Introduction to Electronic Circuits.
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Lecture-5.
Source Transformation, Superposition Theorem and Non-Linear One-Ports.

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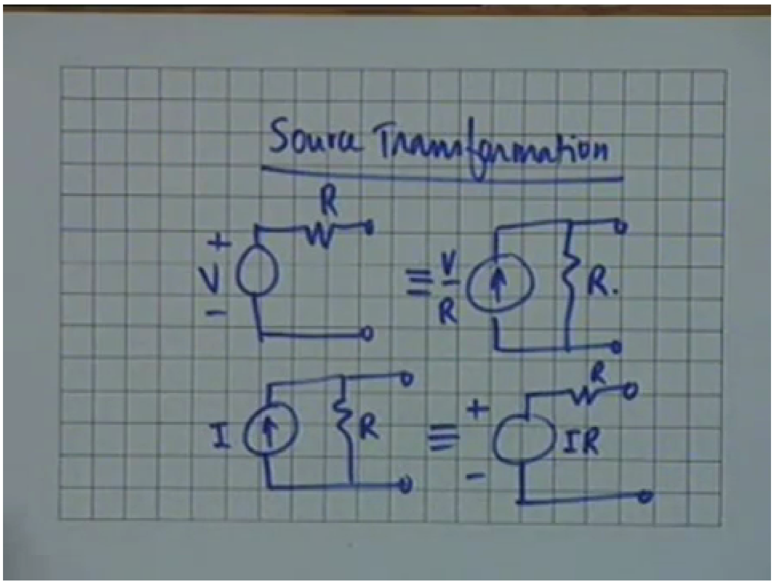

Professor: Lecture 5, 110 and we are going talk about source transformation which I had already introduced last time, we are going to talk about superposition theorem and non-linear one ports and then work out a few examples. The topic of source transformation we have already introduced, this is the application of Thevenin's theorem to a voltage source and Norton's theorem to a current source, no, it is the other way round, application of Norton's theorem to a voltage source, we have said that if there is a voltage source V in series with a resistance R, then this by Norton said is equivalent to a current source V by R in parallel with R.

This is the transformation of a voltage source to a current source, on the other hand if I have a current source I in parallel with a resistance R, then this is equivalent to a voltage source whose value is IR, in series with the instance R. These 2 constitute what is known as source transformation and in many occasions, on many occasions source transformations are sufficient to solve the network. You do not have to write either the branch formulation or the loop formulation or node analysis, you do not have to do any of them. Simple source transformation and commonsense of course are enough to solve the networks. And let us take an example shows this how source transformation enables you to solve a network.

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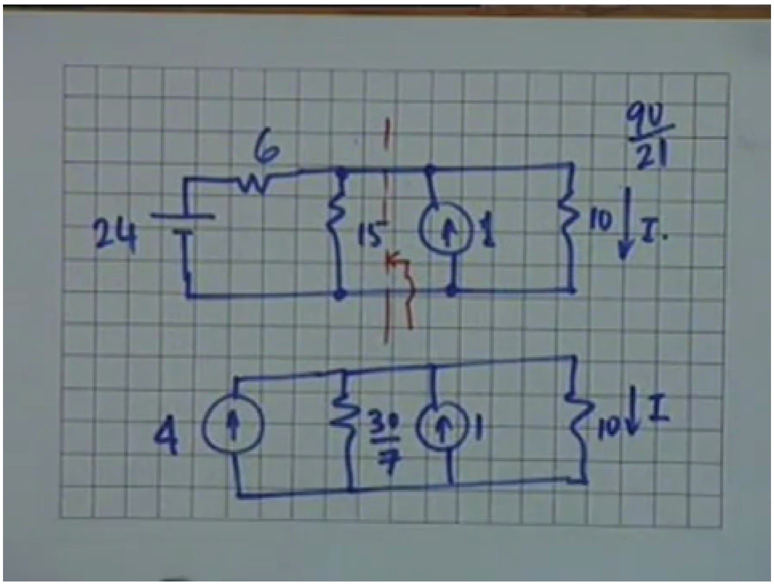

And this is one network which we have, which we have taken repeatedly as an example, this is same network that we shall take 24 volts source, 6 ohms resistance, 15 ohms, then we have a 1 amperes current source in parallel with 10 ohms resistance and it is this term that you wish to find out. We have solved this network earlier, perhaps in the tutorial class also to find out the current I by various methods, branch currents, loop method, nodal method and so on and so forth. Now by source transformation will see that we do not have tried any equations.

If we apply Norton's theorem to the left of this lines, Norton's theorem, that is the voltage source in series with the resistance, then in shunt with another resistance, then you can easily see that this, the short-circuit current, if I short-circuit these 2 terminals, the short-circuit current will be 24 divided by 6 which is equal to 4 amperes and then the equivalent resistance, equivalent resistance or the Norton resistance shall be the resistance looking back with the 24 volts short-circuited, which means a parallel combination of 15 and 6 homes that means 15 times 6, that is 90 divided by 21, which is 30 by 7.

And then you have the 1 ohms, 1 amperes current source and the 10 ohms resistance, this is the current that I wish to find out. Now you notice that both these current sources are in parallel, 4 amperes and 1 ampere, so the equivalent current source we can convert these 2 into a single current source of value 5 amperes, 4 Plus 1.

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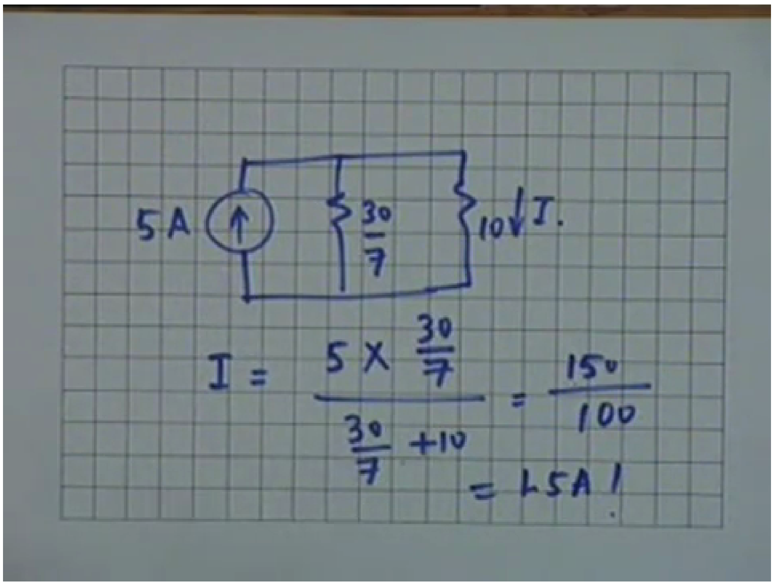

And then the circuit, then the equivalent circuit becomes 5 ampere in parallel with a 30 by 7 ohms resistance in parallel with a 10 ohms resistance and this is I and therefore I can be obtained by Inspection that is 5 multiplied by 30 by 7 divided by 30 by 7 + 10, which is simply 150 divided by 70 + 30, 100, so this is 1.5 amperes, we have got this result again and again. But this illustrates how source transformation is able to reduce a network to a form where you do not have to write KCL, KVL or any loop formulation or node formulation of branch formulation. So source transformation in effect is the result of Thevenin’s and Norton’s theorems are extremely useful in network analysis.

