Introduction to Electronic Circuits.
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Lecture-2.
RLC Components, Energy Considerations, Sources and Circuit Laws.

Professor: Where does the glare come in the monitor?

Student: (())(1:05) directly on my eyes.

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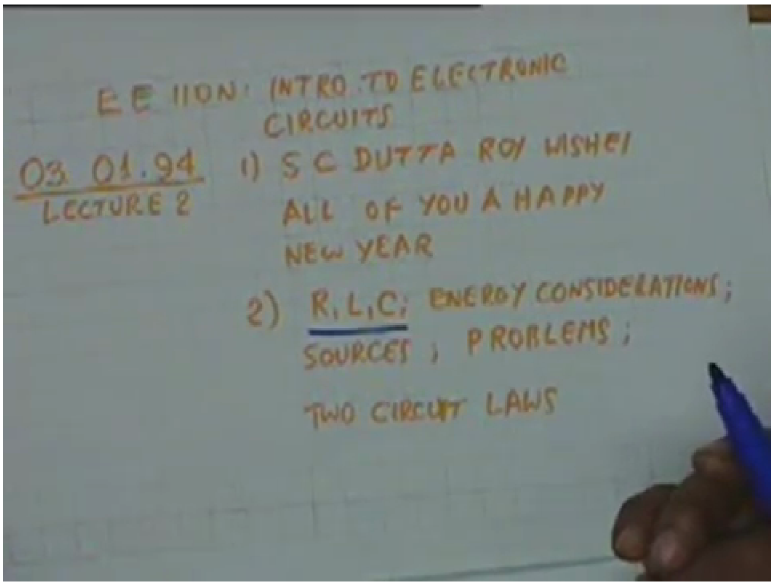

Professor: Oh, coming directly on you, is that okay? Is the recording okay, will the recording be okay? Fine. So the 1^{st} item is we wish all of you a Happy New Year and the 2^{nd} item is we want to talk about the 3 basic components resistance, inductance and capacitance, Energy considerations in them, then we want to talk about sources, current and voltage and we want to work out a couple of problems and if time permits we wish to enunciate 2 circuit laws. This would be the scope of today's lecture. Most of this material is known to you and therefore what we are doing essentially is a review of the knowledge that you already have.

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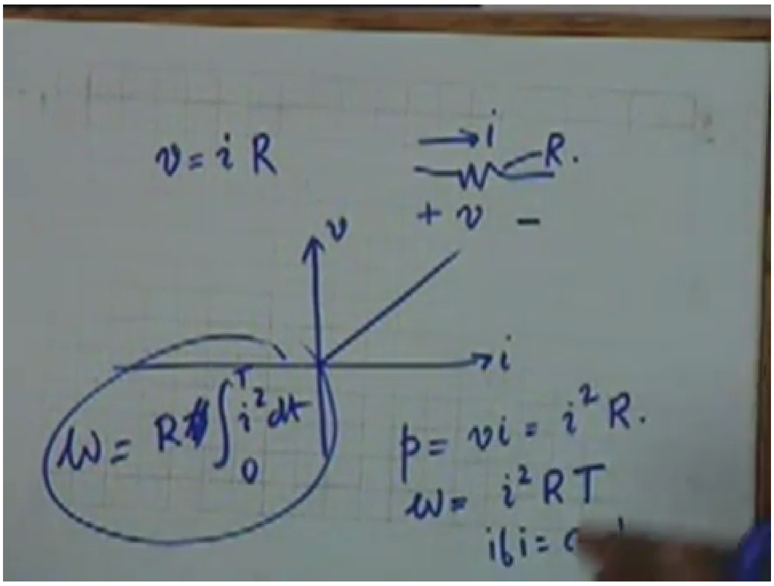

A resistance as you know is defined by, a linear resistance is defined by ohms law, that is the potential difference across its terminals is proportional to the current that flows in it v and i and the value is R. Experimental law is that v, the voltage drop is proportional to i, the more current goes the more with the drop and therefore the proportionality constant is given the name resistance and it is denoted by R. Now if it is a linear resistance, then if you plot v versus i, note the polarity, polarity is v is considered positive , in this direction, that is from where the current is originating v is considered positive and the current going to the other terminal, that the middle is considered negative.

And v, the relation between v and i, naturally them shall be only in the 1st quadrant and it shall be, it shall be a straight line whose slope is equal to R. Now if this relationship becomes non-linear, then we say the resistance is non-linear. Most of the times we shall be considered with linear resistances. In linear resistances, the power, that is the energy consumed per unit time, dw dt is given by the product vi and therefore this is P equal to I square R and the energy that is dissipated in the resistance in capital T shall be equal to I squared Rt if I is a constant, if the current is a constant. If I is constant, if I is not constant, then the relation shall be Rt integral I squared dt from 0 to capital T. This will be the general form, is that okay?

General form would be the integral of R I square dt, no T, I am sorry, R I squared dt integral from 0 to capital T, if the current is a constant, that it will be simply I square R times capital T. This energy is dissipated in the resistor, that is the dissipation means a transformation of electrical energy to heat energy, all right. And this is an irrecoverable process, irreversible process. That is if a resistance dissipates heat, dissipate energy, this energy cannot be recovered, all right. On the other, therefore in a resistance the energy is dissipated and not stored. On the other hand in an inductor for example, well 1st let us take a capacitor.

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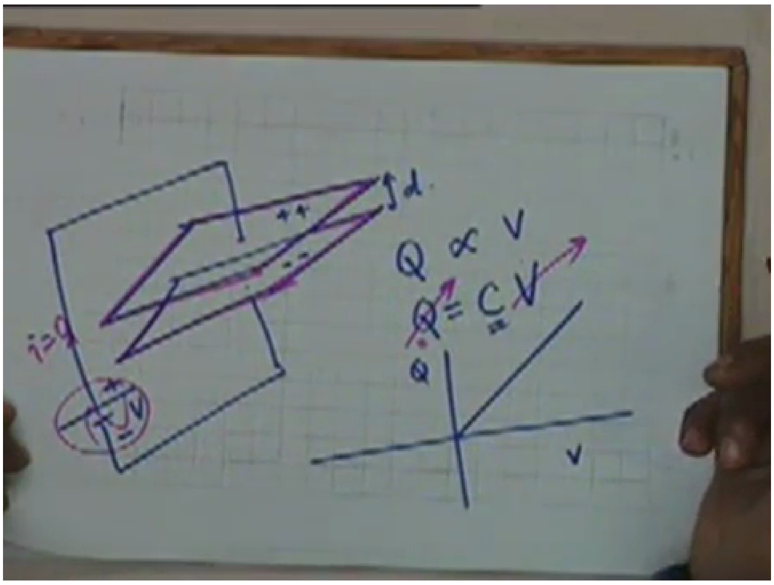

Let us consider 2 parallel plates like this, 2 parallel plates which are separated by distance d. And let us connect the battery voltage V. There are 2 plates, parallel plates like this, all right, submitted by distance, separated by a distance capital d, they are parallel to each other. And we connect a battery across this. Then you know that the above plate shall be charged positively and the lower plate shall be charged negatively. Now if I disconnect the battery, if I disconnect the battery, the charges remain, all right and therefore device is capable of storing electrical charge. Storing electrical charge, the charge does not disappear as soon as the battery is disconnected.

