Experimental Physics I
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Lecture - 41
Determine the coefficient of thermal conductivity of a bad conductor

So, today we will demonstrate the Measurement of Thermal Conductivity of Bad Conductor.

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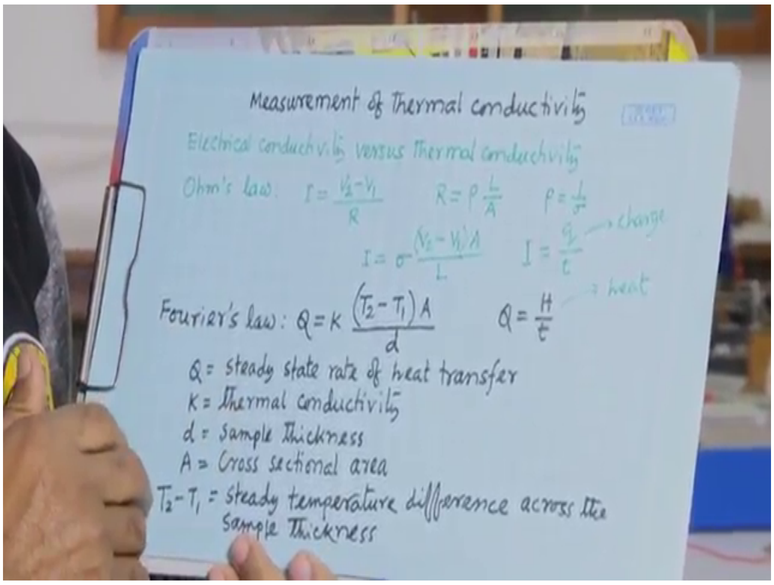

So, let us discuss theory of this experiment. So, you this electrical conductivity; so similarly there is a thermal conductivity. So, if I compare these two, so this Ohm's law that is basically I equal to V 2 minus V 1 divided by R. Here R is resistance and this V is potential. So, V 2 minus V 1 is basically potential difference between the two ends of the register, then current will flow through this resistor is I. So, this is the relation between the current flow under the potential difference through a resistor, right.

And this resistance is equal to rho L by A. So, if it is a wire, so L is length of the wire and A is cross section cross sectional area of the wire and this rho is the resistivity of the of the wire, right or metal of the wire and this. So, resistivity is basically 1 by conductivity sigma. So, if you replace this R with this, so this conductivity or resistivity or say conductivity electrical conductivity will be related like this. So, this current flow through this registers, through this wires or electrical conductors is proportional to the potential difference, proportional to the cross sectional area and inversely proportional to the sorry see here current flow is inversely proportional to the length of this wires, right.

So, from here Q with this sigma equal to 1 can write the formula for electrical conductivity. Similarly this for thermal conductivity, so this is according to Fourier's law this Q, Q is basically H by t, H is heats. So, heat flows per unit time I is charge flows per unit time q by t; so charge flows per unit time in case of electrical conductivity. So, in case of thermal conductivity their heat flows per unit time that is Q is proportional to the temperature difference between the two end of the thermal conductors and also proportional to the area A and inversely proportional to the thickness of this or is a is basically is a equivalent to length.

So, in this case we will take it is a circular disc. So, this A will be the area of the circular disc, here we took this wire and in this case if we take a disc, so this temperature difference between the two surfaces of the disc upper surfaces and lower surface temperature, higher temperature surface is T 2 and lower temperature surface is T 1. If this temperature difference is T 2 minus T 1; so, charge flow from the upper surface to the lower surface from higher temperature to the lower temperature. So, that is heat flows per unit time that is proportional to this temperature, depends of the disc, and it is proportional to the area of the disc and inversely proportional to the thickness of the disc. And this K is basically thermal conductivity.

So, these two relation if you consider, so exactly same. In this case this current flows because of the potential difference voltage difference and in this case heat flows, heat flows because of the temperature difference and also it depends on area and the length or thickness of the conductor. So, Q is, so Q is basically steady state rate of heat transfer. So, from one place to another place the heat will transfer under the steady state condition, means the temperature difference between these two point will remain constant during the flow of heat.

