Experimental Physics - III

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Lecture - 18
To study the Variation of Resistivity of Metal and Semiconductor at Low Temperature Region (continued)

now I will demonstrate measurement of resistivity of a metal and the semiconductor as a function of temperature.

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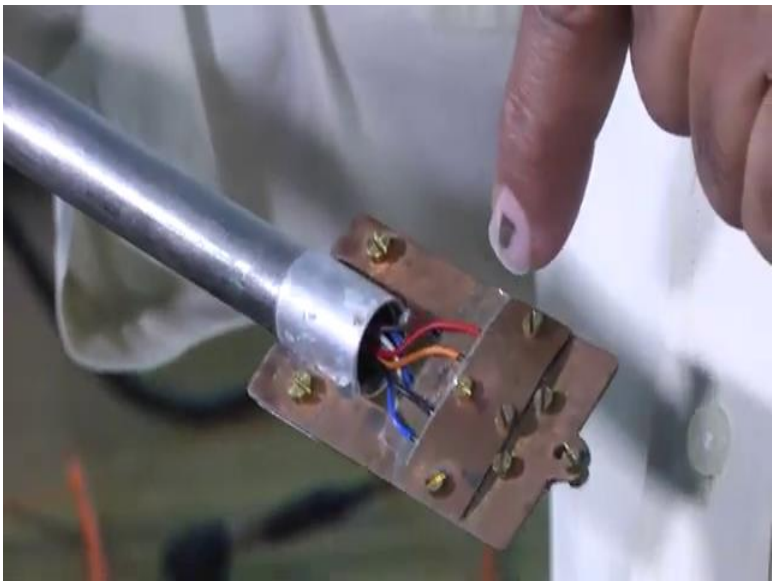

this is very simple experimental setup. I will show you that sample this is a sample holder is a made of copper. We will use liquid nitrogen for cooling this sample. here we have used the copper stripe because, this we will put in the vapor of the liquid nitrogen. And this copper stripe will be cool because, it is the thermally conducted and it will release to the sample.

Now, here you can see just sample is inside; sample is inside it is a metal I think some foil we have taken is a maybe aluminum foil or exactly I do not know. But some foil we have taken for the as a metal. inside the sample is there and then this white part you can see these thermally with this electrically isolate from this tops stripe.

Again tops stripe we have use copper because the temperatures has to reach to the sample. this sample is in touch with this copper. that when copper will be cooled in liquid nitrogen vapor. Then that sample will have the same temperature. Now, here it’s a metal and metal have very small resistance. And change of resistance with temperatures that may be also very small.

here we have used four probe method. here four wires you are seeing, that means, with sample this four connection outer two we will use for current. And inner two we will use for measuring the voltage drop. this exactly the linear four probe method, as I have used this four probe method in case of material stress measurement. same for linear four probe method we have used for metal.

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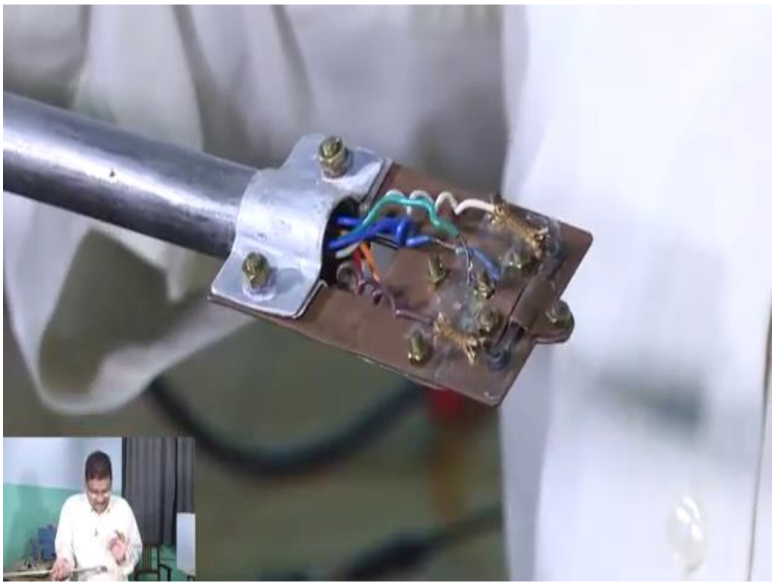

Now, other side we have put the semiconductor again you cannot see the sample. Here again you can see this copper stripe. Now, below this copper stripe this semiconductor material is there. again why we use this copper stripe on top as well as in this bottom means this main stripe, and in between we have kept the sample.

