Fundamentals of Electrical Engineering

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Lecture – 05
Basis Laws

So, basic concept to we have seen particularly the current voltage and that your power and that power supplied and power absorbed, right. So, we will now come to the Basic Laws.

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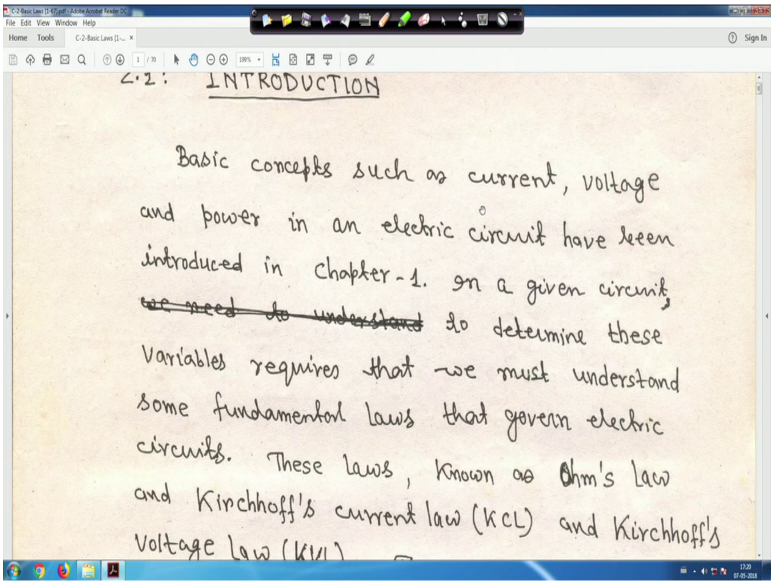

So, generally your in the in the electrical circuit analysis, right the concept such as current voltage and power in an electrical circuit have been we have studied in the chapter 1. In a given circuit may be or to determine these variables requires that we must understand some fundamental laws that given your that govern electric circuit.

So, these laws are known as Ohm’s law and Kirchhoff’s current law and Kirchhoff’s voltage law; that is, KCL and KVL and before that Ohm’s law. So, these laws actually form the foundation upon which the electric circuit analysis is built.

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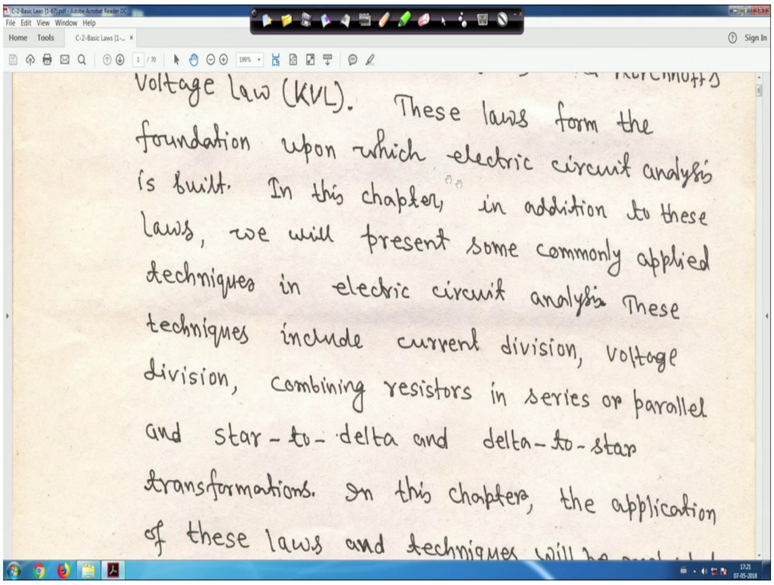

So, in this topic actually in addition to an addition to the laws, we will also involve right some commonly applied technique electric circuit analysis. This technique actually include; the current division, voltage division, combining resistors in series or parallel and star to delta and delta to star transformation, right.

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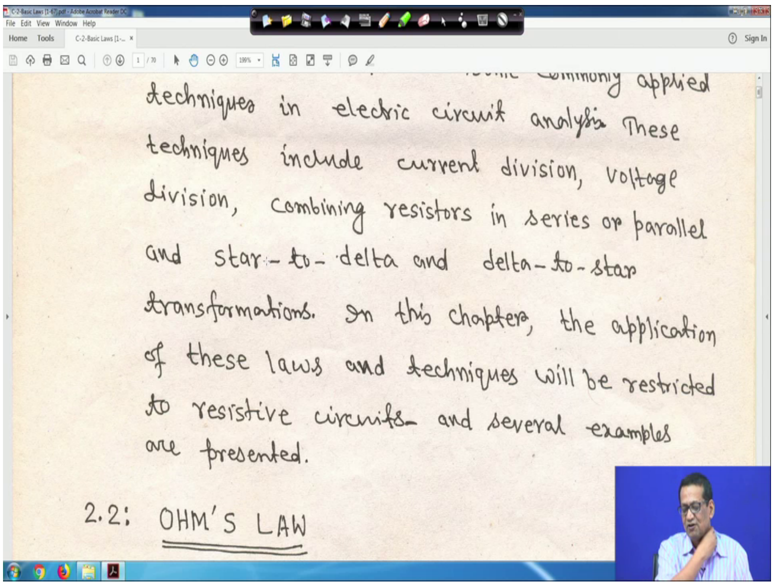

So, in this particularly in that basic law we will see that application of this laws, and the technique will be your what you call restricted to only resistors circuit and several examples are presented. So, in this case we will form we will represent several examples by as the DC circuits. So, we will only consider the resistive part right, but let us try to understand this.

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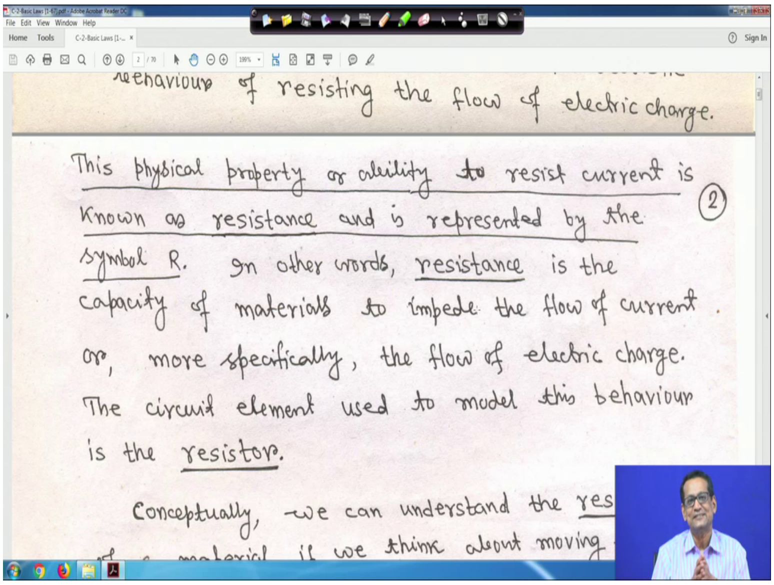

So, first is let us see the Ohm's law in general actually materials have a characteristic behavior of your resisting the flow of electric charge. If you resisting the flow of electric charge means it is basically resisting the flow of current, right.

So, the physical property or ability to resist current is known as resistance. So, that for any material, right it has some physical property or ability to resist current is known as resistance and is represented by the symbol R, capital R these the symbol R. In other words, resistance is the capacity of materials to impede the flow of current or more specifically the flow of electric charge. So, circuit element used to model this behavior is the resistor. So, this is actually that what you call regarding the resistance.

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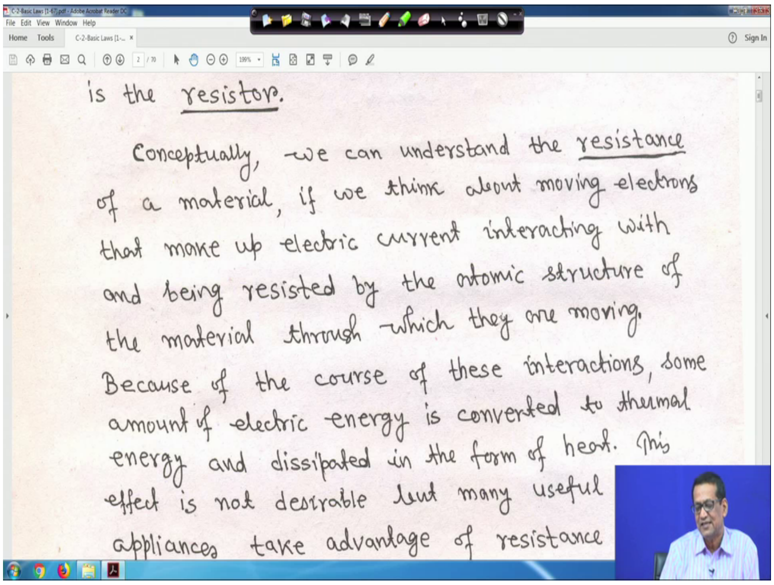

Now, conceptually we can understand the resistance actually of a material if we think about moving electrons that make up electric current interacting with and being resisted by the atomic structure of the material through which they are moving. So, because of the your course of these interaction some amount of electric energy is converted to thermal energy and dissipated in the form of heat. This effect actually is not desirable, but look, but many useful electrical appliances take advantage of resistance heating including space heaters, irons stoves and toasters right.

So, this we take that your what you call that that your what you call the effect of resistance, right. So, if we see that figure this figure 2.1.