So, as this voltage between the two point remain constant during the flow of charge. So, this K is thermal conductivity as this sigma is electrical conductivity, d is the as I told the sample thickness, A is the cross sectional area and T 2 minus T 1 is the steady state temperature difference across the sample thickness. Steady state means with time there will not be any variation of these of this difference, ok. So, this equation is valid under steady state condition, as this is valid under the this also you can do not an steady state generally it is constant potential difference. So, this is the expression relation is according to the Fourier's law of heat conduction.

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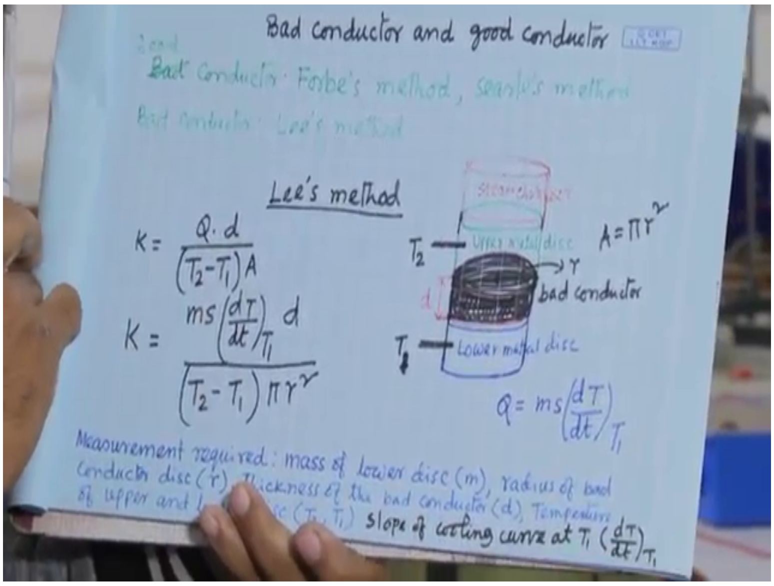

So, let us consider the method which method will follow for this experiment. So, today we are going to demonstrate the measurement of thermal conductivity of bad conductor. So, one can measure also this thermal conductivity of good conductor. So, for good conductor this is common very common methods are these is a Forbe's method, Searle's method; so I will not discuss this.

So, and for bad conductor generally the very common method is Lee method or Lee's method, ok. So, today we will discuss about this Lee's method, this method will be used to measure the measure the conductivity of thermal conductivity of bad conductor, right. So, in Lee's method, so here I have shown this; this is the bad conductor. So, in our setup, so we have taken a bad conductors this is the a rubber disc, ok. So, it can be glass, it can be wood, it can be some other is, so there are yeah there are many bad conductor, thermal bad conductor; so one is rubber, glass, wood.

So, in our experiment we are going to use this disc rubber disc. So, this rubber disc is basically here whatever I have drawn; so this is the rubber disc. Now, below rubber disc there will be one metal disc of same diameter and above of this rubber disc there will be another metal disc. So, we are telling upper metal disc and lower metal disc. So, this there will be thermometers, there will be thermometers to measure the temperature of lower metal disc and upper metal disc, ok.

So, what we will do, we will heat this upper metal disc, so we will used this steam chambers. So, we will boil water and this steam will pass through this through this chambers, and this lower upper metal disc is connected with this steam chamber. So, this temperature of the upper metal disc will increase, ok. So, temperature this we can measure from this thermocouple 2, not thermocouple here we will use basically mercury thermometer.

So, we will we will note down this the temperature of this thermometer 2 and then we will see the temperature of thermometer 1, whether any change of the lower metal disc whether any change of the temperature of the lower metal disc. So, if there is a change of the or the temperature of this lower disc that means, from upper disc temperature or heat is moving is travelling through the bad conductor to the lower disc, ok; so, and that is that is happened.