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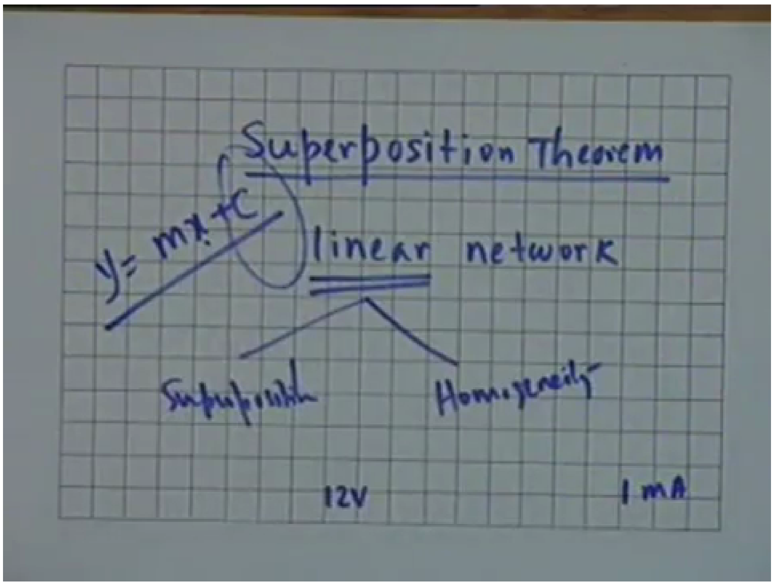

One consequence of linear, resistive network or linear network is the application of the so-called superposition theorem. More than stating it formally, it is important to understand it. It states that if you consider a linear network, in a linear network the current or voltage in any branch. The current or voltage in any branch, any resistance is the superposition of the corresponding quantities, that is currents and voltages due to individual sources, each acting independently with other forces replaced by their internal resistances. Try to understand this and write later. The theorem concerns a network in which there are more than 1 forces, all right.

Maybe there are a few put a sources and few current sources and so on. And you want to find out the current or voltage in any branch of the network. Then the superposition theorem says, what you do is take one source at a time, one source at a time and kill all other sources. What is killing mean, replacing the voltage source by short-circuit and the current source by an open circuit. Independent sources only have to be killed, dependent sources are not to be touched. Once again, exactly like Thevenin's theorem and Norton's theorem, all right.

So it says if you have a number of dependent sources, then determine the response or the current or voltage that you wish to determine due to each source independently, all right, killing all other sources, then you add all the responses, that is you superimpose or superpose also responses, the total response shall be the algebraic sum of this, all right. This is what innocence is the superposition network, superposition theorem. And the most important thing to be remembered about the application is that it must be the linear. The superposition in fact is a consequence of linearity, all right, as you will see later, linearity implies 2 principles, one is superposition and the other is homogeneity.

Linearity involves superposition and the other is homogeneity, which says, superposition means that the response of a given network, my response I mean the voltage or current in a given branch, this branch may be considered as a load. The voltage or current is the superposition of all voltages and currents caused by each source independently of all other sources. All right. And homogeneity implies that if the cause, that it if the source for excitation as it is called is multiplied by a factor of Alpha, then the response should also be multiplied by a factor Alpha.

For example, if a 12 volt source gives rise to let say 1 milliamperes at a certain point in the network, then 24 volt should give rise to 2 milliamperes, all right. This is called, this is called homogeneity and linearity implies both. So a 0 source or 0 excitation should lead to 0 response, all right. Which means that linearity not only the relationship is linear but the straight line must pass through the origin. For example Y equal to MX plus C, although it is an equation to a straight line, it does not represent a linear network because it does not pass through the origin. When X is 0, Y is not equal to 0, the presence of this constant C makes a difference. All right.

And an initially charged capacitor, again is not a linear system as we shall see later. But let us not go further into this, let us concentrate on superposition. Superposition also allows you to solve for network or analyse a network without writing, without writing elaborate equations without solving simultaneous equation, as we shall see. Super position along with source transformations sometimes can solve very complicated networks without writing a single loop equation on node equation and so on. So these are tricks of the trade and we shall illustrate superposition by means of the same example that step is taking again and again.

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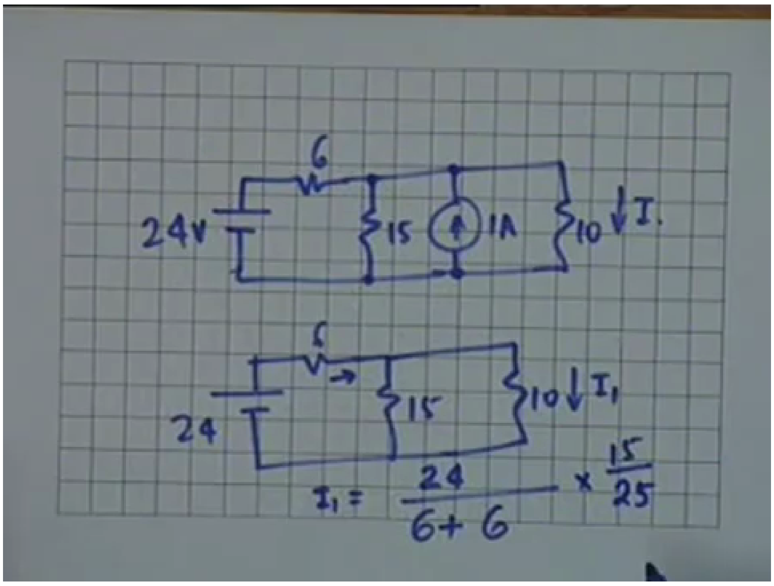

24 volts, 6 ohms, 15 ohms, 1 ampere, and then 10 ohms, we want to find out the current I. Now superposition says, just looking at the network you see that there are 2 sources, one is the voltage source and the other is the current source. So we wish to find the current I, I therefore should consist of 2 parts, I should be equal to I1 plus I2 where I1 is the response to let say 24 volts after killing the 1 ampere source, in other words removing the 1 ampere source or open circuiting the 1 ampere source, that is I1. And I2 correspondingly is the current in the 10 ohms resistance when the 1 ampere source is killed, I am sorry, no, 24 volts source is killed, which means that short-circuiting.

So let us find out these 2 currents, one is 24, 6, 15, the 1 ampere source is killed, so it is open and then you have 10 ohms and this current is I1. Obviously I1 is equal to 24 divided by 6 plus, what is the parallel 15 and 10? That is also 6, multiplied by, this current divides into 2 resistors 10 and 15, so 15 divided by 25, which obviously…

Student: 1.2.

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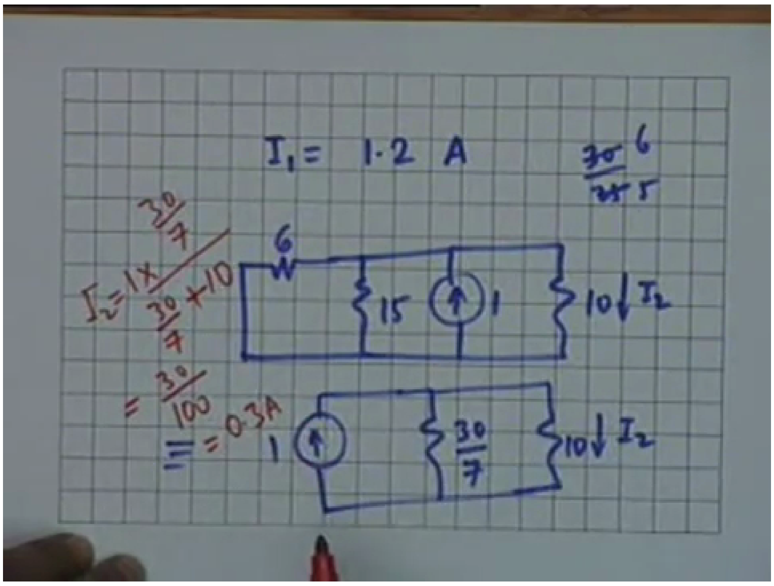

Professor: I1 is equal to 1 point…? 1.2 amperes, but it is not, 5, 2, 30 divided by 25, maybe you are right, 1.2, okay, agreed. Right then the other part is, the other part is that we kill the 24 volts source, so we shall short-circuit this and then we have the 15 ohms, then we have the 1 ampere source and the 10 ohms resistance and this current is I2. So what is I2? Well, obviously the 1 ampere source divides into 2 branches, one flows through 10 ohms and the other through the equivalent of 15 and 6, how much is that? 30 by 7, so what we have is, this is equivalent to the circuit, 1 ampere in parallel with 30 by 7 in parallel with 10 ohms. And this is I2.