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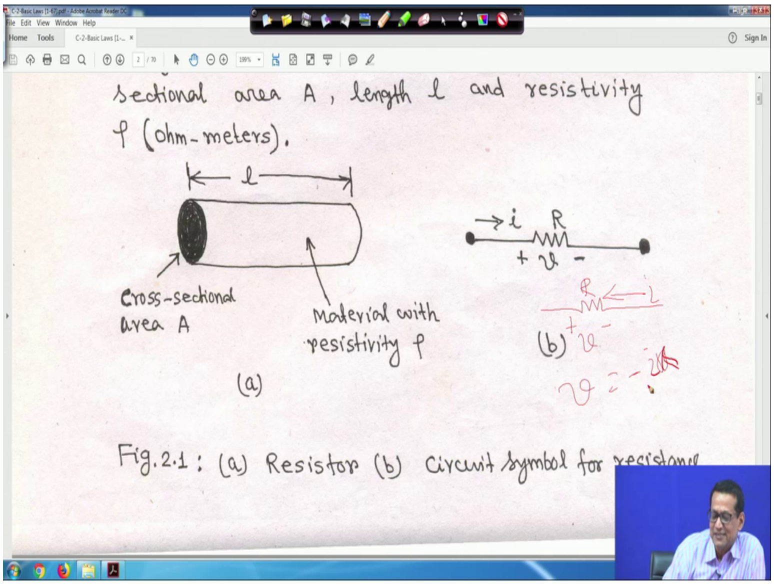

So, figure 1 a it is shows a material with uniform cross section area sectional area of A length is l and resistivity is ohm rho that is ohm meters, right. So, this is your I need not mark it by red ink it is understandable, this is a your what you call uniform cross section is like a cylindrical shape that all wire it looks like a cylindrical shape. And this length l and cross sectional area of it is A, right. So, it is circular and material with resistivity rho, and this is the symbol of the resistance and these the current entering, it is the plus minus right.

So, resistance your resistance is a later we will see that resistor earlier we have seen, but again we will see that a resistor is a passive element. So, it absorbed power. So, that is why this is the current these a 2 terminal, and this is the resistor R and current is entering into the positive terminal across the resistor voltage is v. So, resistor actually absorbed power that is why this way you represent right.

So, because it is a passive element it will absorbed power. So, that is why it is that is why it is your what you call, your plus it is taken and minus it is taken convince noise. But if we reverse the direction also method solving circuit one can do it, but ultimately we will find resistor actually your what you call that absorbing power because current, that is why this conversely is taken this symbol is for resistor, right.

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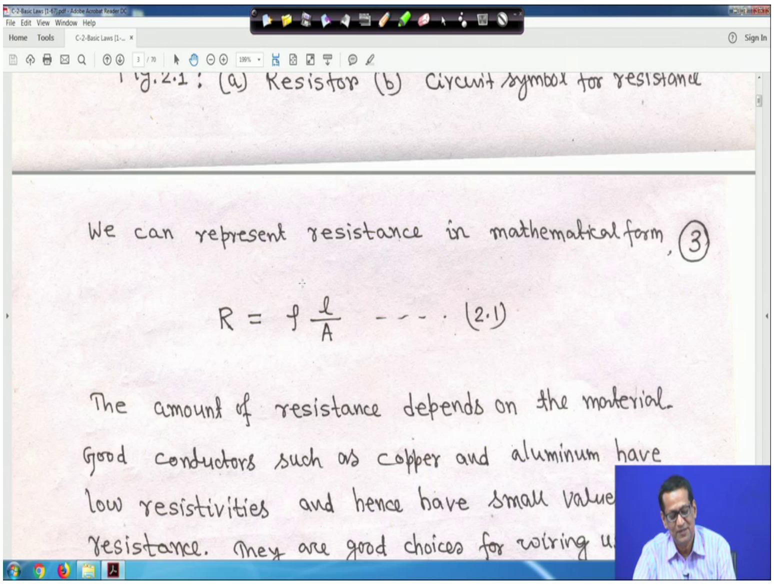

So, we know that from your (Refer Time: 05:09) physics electricity subject, we know that R is equal to rho into l by A, right. So, the amount of resistance that will depend on the material; so, what type of material you are using that it depend like gold ah, silver, aluminum, copper and other thing right. So, good conductors such as copper and aluminum have low resistivity. If you have low resistivity, then you have your; what you call they have the low your resistance, right and hence have small values of resistance.

So, they are good choices for wiring right your used to conduct electric current. In a circuit diagram copper or aluminum wiring is copper or aluminum wiring is not usually modeled as a resistor. If you take a wire you cannot modeled is as a resistor, because wire has a very negligible resistance you can ignore it right, but resistor actually made of your what you call the carbon and some compound alloy, right?

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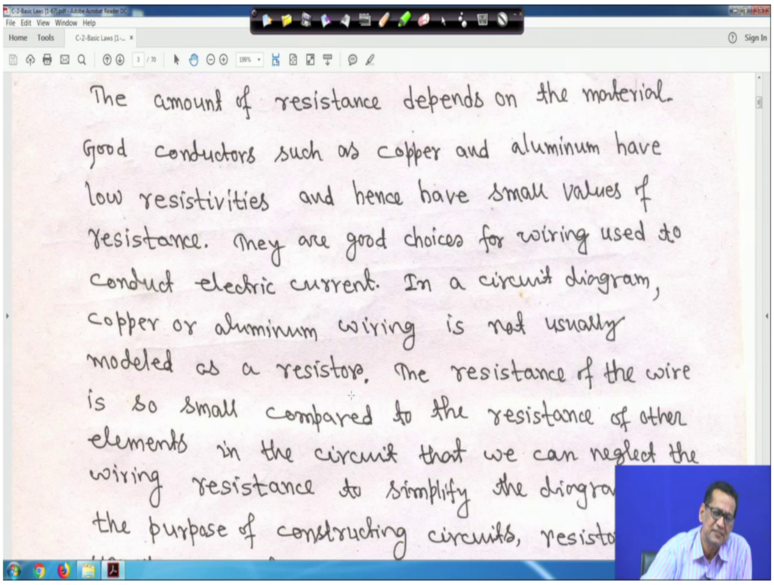

So, in circuit connection copper or aluminum is not usually modeled as a resistor, you will take resistance of the wire in the if you take resistance of wire is 0, right. So, the resistance of the wire is so small compared to the resistance of the other elements in the circuit that we can neglect the wiring resistance.

So, it is also small it is almost 0 will neglect it, right? And for such that our circuit diagram will be simplified. For the purpose of constructing circuit resistors are compound; resistors are usually made from metallic alloys and the carbon compounds, right.

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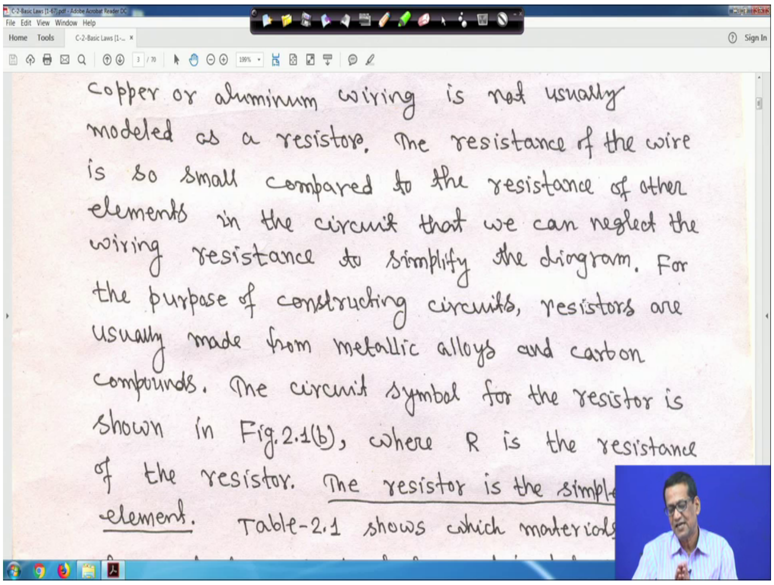

So, in the first year when we will first year when we will do first year lab, there you will see barrier type of rheostat, right. So, the circuit symbol for the resistor is given this is this is the circuit symbol for the resistor is given here and I told you something about these also why you will make it like this, right. So, and there are some materials of I have wrote it for you the resistivity for commonly use material like gold.

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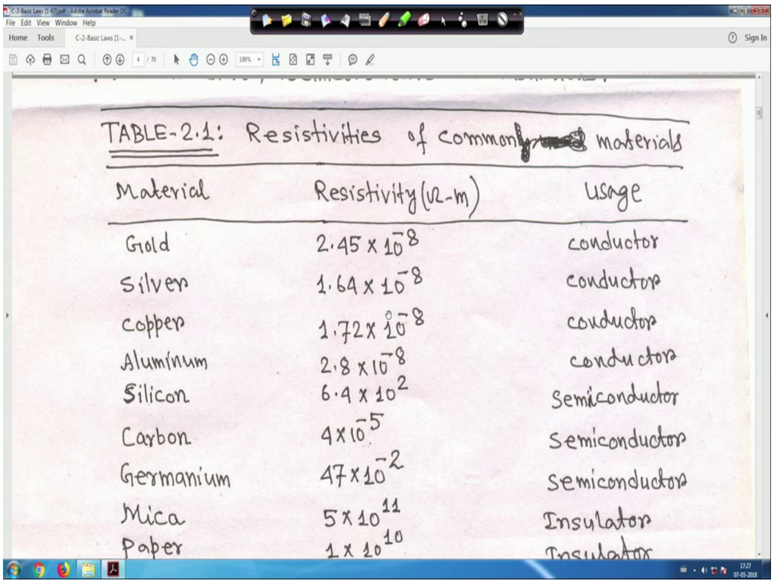
TABLE-2.1: Resistivities of common materials

Material	Resistivity (Ω-m)	Usage
Gold	2.45×10^{-8}	conductor
Silver	1.64×10^{-8}	conductor
copper	1.72×10^{-8}	conductor
Aluminum	2.8×10^{-8}	conductor
Silicon	6.4×10^{2}	Semiconductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Mica	5×10^{11}	Insulator
Paper	1×10^{10}	Insulator

It is resistivity it is ohm meter. So, gold is 2.45 into 10 to the power minus 8, it is a good conductor, but you cannot use it is very expensive.

