Basic Electrical Circuits
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Lecture - 30
Power and Energy in a Resistor

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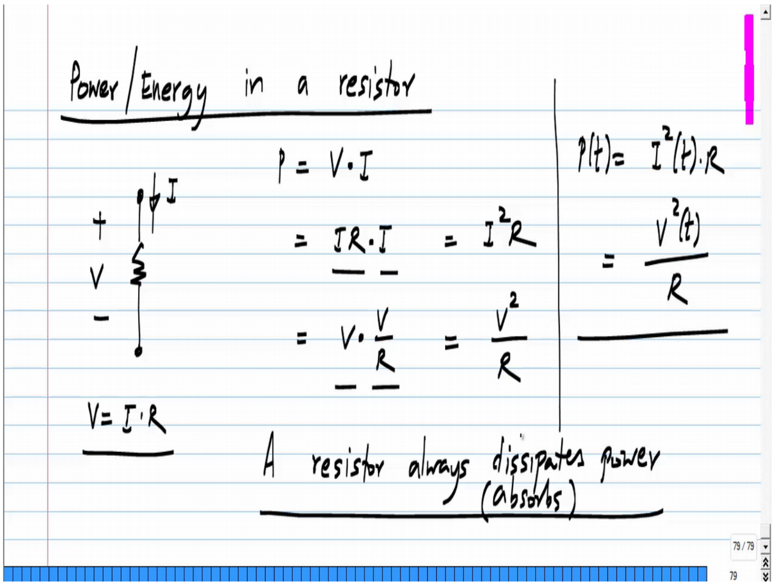

We have defined power and energy in general for a two terminal element. Now I will apply it to all the elements we know one by one, and study their properties. First, we will consider the resistor. As usual like voltage and current with the passive sign convention; and for any two terminal element P of course is V times I, and each of these can be time dependent also, but now for a resistor the voltage is current times the resistance. So, this particular relationship is for the resistor, which can be written as I R times I that is this is the voltage that is current, which is I square R; alternatively it can be written as V times V by R, this is the voltage that is the current, which will be V square by R. Now of course, if voltage or current as dependent on time then power will be varying with time, but the expressions will be the same. This is the power delivered to the resistor which can also be written as V square divided by R. So, this is the expression for the power delivered to a resistor.

Now, one thing we can notice is that because it involves the square of either the current or the voltage and the voltage and currents themselves are real, the power delivered to the resistor is always positive, the resistor always absorbs power so that is very easily seen from the expression of power proportional to the square of the current of square or the voltage. A resistor always absorbs power and where it does go, it gets dissipate in the form of heat. So, if you pass current through a resistor, it will heat up. So, it absorbs power, it actually dissipate it and the power actually goes into heating up the resistor. In fact, that the principle is used any useful gadgets as well; if you have an electric stove what happens is that you pass current through the coil which is really resistor of some sort, the resistance value has been adjusted, so that the amount of power heats it up to a certain extend which is useful for whatever purpose say cooking or something like that.

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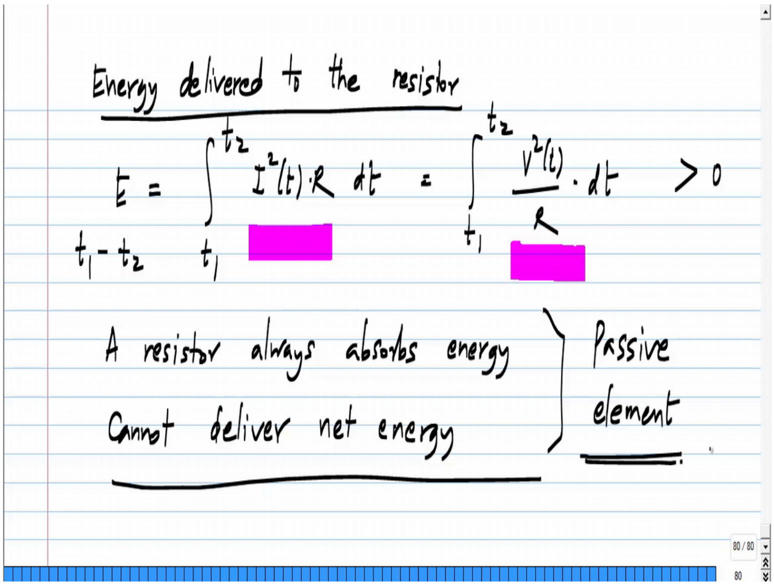

You consider energy delivered to the resistor over any time interval, it does not matter; from t 1 to t 2, it will be I square R dt or t 1 to t 2 V square by R with respect to time and this also obviously is always zero, because the power itself is always zero. So, a resistor always absorbs energy; it can never deliver any energy. So, something that can only absorbed energy, but can never deliver a net energy, it cannot act as an energy source, such an element is known as a passive element. So, a passive element, either the power is always positive, which automatically implies that it always absorbs energy, it can never deliver it, and such an element is the passive element. So, resistor only absorbs power which consequently only absorbs energy it can never generate energy, and provided to the rest of the circuits. Here of course, we are considering resistors with the positive value, where physical resistor always has a positive value. So, here I have to mention that we consider are more than 0, so such an element is known as the passive element.

