**Experimental Physics I**

**Prof. Amal Kumar Das**
**Department of Physics**
**Indian Institute of Technology, Kharagpur**

**Lecture – 39**
# Linear Expansion of Metal

In last class, we have demonstrated the measurement of thermal expansion coefficient of a metal rod. See in laboratory, we have seen the setup for this experiment. So, today let me just explain the working formula of this experiment as well as the procedure of the experiment we followed in the laboratory. And how we should take, we should note down the data from data how to plot the graph and from graph what information we get that we will use for calculation of the thermal expansion coefficient and then also I discuss error analysis ok.

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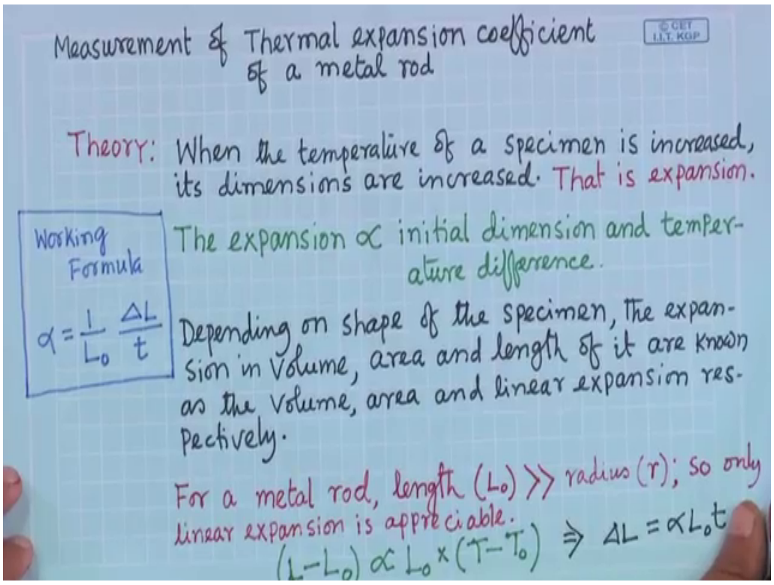


So, measurement of thermal expansion coefficient so, theory of it is a very simple that when the temperature of a specimen is increased; its dimensions are increased that is basically expansion ok. So, this expansion is proportional to initial dimension and temperature difference. So, if you increase the temperature, then its dimension changes. Dimension can be length; it can be width, it can be thickness, it can be radius whatever. So, in all directions basically it will expand. So, depending on shape of the specimen, the expansion in volume area and length of it are known as the volume area and linear expansion respectively right.

So, for a metal rod whatever we take in our laboratory so, its length is very very greater than radius. So, only linear expansion is appreciable. So, there will be expansion in r direction also along the radius. But, but since length is very very greater than radius so, these are negligible, we will neglect it. So, we will so here this change of dimension along the length is the appreciable and that is why taking this specimen in rod form whatever we will measure. So, that is the linear expansion and so, this linear expansion that is basically for digital length is L 0 and at a particular temperature if it is L ok.

So, for this temperature difference T minus T 0 for this temperature difference so, this change of length or this expansion is proportional to original length L 0 into temperature difference. So, that is the del L equal to proportionality constant alpha L 0 T. So, this alpha is nothing, but the thermal expansion coefficient it is not thermal. It is of course, thermal all, but it is a linear type not volume or area type. So, it is a linear expansion coefficient.

So, our working formula is basically alpha equal to 1 by L 0 del L by del t ok. So, this is the working formula. Now, let us think let us think how to design an experiment to measure alpha right. So, when so if you think this way, in you are doing yourself the arrangement and then how you will proceed?