Therefore my I2 shall be equal to 1 multiplied by 30 by 7 divided by 30 by 7 + 10 which is equal to 30 by 100, right. If you multiply by 7, 30 by 100 which is equal to 0.3 amperes. And therefore by superposition, superposition says if you found them independently, simply add them up, all right.

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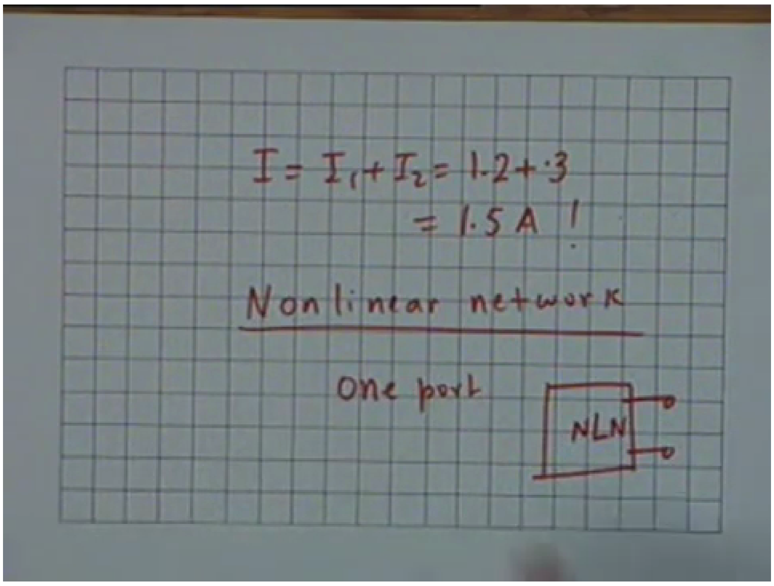

Simply add them up, in other words the required current I shall be equal to I1 plus I2 equal to 1.2 + 0.3 equal to 1.5 amperes, the result which we are getting again and again. Here also you will see, we did not have to, we did not have to write any loop equation on node equation, branch formulation or anything. We did not even make any source transformation, we simply applied superposition. All right, so superposition thus helps you to solve problems. There are some other examples in the tutorial sheet number 2, particularly on (())(16:46). And I urge you to try solving some of them buy superposition.

Next we consider, we have talked about linear network, let us see what happens if we have a non-linear network. And to keep life simple, to keep life simple the 1st consider a non-linear one-port, a non-linear one-port which means a network having available only 2 terminals, only one port or a pair of terminals, a non-linear network N, NLN, okay. Obviously if this is a resistive network, if this network is a resistive network, then we can call it a non-linear resistance, all right. Let us consider 1st a non-linear resistor.

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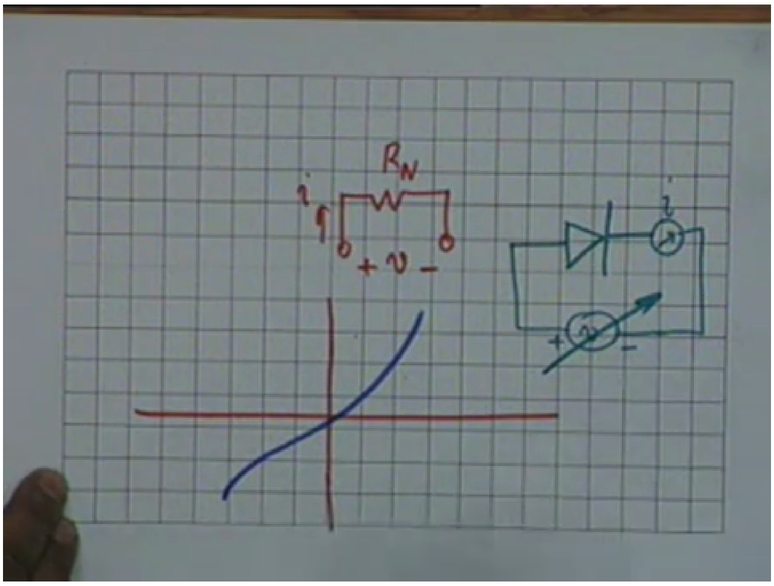

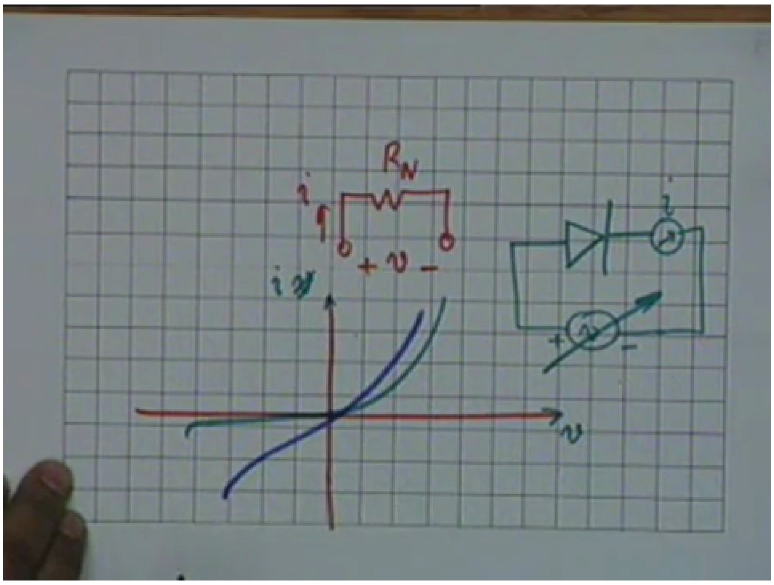

There is no special symbol for a non-linear resistor, so we simply say RN, all right to indicate that it is a non-linear resistor. Now a non-linear resistor obviously does not obey ohms law, ohms law says V should be equal to, V should be proportional to I, all right and the proportionality constant should be RN. Here in a non-linear network, this is not necessary, so V and I are not necessarily related linearly, in fact, one could have a situation like this which is obviously not linear, all right. Such a characteristic is that of an incandescent lamp. If you take an ordinary bulb, a 60 watt bulb and gradually increase the voltage, measure the current, all right, you will get a characteristic like this.

An incandescent lamp is a simple example of a non-linear resistor where V equal to RI is not valid. Another common example is that is that of a diode. A diode whose symbol is this, a diode if you connect a voltage source V and measure the current I, if you connect a voltage source V and measure the current I and vary V, then the current shall also vary and one will see that one gets a characteristic like this, it is very small, this is IV characteristic, this is V, I beg your pardon, this is I and this is V, IV characteristic is such that when V is negative, very little current flows and V is positive, current increases almost exponentially, all right. This is obviously a non-linear resistance.