So, this heat transferred from upper disc to lower disc it will be controlled by this in between this conductor, it is basically our this disc rubber disc, ok. So, it will depend on the conductivity of this, of this, of this rubber disc. So, we will wait and after sometime, so these two temperature will be steady. There will not be any further change of these two temperature with time. So, this is basically called the steady state, ok. So, under the steady state under the steady state what will happen? So, there is no any further change of temperature of this lower metal disc means. But, this heat is flowing all the time heat is flowing from the upper disc to the lower disc.

So, we are getting steady state it means that lower metal disc whatever the heat it is getting from the from the upper metal disc through this conductor thermal conductor, so this gain heat by this lower disc will be equal to the loss of heat from the lower disc. So, where this, how it is losing the heat? So, this by, so this surrounding basically this heats, heat is radiated from the lower disc, heat is radiated from the lower disc, ok. So, it is losing heat due to radiation in the atmosphere and also it is gaining heat from the upper metal disc.

So, when these two gain of heat and loss of heats equal then only this temperature of this one will remain constant, ok. Sothese arrangement we need for measuring the conductivity of this conductor, bad conductor and this method this method is called basically Lee's method, ok.

So, what is conductivity? K equal to earlier we have seen the expression Q equal to K into T 2 minus T 1 into A divided by d. So, now, K is equal to Q into d divided by T 2 minus T 1 into A, ok. So, what is d? Thickness of this disc, this is the rubber disc, A is cross sectional area of this disc, ok. So, if you know the radius of this disc then pi R square, R is radius of the disc will be the area of this of this cross sectional area of this disc. So, pi R square and these d is thickness, and temperature T 2 minus T 1, so that we will get from theses thermometer attached at the at the upper metal disc and the lower metal disc.

And then so, this we have to measure basically the thickness of this disc or thickness we will use the screw gauge for measuring the thickness of these of this disc we have to measure radius of these disc. So, we will use either slide calipers or metre scale to measure the measure the radius of this disc and temperature as I told that we will get from this thermometer T 1 and T 2, ok. And now, we have to measure Q; so that is the main task of this experiment.

So, Q, what is Q? Q is basically in steady state condition how much heat is flowing from the upper disc to the lower disc per unit time, ok. So, basically rate of flow of heat from upper disc to the lower disc. And as I told the as long as it is in steady condition this heats whatever transferring from upper to lower disc, so that will be equal to the equal to the lost of heat by the lower disc by radiation. So, this heat this Q perform for a for a particular per unit time. So, this Q is basically ms t, ms t, ok and now, T by temperature T, temperature T by time t, so that will be basically the rate of change of temperatures, ok. Rate of change of temperatures per unit time so that is dt, but here this temperature in our case; so that we have to see.

So, basically Q or H, H equal to ms t, ok. Now, H by t, time t; so that is Q, so that is why this time t is there we are writing dT by; dT capital T temperature divided by d time t, small t, at T 1. So,. So, this Q we will find out using this relation. So, radiation by the lower disc with time radiation by the lower disc with time, so if we can measure the change of temperatures of this lower disc with time, with time, and this change if we can find out at a temperature T 1, so we can find we can get this capital T, ok; so, this we tell this.

So, this how we can do? We can do this is after getting these steady states, after noting down all these things, so what we will do, we will just heat this lower disc whatever T 1. So, around 10 degree temperature we will increase this lower disc, then we will remove this heat chamber, and keeping these bad conductor on top of it, so we will just allow it to cool. So, no heat is coming from upper metal disc. So, only now is due to radiation it will lose heat and its temperature will decrease. So, this will be this will cool with time. So, we will note down the cooling of this lower disc with time. So, at every say 1 minutes or 5 second or 10 second or the that we have to see how the how the temperature is changing, ok.