Therefore it acts as a storage of charge and it is found that the charge stored in the device is proportional to the potential difference v that is applied. That is if you increase the battery voltage to twice its previous value, then the charge doubles. And therefore Q is proportional to v and the proportionality constant is given the name of capacitance. This is the capacitance for storing electrical charge and is given the symbol C. Now naturally if it is a linear capacitor, then the relationship between Q and v is a straight line with the slope of C and this is called a linear capacitor.

Not all capacitors are linear, for example there are devices called varacter diode in which the capacitance varies as the square of the voltage and therefore there is a capacitance is non-linear, the charge is not linearly related to the voltage. If it is linearly related, then we say it is a linear capacitor. It is not a current voltage relationship, this is what I want to point out, the linear written does not exist between current and voltage, it is between charge and voltage, this is the basis of linearity. Now if Q is a constant, if Q is a constant, then naturally, if v is a constant then Q is a constant and therefore no current flows.

If there is a battery, the battery will not deliver any current, i shall be equal to 0 if v is a constant. On the other hand if v varies, then obviously Q also varies, if v varies then Q varies and if Q varies, then there should be a flow of current which is proportional to the rate of change of charge.

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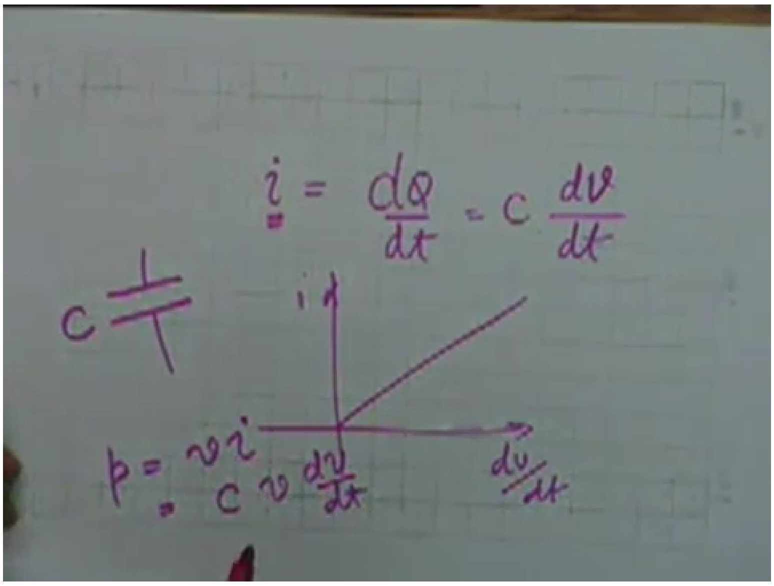

In other words if the charge in a capacitor varies, then the current flowing through this shall be given by i equal to C, i equal to dq by dt which will be equal to C dv by dt, let us give the small simple, small v, i equal to C dv by dt. And therefore the current voltage relationship is no longer linear. What is linear is the current and dv dt relationship. That is if I plot current versus dv dt, not v mind you, then this relationship shall be linear exactly like the charges linearly related to the voltage. All right. And the usual, the symbol for a capacitance is this, that is 2 lines parallel to each other and the value of capacitance is written by its side.

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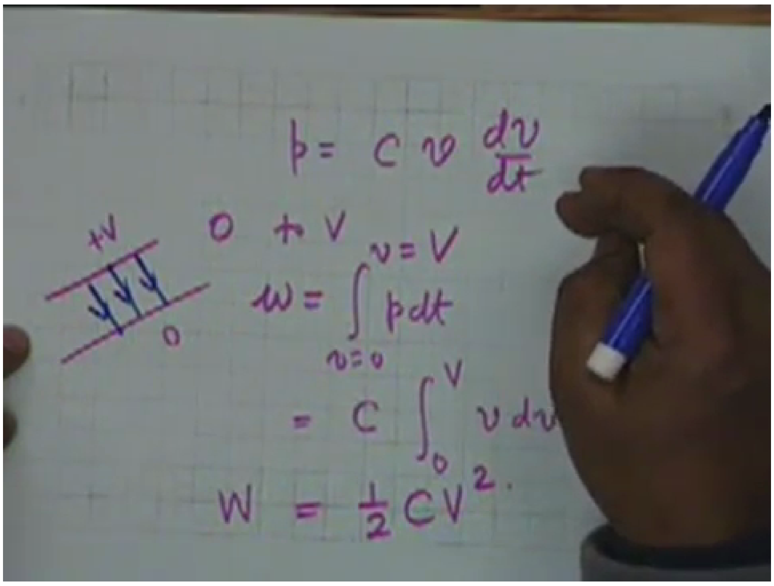

Similarly for, well, what about the natural? The power again in this case is given by vi, power is the product of voltage and current and since I is C dv by dt, therefore power is Cv dv dt, right. And therefore if we charge a capacitor from 0 to voltage let say capital V, if we charge a capacitor from 0 voltage to a voltage V, v is equal to C we dv by dt, if we charge a capacitor from 0 to voltage V, then the energy that is stored in the capacitor shall be given by integral P dt, integral P dt from v equal to 0 from 2v equal to capital V. And this therefore is equal to C integral 0 to capital V, v dv, dt and dt cancel, the rate of change with respect to time and therefore the energy stored in the capacitor is half C v square.

Why is it stored and not dissipated like in a resistor? Because this energy can be extracted, can be recovered from the capacitor. If you leave the capacitor after charging to a voltage capital V, if you leave it in that, if you do not disturb it, it shall maintain its charge for time immemorial, time at infinitum, all right. And therefore this energy can be recovered, for example if you take a capacitor, charge it to a voltage capital V, then the short-circuit the 2 terminals, that is the 2 terminals you connect by means of physical resistance wire, then a spark passes and the wire gets heated.