Reason is that these sample will reach to the same temperature of the copper stripe. copper stripe is a very good thermal conductor, because of that we have used this copper stripe. from this semiconductor we have taken these two connection, these two connection we have taken.

Here you can see these two connection we have taken, I should not disturb much. these two connection you have taken here we have used two tops. Means from these two connection we are we are applying current, constant current through these through these two connection. As well as these two we are measuring the voltage between these two connection.

Now, two probe you know that contact resistance will contribute in the total resistance. but since the semiconductor resistance is higher contact resistance can be may be negligible compared to the sample resistance. that is why here we do not need to use four probe method, two probe method is good enough. that is why here two connections here two connections for the semiconductor two probe method.

Now, here these two connection is this is the platinum resistance, this is the platinum resistance here. we have taken connection these two outer collection is for as a thermocouple. resistance of these platinum, we will change with temperature. Now, from the actually measuring the resistance of this platinum we can tell what is the temperature. from calibration curve one can find out.

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these I will put I will put inside this one. This thermally isolated tube thermally isolated tube. I will just have fixed it let me check the hole yes. I will have fixed it; I think one has to do it. I have opened it to show you, but generally we do not open.

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now you see this in experimental physics I; I showed you this screw driver screw. now, it is useful. I have fixed it with this rod and the all connections are coming out this rod is here this Teflon is there. through Teflon electrical isolated this all wires are coming out.

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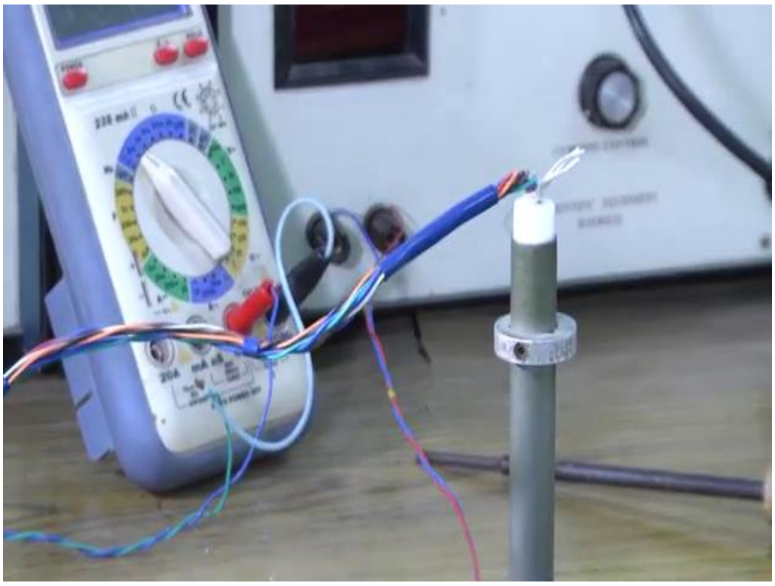

how many wires are coming out? for metal four wires, four probe method, two for constant current and two for measuring the voltage. this four wires from here, this four wires are going to the set up. These two are here these two are here this is the constant current source. two these two for four probe for metal. these two are for the passing constant current to the metal. And other two wire we have connected you can see we have connected other two wire we have connected here it's the micro voltmeter.

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it will measure the voltage drop of the metal. this four connection for metal, and two connections two connection for the semiconductor, as I told that two probe we are using. these two connection, these two we are giving here this constant current source here also I need constant current source. current will pass through this to two probe to contact and from this two contact itself we will measure the voltage.

from this same connection we have taken for the volt meter. Here this is the volt meter digital panel meter V DC. voltage DC voltage this is the volt meter. this part is for semiconductor for current and voltage, this part is for metal for current and voltage. Now, this four wires and these two wires, six wires and two more wires as I told this platinum resistance is there for measuring the temperature. this two we are we have connected here is a mustimeter.

