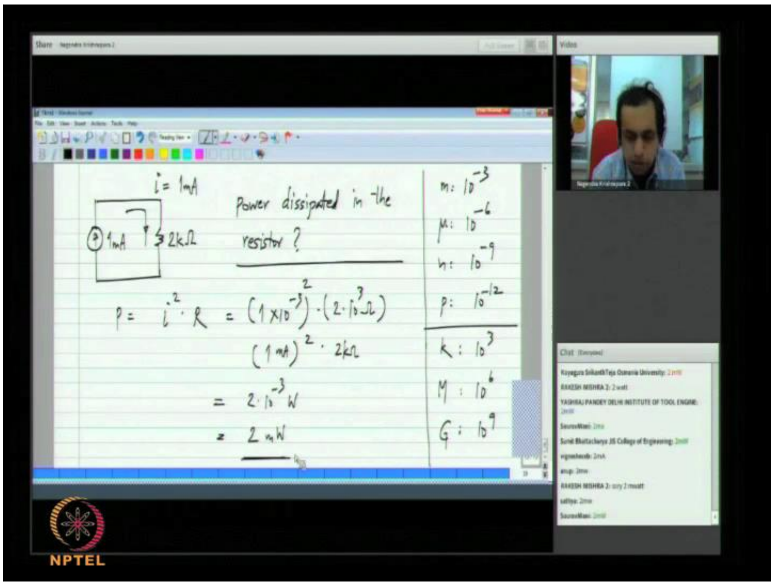

Now, again we can do couple of calculations just to get you used to these calculations. Let us say I have 1 milliamp current so, second all of you know the milli is 10 to the minus 3 and micro is 10 to the minus 6; nano is 10 to the minus 9 and pico 10 to the minus 12; these are the ones which we use frequently used. So, 1 milli amp and a 2 kilo resistor connected across it. Now, the question is what is the power dissipated in the resistor and how much power is dissipated in the resistor? Please answer this how much power is dissipated in the resistor.

So, now, the current here i is 1 milli amp and the power dissipated is nothing, but i square times R which is 2 times 10 to the minus 3 this is 2 milli amp square time 1 milli amp not 2 milli amps 1 milli amp times, which is 2 kilo ohms. Kilo ohms are nothing, but by the other subscripts. So, other prefix is more than unity are kilo 10 to the 3 and mega is 10 to the 6 and giga of 10 to the 9. So, this will give you 2 times 10 to the 3 ohms and the result will come out to be 2 times 10 to the minus 3 watts or 2 milli watts. So, the power dissipated is 2 milli watts some of you said its 2 watts, but please mind these units properly.

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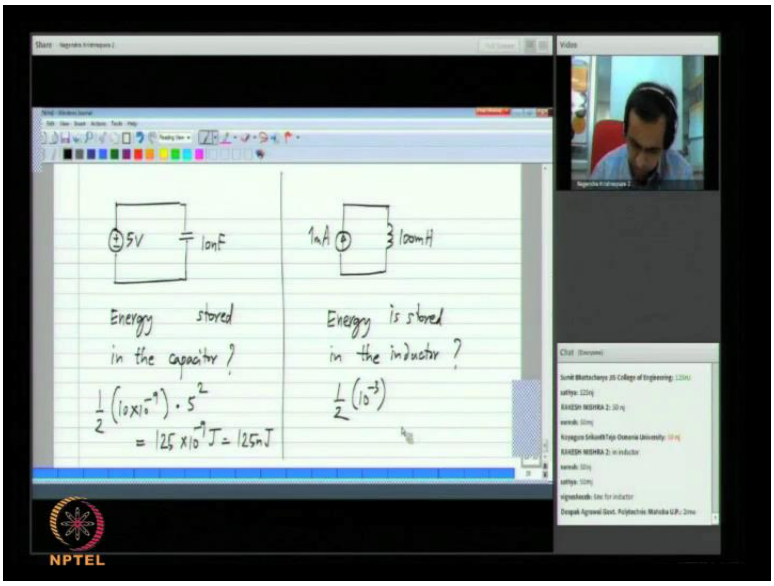

Now, next is let us saying I have a 5 volt voltage source across a 10 nano farad capacitor. How much energy is stored in the capacitor and how much is that? Please calculate and similarly you can also calculate if 1 milli amp is flowing through a 100 milli henry inductor. How much energy this stored in the inductor, I think by the way you got this it is just simple arithmetic here. It is half and 10 nano farad, which is 10 times 10 to the minus 9 times farads times v square, which is 5 square which gives you this is 25 25 times 10 is 2, 50 divided by 2 is 125; 125 times 10 to the minus 9 joules or 125 nano joules.

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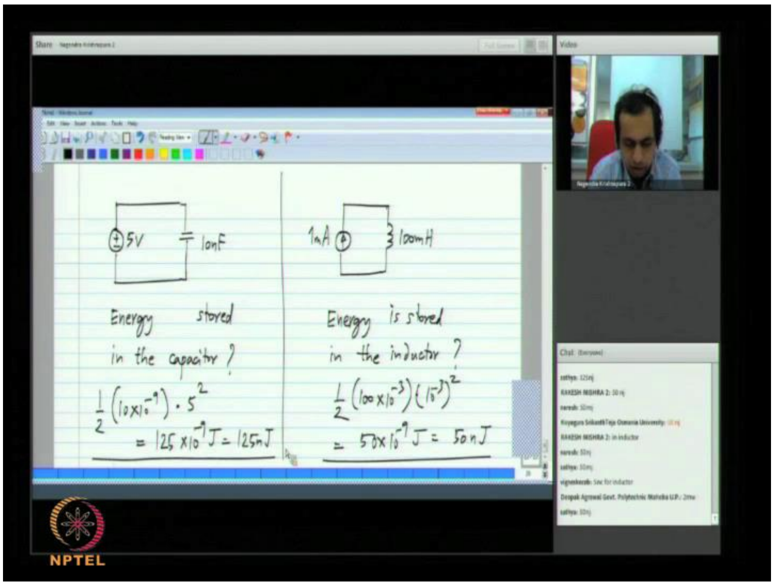

This case the inductor energy is half L i square the current is 1 milli ampere which is 10 to the minus 3 amperes times. The inductor is 100 milli henries, which is 100 times 10 to the minus henries times 1 milli ampere which is 10 to the minus 3 square and this gives you 50 times 10 to the minus 9 joules or 50 nano joules. So, you should be able to do any of these calculations by yourselves from here onwards. Any elements or any simple circuit it should be calculate voltage and current in each element and then calculate; how much power over energy is dissipated or delivered in each element any questions about anything we have done so far.

So, what we have learnt in this energy is definition of power and energy in electrical elements and inductor and capacitor store positive energy and they can also recover they would not really dissipate or lose any energy. So, that is an important feature that distinguishes them from resistors, which constantly lose energy. They all continuously dissipate power as long as some current is flowing through some and the voltage source and the current source are the sources of energy, but it is possible for them to still dissipate energy or power.

So, there no further questions what will do is will stop here and continue with the next class, where will discuss another element which is known as the mutual inductor and then move on to circuit analysis any questions. Then, I will see you in the next session.