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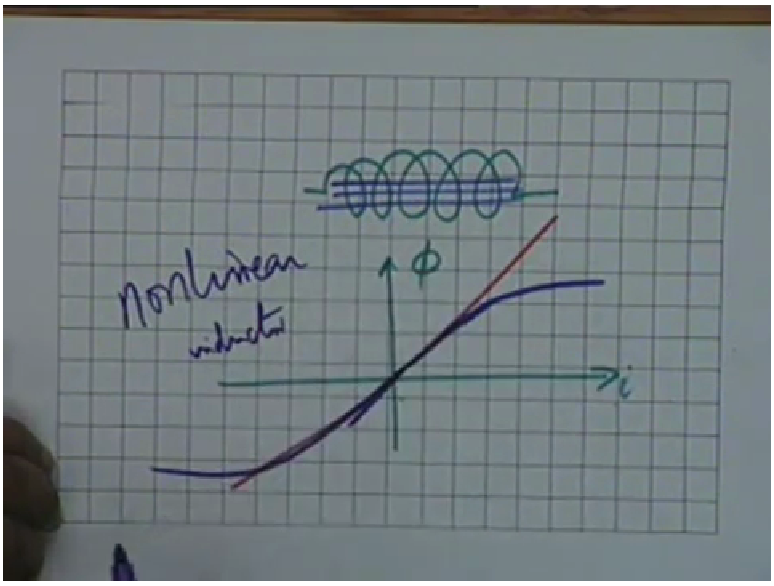

There are many other examples of non-linear resistance. There are examples of non-linear inductors and capacitors also. For example if I make an inductor, how do I make an inductor? I simply, I take a core like this and wind turns of wire around this. If this course, if this core is non-magnetic, for example a piece of pencil or a piece of wood, then the flux current relationship phi versus I is fairly linear, is fairly linear, okay. On the other hand if this core consists of iron which is a magnetic material, then as you know iron, the amount of flux with increase in current tends to get saturated, that is, that is what happens is up to a certain extent while it is linear, and then the flux tends to get saturated.

Similarly, similarly the other direction, it tends to get saturated. And you know that if you bring back the coil, if you bring back the current to the previous value, it does not follow the same path and that is this famous hysteresis phenomenon, all right. The point that I am mentioning is that the flux versus current relationship which should be linear for a linear inductor, if you use iron at the core, then it tends to become non-linear. And therefore iron core, it is an example of a non-linear inductor.

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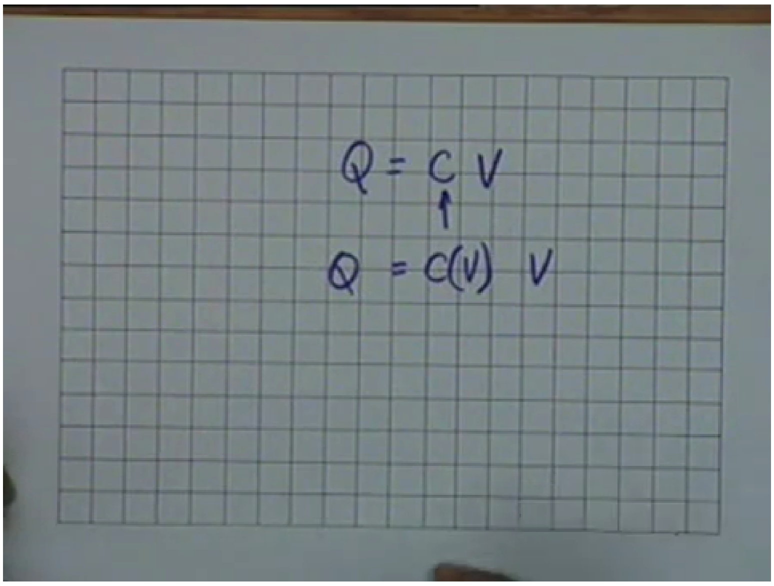

Similarly as you shall see later, you can make a semiconductor device in which the capacitance is proportional, well in a linear capacitors, the charge should be proportional to voltage. C should be a constant, it should be independent of voltage. You will see semiconductor devices later in which the capacitance is a function of V. If the capacitance is a function of V, then obviously Q versus V plot shall no longer be a straight line and therefore it becomes a non-linear capacitor. So we can have a non-linear resistance, we can have a non-linear inductor and a non-linear capacitor.

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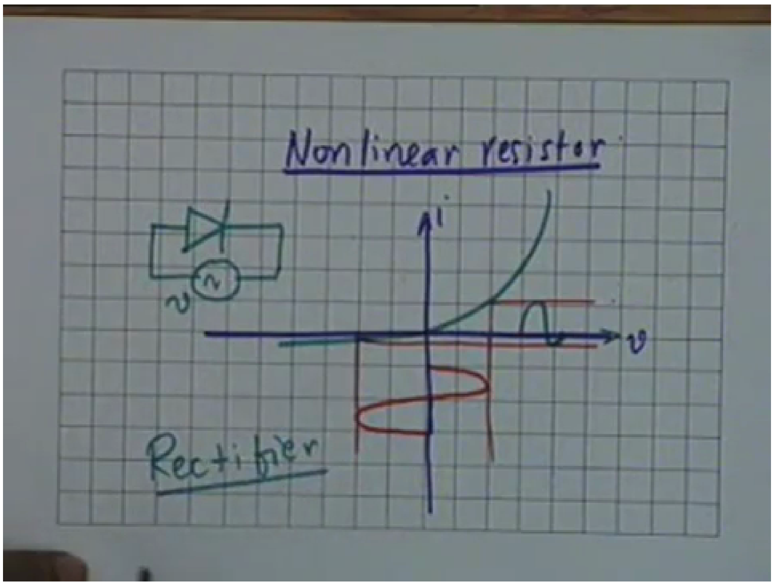

Let us concentrate our attention on 1st non-linear resistors, non-linear resistor. How does one characterise a non-linear resistor? Well, one of the, one of the ways is to use instead of analytical method is to use graphical method. For example suppose we have a diode, suppose we have a diode in which the VI characteristic is like this, this is VI for negative V the current is very small, for positive V the current increases almost exponentially. And then what to do is you apply let say sinusoidal voltage to the diode. That is you have a diode this is a symbol for a diode, you apply a sinusoidal voltage V.

Sinusoidal voltage means that the voltage varies like this let us say. Suppose the voltage varies like this, this is sinusoidal, ignore the slight deviation from sinusoidalness, this amplitude is equal to this amplitude. Now if you plot the corresponding current, if you plot the corresponding current, obviously at this stage the current would be this much, all right. So if you extend this horizontal line and at this peak the current will be this much, very small. And therefore the current waveform shall no longer be sinusoidal, it would be distorted, it would be like this, there would be very little of current when the voltage is negative.

The current flows merrily when the voltage swing is positive, in other words the diode, this non-linear resistor favours a positive voltage, it discriminates against the negative voltage. And therefore this diode, the diode acts as what is known as a rectifier. That is it accepts the positive half of the voltage, it rejects the negative half of the voltage and that is why you could convert an AC to a DC, a unidirectional currents. And if you put a DC metre, then you shall measure the average value, the average value, okay. So a diode, non-linear resistor therefore can be used as a rectifier.

Similarly you can have other examples of non-linear resistor and a non-linear resistor, the network analysis problem can be solved graphically. We shall see other examples, we shall take a fairly complicated example a little later of a non-linear, of a separate containing non-linear resistors. But let us look at an analytical method, this is the graphical method, this is, this is graphical method, understood? You look at the voltage, this is the voltage axis, if you look at the voltage variation, the corresponding current you plot it and you see, this is what you wanted to find out, the current I. So if the characteristic is given graphically, then you can find out the output.