Silver also 1.64 into 10 to the power minus 8, it is a good conductor, but silver also expensive you cannot make it, but copper and aluminum 1.72 into 10 to the power minus 8 is a good conductor. Aluminum also 2.8 into 10 to the power minus 8; that it also good conductor. Other thing are semiconductor if just for computational purpose that conductor semiconductor and your insulator material just I given a table.

Now, silicon is 6.4 into 10 to the power 2 it is semiconductor, carbon also 4.4 into 10 to the power minus 5, it is your semiconductor. And germanium 47 into 10 to the power minus 2 it is a semiconductor. And mica it is 5 into 10 to the power 11. So, insulator these all ohm meter all ohm meter; ohm meter unit is given here, ohm meter and paper one into 10 to the power 10 this is insulator. So, may conductor semiconductor and insulator and there resistivity something I have taken I have kept it here right.

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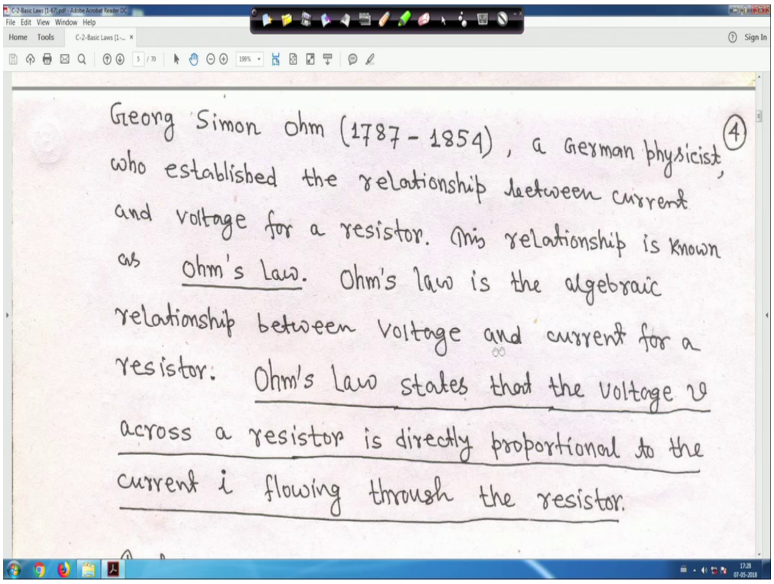

So now ohm that is GS Ohm actually is a lifespan was 1787 to 1854. So, here German physicist actually who established the relationship between the current and voltage for a resistor, right. So, this if this relationship is known as your Ohm's law. So, Ohm's law is the algebraic relationship between voltage and current for a resistor. So, actually Ohm's law states, the voltage v across a resistor is directly proportional to the current i flowing through the resistor.

I mean if you have a resistor and current is flowing through this resistor say this current is i and across the resistor is voltage is v. So, v is proportional to i, now v is equal to Ri that constant of proportional take to R that is called resistance. So, that is your v proportional to i, that is this is equation 2, 2.2 for chapter 2 or v is equal to iR, right.

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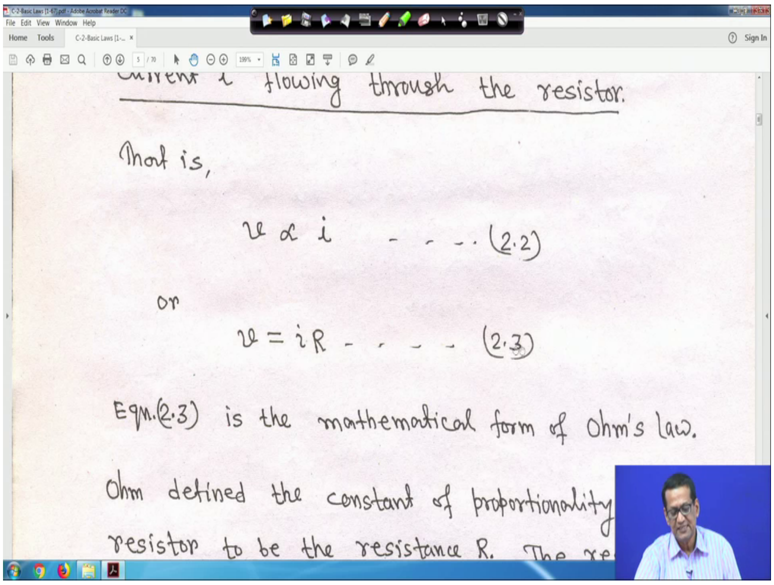

So, equation 3 that is 2.3 is a mathematical forms of form of Ohm's law.

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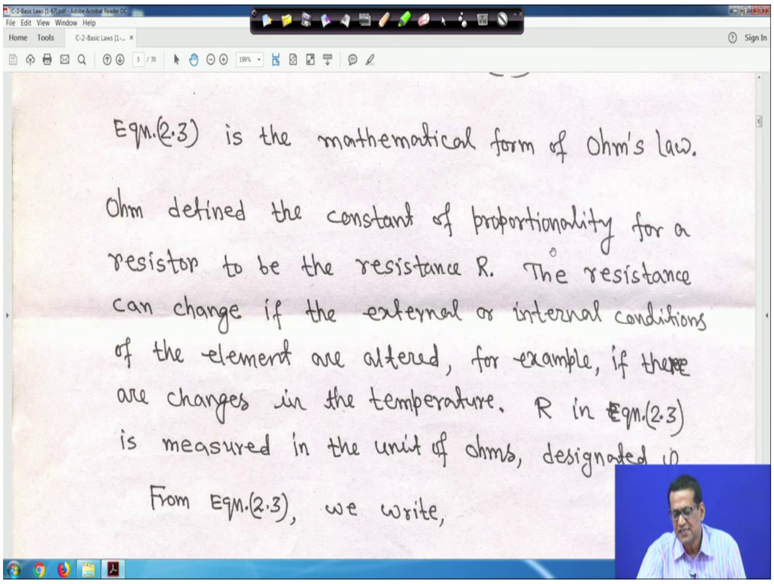

Ohm defined the constant of proportionality for a resistor to be resistance R. The resistance can change if the external or internal conditions of the elements are your altered.

So, that it can be change if you internal or external things are that element altered; for example, if it a temperature increases so, resistance change right =. So, if there if there are changes in the temperature so, R will change. So, R in equation 2.3 is measured in the unit of ohm designated as ohm, right. So, equation 2.3; that means, these equation these equation 2.3 right.

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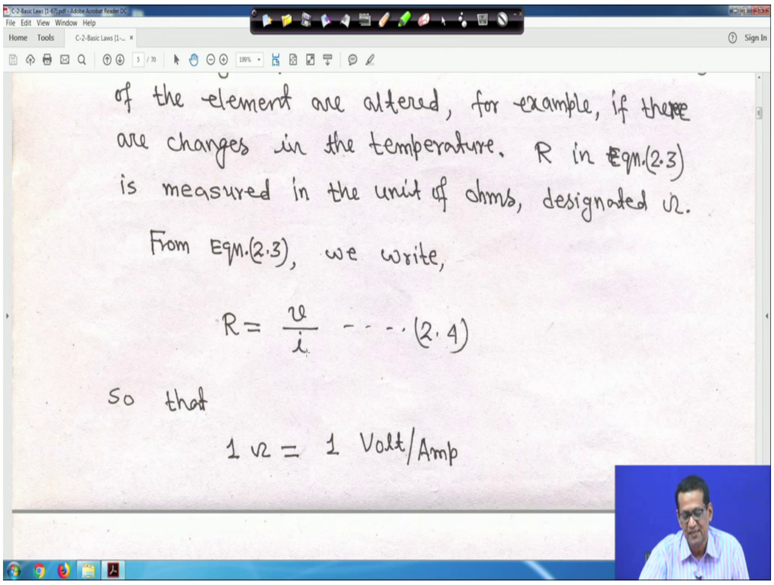

We can write that your R is equal to v upon i right; that means, v is volt i is ampere and R it is ohm. So, one ohm is equal to 1 volt per ampere. So, this is a understandable a simple thing this is a understandable to you, right.

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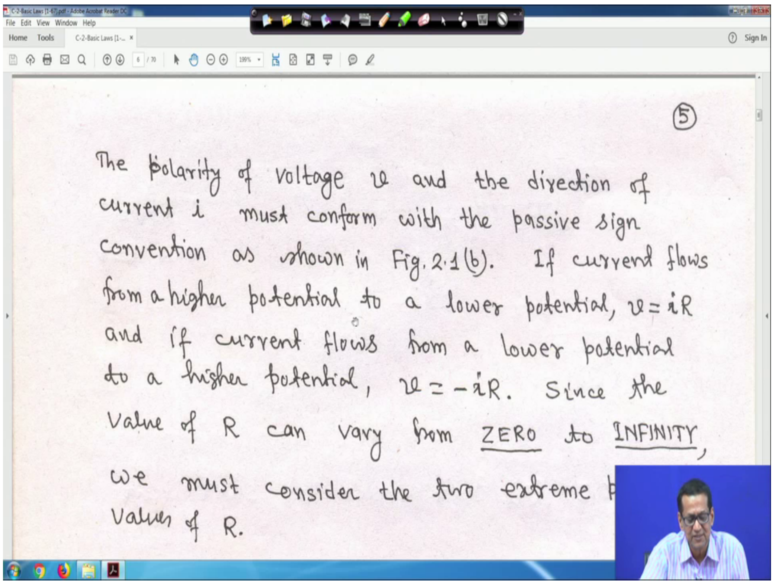

Now, the polarity of voltage v and the direction of the current i must conform with the passive sign convention as shown in figure 2.1 b. 2.1 b means this figure I showed you earlier this figure, this figure 2.1 v. I told you that R is a R is a passive element resistor is a passive element and current entering into the positive we have taken plus minus and assuming current entering a positive terminal. So, it absorbed power and across this voltage is v, v is equal to iR. So, that this is that convention this is the convention this is figure 2.1 b I told you earlier also, right.

So, in therefore, your this if current flows from a higher potential to lower potential, right v is equal to iR it is true and if current flows from a lower potential to higher potential, then v is equal to minus R. The meaning is something like this, let me go to this a figure 2.1 b, right. So, it is showing current your plus i this way; that is, higher potential to here it is mentioned that higher potential to lower potential, right.