So, we will take data for cooling of this lower disc; so temperature versus this time. So, we will start this T 1 plus 10 degree and then we will go down up to T 1 minus 10 degree. So, this then it will draw this temperatures of this lower disc versus the time, so this we tell the cooling curve, ok. So, from cooling curve we will find out. So, this will be the slope d capital T by d small t at a T 1. So, at T 1 we will find out the, we will find out this slope. So, if we can find out the slope then if you know the mass of the disc lower disc and the specific heat of the lower disc then we will get the key, ok. So, this is the final formula or key formula for this experiment.

So, we have to measure the mass of the lower disc or if we supplied radius of the bad conductors are we have to measure thickness of the bad conductor we have to measure and temperature of upper and lower disc T 2 and T 1 we have to measure. Also, we have to find out slope of cooling curve at T 1; so, that is this, ok.

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So, basically, so let me show you, let me show you the our set up for this experiment our setup for this experiment. Say actually we have started to heat, we have started to heat this heat chamber. So, here you can see this is the heat chamber and then this upper metal disc is attached with this chamber here. So, top part you can you can tell that is the that is the heat chamber come or steam chamber come this upper metal disc. And this below one is the lower disc, lower metal disc and in between there is a; we have already put there is a this same rubber disc between these two metal disc, ok.

So, now this is the we are boiling water in this chamber. So, now, this steam is coming to this to this upper disc, and so this is the in inlet of this steam and this is the outlet of the steam. So, you can see this steam is going out steam is going out steam is going out. So, one as to be very careful, ok, so because this is the temperature is almost this 100 degree centigrade, 100 degree centigrade, ok. So, now, this we have attached two thermometer. So, this is the thermometer, this is the T 2 in upper metal disc and this is the thermometer T 1 that is why it is in the lower metal disc. So, from this two thermometer we will get the temperature of the upper disc and the temperature of the lower disc, ok.

So, first what we have to do? So, we started heating. So, we have to note down basically, we have to note down the temperature of T 2 and T 1. Now, it is the temperature here lower one I can see it is around 59 and this upper one I can see its around I think let me check, yeah, I have to see where it is. Yeah, it is it is close to 70, it is close to a 70 and this one is close to 60, it cost 60. So, you have to note down the temperatures T 2 and T 1 you have to note down the temperatures for see the steady state.

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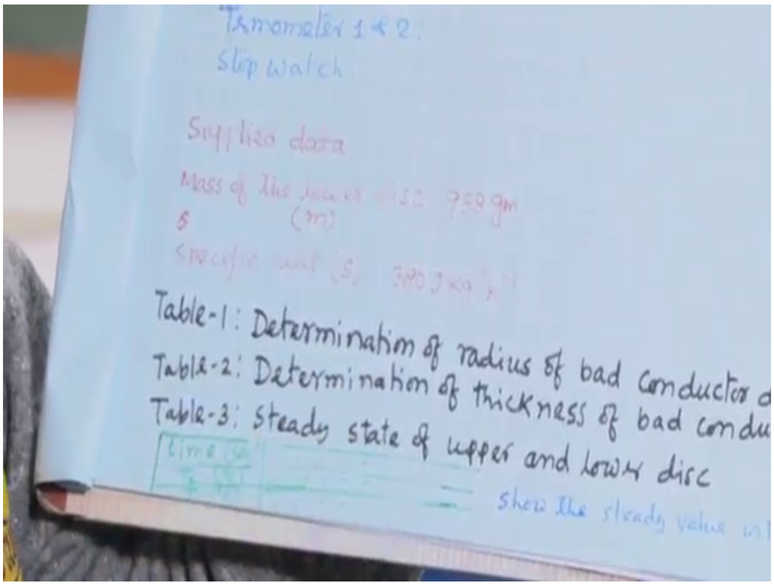

So, this table 3 steady state of the upper and lower disc; so time t and this temperature of thermometer 2 and thermometer 1 in degree centigrade.

So, now if we start to take this temperature; so here time 0, this temperature is T 2 is say 70 and T 1 T 1 is lower one is say 60, ok. So, now, after 30 second I will take again reading. So, whatever the T 2 and T 1 I have to note down then after 60 second, I will take after 90 second after 120 seconds. So, I will take the reading. So, when I will see the temperature of T 2 and T 1 is not changing with time then I will be sure that it is in steady state, with time the temperature of these two are not changing, ok.