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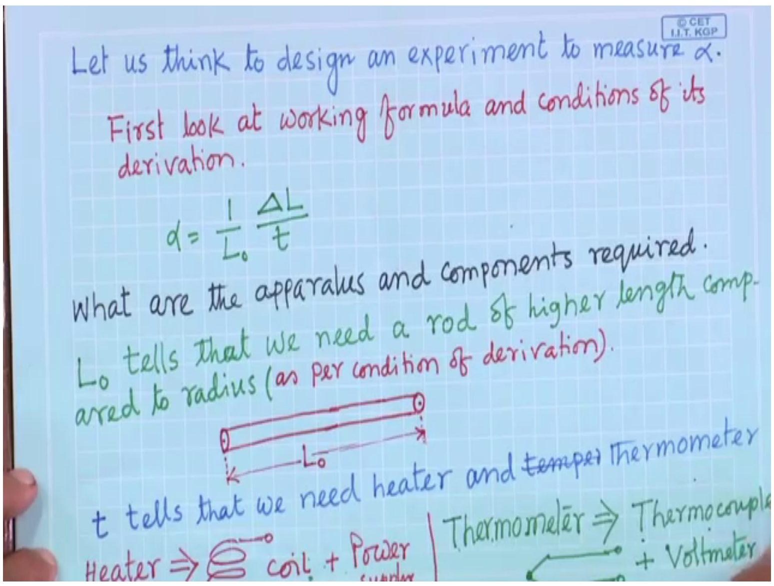

So, first look at the working formula and condition of it of its derivation, working formula is not enough, you should know how it is derived because during derivation there are some conditions applied and in experiment you have to fulfill those conditions. This is very important. So, that is why everybody should know the derivation of the working formula. So, you will know the condition of the derivation and that conditions have to be satisfied in the experiment ok.

So, what are the apparatus and components required for designing this experiment or for this experiment? So, again looking at this working formula, you can tell you can arrange the apparatus and components. So, L 0 tells that we need a rod of higher length compared to radius as per condition of derivation ok. So, if length is higher, it would be better; your error will be less ok. So, that is that was the condition for derivation. So, this one has we need a rod of a particular length L 0.

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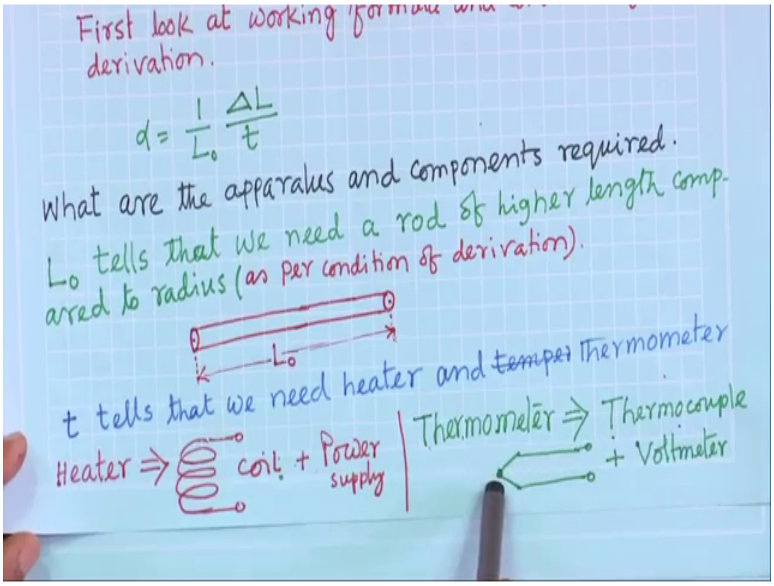


Then t in derivation; t is there in working formula. So, t tells that t means temperature right we have to change the temperature of the sample of the specimen right. So, how to change the temperature? So, we need heater as well as we have to read the temperature of the specimen ok. So, we need thermometer ok. So, heater is nothing, but so, this we can take a coil and we will insert this rod into this coil ok. So, heater is basically is coil and we need power supply ok.

So, from power supply, we will send current to this coils ok. So, then there will be heat and due to heat there will be change of temperatures of the specimen inserted into this coil ok. And then we need thermometer as we have to read the temperature at the specimen region. So, we need thermometer. Thermometer here will say we will take thermo couple, different kinds of thermometers are there. So, thermocouple is one of the many commonly used thermometer.

So, thermocouple so, basically two dissimilar metals have a junction. So, the junction have to be placed near the sample near the sample and then there will be thermo emf voltage so that we have to read these voltage. So, we need voltmeter and basically then this should be calibrated voltage versus temperature this should be calibrated. So, these are from basic one can think this way, but things are available with commercially. So, you have to collect these things, this thermocouple, thermometer so that thermocouple based thermometer. So, if you buy commercially so, this data arrangement this thermocouple which will be placed to the sample place and the we have to; so, there will be voltmeter is which is calibrated with the temperature.