So, if the current flows from a higher potential to lower potential v is equal to iR, but if it is current flows from a lower potential to higher potential, v will be is equal to minus iR; that means, your that means, let me let me just for your understanding. So, I mean this is this is one, but if it happen so, if it happen so say this is I making plus this is minus, this is my resistance R, and if the deduction of the current is like this, this is i these voltage is v, then v will be is equal to minus iR.

Because current is flowing from lower potential to higher potential, right. So, it will be v is equal to minus iR, but when we will solve the numericals and other thing we will find that actually later we will see that your what you call that resistor is passive element final it will absorbed power if v is equal to minus R it happens you will find that I will be negative. So, ultimately v will be is equal to iR because direction will change right.

So, in this case so, that means, it if direction of the current change it will be v is equal to minus iR. Later when see when we will go for KVL equation we will see that, right. So, let me let me clean this one. So, this is clear to you, that which is higher to lower and lower to higher potential, right. So, that is v is equal to minus R, since the value of R can vary from 0 to infinity, R may be 0 to infinity. So, we can so, we must consider the 2 extreme possible values of R that is when R is equal to infinity and when R is equal to 0.

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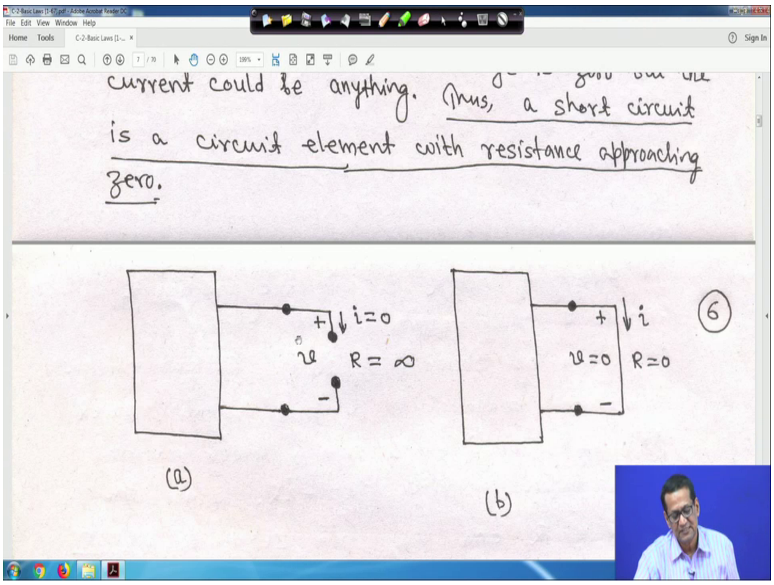

So, for example, look at this circuit before explanation suppose this is a this is an this is a your what you call some electric circuit represented by your just a simple box, right. And this is open, so that means, R is equal to infinity; that means, current is 0. So, when R is equal to infinity or R tends to infinity i is equal to v by R so, if R tends to infinity I will be 0. So, it is called when R tends to infinity means is says it is an open circuit, right?.

And when R is equal to 0 just connect it like this without no other electric elements simply wire. So, approximately we are not considering the resistance of the wire it is neglected. So, when R is equal to 0 so, your i is equal to v by R, right. So, R is equal to 0 means it is a short circuit it a huge current will flow. And in that case v is equal to 0.

So, for open circuit v is there, but i is 0, right ? When R tends to infinity, but when it is short circuit when you short it suppose these 2 terminals are shorted. So, I will be there because it is a close path, i will be there current will be high, but R is equal to 0. But v at same time v is equal to 0, because b is equal to iR if R is equal to 0, then v is equal to 0. So, that is why v is equal to 0 short circuit, this is an open circuit.

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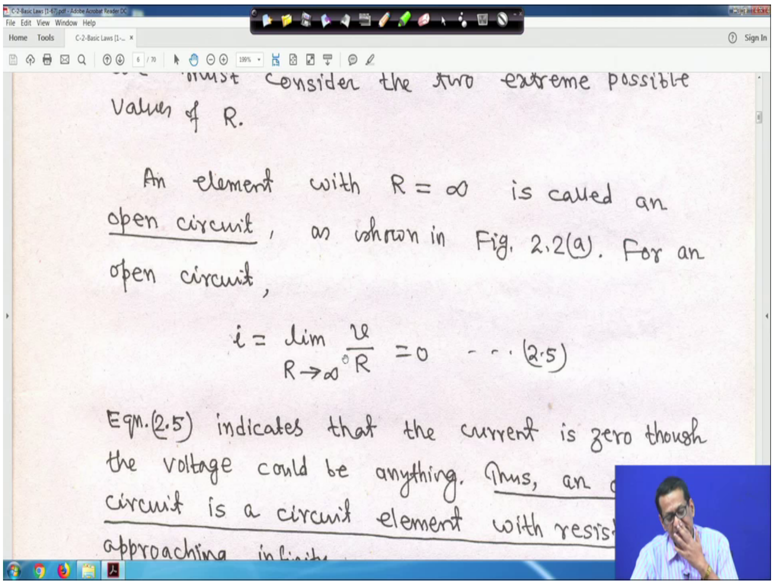

So, that means, when I R tends to infinity limit b by R will be 0, right. So, it is an open circuit when i is equal to 0, similarly when b is equal to iR, when it is a short circuit, right. So, R tends to 0 so, v is equal to 0, but i is not 0 for short circuit it will be fault actually, it will carry huge amount of current and if short circuit happens your are electrical devices or elements will be damaged also, right. So, this is the this is the your 2 cases for short circuit and a open circuit and short circuit, open circuit means resistance is infinity, short circuit means resistance is 0, right.

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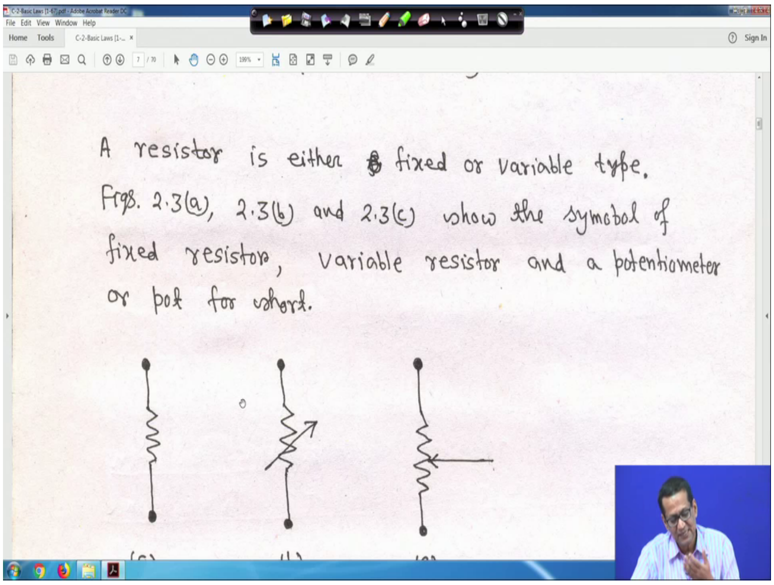

Now, 3 you have to understand each and everything as symbol also. So, a resistor is either a it may be either a fixed resistor or a variable type, right. So, there are 3 different symbols are shown, this is actually this is fixed type this is 2 terminals are there. So, this is a fixed resistance R. Say right this is a fixed resistance.

Now in this case this is a variable resistance whenever cutting an arrow through it, right. So, this is actually variable resistance; so when we will do first year laboratory, you will see the fixed or variable resistance in the same one terminal will be 1 3 point if we fixed it on the both the end of the resistance a resistor will find is a fixed value, but one point is a fixed point another is a variable point, when we will do first year laboratory if the barrier type of rheostat you will see this.

And third one this one and wiper is there this is a this is also variable, but this is symbol of this potentiometer. Perhaps in physics lab in your in your (Refer Time: 16:42) you might have seen it, right this is a potentiometer.

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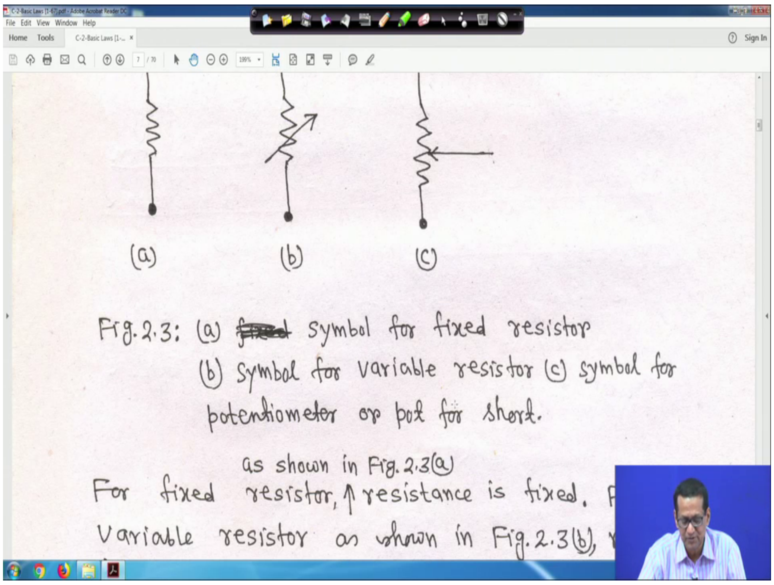

So, this is third one is symbol for potentiometer or pot for short, right. So, this is a potentiometer and this is a variable resistor, whenever making the arrow means this indicates a variable, but this is a fixed one. So, these are symbols so, everything is written here.