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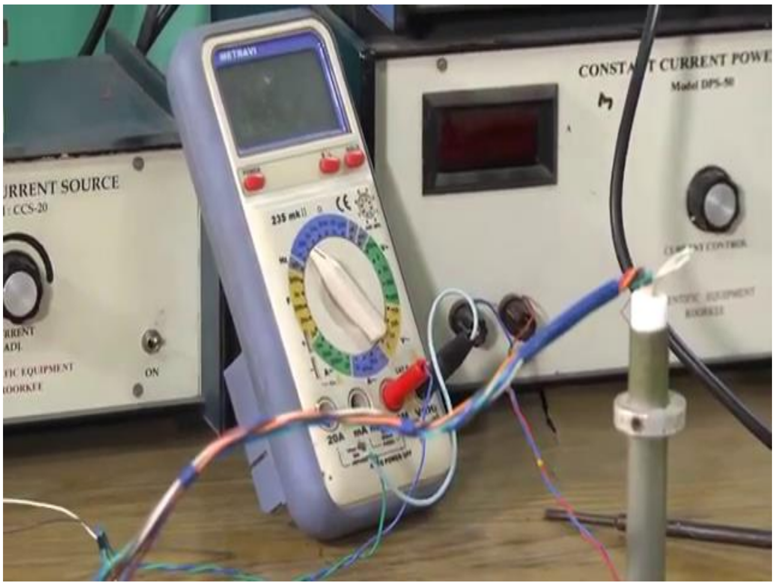

multimeter here it will show; it will show the change of resistance of the platinum. that platinum resistance will change with temperature and there is a calibration table supplied by the company. for different platinum resistance what is the temperature that calibration chart is available with us. this is the calibration chart this is the calibration chart.

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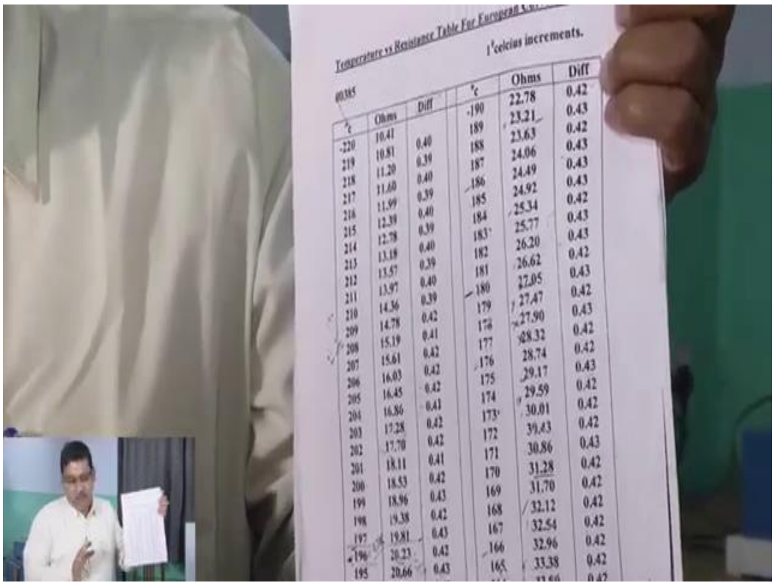

this is an ohm this is the resistance at different temperature. these voltmeters will tell us the resistance of the platinum and corresponding temperature will get from the table. what do we have to do we have to initially let us just start the experiment. When we will start the experiment let me switch on; let me switch on everything let me switch on and this is for this one. I have switched on in this setup.

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Now, here this for metal current is 0 constant current pass it to the metal it is 0. here metallic voltage has to be 0. here 0 adjustment is there that voltage drop should be 0 because current is 0. I set at 0. this for metal; now this is for semiconductors. here current 0 here I do not have adjustment it's the 1.5 negativity showing. I do not have option to adjust, but let me check it no. it is some value is this showing, but this I do not have option to make it 0, but this one can just keep note.

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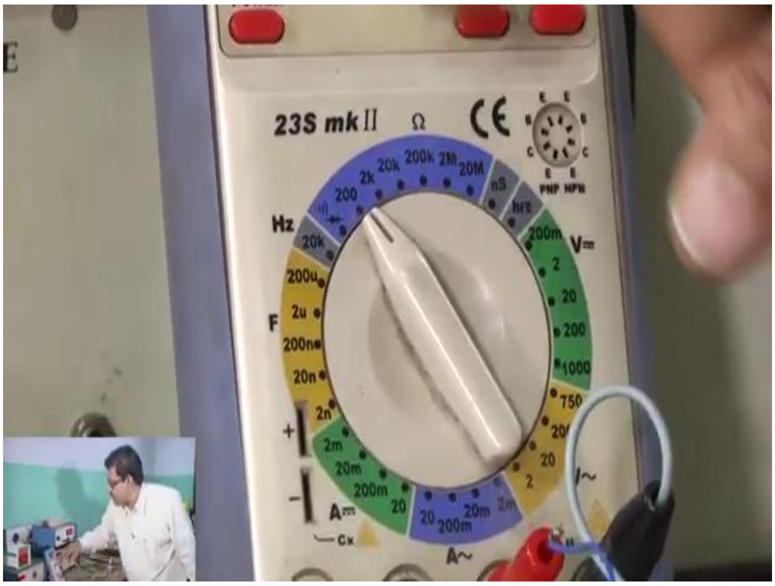