So, basically you will not read the voltage, but directly we read the temperature because that is why this as a whole the set up for measuring temperature is this unit last is another. We tell generally it is a basically as a whole we can tell thermometer. So, it is a two components: one is this thermocouple and another is this meter ok. So, this meter will give you the reading. So, how it is giving the reading to understand that one? So, what are the components is there? So, how company made that one? So, that we should know better than even any other people. So, this we need the temperature measurement arrangement and heating arrangement ok. So, this detail is there, we need heater and thermometer.

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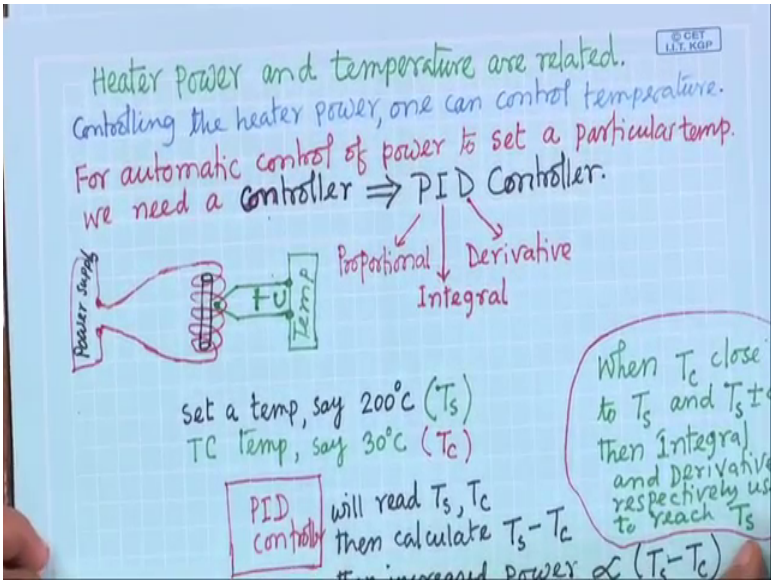


So, then basically heater, let me tell slightly more about this temperature measurement and this heater power. Heater so we have heaters so and then power supply, we are giving power to the heater and then temperature is changed at the sample place ok. That temperature is, we are reading this temperature from using the thermocouple, thermometer and so this power heater and this temperature related. If we increase the powers a temperature will increase the relation is not is not proportional initially may be proportional, then its it may be non-linear ok, but they have a relation ok.

So, controlling the heater power one can control temperature. So, it is possible to control automatic control. So, for automatic control of power to set a particular temperature, we need a controller. So, manually you can control, but instead of manual control so automatic control is possible. So, for that so that we tell this a controller and this controller generally it is in market the commercial are that is called PID controller ok.

So, because this controller have some arrangement, what is the arrangement it should have? So, say if I set a temperature, I want to get 200 degree centigrade. So, this is a set temperature Ts and thermocouple temperature at the beginning say it is 30 degree centigrade, it is a 200 degree centigrade Ts and this initial beginning temperature or temperature thermocouple temperature basically that is the we are telling this Tc ok.

So, this controller PID controller will read Ts whatever we have set and this then Tc from thermocouple, it will detect it will read this Tc, then it will calculate.

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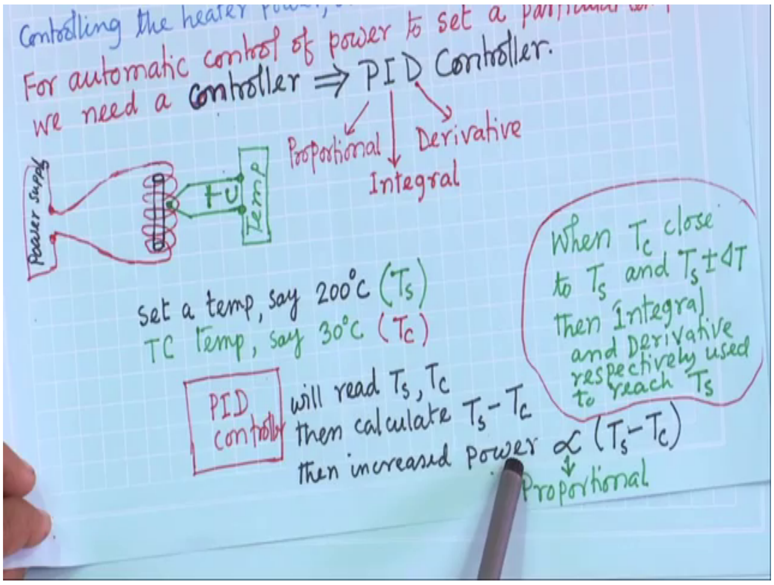


It is a basically controller, it can calculate. So, electronic circuits are there ok. So, it will calculate difference between these Ts and Tc, then increase power proportionally to the difference of this temperature. Initially it will increase power which is proportional to the difference of temperature because initially there will be big temperature difference. So, it increase proportionally. So, that is all this proportional PID P that proportional that is coming.