And therefore this energy can be recovered from the, from the capacitor and therefore this energy is stored energy. Now how does it store energy? If there are 2 plates which are class V and 0, then you know the lines of force, the lines of force start from the positively charged plate and go towards the negatively charged plates. This is the direction of the lines of force, what is the direction of the electric field? Same as that of the lines of force and therefore if I put a positive charge here, this positive charge shall go towards the lowest potential, that is 0 potential. All right.

The point that I was mentioning is that this energy is therefore stored in the electric field that exists between the 2 plates, as I said if there exists a charge or a set of charges, then an electric field is said to be created. Because another charge out into this field feels a force of repression or attraction and therefore there is a field of force and the field of force is called the electric field. Therefore in a capacitor the energy is stored in the electric field.

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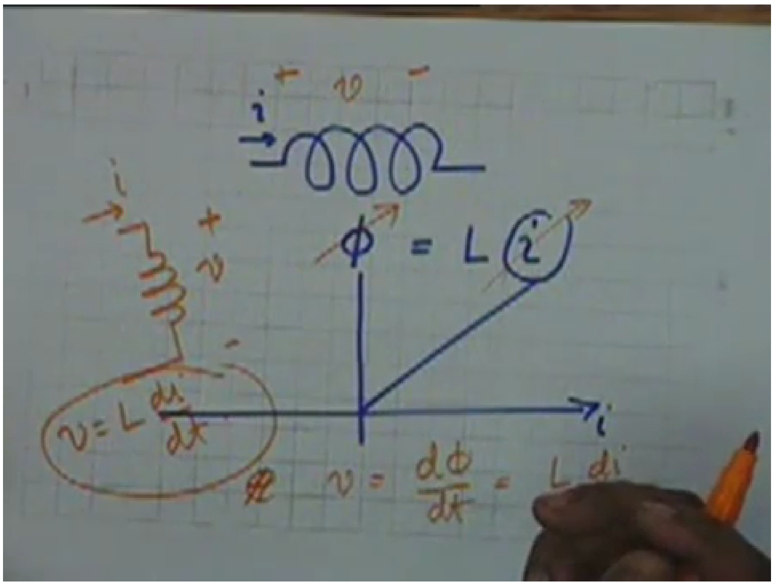

On the other hand if I take an inductor, an inductor physical manifestation is that of a coil, if you take as a resistance wire and wind it let us say around this pen, then it becomes a coil and it behaves as a inductor. Its property is that if the current passes through it i , then a magnetic flux is generated around this coil and the flux experimentally it has been found that more the current, the more the magnetic flux. And therefore Phi is proportional to i, the flux is proportional to i and the proportionality constant is i. Linearity of an inductor implies that if I plot Phi versus i, it is a straight line with the slope of capital L.

If, if it is not linear, is the relationship is not linear, then we say the inductor is non-linear. For example, an iron core inductor, as you know if you increase the current sufficiently, the core tends to get saturated and that for you get all those hysteresis phenomena and all that. Whenever saturation occurs, it is a display of nonlinearity, the flux current relationship no longer remains linear. Here also if the current remains constant, then the flux remains constant. On the other hand if current varies, if current varies, then the flux varies the Phi, Phi varies and then a voltage is generated across the inductor and this voltage is given by d Phi by dt and this is equal to L di by dt. Our convention would be that if this is the inductor and the voltage, the potential difference is v, the current is i, then v is equal to L di by dt. This would be our convention, whenever we draw a circuit element called an inductor, this will be the sense of polarities that we shall adopt.

Now an inductor source energy, it also stores energy but not in the electric field now it is in the magnetic fields because an inductor is associated with moving charges. Unless a current flows, it cannot generate a flux and therefore and therefore the energy is stored in the magnetic field and this stored energy can now be utilised. For example, for inducing voltage in a nearby inductor, all right. Energy can be transferred from one inductor to another, if you place a nearby inductor in the magnetic field of force, then the 2nd coil develops any EMF across it, all right.

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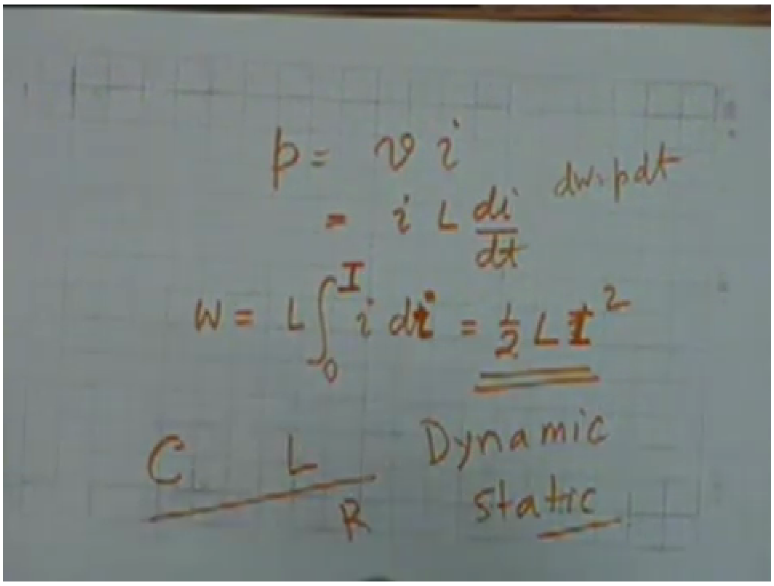

So energy can be transferred and here also if you write the power expression which is vi and which is equal to il di by dt and therefore the energy that is stored in the magnetic field is given by integral 0 to t in time capital T, if the intestines is L, then i di, I beg your pardon 0 to capital I because t cancels out and this is, what did I do, I made a mistake, i di, okay, dt cancel because W, dw is equal to ddt. And therefore dt and dt cancels and therefore what I get is half LI square, half L I square. And therefore an amount of energy half L I square is stored in an inductor in the magnetic field. And in that sense a capacitor and an inductor, they are both energy storage elements and they are called dynamic elements, dynamic.

Whereas a resistance which does not store energy, which only dissipates energy is called a static element, all right. A circuit which contains only resistance can be derived by an algebraic equation, a circuit which contains only resistance can be described by algebraic equations, whereas a circuit which contains at least one energy storage element, either an inductor or a capacitor, at least one, you cannot describe the circuit by means of algebraic relationships, you have to use a differential relationship. And wherever differentiation with respect to time is involved, the system or the circuit becomes dynamic because its property changes with time. All right, so capacitance and inductance are dynamic elements and a resistance is a static element.