because these value will be negligible compared to this other our data. now, here it is showing it is showing 108.26. This resistance it is resistance it is 200-ohm range, 108.26-

ohm resistance platinum based. for that what is the temperature from this chart I can tell you, from this chart I can tell you.

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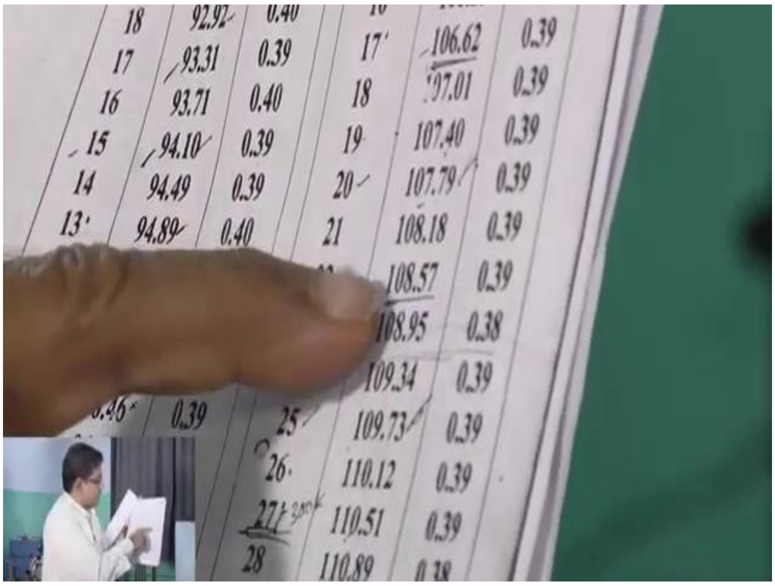

here it is 108; that means, it is a I have to go 108. I have to go 108 here. You see here 108.18, 108.56 57. here you see this temperature between 21 and 22. temperature is an average temperature you can tell that 21.5. Now, is the wintertime it is a December of end. room temperature is around a here 21.5. I have to note down this we have to make table.

this what is the resistance of the thermometer whatever we are getting here and corresponding temperature from the chart we will note down. now, in which way we will vary the temperature here. here also we will look down this 0 current, for that what is the voltage. if you have any adjustment just adjust it otherwise just keep note here also for semiconductor 0 current and negligible whatever the voltage just keeps note down. Because this is the error we do not have adjustment.

now, how I will vary the temperature in this experiment? what we will do, we will put liquid nitrogen in this tube and liquid nitrogen this we kept the sample is up. we will put liquid nitrogen liquid nitrogen will be the at the bottom of this tube. Then it will generate vapor and this sample will be in that vapor and temperatures it will reach to the liquid nitrogen temperature, it takes time.

and then we will allow to for natural heating up of this because, surrounding temperature is 21 degree centigrade and inside temperature will be liquid nitrogen temperature liquid nitrogen temperature. with time what will happen this it will be vaporized this all nitrogen will be vaporized, and the there is a due to this there because of the high temperature difference between the environment and the sample place.

That is a liquid nitrogen temperature and environment is a liquid nitrogen temperature is it is 77 Kelvin. That means, it is minus or nearly it is a minus 200 degree centigrade, minus 200 degrees centigrade. 73, 173 and 77, 4 is a minus 196 degree Kelvin.

approximately it is the minus 200 degree centigrade and environment is past 20 centigrade 21 degree centigrade. because of the high difference of the temperature thermal, there will be a thermal conduction, thermal conduction . this sample place will be because of this thermal conduction thermal.

this temperature will from environment temperature will go to this system and as if it will heat up, it will heat up slowly with times. that natural heating up that this procedure we will use, but in very good system. Generally, people keep the heater and this should be that is PID controlled it is called proportional differential integrated proportional integrated and differential PID control.

but that arrangement we do not have. in that case you can control the temperature and keep stable for any temporary temperature. that arrangement is costly; we do not have here. But here in natural way we will heat up the sample from the liquid temperature to the higher temperature with time.

now what we will do? Let us I think I should put liquid nitrogen it is this one. Let us put liquid nitrogen if we if I put some current here metal it’s an ampere. it is if I apply this is say 0.1, 0.2 in this case let me apply 0.2 ampere current, 0.2 ampere current to the metal. Corresponding voltage at this temperature we should note down.