So, we have to continue to take reading and we have to show that it has come in steady state, ok. So, generally steady state in this experiment we have taken data. So, these steady states generally it comes; it depends on the atmosphere, it depends of the atmosphere. So, steady state here we have noted down generally it comes, yeah. So, this T 2 around 97 degree centigrade and T 1 is 88 degree centigrade. So, these difference comes around 9 to 10 degree centigrade. Sothis is the, first part of this experiment is to find out the steady state.

Now, we have to take data of T 1 and T 2 as a with time. So, then when it will come in steady states. So, then what we will do? And in the meantime what you can do? In the meantime so we have to measure the, we have to measure the, we have to measure the radius of these of this disc. So, we will we can use this we can use this slide calipers for measuring this. So, you know how to use slide calipers already we have discussed. So, just we have take reading diameter of this and then half of it will be the same.

So, now here generally we do not take this one we just measure we use this slide calipers and measure the, measure the, measure the diameter of this lower disc because the diameter of this rubber disc is same as the diameter of this lower disc. So, generally we measure the diameter of this lower disc. So, we assume that diameter of this disc, rubber disc is same as the diameter of this one, ok or since this diameter is in Q centimeter.

So, you can use also meter scale for measuring this one, we can use also meter scale, for this one. So, it is around 11. I can see around 11 centimeters. So, either you use meter scale or you use the slide calipers for measuring the diameter or radius. So, when you will use this one, so this is slightly may feel difficulties. So, instead of this we will use the this lower disc for measuring the diameter or radius assuming that the diameter of this two that lower disc and this rubber disc is same, ok.

So, then we will measure the thickness, using the screw gauge we will measure the thickness and again you know how to measure, how to use this slide calipers, not slide calipers this is the screw gauge. So, in this screw we will take the; we will take the reading of this or this disc. So, again you have to be careful because you do not we should not press much because this is the rubber. So, we have to take reading of this at least in few places 3 4 reading high reading we have to take and then we have to find out the average, right.

So, using the slide calipers or this screw gauge how to how to measure the length, breadth, thickness, radius. So, that we have discussion already you know. So, we have to do that, we have to do that and this you will write in a table; so, determination of radius of bad conductor disc. So, using the using the using the using the metre scale or slide calipers, so whatever you wish. So, you have to you have to take data for this table 1, table 2, this is the for the data for the thickness of the bad conductor, right.

So, you have to note down then steady state for steady state you have to note down. Also, you have to note down the least count of the instrument, least count screw gauge. So, in this case whatever this least count you should you should see and write. So, it is the screw gauze that we know this is 0.001 centimeter slide calipers 0.0; I think this one 0.002 centimetre, or if we use metre scale then you have to write it is a 1 millimetre, 0.0; so 1 millimetre means 0.1 centimeter, ok.

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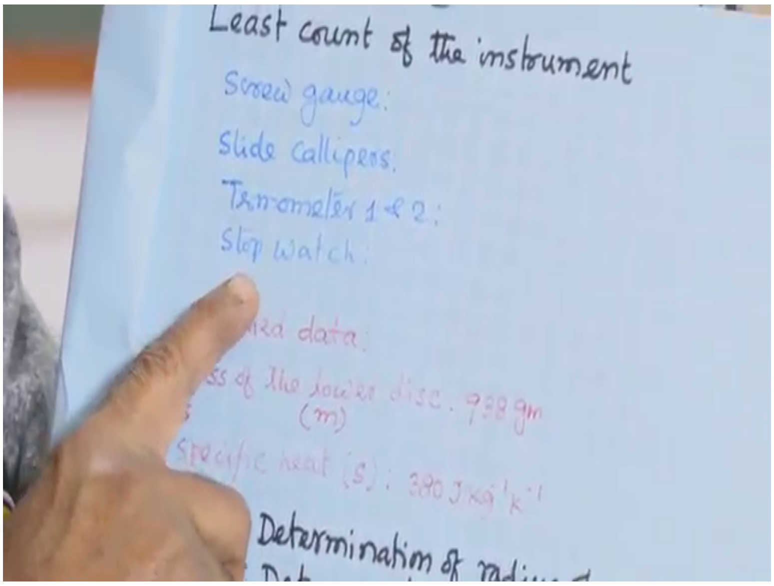