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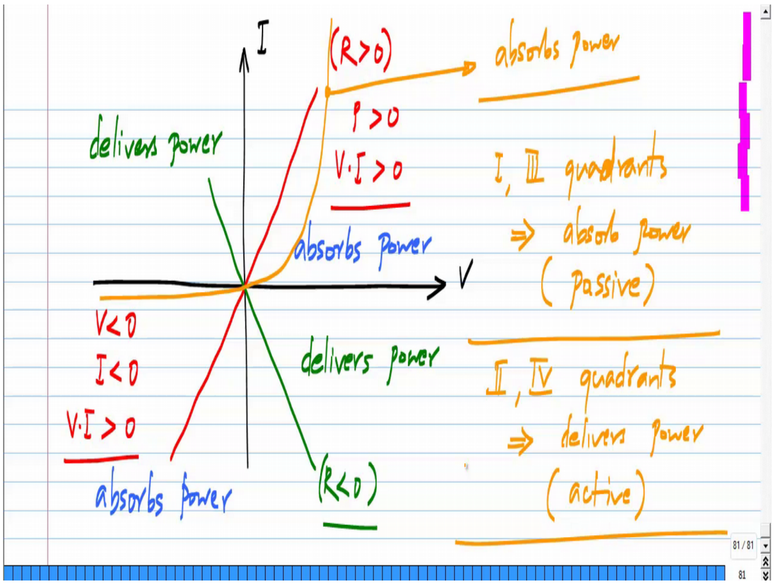

We can also see graphically if I plot the I V characteristics of resistor, this we have done earlier while discussing resistance. Now whatever the value of the resistor, the curve is always a straight line with the positive slope. Again I am considering the resistance to be more than zero; we do not consider negative resistances here, we consider physical resistors here which have a positive resistance. So, now, the characteristic is a straight line which passes through the origin, so that means that it lies in the first quadrant and the third quadrant. And in the first quadrant of course, both V and I are positive, so the product is positive so that means, that the power is greater than zero as we have defined it. The power we have defined is the power delivered to the resistor, power delivered to the element; this is the significance of the passive sign convention.

Passive sign convention is such that if you take voltages and currents according to the passive sign convention and multiply it, the result will be positive if the element is absorbing power. Now in the first quadrant, both the voltage and the current are positive, so the power is more than zero, clearly the element is absorbing power. And in the third quadrant, the voltage is negative, the current is also negative, but V times I would be obviously positive so that means, that again the element is absorbing power. So, resistor is in the first and third quadrants, so it always absorbs power. Here when I say absorbs for we are talking about the element who’s V I characteristics we are plotting. Now conversely if it happens to be in the second and fourth quadrants, it delivers power. So, if you happened to have a negative resistor, it will deliver power, because the slope would be negative, but of course, such a resistor cannot be physically realized, you can realized them it using active circuits and that part is outside the scope of this course.

Now, I will generalized here of course, resistance has a straight line characteristics; even if an element does not have a straight line characteristics, as long as it lies only in the first and third quadrants, which means it has to necessarily pass through the origin it will be a passive element, because it will only absorbed power. So, let me draw one such a example here, this element may be familiar to some of you, there is something called diode and its characteristic passes through the origin, and it look something like this roughly. It is non-linear, so it is harder to analyze circuits with diode, but one fact certain that because the characteristics lie only in the first and third quadrant, this also absorbs power. So, if you are in the first and third quadrants, it means that you absorb power that is we are referring to passive mode of operation and element which is only in first and third quadrant is necessarily passive element.

If you are in the second or fourth quadrants, the elements deliver power, so it is active, if it is operating in the second or fourth quadrants. Later, we will see elements such as voltage source or current source which can either the deliver power or absorb power. So, from this part a couple of things should be clear; first of all resistor always absorbed power; consequently it always absorbed energy, it is the passive element. And we also discussed as a characteristics and the implications on passivity. If you have IV characteristics in the first or third quadrant then the element is passive; if it happens to be in second or fourth quadrant, it can be negative. Later, we will see elements which can be either passive or active depending on the quadrant in which it is operating, it could be either passive or active.