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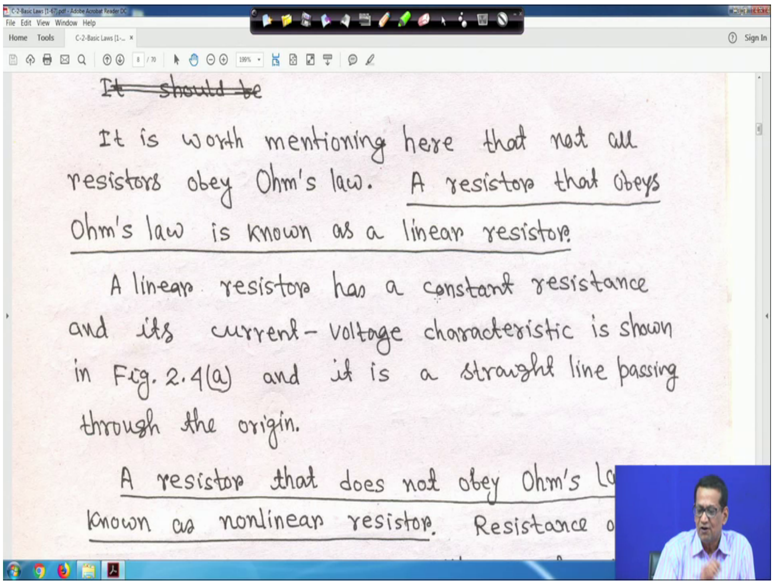

So, not telling it again right, now, it is what mentioning here that the all the resistors all the all that here that not all the resistors actually obey Ohm’s law, right? Because resistors may be non-linear in that case, it does not obey the your Ohm’s law. So, a is a resistor that always that obey is Ohm's law is known as a linear resistor. So, I have underlined these one so, a resistor that obeys Ohm's law is known as a linear register.

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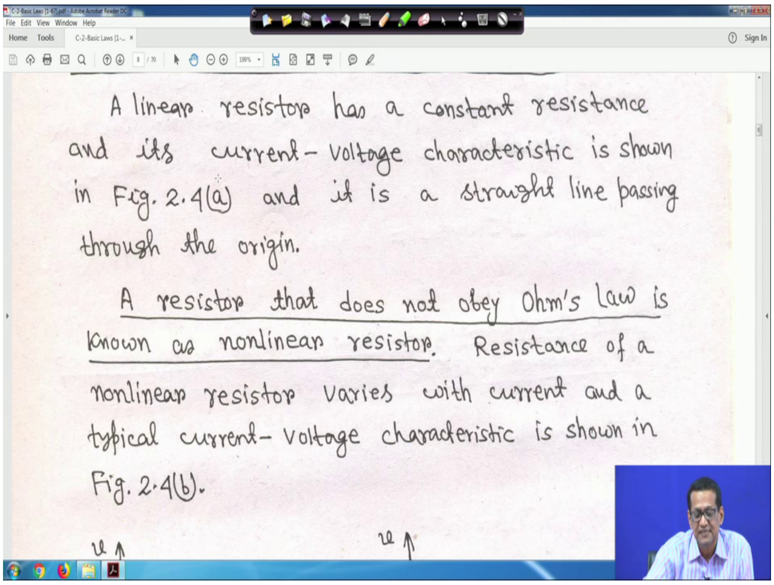

So, a linear resistor has a constant resistance, and its current voltage characteristic is linear right as shown in passing through the origin.

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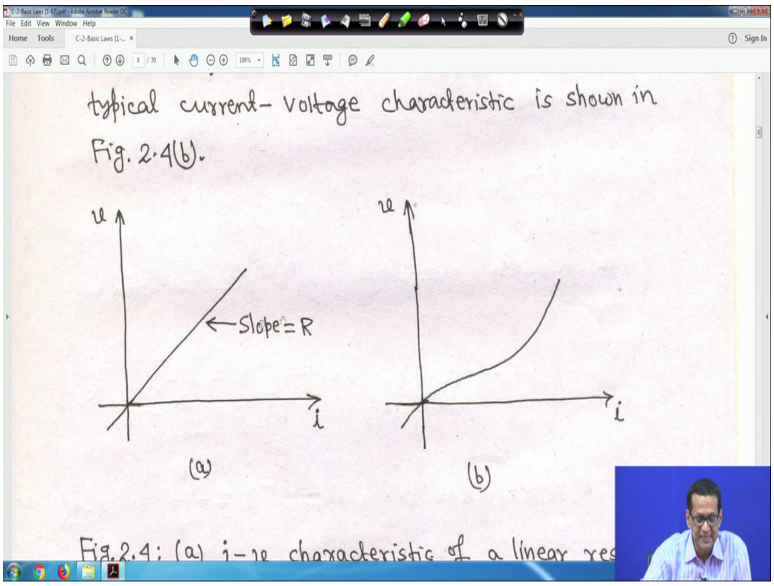

If you see this is a linear register characteristic it is slope is R, it is passing through the origin since a this following this follows Ohm's law, right? Because it is a linear characteristic.

But if you see, but this characteristic v by i, it is not from not a straight line it is some kind something like a curve linear, right. So, so, resistance they does not obey Ohm's law is known as non-linear resistor. So, resistance of a non-linear resistor actually varies with current and typical current voltage characteristic is this is the typical current voltage characteristic.

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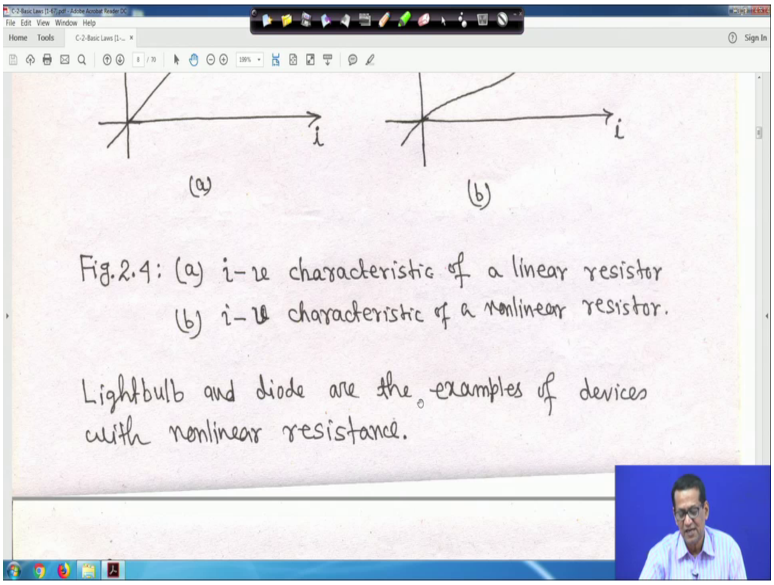

For example, your light bulb and diode are the examples of devices with non-linear resistance.

So, I mean any devices obeys, I mean a it obeys your Ohm's law, that is a resistor that that is a call a linear resistor. If it is not that is non-linear resistor simple thing, right. So, this is the iv characteristic of a linear resistor the first one iv characteristic of a non-linear resistor, right?

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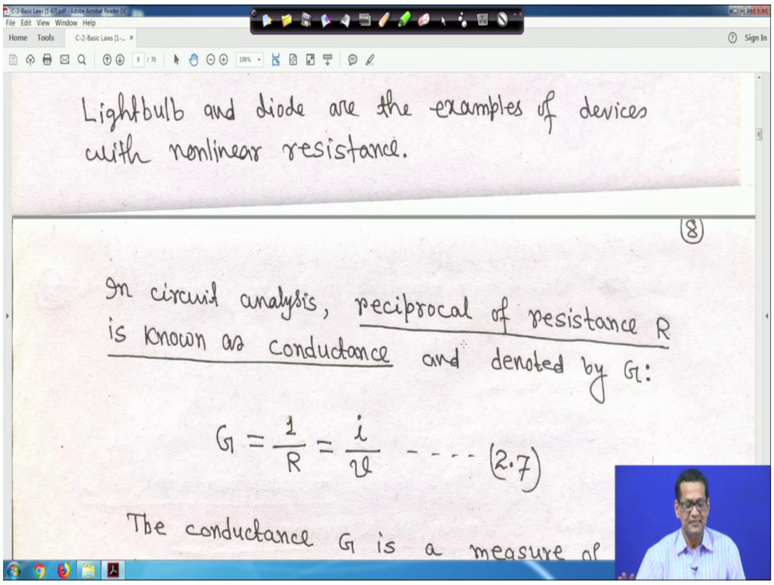

Now, in a circuit in a circuit analysis we always represent one thing reciprocal of resistance R; that means, is known as conductance, that we reciprocal of resistance we defined as a conductance, right. For example, if G is equal to 1 upon R, right. R is you know that b is equal to b is equal to iR right b is equal to iR then 1 upon R is equal to i by v. So, that is why G is equal to i by v, right?

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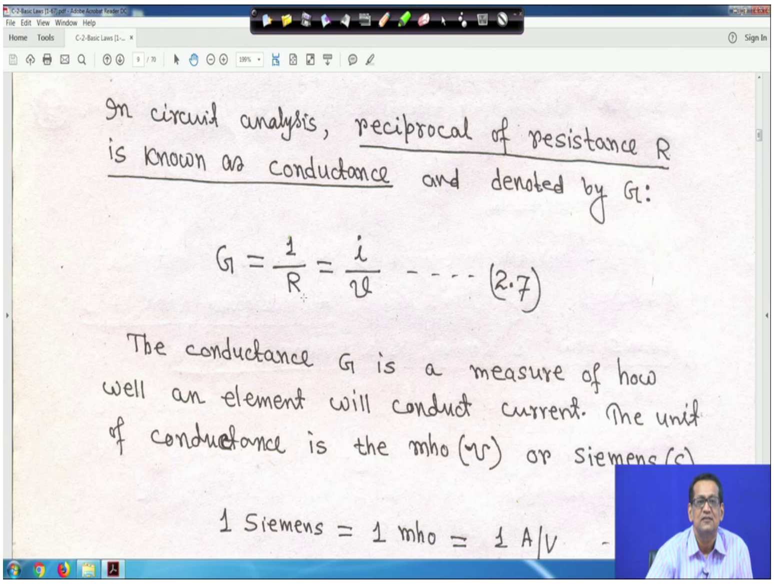

So, the conductance G actually is a measure of how well an element will conduct current, this is actually the idea. So, conductance G is a measure of how well an element will conduct your current.