And then when T c this thermocouple temperature, all the time it is reading all the time this controller is reading the T c and taking difference and changing the power. So, this is when this T c close to Ts and it is T s plus minus del T; del T is very small, then it will use basically it will use integral and derivative respectively to reach Ts. So, I am not telling data. So, this is the different circuit, you can use for integration, derivation, difference, addition, calculator right. It can do it.

So, then when it is closed so, it use integration and derivative method to reach the temperature T. So, that is why it is called PID controller. So, we will use we will use this PID controller so, then you can just set temperature and then automatically a, it will change the temperature and reach to the a set temperature within few minutes probably. It depends on the power of the controller and range of the temperature.

So, then for so from working formula for L 0, we need metal rod; then for T we need the heater, we need thermocouple, thermometer, we need some controller, PID controller ok.

So, now, in laboratory you have seen all this just we have used a single box type instrument. So, in that instrument all these things put there. So, power to the heater. So, power is there and then just yeah so this unit as a whole, this unit basically it is connected to the heater. As well as they are for thermocouple, this arrangement is also there and also this controller also there. So, as a whole this one unit have all these things for changing the temperature of the specimen. So, all arrangement is integrated in a single unit. So, this so commercial it is available or do you have to tell company. So, I need this kind of this kind of function. So, they will build for you and give you ok.

So, you do not need to do everything, but you should know what you want and you should know where you can get ok. So, you need to contact to proper company and they can do your, they can do customer designed power supply or controller or whatever.

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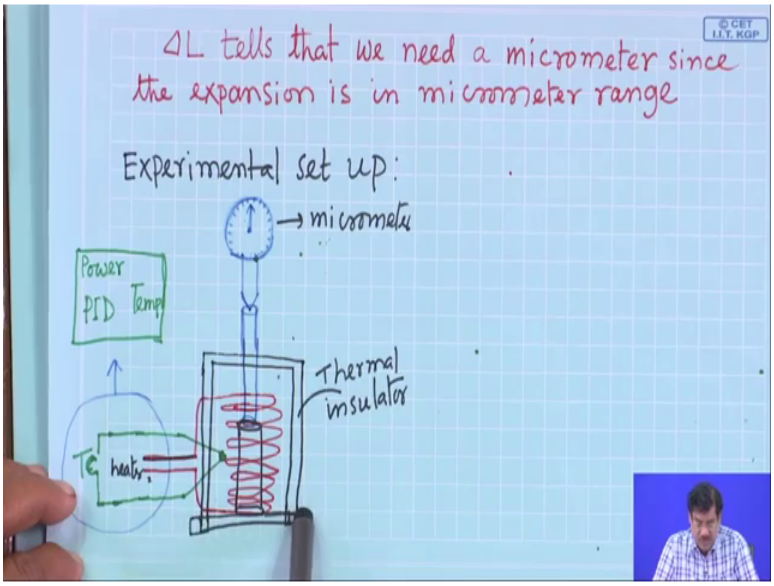


So, then next another parameter is there is no working formula that is del L that is del L. So, del L tells that we did not show this expansion and we need to measure this expansion, we need a micrometer since this expansion using a micrometer range. So, then we tell this so micrometer which will read the expansion in the range of micrometer ok.

So, these so these also commercially available only you have to collect it this micrometer also it has different range. So, you have to collect proper range of the micro meter. So, now, all this apparatus comparison it and then you have to assemble them. So, there that will be your experimental setup.

So, I have a rod this rod ok; expansion of this rod, I want to measure. So, this vertically put on a platform and then there is a this coil around this around this rod and then thermocouple one end of the thermocouple have to be there ok. Because this I am showing because in laboratory, you had seen this we cannot see this rod and this thermocouple, this part we cannot see because it is sealed in thermal insulator. It is sealed in the thermal insulator so, that is why we cannot see, but inside what is there. So, nothing, but this arrangement is there ok.