And, now here I will apply current I will apply current say in case of this is 0.4, say 1 milli ampere current I will put here 1 milli ampere current I have put here. corresponding voltage at this temperature you can see here. Now, I when I will put liquid nitrogen temperature will change will lower what we will expect.

this current in both cases should remain constant. And this voltage resistance if whatever the resistance will change that we will see in terms of voltage. in this case in case of metal when temperature is lower resistance will be lower. here we are expecting that resistance temperature lower resistance will be lower voltage drop will be lower.

here we are expecting that voltage will decrease in case of metal. Because v by i that is the resistance and in this case in case of semiconductor we will expect that temperature decreasing then resistance will increase resistance will increase and voltage drop will increase. here we will expect that the voltage will increase. here voltage will decrease and here voltage will increase when we will put liquid directly.

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Let us see whether it happens or not. I think Mr. Prasanta he takes care of this solid state physics laboratory. one has to put liquid nitrogen very carefully as I told this temperature difference of for body and the liquid nitrogen that is the temperature difference is more than 200 degree centigrade. it will burn your out it will burn your hand or leg if this liquid nitrogen falls on your hand or leg. one has to do very carefully.

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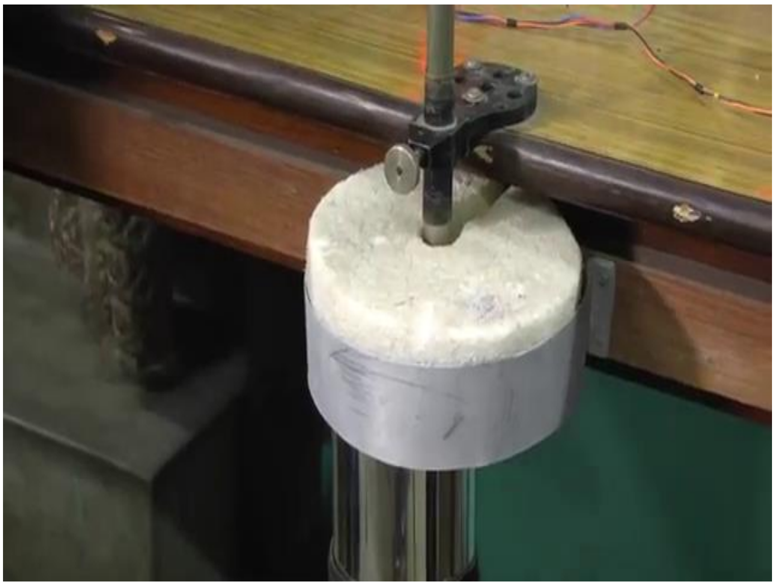

what we have done we put poured the liquid nitrogen and they just covered up with some it is a cover up very cold it is very cold. now here you see in this case what you are seeing what about the value was there that decreased, the decreased and here whatever value here was there now it is increased you know. earlier it was 0.55, something some reading was there and now it increase 1.013.

as I mentioned that in case of semiconductor resistance will increase when temperature decrease. voltage will increase that is happened here and in this case some value was there now it is you see it is it become just 0.

at liquid nitrogen temperature now you see here as I told this reading was 100 108 108.26, now it is 21.1 this platinum resistance it is 21.1. And for 21.1 what is the temperature. From this chart we will see this is the; this is the 21.1 here you see 21.08 and 21.51 in between temperature is 94 93 94 it’s the minus sign here minus is given minus 220, minus 219 etcetera.