So, you have to note down. And then for thermocouple thermometer what is the, so this least count is 1 degree centigrade 1 degree, ok. Stopwatch, we need stopwatch, so I need one stopwatch. So, for stopwatch also we have to we have to note down. Generally, stopwatch I have shown you earlier also same stopwatch we will use. I think here it is, so this 0.01 on second this is least count of the stopwatch. So, that we have to take and supplied data this mass of the lower disc is are 938, this is the 938 gram, it supplied and specific heat also supplied 380 Joule per kg per degree Kelvin; so these are supplied. So, all these you have to note down, right.

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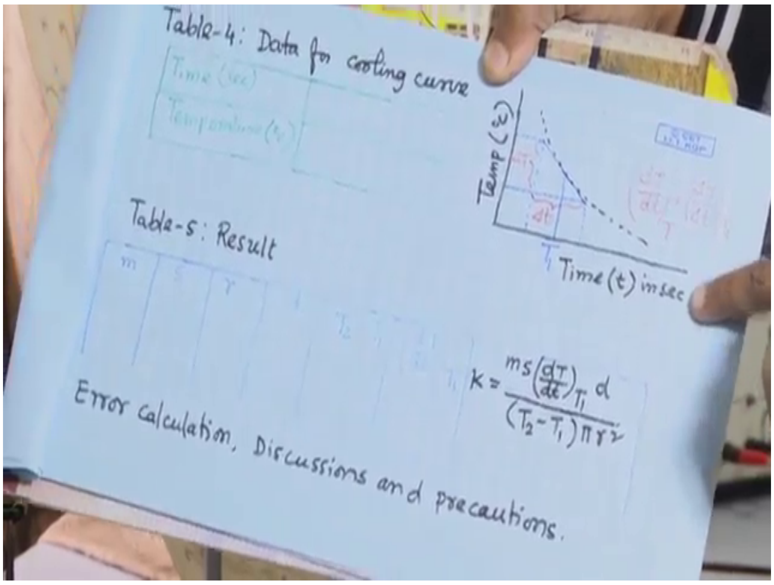

Now, we will go for main part of the experiment that is that is the cooling, data for cooling curve, ok. So, what we will do? As I mentioned that, so we will heat this lower disc, we will heat this lower disc whatever the temperature steady state temperature I think it has come steady state temperature. Now, yes, it is the; I can see it is yeah more or less, it is the 90 degree centigrade. So, this is the steady states of this and that one is the 98, that T 2 is 98 and this T 1 is 90, ok. So, it has come at steady state.

So, now, what we will do? We will just we have to stop heating, we have to stop heating and yes I will take out this first I will take out this thermometers T 2, I will take out this thermometer T 2 and then I have to I will stop this heater. Heater switch is this one I guess. Heater switch is which one? It seems this one. So, I will take out this switch. So, I stop heating this water, ok. Now, I have to, I will take out I will take out first. So, what I will do? I will take out, I have to take out first this rubber one, and then I will just put on it, I will just put on its to increase the temperature by 7, 8 degree or 10 degree, ok. So, its temperature is increasing its temperature, its increasing, yes; so yes.

So, this way when it will be it will be just 97 or 98 or 100, so then I will just take out this one and put back this, ok. So, now, I have to take out this one from here, and yes, I put it here. I have to be careful, I have to be careful, one has to be careful otherwise it will fall down, ok. So, now, what I will do? So, I have to take watch, I have to take watch, I have to reset it. I think you give me that watch, you give me that watch, it has some problem, ok; so, yes; start, stop and this reset, ok.