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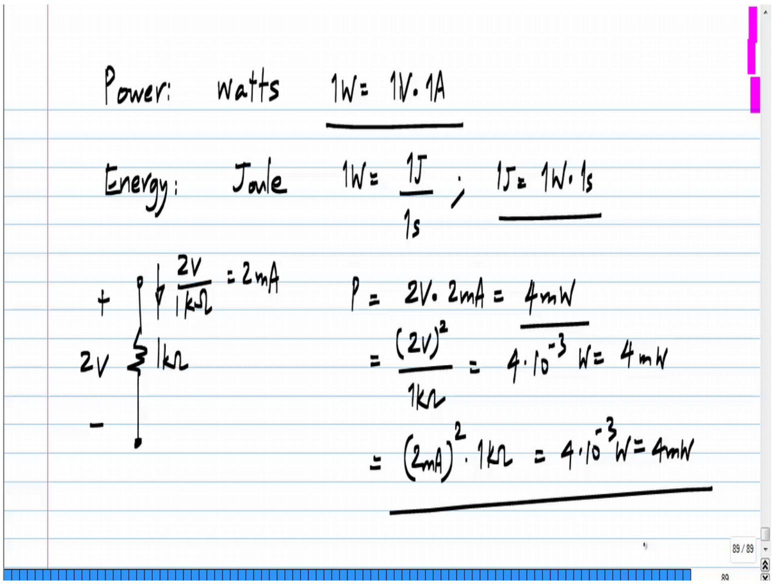

Now, the units of power are as you know watts; for electrical power 1 watt equals 1 volt times 1 ampere. The unit of energy is a joule; and 1 watt equals 1 joule per 1 second; 1 joule is 1 watt times 1 second. Let us consider simple case, we have a 1 kilo ohm resistor with 2 volts across it, by ohms law we know that the current is 2 volt divided by 1 kilo ohm which is 2 milli amp. So, the power dissipated in this when 2 volts is across the resistor is 2 volts times 2 milli amps which is 4 milli watts. Now you can also calculate this as V square by R which is 2 volts square divided by 1 kilo which is 4 10 to the minus 3 watts which is 4 milli watts; obviously, will get the same answer if you use I square R which is the square of the current times the resistor. We have milli amps squared here, so this is 10 to the minus 6, this is 10 to the 3. So, we have again four times 10 to the minus 3 watts which is 4 milli watts. Obviously, all these should give the same answer because all those formulas or formulas for the same thing the power dissipated in the resistor.

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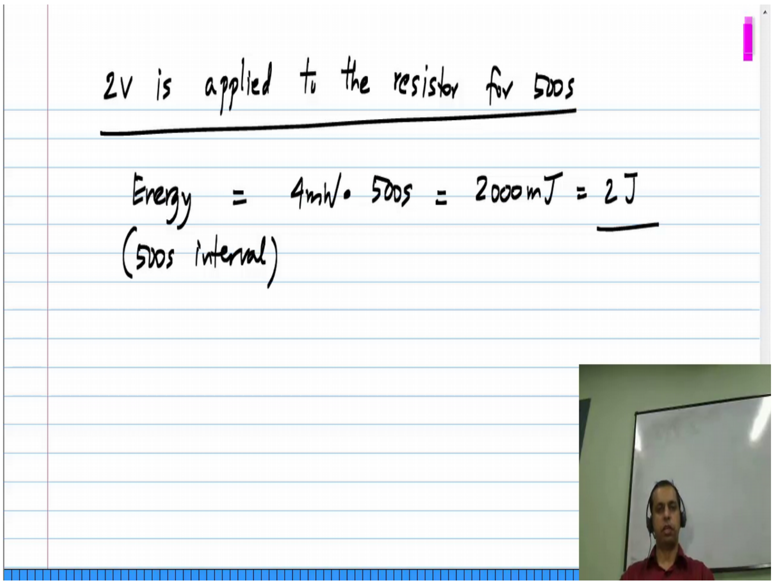

Now, let us say this 2 volt is applied to the resistor for 500 seconds; so the energy delivered in this 500 seconds interval is the power which is 4 milli watt times the time which is 500 seconds. We have applied a constant voltage, so we just have to multiply by the time interval the power by the time interval if the voltage were time varying the power would be time varying and would have to integrate over this time interval. This will turn not away 2000 milli joules or 2 joules of energy; very simple calculation, but as on as you know the voltage across a resistor or current through resistor, you should be able to calculate the power delivered to the resistor or energy delivered to the resistor in some given interval.