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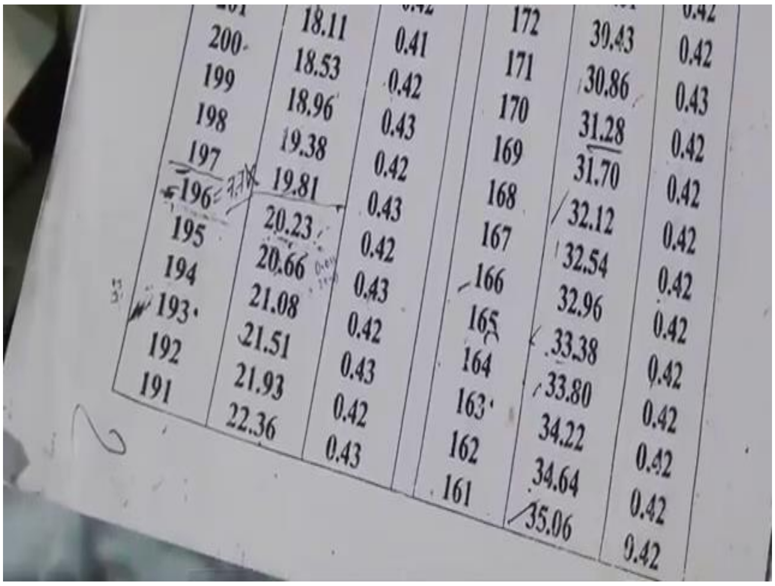

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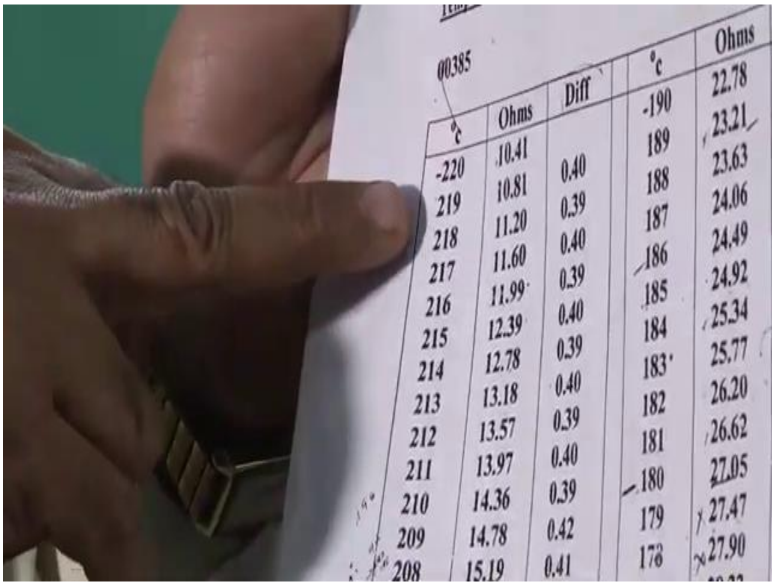

it’s a some minus 190 194. as I told liquid temperature is minus 196 minus 196 this 77 Kelvin. Now already our sample is at 194 because this is 21.2.

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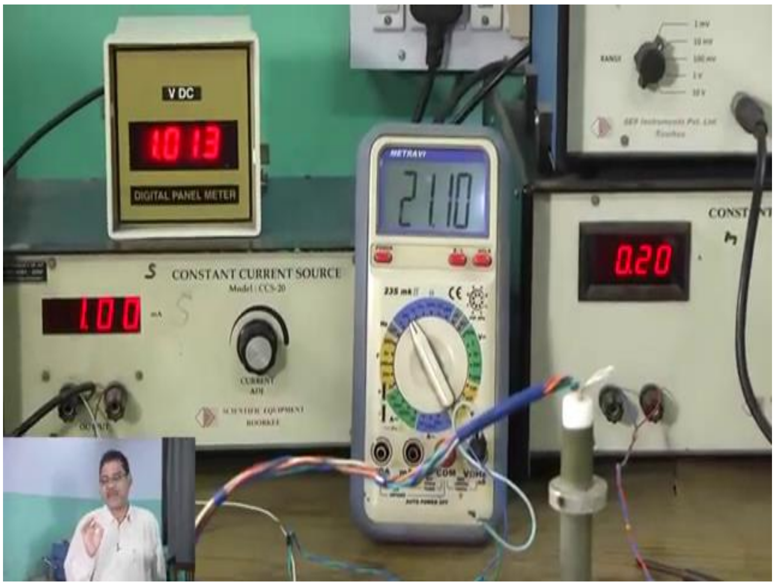

Now, what is the value is the 21.2. it is exactly it’s not at the liquid nitrogen temperature or here you see this platinum thermometer is a very good thermometer for measuring temperature. just simple just using this voltmeter and using the volt meter and a piece of platinum wire we have used, and just we are measuring the resistance.