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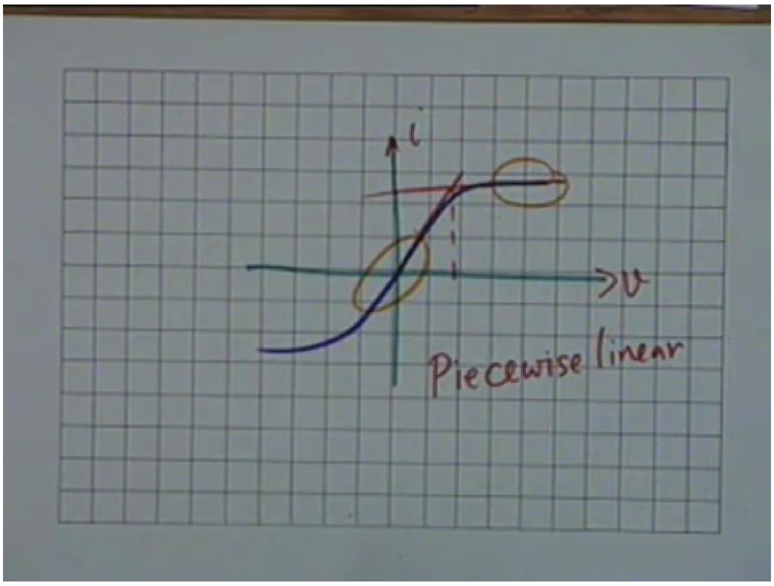

Here the input is the voltage and the output is the current. One can also do this, as you will see later in electronic circuits that if I have a characteristic which is not linear but let us say a characteristic like this, all right. Obviously this is not linear but what one can do is, one can approximate this by a number of straight lines. For example this part is fairly straight, so what you do is you approximate this by a straight line like this and this part can also be approximated by another straight line. So what one does is that part of the characteristic you approximate by a straight line like this and the rest of it by another straight line like this or slopes are different. All right.

As you will see later such approximations are obvious name is given piecewise linear approximation. That is you choose pieces of the characteristic curve, pieces of the curve, this could be voltage current relationship for a flux current relationship for a charge voltage relationship, you choose parts of the curve and approximate this by a straight line. You choose another part approximated by another straight line, so these are piecewise linear approximation. For example if the device, if the device is operating, let us say, if the device is operating in this region, then obviously you can treat this device as a linear device.

Or it devices operating in this region, it does not go through low values at all, then obviously you can again approximate it by a linear device and this is what we shall do. The transistor for example is a highly non-linear device but we shall operate it in such a region that it can be approximated by a linear device. And if we can do that than our analysis becomes extremely simple and transistor used as an amplifier is an example of a non-linear device being operated in the linear region as we shall see in more details later.

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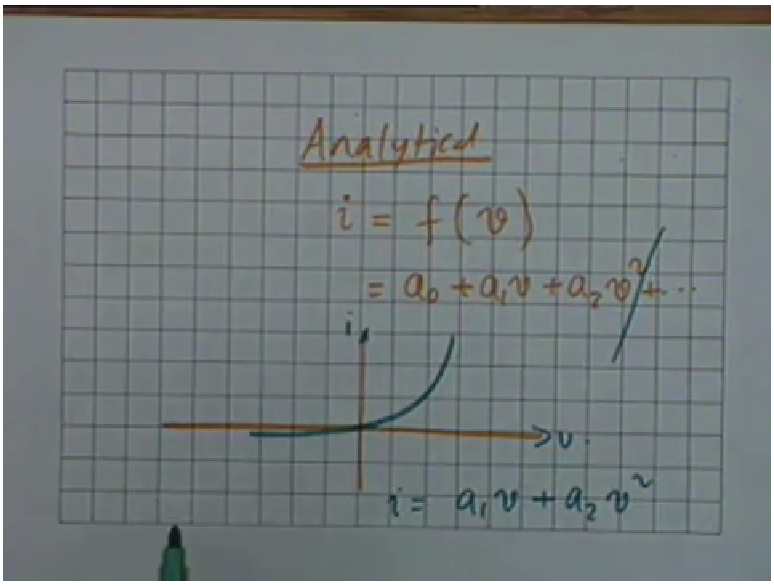

Now besides graphical characterisation, we can also have analytical characterisation. What we do is, suppose we have a non-linear resistor where I, the general characteristic of a non-linear resistor shall be not I equal to V by R but I equal to some function of V, all right, some function of V. And you know that such a function can always be expanded into a power series. That is I can write this as A0 plus A1 V plus A2 V square and so on, all right. If you stop, if you stop at the 2nd term, then obviously there is a linear approximation. If you stop at the 3rd term, then it is a quadratic approximation, if you stop at the 4th term, cubic, and so on and so forth. So both terms you accommodate, the better is the approximation, all right.

For example if you consider a diode, once again we have characteristic of a diode and you want to approximate it by let us say up to the quadratic terms, that is squared term, all right. Then you notice that because I equal to 0, when V equals 0, this is I and this is V, therefore A 0 term shall be equal to 0. That is what I have is I equal to A1 V plus A2 V squared, all right. A 0 term is equal to 0 because V equal to 0 means I equal to 0, all right. Suppose to the diode, to this diode, which is approximated by a quadratic characteristic like this, suppose you apply a sinusoidal voltage.

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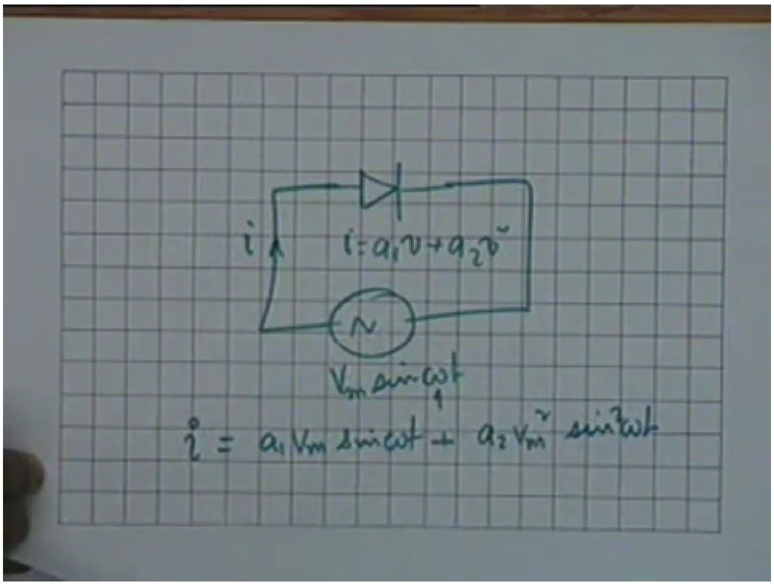

That is to the diode which is approximated by I equal to A1 V plus A2 V square, you apply a voltage source which is VM sin of Omega T, VM sin Omega T, all right. What would be the current? Obviously all that you have to do is to substitute VM sin Omega T for V and find out I and therefore the current in the circuit shall be A1 VM sin Omega T plus A2 VM sin squared Omega T, all right, this would be the current. But we need to see what effect this nonlinearity has on the output frequency, the input frequency is omega, radians per second, what are the output frequencies, you notice that cosine of 2 Omega T is equal to cosine squared Omega T - sin squared Omega T which is 1 - 2 sin squared Omega T.

And therefore sin squared Omega T is equal to 1 - cosine 2 Omega T divided by 2, is that okay? Therefore my current I can be written as A1 VM sin Omega T plus A2 VM squared by 2, this is to be multiplied by A2 VM squared, so A2 VM squared by 2 - A2 VM squared by 2 cosine of 2 Omega T. And you notice that if this diode was a linear resistor, then voltage VM sin Omega T should have a current which is A1 VM sin Omega, that is always this term should have been present, is not that right, if it is a resistor. What has nonlinearity done to it?