You must understand, I repeat what we mean by a linear league resistor, linear capacitor or linear inductors. A linear inductor does not mean that the voltage current relationship is linear, is not that right? A linear inductor means the flux current relationship is linear, all right. The linear capacitor means that the charge voltage relationship, Qv relationship is linear, linear resistor means the vi relationship is linear, this must be kept in mind.

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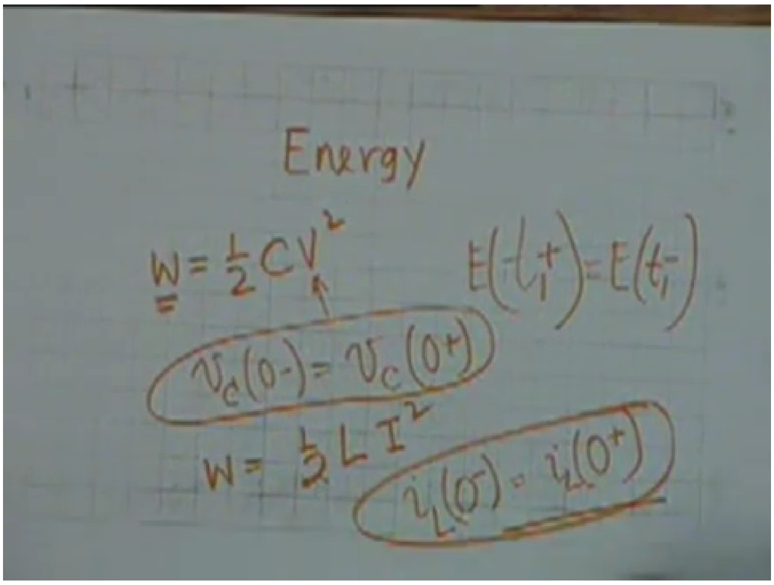

Now as you know energy under any circumstances cannot change instantaneously, whether it is a mechanical system or an electrical system, the total energy cannot change instantaneously. For changing the total energy of a system you do require a certain nonzero amount of time because if energy can change instantaneously by definition dw by dt which is the power becomes infinite. An infinite power can either be achieved nor can be conceived of and therefore one of the fundamental relationships is that if you fix any time let us say t1, then the energy at time t1 plus must be equal to the energy at time t1 -. In other words just before t1 whatever the energy is, must be the same as the energy just after t1.

And therefore if that is so, then you remember that energy in a capacitor is half Cv square and therefore since energy cannot change instantaneously, the voltage across the capacitor cannot change instantaneously I just, is in that right? In other words vc in general it shall be true that vc 0 - would be equal to vc 0 plus where vc is a voltage across the capacitor. In a similar manner energy in an inductor which is given by half L I square, since W cannot change instantaneously, therefore il, current and inductor at 0 - must be equal to il 0 plus.

I must point out that this 0 is an arbitrarily fixed reference, it could be t1, it could be t2 or whatever it is, we have taken this as 0 as the point of reference. These 2 principles, that the energy, that the voltage across the capacitor cannot change instantaneously and that the current in an inductor cannot change instantaneously will be extremely useful in analysis of circuits, electronic circuits or otherwise.

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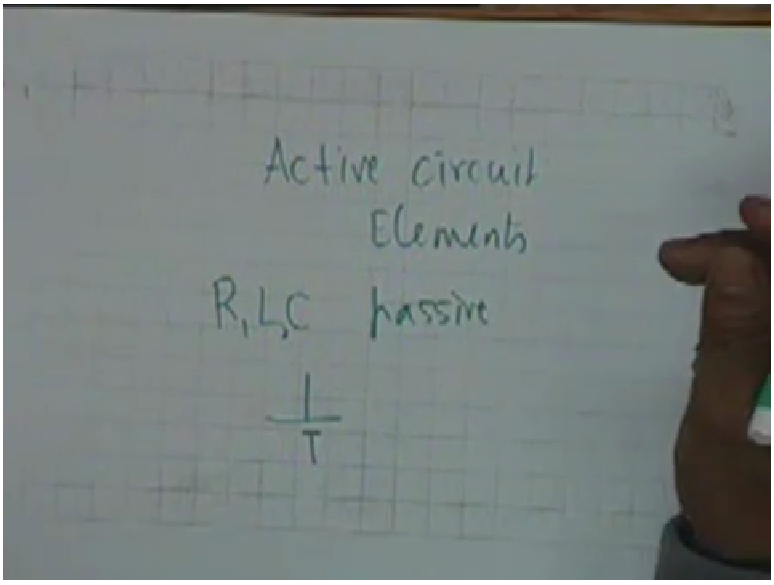

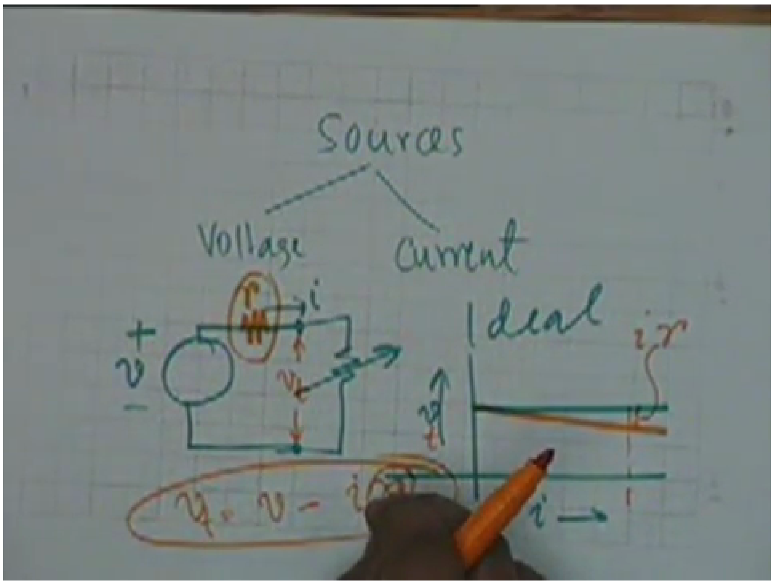

After introducing these 3 elements and they are energy relationships, let us look at some active elements, active circuit elements. The 3 elements R, L and C are called passive because they cannot generate energy, a resistor can only dissipate energy, it cannot store, it cannot generate. And inductor in order that it stores magnetic energy, it stores energy in the magnetic field, it must be fed with the current, it cannot generate on its own. In a similar manner a capacitor cannot generate energy. Any device which cannot generate energy, it can either dissipate or store which is called a passive device.