And then this thermocouple and this heater that is connected to this that one unit where basically this power temperature and PID this all are integrated ok. So, you have to connect there. So, this will control the temperature of this of this place and tell me the temperature also and now we have put micrometer on top of this rod, but not directly because this is the hot one and inside the coil. So, we use another rod. It is a same; it is made of quartz glass type basically thus it can bear higher high temperature ok. So, a piece of glass sort of similar dimension will be taken and just put between on top of this.

So, when it will expand so, this is the base. So, it cannot so, other end is free. So, expand it will go up, then this quartz rod also go up and it will push this screw of this micrometer. When it is put this screw so, this there will be change here and you can see the reading and that reading you have to note down basically ok. So, this is the experiment setup and you have seen this setup in our laboratory ok. So, then you start taking data.

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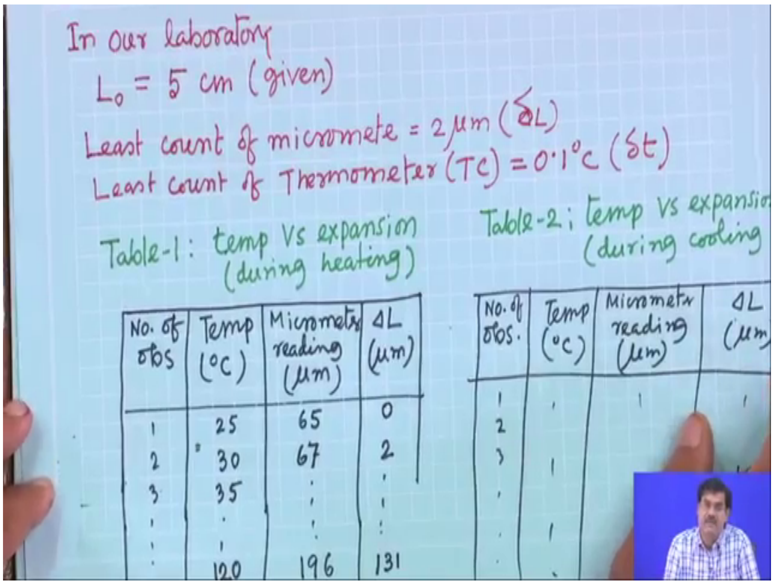


So, in laboratory in our laboratory so, there is this rod again it is inside, we cannot take out. So, this is L 0 is 5 centimeter in our laboratory. It is a given, it is a taking higher length is better, but it is taking too high is difficult to get the uniform temperature around you know. So, one have to be optimized and least count of the micrometer you have to note down 2 micrometer in our case. List down the, you have to note down because this for other experience I have described all these things. So, I will not tell you in detail just I am showing. So, least count of thermometer is 0.1 degree centigrade.

Now, this just to 2 table we will make. One is to both of temperature versus expansion, but one is during heating and another is during cooling ok. So, from the room temperature is at 25 degree centigrade micrometer reading. Note down this say in our case, it was 65 micrometer, then I will change the temperature. So, what we do? We set the temperature say 200 degree centigrade and then its temperature is increased it takes time. So, at every 5 degree difference, I will note down the; I will note down the micrometer reading ok, then del L will be basically just you have to subtract this 64 from all data's and then corresponding this delta L expansion for this at different temperature you will get you will get. So, that is basically delta L during heating and this is the delta L during cooling ok.

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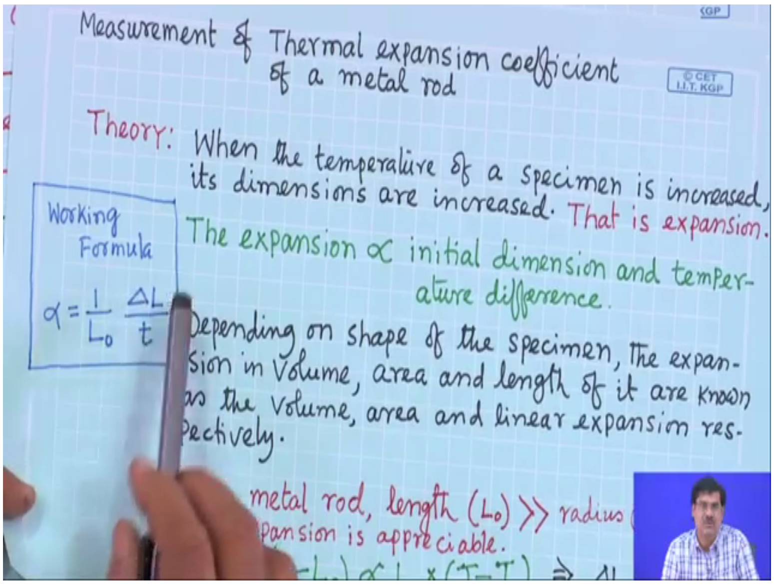


Now, from this working formula, you can see this alpha equal to 1 by L 0 del L by t. So, I can plot graph del L versus t and then from the graph the slope will give you this del L by t. So, I will find out the slope ok.