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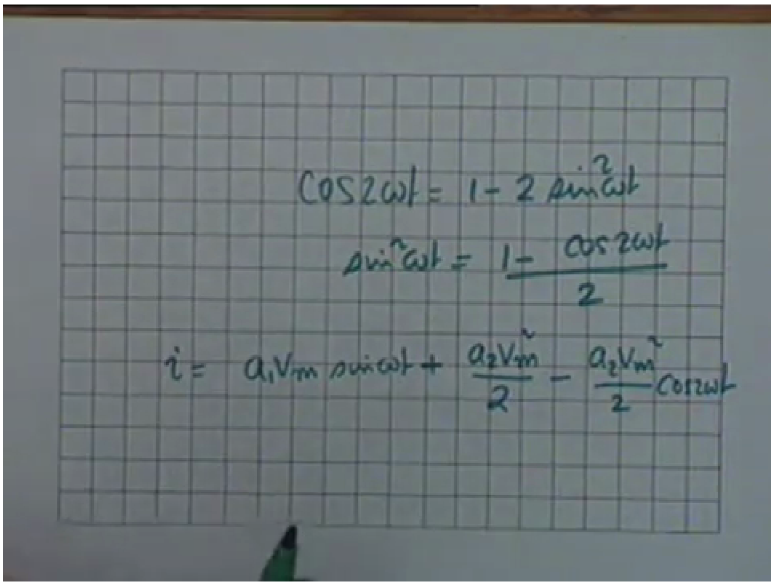

Nonlinearity has brought in a constant, a DC term, which would not have been present if the diode was a linear resistor. So nonlinearity brings in rectification. What does this mean, this is the average value. If you take, if you have a doubt over a large intervals of time, then this will be the DC value. If you put a DC metre in the circuit, the metre will read A2 VM square by 2, all right. This was not there in the input, the input was the pure AC and you get a DC out of it, so that is rectification. Number 2, in addition there is a term whose frequency is twice omega.

Now if Omega is called fundamental, then twice omega is the 2nd harmonic, twice omega, any frequency which is related to another frequency by an integer is called harmonic. The 1st harmonic is the fundamental, the 2nd harmonic has a frequency twice omega and therefore this generates a 2nd harmonic, the diode generates a 2nd harmonic.

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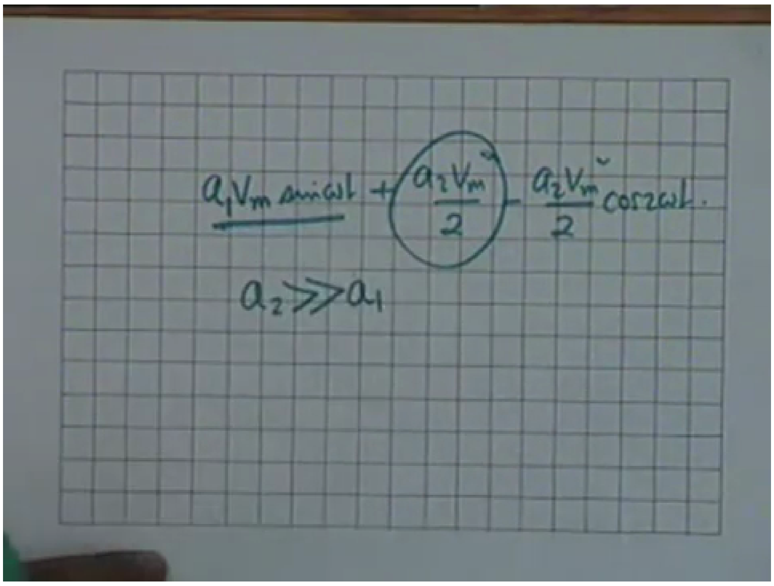

Now let us look at this a little more carefully, a diode with a quadratic characteristic can generate A1 VM sin Omega T plus A2 VM square by 2 - A2 VM square by 2 cosine of 2 Omega T. Suppose, suppose I have, I arrange things such that A2 is much greater than A1, A2 is much greater than even, all right. Then obviously the 1st term will be negligible compared to the 2nd and 3rd terms, all right, agreed. And you somehow I can get rid of the DC term, how, if I put a capacitor in the circuit, it will not allow a DC to pass. So the current would be simply, this is negligible, this is blocked by a capacitor, so the current will be simply frequency twice omega.

In other words the diode then acts as a harmonic generator. If you have original signal, if you have original input as 50 hertz, then you can generate 100 hertz from it, all right. Similarly if the diode had a cubic term, you can generate a 3rd harmonic because in sin cube omega can be written in terms of sin of 3 omega, all right. So a non-linear resistor is not necessarily an undesirable element, it can be used to generate harmonics, that is multiples of the given frequency. Next, suppose, suppose I retain only the DC term, how do I do that? Suppose I shunt the diode by a capacitor, the capacitor does not pass DC, I shunt the diode, that is I connect a capacitor across the diode.

Then all the alternate, all the AC current, the A1 VM sin Omega T and A2 VM square by 2 cosine 2 Omega T, they pass through the capacitor, so I am left with only the DC component. And therefore the diode can be used as a rectifier, all right. Suppose yet another instance, suppose I get rid of the DC term by using a capacitor, I get rid of cosine 2 Omega data, I reject by means of a suitable circuit, then I should be left with A1 VM sin Omega T and this

A1 is greater than 1, do not you see that this acts as an amplifier? If A1 is greater than 1, then the maximum amplitude was VM, now I have increased it to A1 VM.

So a non-linear resistor is not necessarily an undesirable phenomena, it can be used to your advantage in a circuit.

Student: Excuse me sir.

Professor: Yes.

Student: In this case, when you are talking about amplification, we are giving A1 VM term if A1 is greater than 1. But this is the current in the circuit, and not the voltage, and what we have applied is the voltage.

Professor: That is right, we drop a (())(38:47), we pass this through a resistor and get the voltage. The voltage can be greater than the input voltage, you are quite right. A1 VM sin Omega T is not a voltage, it is a current, so what all you have to do is pass it through a 1 ohms resistor, then this current will be converted to voltage. All right. Good. Now let us take an example.

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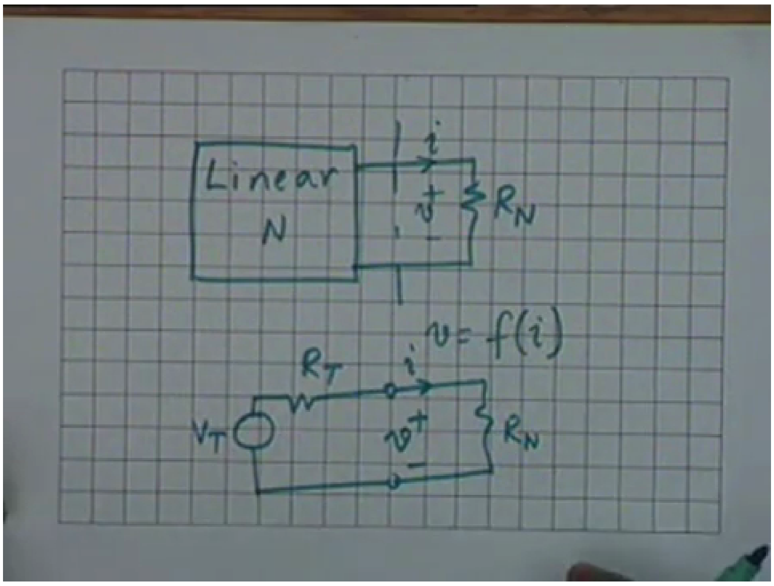

This example concerns, I want you to follow this carefully. This is the 1st acquaintance with the style of analysis that we shall adopt in electronic circuits. We have a linear network N which is feeding a non-linear resistor RN The non-linear resistor RN is characterised by a voltage current relationship which is let us say V equal to F of I, so function of I. As I said earlier I could be approximated by a power series which has to be truncated at a certain power, all right. What we are interested in is to find out the value of V and I, when the linear network N is excited, that is it contains resistance, voltage sources and current sources.

There can be dependent as well as independent voltage and current sources. We are interested in solving for the voltage and the currents across the non-linear resistor. There is a special kind of a circuit, the linear network is being considered as a driver and the non-linear resistor is being considered at the driven element, all right. Now since this network is linear, you can always replace it by its Thevenin equivalence. So let us say we have a VT, then in series with RT, all right, this is equivalent of the linear resistor, then we have the load which is RN and the voltage and current V and I, all right. How do I find out V and I, that is the question.