On the other hand an active, an active device is one which can generate energy. A battery for example is an active device, a rotary converter or an electrical, electromagnetic generator, rotating electrical machine which generates electrical energy is a generator. Now there are 2 kinds of active circuit element that we shall basically be concerned with and these are, these are voltage sources or current sources, voltage sources and current sources. Now note these definitions carefully. A voltage source is a generator which maintains its terminal voltage, terminal voltage constant irrespective of what you connect across its terminals.

That is even if the load is changing, if the load changes then what changes is the current, but the voltage across the terminal remains v plus irrespective of what the load is. And therefore this is called a voltage source or sometimes the word, the adjective ideal, ideal is appended to it, ideal, ideal, for an ideal voltage source naturally if I plot we versus i, the terminal voltage versus current, it remains a constant like this. In an actual source however, in actual battery for example or an actual electron magnetic wave generator, the voltage usually falls as the load current is increased. In an ordinary power supply as you shall see in the laboratory, if you take more current than the terminal voltage decreases.

And this nonidealness can be accounted for by introducing a small resistance here and this resistance is called the internal resistance of the source. A non-ideal voltage source shall be modelled as an ideal voltage source v in series with a resistance r and therefore if you plot the terminal voltage, now let us call it vt, if you plot the terminal voltage vt versus i, then what will happen, the curves shall no longer remain parallel but it shall droop because vt as you can see is v - Yr. And therefore it is an equation of a straight line but it slow, it decreases as i increases.

And at any point, at any point if this is the current, then this difference is i times r. Is that clear the difference between an ideal voltage source and an nonideal voltage source? Is this clear?

Student: Will this line always be a straight line?

Professor: Will this line always be a straight line, yes. If this resistance is linear then this line shall always be a straight line. If you have a linear resistance because what you get is this, the terminal relationship is given by vt equal to v - ir which is any question to a straight line provided small r is a linear resistance. That it does not depend on either the current or the voltage. Alright, situation is slightly uncomfortable if we consider a current generator.

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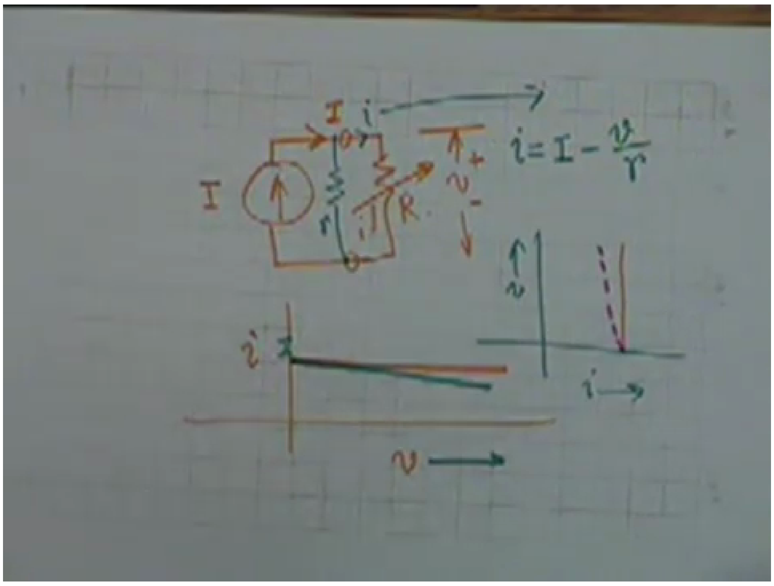

A current generator I, capital I might maintains a constant current irrespective of what the load is. If the load changes then what changes is the voltage v, not the current. The current capital I remains the same, that is a constant, current generator maintains its output current the same irrespective of what load you connect. So if we plot i in the load versus v, then v changes but i does not change, all right. In a practical current source, you must follow this carefully, in a practical current source usually the current drops as you increase the load resistance. Usually the current drops like this and this can be modelled, this crop can be modelled by introducing a parallel resistance like this here, small r.

Under this condition you see the current in the load, currently the load, the green colour I am using for nonidealness, the current in the load shall be given by capital I - what, small v divided by small r which is a linear relationship and therefore as v increases, as v increases, this term increases and therefore the current i decreases. Now if I had drawn, we shall have such gains in the tutorial class, if I had drawn the other way round, suppose we draw v here and i here, what kind of characteristic I would have got? For an ideal source it would be a vertical line, for a nonideal source tilted towards, is it this way?

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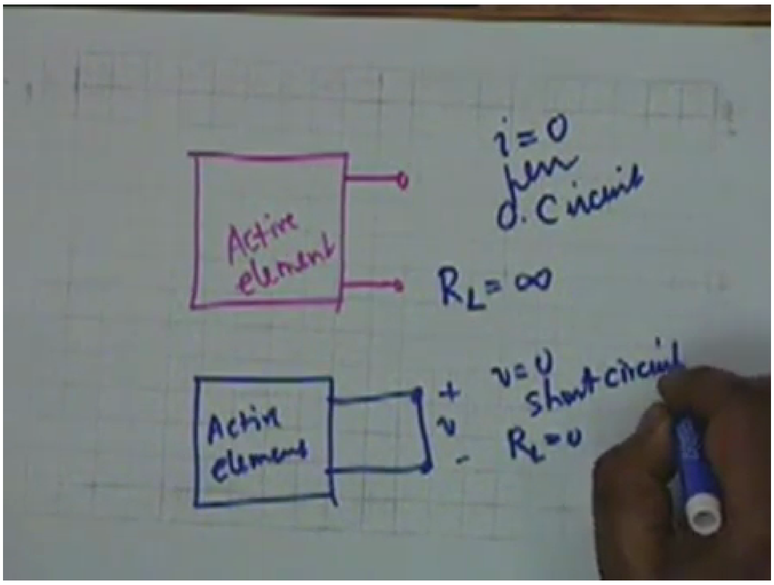

Okay, that is wonderful, we will have all such orientations in the tutorial class and we shall consider, consider tricky problems where it is slightly, it takes a bit of time to figure out what kind of shape the voltage current, current voltage characteristics are. 2 particular case of termination shall be important, termination, that is you have a, you have a let us say active element, design either current source or voltage source, it could be ideal nonideal, I am representing this by means of a box with 2 terminals, all right. Now 2 particular cases of termination are extremely important in electrical engineering and electronics. That is if there is no termination at all, that is the load of resistance is infinite, then this condition is known as the open circuit, OC, open circuit means the circuit is open and therefore no current can flow. All right?