So, the 0; so here I have to note down, so its yes, it has some temperature yeah, it is it is a decreased I think started it is a 88, ok. So, if temperature is I think I have to start before I should not wait this much. So, I think it is a around yeah it decreased to yes. So, again I have to heat this one and I have to increase these temperature to 97 98, ok. So, because the 90 is the it has steady state temperature. So, I have to heat it is around 100 or close to 100 and then I have to start this watch, ok. So, now, this temperature will decrease with time; so I have to note down.

So, at say, at 0 second I will I will write this as say 98 and then when it will be 97 what is that which time, that I will note done this time, this 97, then 96, 95, 94 and corresponding time I will note down or I will note down the times 0. And then say after 10 second what is the temperature that I will note down, after 20 second, 30 second, 40 second. So, this way I will note down with temperature with time and corresponding the temperature from this thermometer.

And I have to take reading if it is 90, so from 98 to 88, ok. So, 90, not 88, so it is a around 82 or 80 I will take reading. So, then basically we will plot, we will plot the temperature, we will plot the temperature in x axis and sorry time in x axis and time is in x axis and temperature in y axis and then this temperature if you plot it will vary like this, it will vary like this, ok.

Now, temperature in middle be generally around middle this will be the temperature T 1, I have to find out temperature T 1. Now, around this, so here then at temperature T 1 I will draw a tangent, I will draw a tangent. Now, this from tangent basically I will find out the slope, ok. So, capital del T and small del t. So, from this graph I can find out. So, this will be the basically slope; so then it in expression of K. So, this dT capital T by d t small t. So, this at temperature T 1, so this we will get from this cooling curve, ok and other all data we have.

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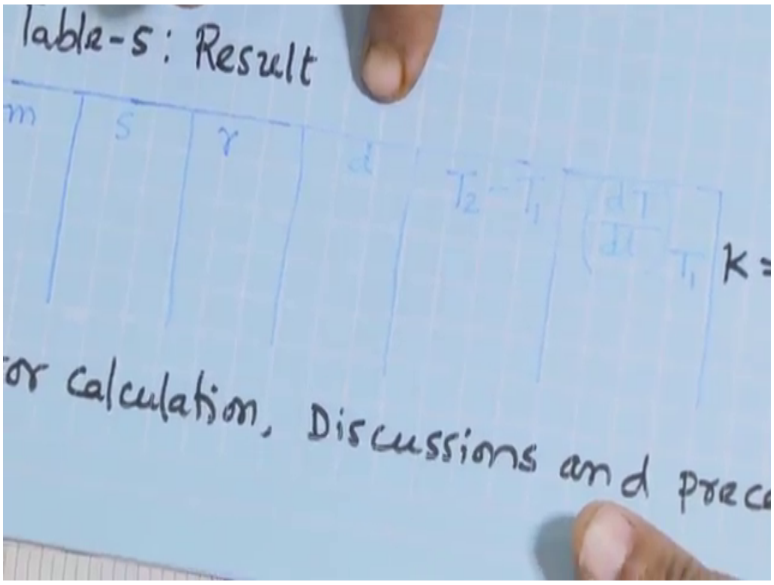

So, in table, another table I will make, so there I will note down all this parameter m, s, r then d, right and then T 2 minus T 1, and then from this graph dT by dt. So, then I will get the value of K, ok. So, this will be our result, ok.

So, after doing all these things we to do another calculation and then, discussion and precautions for this experiment ok. So, I think this a simple experiment, but one has to be very precautions during this experiment because you are dealing with the boiled water, ok, this steam this temperature is almost 100 degree centigrade. So, your hand may burn if your hand may burn, if you just be careless. So, really you have to be precautions and (Refer Time: 40:44) doing the experiment.

And main part of this experiment is basically this cooling curve, others are is take forward it is very simple. But this one is yeah take this curve, this data very carefully and plot and then find out the slope at T 1 and then you can you will get the result. So, you have to report this result with the error calculation ok.

So, thank you. I will stop here.