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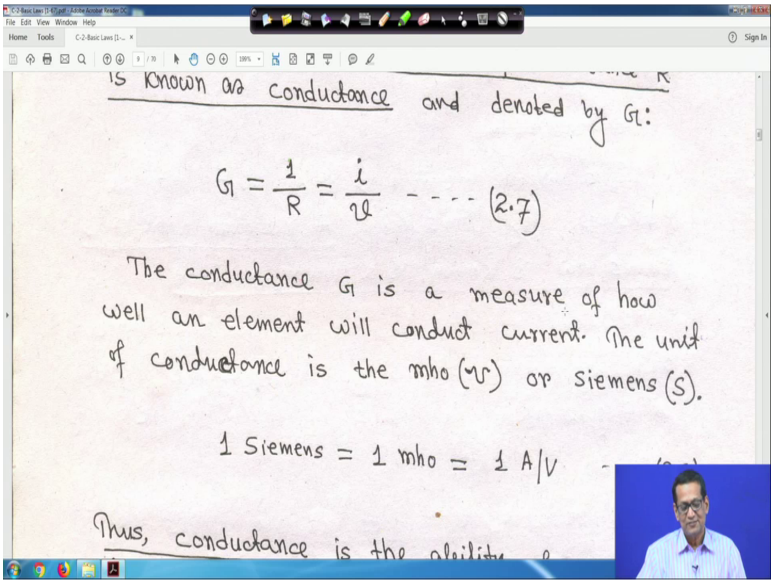

So, the unit of conductance is mho or siemens. So, either actually ohm is the unit of resistor resistance. So, it is reciprocal of that that is why it is mean mho or symbol is also just opposite right or siemens. In short it is s that is the your unit of the conductance.

So, 1 siemens is equal to 1 mho is equal to 1 ampere per volt, these a conductance i is the ampere v is the volt so, ampere per volt. So, 1 siemens is equal to 1 mho is equal to 1 ampere per volt this starting I have started this thing from the very you know beginning such that such that nothing will be left out hopefully, right ?

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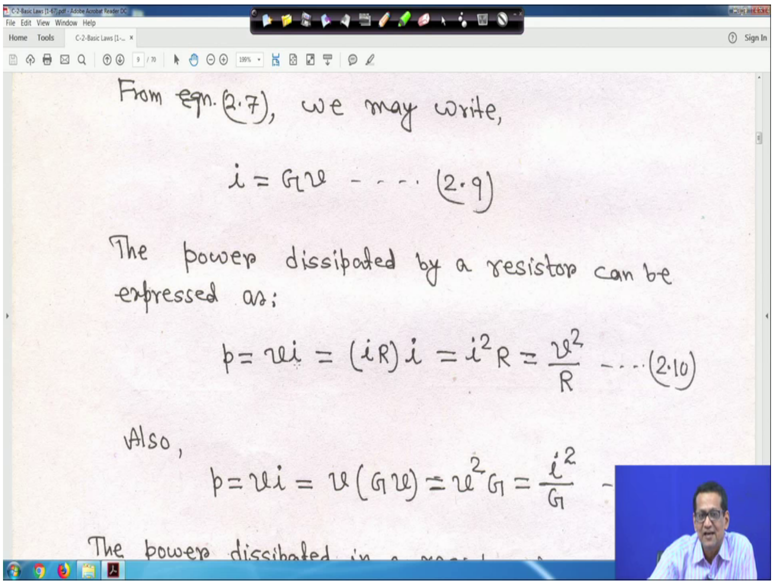

So, thus conductance is the ability of an element to conduct electric current. So, this is that that is why I have underlined here, the conductance is the ability of an element your what you call to conduct electric current.

Now, equation 7, right from equation 2.7, if these equation i is equal to Gv from this equation, right ? So, from this equation actually i is equal to conductance into voltage Gv, now the power dissipated by a resistor can be expressed as p is equal to you know vi, right, I am not writing by pen here it is a understandable p is equal to vi and v is equal to iR. So, here I put v is equal to iR; that means, it is i square R, right is equal to v square upon R.

Because i is equal to v by R this one if I write for you, just hold on. So,. So, this is actually i square R so, i is equal to also we can write now. i is equal to v by R; that means, v square by R square into R, that is equal to this one v square by R, right?

So, i is equal to your what you call v square, i square R is equal to v square by R. So, let me let me remove this one clean this one, right?

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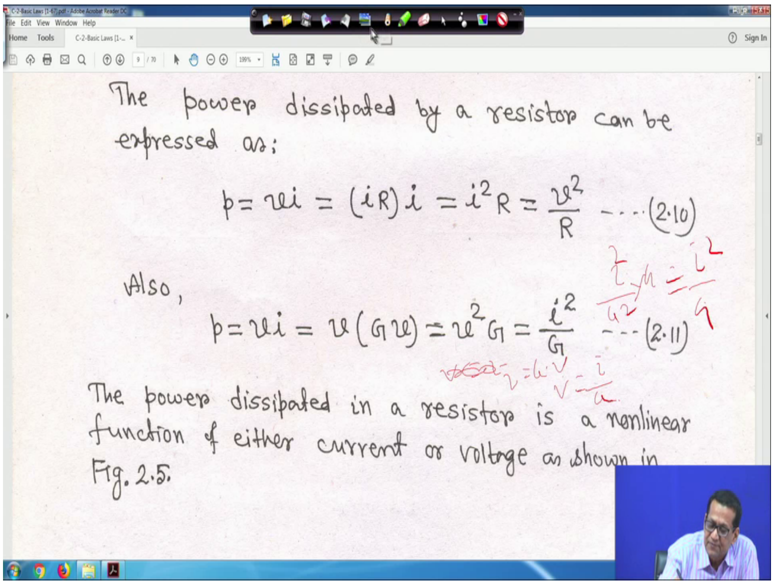

So, this is that means, p; that means, R is always positive, and it is v square. So, power loss across resistor is always positive it absorbed power, right ? Very simple thing, but we have to try to understand this, right. So, p is equal to vi a resistor is a passive element it absorbed power, and R is always positive for any circuit you take R is positive, and it is v square whatever may be the v plus or minus is square means always positive. So, p is equal to v square by R always it is positive where i square R always positive; that means, it absorbed power.

Similarly, also just other you can write p is equal to vi, now it is v, but in terms of conductance i is equal to G into v; that is v square G, right ? Or you can you can you can make if it is i square, G because v is equal to your what you call your i is equal to Gv, right, i is equal to Gv. So, v is equal i is equal to Gv. So, v is equal to i by G, if you substitute here v is equal to your i by G I making it for you just one line.

So, if it is v is equal to your ah, your what you call just 1-minute, sorry this is i is equal to your G into your v, therefore, v is equal to your i by G. So, if you substitute here v is equal to i by G. So, it is i square by G square into G that is your i square by G. So, this is what your got, right? So, this is i square by G so now, let me clean it, right?

So, the here also it is v square i square, here I mean G is taken positive it is reciprocal of resistance. So, conductance is always positive it is v square or i square; whatever may be the positive or negative value, vi does not matter if this p is always positive, right? That means, it is that means, it show that your what power dissipated in a resistor your what you call it is actually it is a absorbed power, right? Resistor observed power so, power resistor is a non-linear function of the either current or voltage this is it is a parabolic type p is equal to i square R is equal to v square by R or p is equal to v square G or i square by G it is a parabolic type of functions, right.

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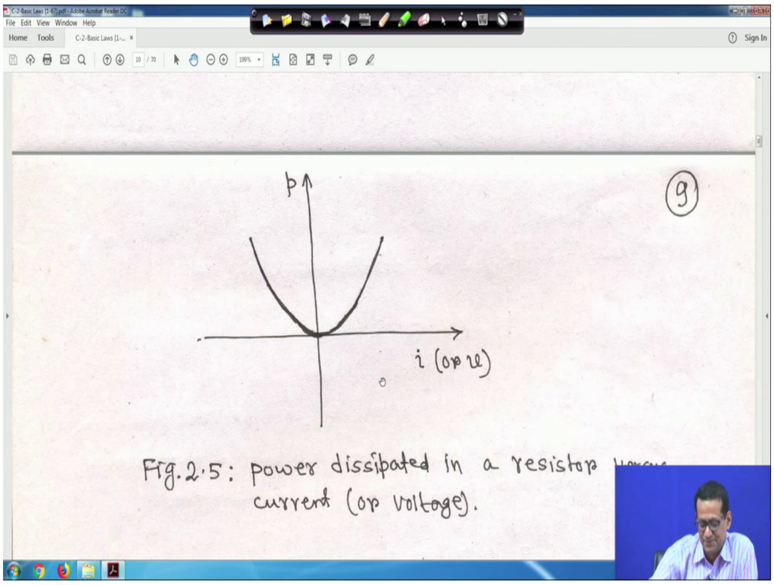

So, it is graph will be either this side you plot i or v, this is power it is a parabolic function just I have drawn right.

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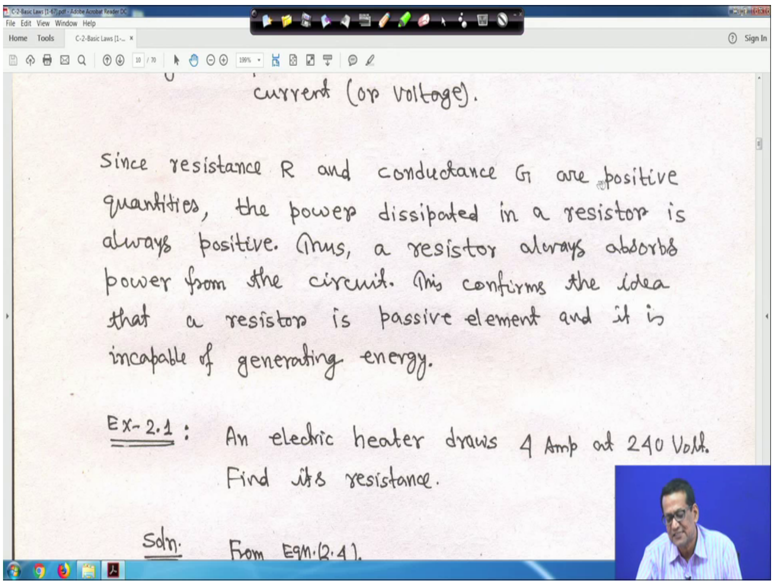

So, since resistance R and conductance G are just what I will told, that it is positive right quantities the power dissipated in a resistor is always positive. I told you thus a resistor always your absorbed power from the circuit it absorbed, right this confirms the idea that a resistor is passive element. And it is incapable of generating energy, this is very important for you. When we will listen this video, right just see that what; what we are discussing, right.