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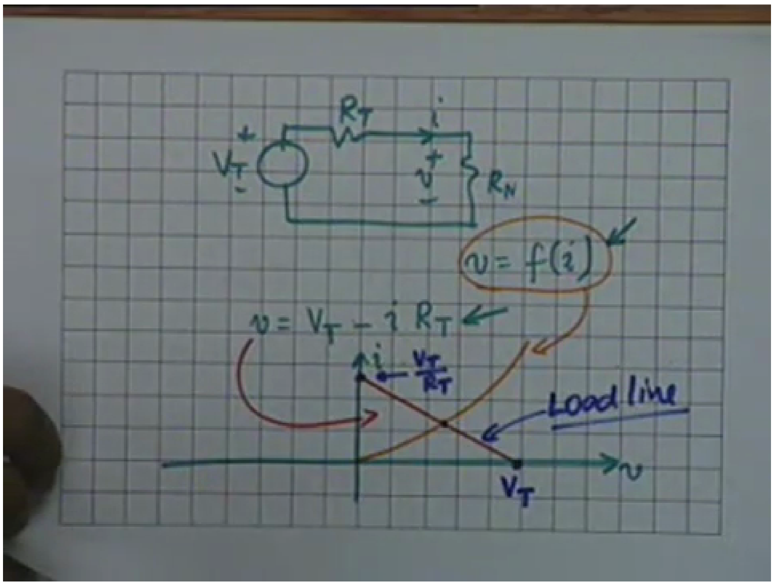

If you look at the circuit once again, the Thevenin equivalence VT plus - series RT, then RN, V and I is so that one of the relations, one of the relations that V and I have to satisfy is that V equal to function of I, this is because of the constraint by the non-linear resistor, this is a non-linear resistor characteristic. You also notice that V must be equal to VT - I RT, therefore V and I must satisfy this as well as this, which means that you have to solve these 2 equations simultaneously to get the values of V and I. In a linear resistor, finding out either the current or the voltage suffices, in a non-linear resistor, no, you have to find both, you have to find both V and I because both V and I are not related by a simple relationship, all right.

So how do you solve this? You solve it graphically, okay. You solve it graphical thing, that is what you do is you make a plot of V and I come all right, let us say that V equal to F I, this non-linear relationship is let say like this, V equal to F I. And suppose V, small v is equal to VT - I RT, what kind of a curve does this represent?

Student: Straight line.

Professor: Straight line and this straight line is something like this, where this value corresponds to what? This value corresponds to V equal to 0 and therefore VT by RT and this value corresponds to I equal to 0, so this is equal to VT. So all that you have to do is to locate the point VT on the voltage axis and locate the point VT by RT on the current axis and join them by a straight line. Obviously the solution to the circuit is the intersection between the 2 graphs because V and I have to satisfy both of these equations. And this is the style of solution that we adapt for all transistors or active electronic circuits that we will study later.

This Red Line is called the load line, for reasons to be understood later, this Red Line is called the load line and this is the device characteristic and it is intersection between the 2 which determines, which determines the current and voltage. As I said both are required, it is not sufficient to find out the voltage only or the current only, both of them have to be specified. And it is in this context that we shall take a fairly nontrivial example. This example concerns the series connection of 2 non-linear resistors.

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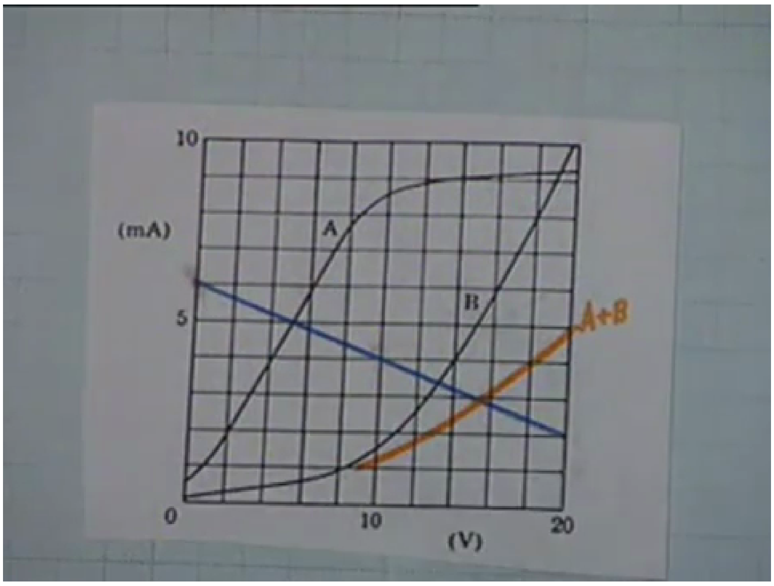

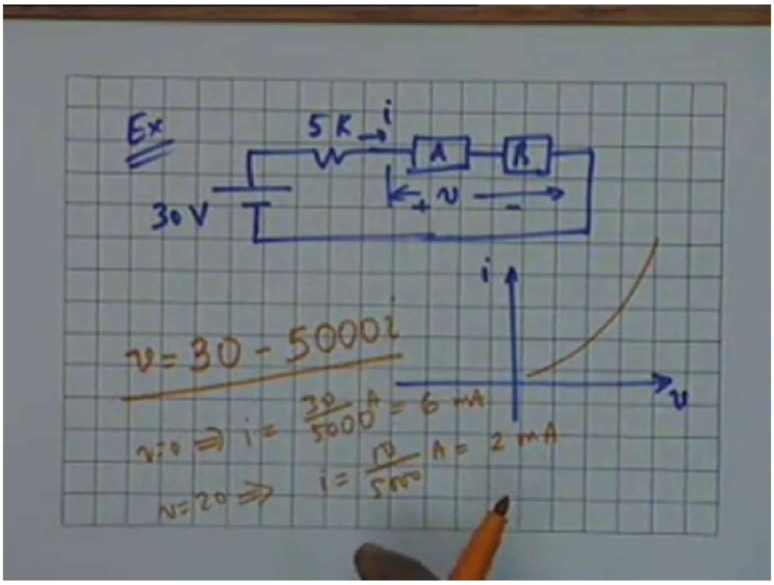

A 30 volt source in series with 5K, this is connected in series with 2 non-linear resistors A and B, all right. 2 non-linear resistors are connected in series and the characteristics of both A and B are given. What we mean by characteristics? A plot of I versus V or V versus I, this is given. What you have to do is, if this voltage is V, the composite device, that is A and B in series and this current is I, the 1st thing you have to do is to have the composite characteristics, that is plot I versus V. How do you do that?

Student: Add the 2 graphs.

Professor: Add the 2 graphs, that is you know I versus VA and you know I versus VB, so set a particular I, read VA and VB, add the 2 and plot a new point. Let me show you, I have actually done this. Is this graph visible?

Student: Yes.

Professor: Yes. Okay, so this is the characteristic of the device A, this is a characteristic of the device B, so what we do is for example, take a current of 2 milliamperes, 2 milliamperes. I agreed V1, VA, let us say this is about 2, all right, I also read VB, that is the other curve and this is about 11. So 11 + 2 is 13 and this is what I plot here, 13. This orange curve gives the characteristic of the composite device, that is I fix 1 milliamperes, 2 milliamperes, 3 milliamperes and so on at each value of current I read VA and I read VB, then I add VA and VB, so this is the characteristic. All right. You do not have to draw this, it is the problem given in the textbook, you can take that and work it out yourself.

Now the next question is you have plotted I versus V, then what you are required to find out is I versus V for this circuit, for this particular circuit. I versus V is one characteristic, the other, the load line obviously is given by V equal to 30, 30 volts -5000 i, is that okay? V, this voltage is equal to the source voltage 30 - the drop in 5 K, that is 5000 times I and you have to plot this line also, this is what I have plotted here.