Student: (())(29:19).

Professor: Pardon me?

Student: Can you repeat that part?

Professor: Can I repeat that part… One of the conditions of the load, one extreme condition is that the load is infinity, load is infinity means no resistance is connected across the 2 terminals. If no resistance is connected, then the circuit is open and therefore no current can flow and therefore this is called the open circuit condition, open circuit. On the other hand you could also have a situation in which no voltage can drop across the terminals, that is you connect them by a 0 resistance wire, that is RL is equal to 0.

If RL is equal to 0 then whatever current flows through RL, it cannot drop a voltage and therefore v, the terminal voltage is equal to 0. And this condition, well open circuit is the condition for i equal to 0 and short-circuit is the condition for v equal to 0, this is called a short-circuited condition, short-circuit, short-circuit is usually accompanied by a spark because of the large amount of current that can flow, virtually it has 0 resistance. And if this way, this is an ideal voltage source, if this active element is an ideal water source, then how much current can flow, infinite amount of current.

Which also points out to the fallacy of conceptualising an ideal voltage source. An ideal voltage source naturally cannot exist. If it if it can exist, then it should be, it should be capable of delivering infinite amount of power, which is not possible, agreed. And therefore an ideal voltage source is a conceptualisation only, it helps in analysing electrical and electronic circuits and therefore we are beat of an ideal would they source, an ideal, similarly an ideal current source cannot be, cannot be realised in the laboratory. What would happen if you get an ideal current source? You can generate almost infinite voltage, is not that right?

An ideal current source if it passes through an infinite resistance which is an open circuit, you see the fallacy, open circuit means the current cannot flow but on the other hand if the source is ideal, then obviously the total current should pass through an infinite resistance and the voltage should be infinity, therefore the power that it is capable of delivering shall be infinity and therefore it is also a hypothetical element only.

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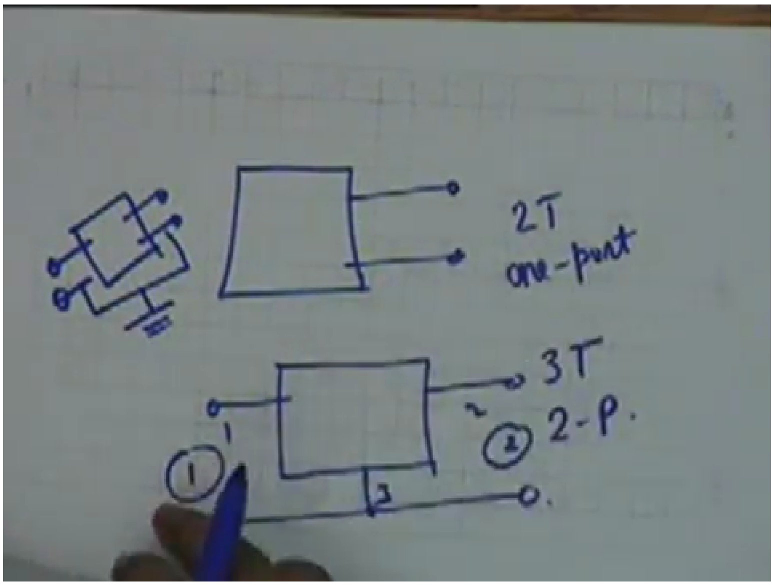

So, well I have also introduced incidentally the concept of terminals, which is very easy to see, that if you have a circuit, if you have is an electrical circuit which has only 2 terminals available, then it is simply called a 2 terminals circuit, okay. It is also called a one port, one port, well the concept of a port is exactly like that of a ship docking at port. Well since this is an electrical circuit, an electrical ocean, what you can dock in is either a water source or a current source or a load. So what all that can be done is to connect from here to here you can connect a voltage source or a current source or a resistance.

So it is called one port, it has only one port. Suppose you have a circuit in which there are 3 terminals like this, well actually the both of these are the same, 3 terminals like this, then you can dock in 2 sources, all right and therefore this is called a 3 terminal network, 3 terminals circuit or a 2 port. If a circuit has more than 2 ports, it is called a multiport, all right. You can have a 3 port circuit, the number of terminals shall depend on whether there are any common terminals or not. For example in this circuit, this terminal 3 let us say is common between port 1 and port 2.

You could have with 2 port which has exactly 4 terminals like this, this is a 2 port, all right. You can also have a 2 port which has 3 terminals in which these 2 are connected and usually they are connected to ground, all right. Now enough of concepts, let us work out a couple of examples.

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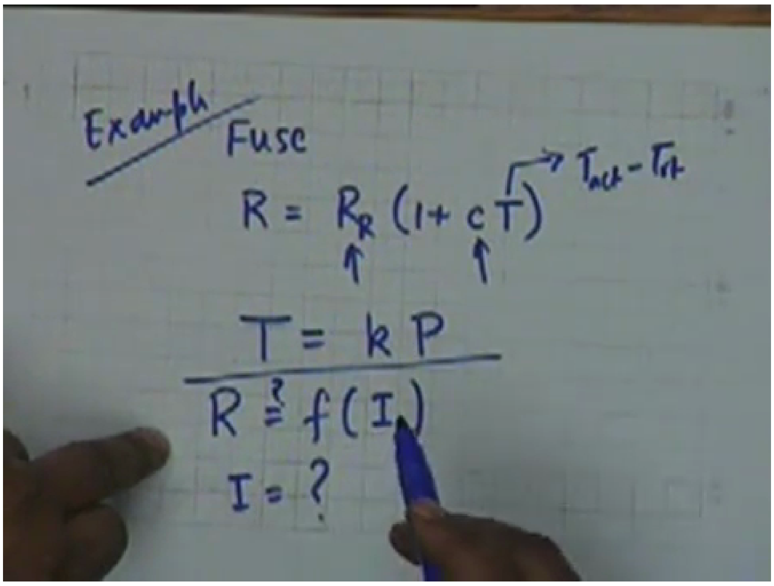

The 1st example that we take is that of a fuse. You know what is a fuse, it is used in domestic power supply, there is a fuse wire which blows up if the current exceeds a certain limit, all right. A fuse is a non-linear resistor, because if the current goes high, the voltage drop across it is such, or the heat generated is such that it lasts, it blows off, so it disconnects the electricity and saves all the equipments in the house from being damaged, from passing high current. A fuse, it melts when the current becomes excessive, the resistance, it is given that the resistance of a fuse is given by R equal to RR 1 plus C times T. Alright, it is given that the resistance of a fuse is a function of temperature, capital T is the temperature rise above the room temperature, that is capital T is actual temperature - room temperature. Okay.