Now, up to this your Ohm's law and this thing let us come now to a small example, right? An electric heater draws 4 ampere and at 240 volt.

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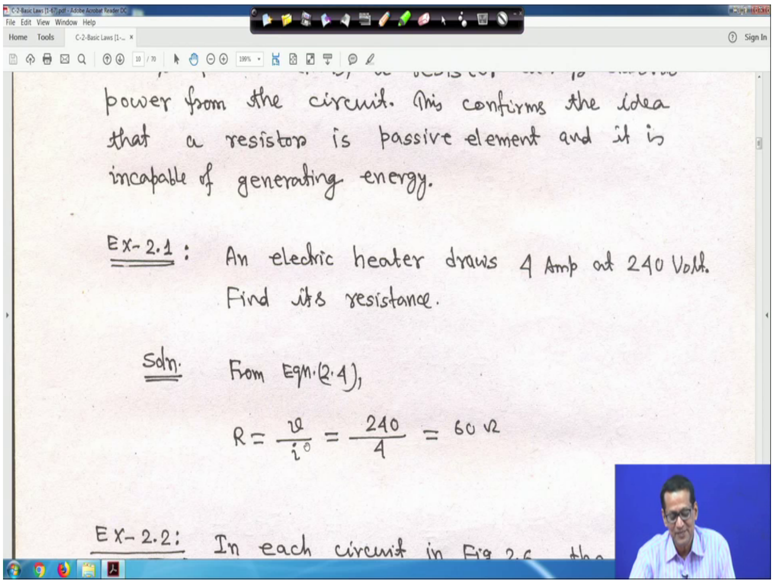

So, find it is resistance so, we know R is equal to v is equal to iR. So, R is equal to v by i v is equal to 240 and i is equal to 4 so, 60 ohm the resistance, right.

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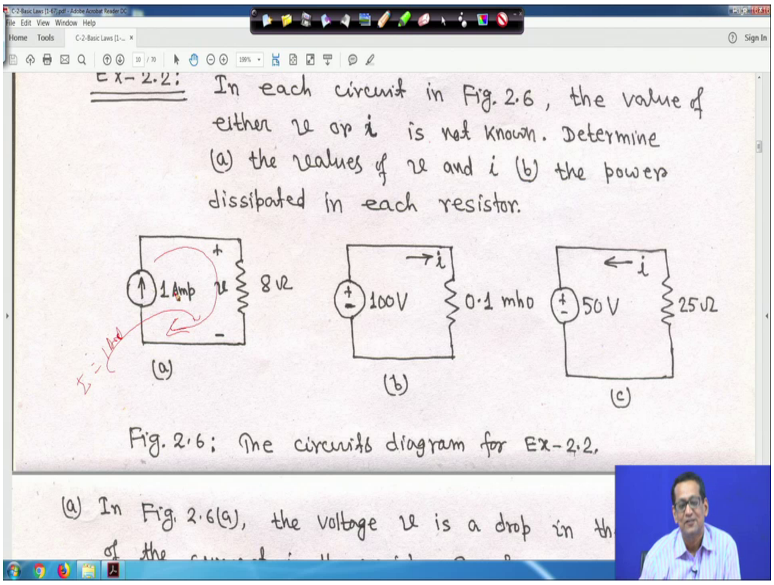

Another small example in each circuit in figure 2.6, right; so, this is 3 circuits are there the value of either v or i is not known. Ri we have to find determine the a the values of v and i b the power dissipated in each resistor. So, you have to find out v or i v or i right whatever it is known are unknown, unknown quantities you have to find out.

Now, look at this circuit is a current source one ampere, right? And this is your this is this current is entering the positive terminal. So, v is equal to iR so, i is one ampere and R is equal to 8 ohm. So, it will be v is equal to 8 volt. And it is your current is flow entering into the positive terminal, right that is flowing from higher potential to lower potential. So, it will be positive so, v is equal to iR. So, it is one into 8 so, v is equal to 1 into 8 8 volt.

Now, second case is, it is I hope I am not marking it by pen I think it is simple think. So, it is understandable to you, right? This one ampere means this current is flow this one ampere flowing through this circuit, I mean, just let me make it one thing for you these i is equal to 1 ampere. So, the current is flowing like this current is flowing this one ampere current is flowing like this, this is actually showing it this i. So, this i is equal to one ampere, this is what is shown here, right?

So, let me let me let me clean it. Similarly, just hold on, similarly this is mho this is actually this value is G is given, this is 0.1 mho G is given conductance is given, right.

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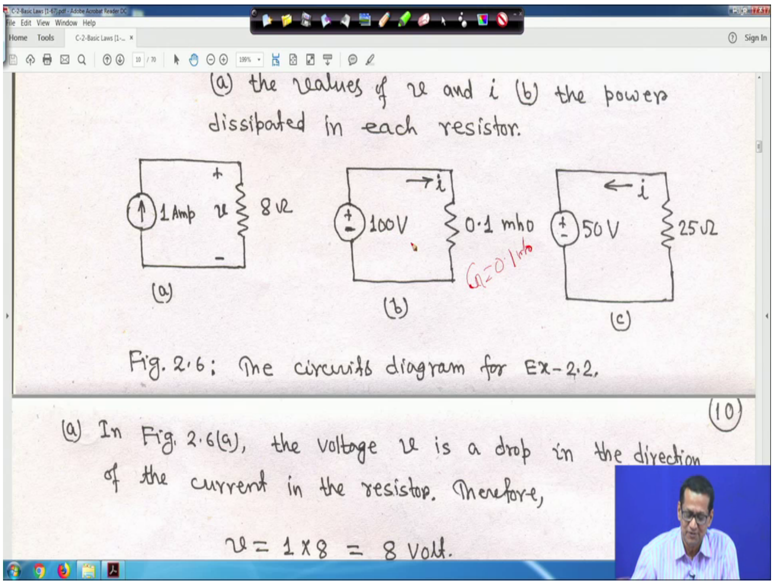

So, this is actually G is equal to 0.1 mho conductance is given of the circuit, right. So, so, in this case a voltage is given your 100, 100-volt that is 100 volt. So, you have to find out that what is the current. So, just let me let me clean this one, right?

So, in this case just hold on ah, in this case your i is equal to actually you know this think i is equal to Gv, right i is equal to G into v.

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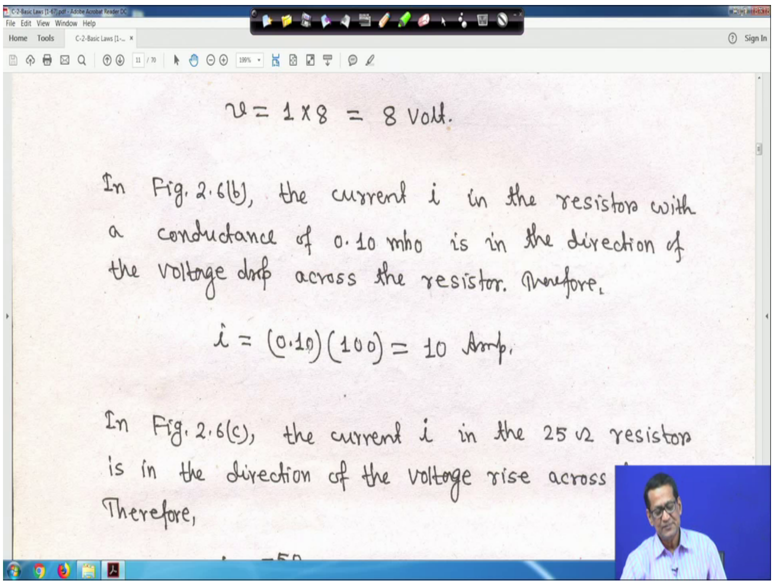

So, it is G is 0.1 and it is 100 so, i is equal to 10 ampere, right. So, it is i is equal to Gv, now another thing is that there actually your what you call this is 50 volt, and this is 25-

ohm resistor, but look at that this current actually flowing this means current entering into the plus terminal. Later you will find this things will be easier when we will come to the KVL equation, but write from the beginning current is entering into the ; that means, current is flowing from your higher potential this thing higher potential to lower potential, right.

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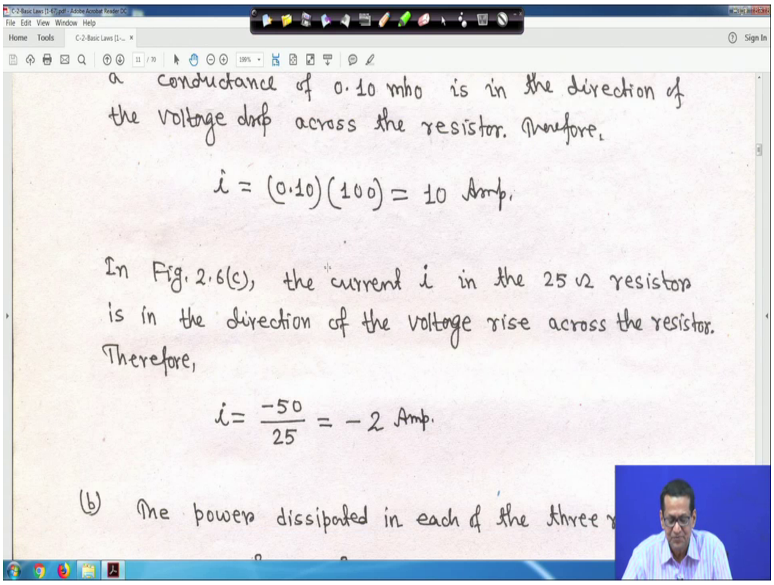

So, in this case, if you come to this that ; that means, the direction of the your voltage rise. So, 25 resistor and the direction of the voltage rise across the resistor. So, i is equal to minus 50 by 25 is equal to minus 2 ampere, right. So, because this is in the direction of the your what you call in the voltage rise. So, that is why the negative sign has come. So, that is why it is your i is equal to minus 50 by 25 that is minus 2 your ampere, right.