Now, from calibration curve from calibration curve we are able to tell this what is the temperature. these are another type of thermometer like thermocouple we are using for measuring temperature. Similarly, platinum thermometer we are using for measuring temperature. it is the let me is that 21.1. it’s a temperature is 194 194 minus 194 corresponding you these are in centigrade in Kelvin is the is around I think 79 Kelvin; in Kelvin it is a 79 Kelvin.

now, we have to wait I can open it. Now what I want, I want the increase of the I want to increase the temperatures of the sample I do not have heater in natural way I want to just I will allow to vapor go out.

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I think almost all liquid has vaporized slightly some you know what will happen with time? It will change the temperature very slowly at least it will take more than an hour to come off at the room temperature.

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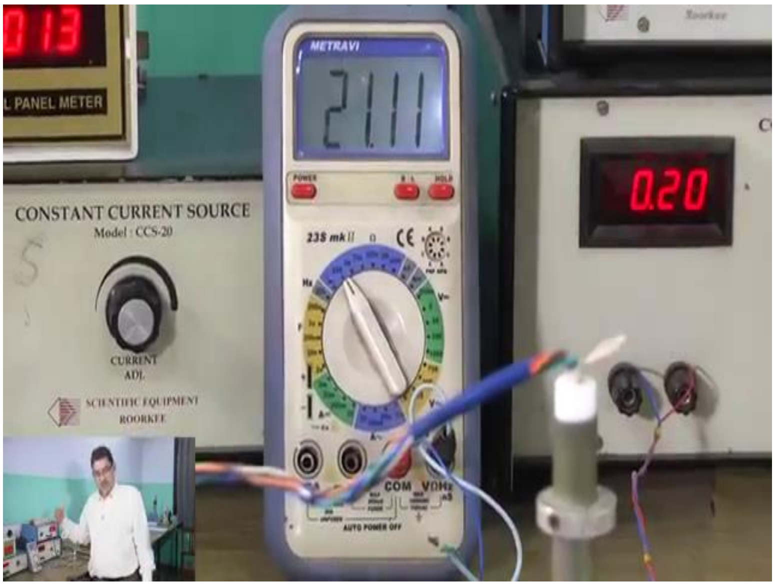

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here I will do at this change of the resistance of thermometer corresponding temperature I will get and for that temperature what is the voltage from here and here from metal and for semiconductor I will note down. now, it will take time.

Now, it is still at the same temperature 21.1 now it is started to change no I just I think this connection disturb. I think just here I was able to show you that it was at room temperature what is the voltage for metal for metal and for semiconductor for particular constant current. voltage when I decreased the temperature of liquid nitrogen. voltage will increase in case of semiconductor and voltage will decrease in case of; in case of metal and that is happened.

Now, temperature will increase this voltage in this case voltage will decrease, in this case voltage will increase. with time there will be change of temperature we have to note down this temperature from this thermometer platinum thermometer and corresponding voltage for metal and this semiconductor we have to note down for particular constant current for metal and semiconductor that we have to note down.

Then just we have to divide it we have to divide the voltage by the that constant current and then we will get resistance. Now, resistivity how we will get resistivity we will get data will be supplied to your rho equal to; rho equal to r l a by l. what is the dimension of the sample that will be supplied to you. What is the an and l you will know and then resistance you are measuring from v by i at different temperature. you will get the corresponding resistivity at different temperature.

then plot resistivity at different temperature and from the plot you can see the nature of the change of the resistivity as a function of temperature and hitting that curve you can find out the temperature dependence of resistivity of that material. for metal but for different material it’s it can show it will show the different kind of variation is the always increase always increase, but the slope etcetera linearity it is an exponent this as I told this it is a polynomial of polynomial function.

other higher terms will contribute also. it will whether it will contribute or not whether that will depend on the type of metal as well as it will depend on the range of the temperature. one can study the temperature dependence of metal and semiconductor from this simple experiment. I think is still it is 20 it will take time. Initially I think it start to warm of it at least it will take half an hour and then after that it will just drastically I think still some liquid nitrogen is there.

that is why it is maintaining the temperature at the same temperature because these value are still same. these I explained and this is just now we have to go down the data with time as temperature will increase. I will stop here.

Thank you.