Capital T is the difference between the actual temperature in the room temperature or it is the rise above the room temperature. C is a constant, proportionality constant and R sub R is the resistance of the fuse at room temperature, all right. It is also given that the temperature rise above the room temperature is given by, is proportional to the power that is being fed to the fuse. That is capital T, the rise above the room temperature is equal to some constant K times P. What is wanted is, determine an expression for R in terms of the current I and evaluate the current I such that the fuse blows off, this is the problem.

All right, you understand what we mean? A fuse can be sufficiently accurately model by relationship like this was the resistance is given by the resistance at the room temperature multiplied by 1+ a constant times the rise of temperature of the fuse above the room temperature. And this rise is understandably proportional to the power supplied, that is more power supplied, the more will be the heat regenerated, the higher would be the would be the rise of temperature. The question is to find out R as a function of I and to find out the current I which the fuse blows off.

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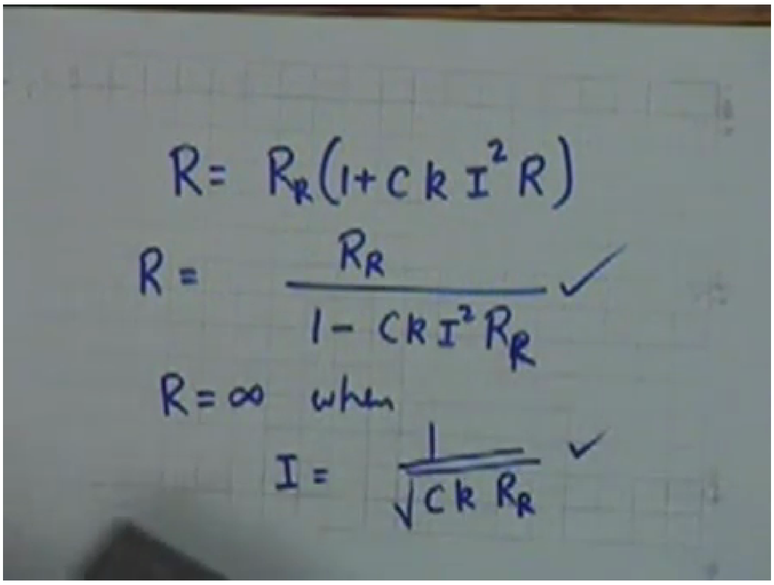

Now you can see that capital R is equal to RR 1 plus CK, P, capital T is KP and P is I square R and therefore capital R, if I take this term is the left-hand side becomes equal to R R divided by 1 - CK I square RR, agreed. This is therefore the expression. Now what is the relationship between R and I, is it linear, no, it is a non-linear relationship. Capital R, you see a resistor should not depend on the current at all, a resistor should not depend on the current that flows. Therefore it clearly shows that the fuse is a non-linear resistor. Number 2, at what current does it blow off?

Now when it blows off, capital R becomes infinity, blows of means what, it becomes open circuit and therefore capital R becomes infinity, capital R equal to infinity when I, when the denominator term becomes equal to 0. And therefore I becomes equal to 1 over square root of CK RR. That is the solution to the problem. Is that clear? A very simple problem. Any question on this? No.

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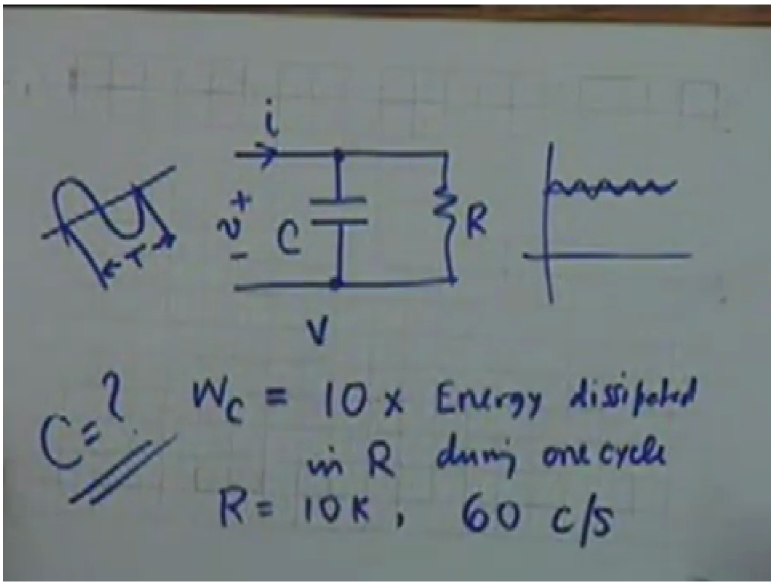

Let us take another problem, this problem is, the connection of a resistance and a capacitance in parallel. You know what is parallel connection and what is series connection. In a parallel connection the potential difference across the elements are the same, in a series connection the current in the elements are the same, okay. This is a parallel connection C and R and this circuit is used to smooth out, to smooth out the fluctuations in the current i, all right. If i is not a constant, if i is not a constant, let us say i is something like this, i is a constant on which is super, super imposed a small sinusoidal AC, then circuit smooths out this irregularity.

In other words the voltage v will approximately be a constant. The voltage shall not display the ripples in the current. And therefore this voltage shall be approximately constant and let this constant voltage be equal to capital V, all right. In that sense the circuit is said to be a filter, it is as if it filters out the small ripples in the current, all right. Now, for good filtering it is said that the capacitance should be able to store, WC should be able to store 10 times as much energy, WC, the criterion is that the energy stored in the capacitor should be 10 times the energy dissipated in the resistance R during one cycle, during one cycle.

That is if you take the sinusoidal, then this is one cycle, this is capital T, all right, during one cycle of the ripple, the energy dissipated is the resistance, 10 times that should be the energy stored in the capacitor, this is the criteria that is specified. It is also specified that capital R is 10 K, capital R is 10 K, you know what is K, K is 10 to the power 3, kilo is 10 to the 3, so 10 K is 10 to the 4 ohms. R is 10 K and these ripples are at 60 cycles per seconds, 60 cycles per seconds. That is in 1 seconds there occurs 60 such cycles, all right. What you are required to do is to find out capital C, all right.