This is the load line, for example when small V equal to 0, the current shall be 30 divided by a 5000 which is equal to 6 milliamperes, that is the point, when small V is equal to 20, then 30 - 20 is 10 no, this is not clear what I am doing. Okay, look at the load line, when small V is equal to 0, I equal to 30 divided by 5000, which is equal to 6 milliamps. When small V is equal to 20, then I equal to 30 - 20, that is 10 divided by 5000 amperes, which is equal to 2 milliamps, 2 points are enough for a straight line.

So I mark this point and this point and join them by a straight line. So the intersection gives me the values of V and I and you can read this as small V, I get that is 15.5, this is 15.5 and small i, that is the current is about 2.9 milliamperes. So I know the current and I know the composite voltage, do I know the individual voltages? No? 2.9 whenever it intersects the curve A is VA, wherever the line intersects V, I know VB. So I know VA and VB, then do I know the power dissipated in the 2 resistors, yes I do.

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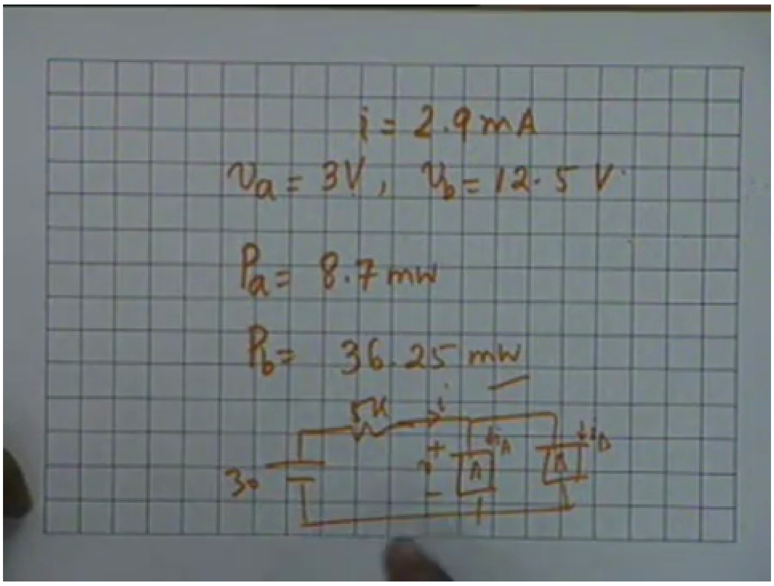

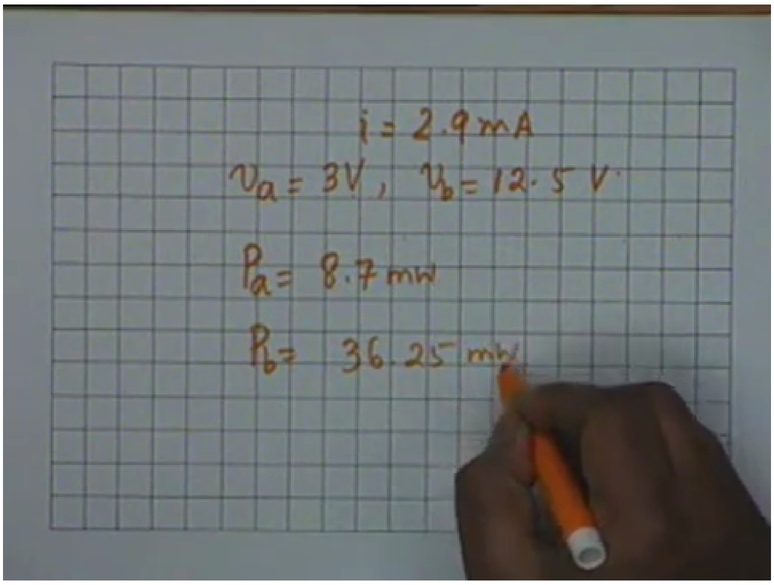

The current is the same, you multiply the current by the voltage and the end result, my end result is that VA is equal to 3 volt, you can verify this, this is the problem given in the textbook. VB equal to 12.5 volt, so PA and the current I is 2.9 milliamps, so PA is 8.7 milliwatts, 3 multiplied by 2.9 and PB, the current, the power dissipated in the resistor B is 2.9 multiplied by 12.5 which is 36.25 milliwatts, these are my results. And this is a fairly complicated example, all right. As a, as an exercise for you to bother about, let us say A and B are connected in parallel, then how would you solve the network? If A and B instead of series connection…

Student: Add the currents…

Professor: Add the currents, therefore you have to take this characteristic in the, in the other way. That is the voltage in the same, so for example if the voltage is 10, then you have to read the current from here and you have to read current from here and add the 2 currents. Well I leave that to you as an exercise. But should we drive them by means of a voltage source or a current source? Can we work out the same circuit, that is a 30 volts source, 5K, then A and B are in parallel, what I want to find is VI, also IA and IB, can I do that? Yes, why not. Or is there a specific problem?

All that you have to do now is to fix the voltage, to draw the characteristic, take a certain voltage, draw a vertical line and see what the values of the currents are in the element A and in the element B, add the 2 currents that you get high and therefore you can plot V versus I. Then on this plot you draw the load line, mark the intersection, that gives you V and I, then you divide IA and IB, all right. Yes…?

Student: (())(52:47) I is equal to…

Professor: Load line will be the same, that is V equal to VT - 5000 I, when I is in amperes, load line will be the same, whereas this V, this voltage - the drop in characteristic. All right. Is that, is that okay? Now one tricky question is, is about the superposition theorem. In superposition theorem, I told you that the current and voltage in any element can be obtained as a superposition of the current and voltage that would have existed is each source acted independently after killing all other sources, all right.

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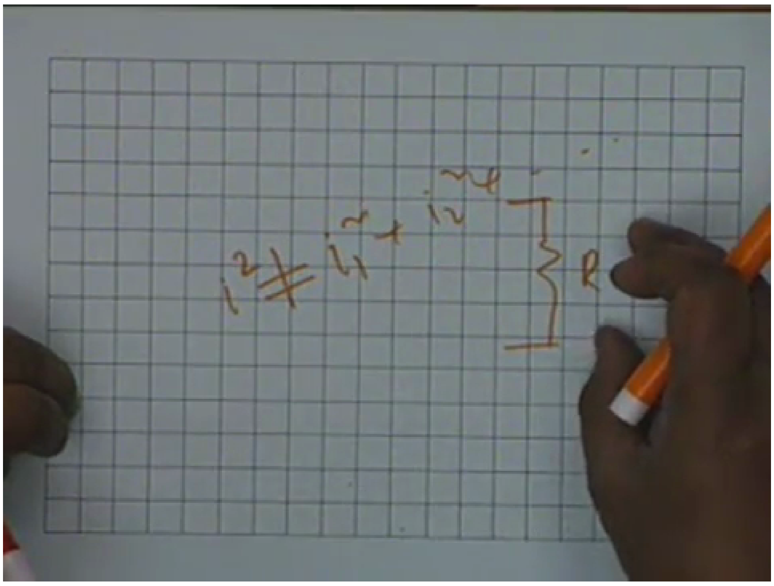

Now can I apply this principle to the calculation of the power, that this, that is I have relevant let us say R and I wish to find out the power consumption, power consumed by R. I find the power due to one source acting independently, I

Student: (())(53:55).

Professor: Why not?

Student: (())(53:58).

Professor: Because I square is not equal to I1 square plus I2 square and so on, all right, that is the reason. Superposition does not apply to relationships which are not linear, all right. Voltage is IR, or current is V by R and therefore you can add V1 and V2 and obtain the. Now this mistake, this mistake is very often committed by students. Power cannot be obtained, power, energy, they cannot be obtained by superposition, it is only voltage or current. Next time, next time we will go to a new topic, that is signal, different types of signal and their processing. That is all for today.