So, this is actually voltage source, right this is one resistor this voltage source. So, it is from the voltage your from the higher your what you call in the direction of the voltage rise, because it will encounter plus first one is the KVL thing at the time things will be easier. So, this is your what you call minus 2 ampere.

Now, now last b part is your part b, this thing the power dissipated in each resistor here. We have seen the current is one ampere and it is your what you call R is equal to 8 ohm.

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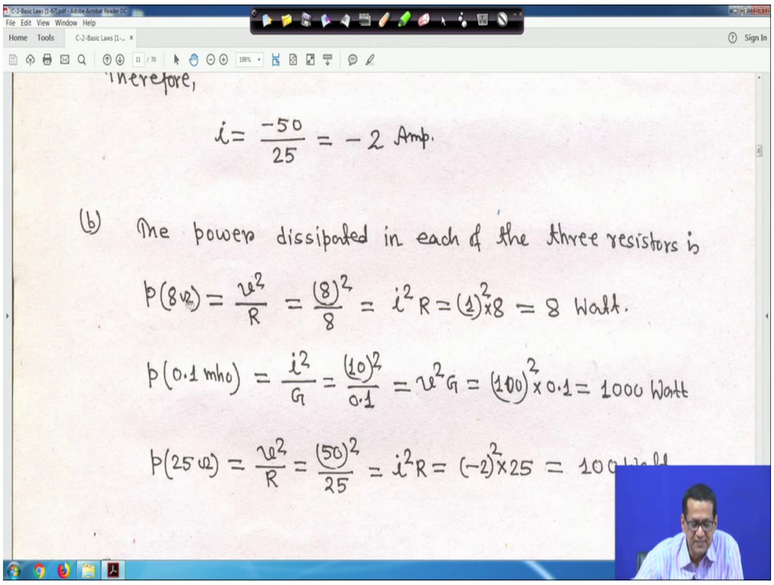

So, in the first case, the that is v square by R, that is power a absorbed by the resistor 8 ohm. So, bracket I am writing a power this 8 ohm means power absorbed in the 8-ohm resistor v square by R. So, v square actually v is 8, we have computed divided by R is 8 ohm. So, it is equal to the same thing i square R. So, i is 1 1 square R into 8 actually it is 8 watt. It is also 64 by 8, 8 watt i square also 1square R 8. So, it is 8 watt so, it is understandable.

Similarly, that second circuit that there G is your 0.1 ohm, this G is actually sorry 0.1 mho, and voltage is 100 volt. So, in this case you can see that power your basically it is a resistor say. So, it is your what will be the power absorbed. So, i square by G so, i is 10 ampere. So, 10 square by G is 0.1. So, it is equal to same thing v square G is equal to v is 100 volt, and G is 100 square into G is 0.1 ultimately it will become 1,000 watt, right.

Similarly, your 25 ohm that is this circuit, this circuit 25 ohm resistor, right? Whatever may be the current it does not matter, right. So, it is v square by R is equal to 50 square by 25, and is equal to also i square R i is equal to minus 2 square into 25. So, ultimately 100 what I told you that for whatever may be the direction of the current or the polarity of the voltage plus minus that power your absorbed by the resistor, resistor absorbed power it sign will be always positive, right?

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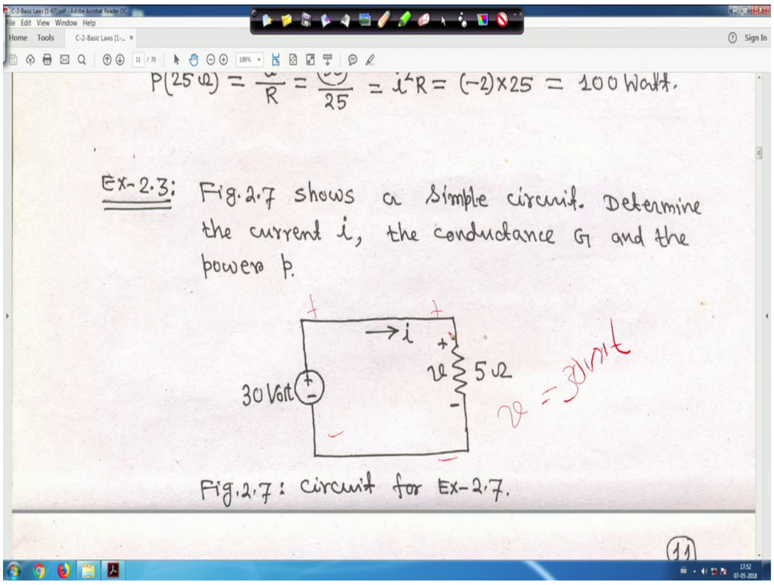

So, in this so, all this cases, you can see it is 8 watt thousand watt or 100 watt all the cases resistor actually absorbing power, right this is, this is another small thing that figure 2.7 shows simple circuit than the current i the conductance G and the power p. So, it is 30-volt source, and here one resistor is there and it is 5-ohm resistance and current flowing through this your is i, right.

So, in this case voltage across in this case there is no other element here, right no other element. So, this is 30 volt; that means, just for your understanding only this voltage is 30 volt. So, this is plus minus means this is plus minus. So, this voltage is whatever plus minus means this is also plus minus, this 30-volt means is to same voltage will be impress across this your resistor; that means, my v will be is equal to your 30 volt, right so, same voltage.

So, understandable it is very simple thing this is plus minus is plus minus. So, there is no other element here. So, plus minus and so, whatever voltage is here same voltage is here because no other element. So, there is no voltage drop later, we will see this. So, v will be is equal to 30 volt. So, let me clean this one, right ? So, then what then what will be the current then?

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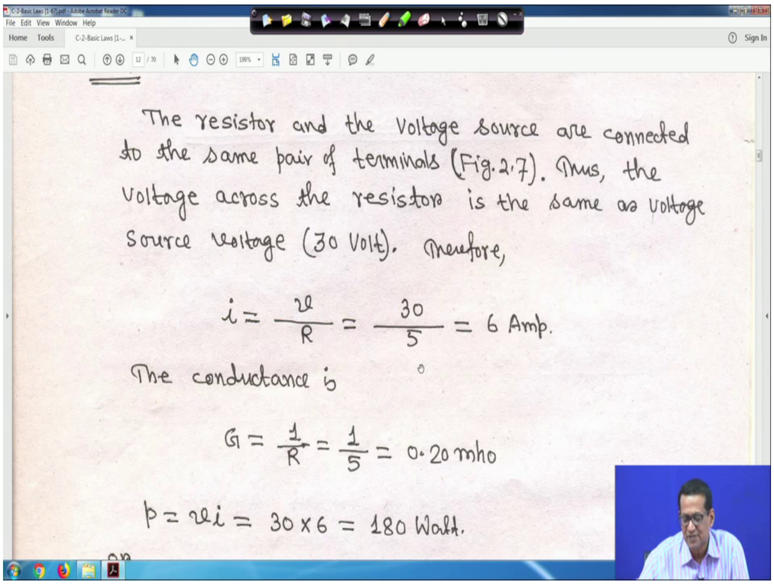

So, current will be i is equal to v by R is equal to 30 by 5 is equal to 6 ampere.

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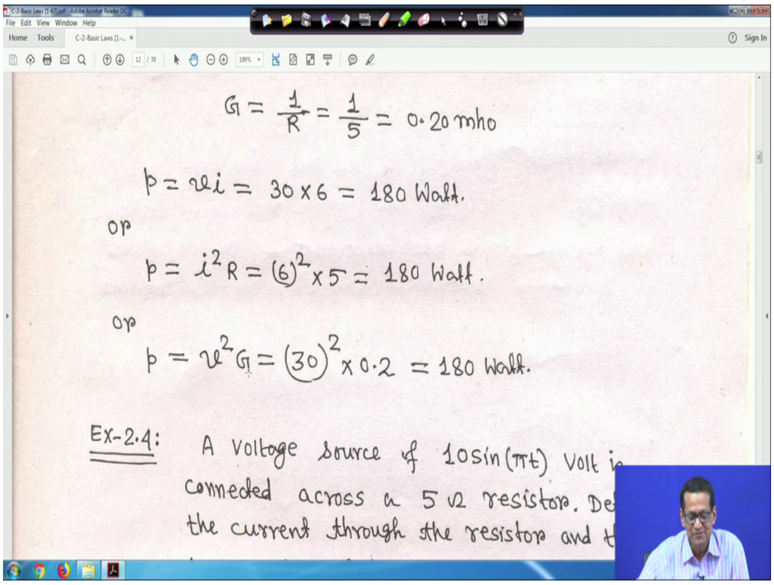

So, conductance is G is equal to 1 upon R. So, 1 by 5 so, 0.2 mho, because reciprocal about. So, power is equal to v into i is equal to 30 into 6. So, 180 watt this we can calculate, or p is equal to i square R that is 6 square i is the i is 6 ampere, we have calculated this 6 ampere 6 square into 5.

So, 180 watt or p is equal to your v square G, that is your 30 v is 30 volt. So, 30 square into 0.2 that is also 180 watt the way one you can compute the your power, but is a resistor. So, it will be power absorbed. So, all these cases sign is positive.

Thank you very much, we will be back again.