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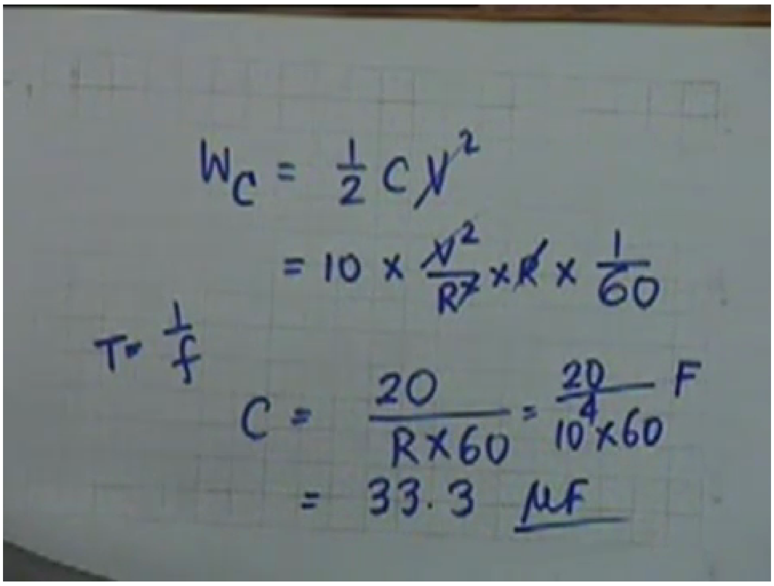

Now the solution, do you understand the problem? Is the problem clear? Okay. Another solution to the problem lies in writing the relationship for WC and energy dissipated in the resistance. WC is half CV square, all right, this we have already derived. This should be 10 times the energy, energy dissipated in resistance, what is the energy dissipated in the resistance? I square R but I square is v square diverted by R square times R times T, capital T. Now what is capital T, capital T is 1 over F, all right. 1 over F, F is the frequency, okay, cycles per seconds, so it will be 1 over 60.

And therefore I get C as equal to 20, all right v square v square cancel, C is 20, R and R square, 20 divided by R times 60. Put down the value of R, this is 20 divided by 10 K is 10 to the 4 times t and the unit shall be farads, okay, after the name of Michael Faraday, all right. And this, you can calculate this as 33.33 microfarads, that is it. These are 2 advanced problems given in the book and you can see that they are not, not quite difficult as long as you understand what the problem is. And it is extremely important that you understand the problem because it is said that once you understand the problem, half of the problem is solved, there is enough is simply calculation.

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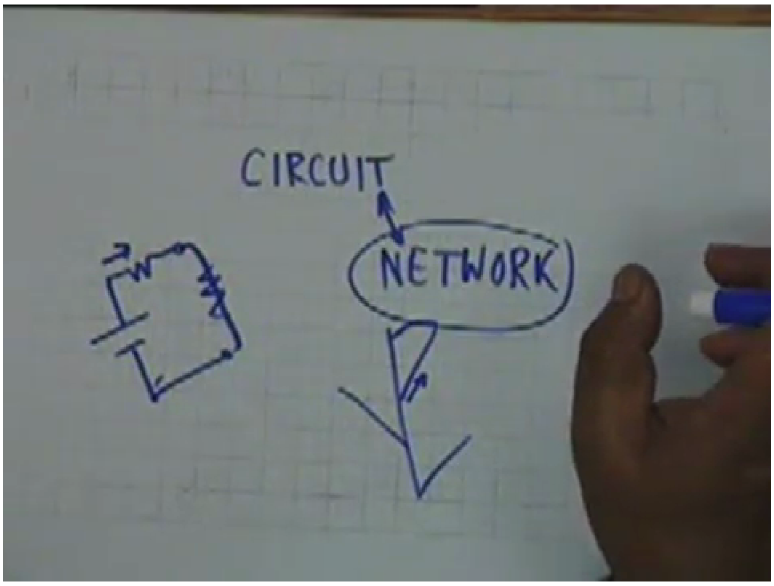

I would like to conclude this class with a discussion on the 2 words which I have intentionally not used so far, network. We said that our course is introduction to electronic circuits, all right and they have already said circuit elements. Circuit elements could be passive or active and we have said energy maybe energy shall be dissipated in a resistor, energy shall be stored in an inductor or capacitor, energy can be generated in an active device and so on. However as we shall see, as we go through the course in the textbook as also in my lectures, I shall almost use these 2 words circuit and networks interchangeably come almost interchangeably.

But there is a difference between the 2 terms, a circuit necessarily provides for at least one closed path for the flow of current, a circuit necessarily should provide a path for flow of current so there and path means a closed path, that is if a current originates somewhere, let us say in the battery, then there is a resistance, it cannot be left like this, there must be a closed path for a current to flow, the current if it is open circuit, then the current shall not flow. And therefore a circuit necessarily has at least one closed path. Now this path could be a short-circuit or could be through another resistance, all right. So a circuit necessarily shall have at least one closed path.

On the other hand a network is a more general term, network is a more general term, a network may contain circuits or may not contain circuits. For example if you have a tree like this, well this is a network, you say it is a network of branches, leaves but it does not contain a circuit. That is if a chemical starts rising up like this, it cannot come back to the free unless you provide another path like this which happens in the big Banyan tree for example, you have those (())(47:04) roots and therefore the chemical, the juices flow in a circuit. The point that I am mentioning is, in network is not necessarily a circuit, a network may not contain a circuit at all.

A circuit is a more general term than a circuit and when you say, when you in a few theorems for example, you will use the term network theorems because they are applicable to more general situations, all right. Whereas when we say about laws, with a circuit loss, KVL, Kirchoff's voltage law and KCL, Kirchoff's current law, they are both circuit loss because in a network there is no significance of these laws. These laws apply to closed paths, is that correct, closed paths.

What about KCL, KCL applies at a node, the total current entering must be equal to total current leaving. But there is a presumption that there exists a current, one or more current and therefore there must be a circuit. Right. And therefore the KVL and KCL are circuit laws, on the other hand when we enunciate theorems, which apply to circuits as well as non-circuits or a combination of them, we say network theorems. And we shall study circuit laws and network theorem in tomorrow's lecture.