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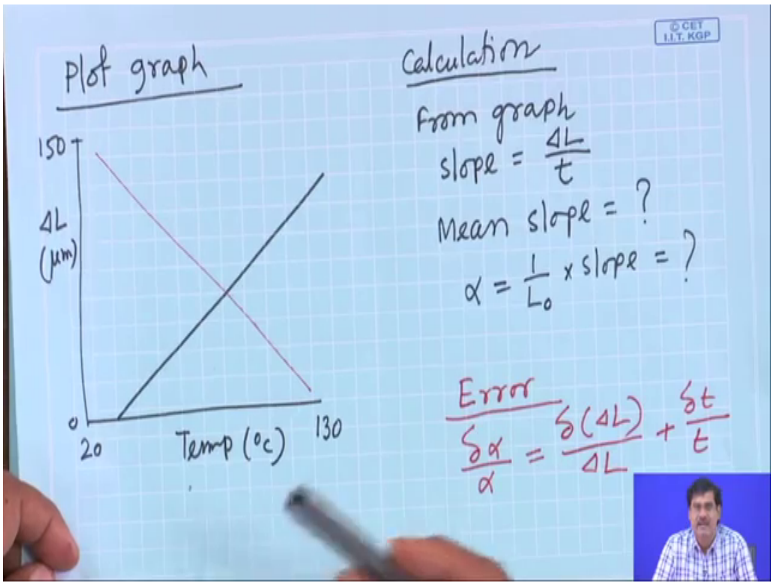


So, let us plot graph you say in same graph, we can plot all this during heating and this is during cooling or you can use separate graph and then you just take find out the slope of this two graph. Find out the slope of this two graph and then take average of this two slope; take average of these two slope mean slope, find out the mean slope and then calculate alpha L 0 is 5 centimeter slope, you got from this graph and then you will get the result ok. And then error calculation is very simple.

So, the basically del alpha by alpha equal to del of delta L by delta L. Now delta of del L by del L plus this is the one error, this we are measuring at this measuring this temperature. So, delta t by t ok; delta t is 0.1 del L delta of del L that is basically 2 micrometer 2 ok. So, and del L so here you can just take one point, you will get some this temperature for that temperature what is the del L you will find out for a particular temperature and corresponding del L, you can take for calculating the of error.

So, just put value of del L and t from this one point of on the graph and calculate del alpha ok. So, then how to write result that I discussed many times just you will find the data and then you should discuss there will be discussion and there will be peak version of the experiment ok. So, all those things I have discussed I will discuss more for other experience also. So, this is a very simple expression. So, today mainly I try to tell you just you are going to the laboratory and blindly you are doing experiment that you should not do. You can think yourself ok; if you know the derivation of the working formula, if you the experiment then you know the experimental condition, what condition we need for experiment, then you can think yourself what are the apparatus I need to measure those parameters which are in working formula ok.

So, you have to collect one after another and then you have to assemble and then you proceed. So, this way just should think and when we will go to laboratory for doing experiments so you search in the setup where those things are. You should ask your teacher or your this lab technician where are those things. So, you are measuring the thermal expansion of a rod, but you do not know where is the rod everything is ready just you are just rotating the knob and taking data.

So, that is not good. First you should search where is the rod, then I have to measure temperature this. So, there must be thermometer ok. So, for thermometer, what is the arrangement there then ok? So, to change the temperature, you need some heater kind of things or some arrangement. Here we are using heater, heater can be in different form itself.

So, if you initially prepared so means if you think how to design the experiment so, then you will not right now you will not design, but you are going to perform the experiment.

So, when you will go to lab, you first just try to find out where are those things, whatever you thought or you can find out, you can think alternative way to do it ok. So, what can be other alternative for measuring temperature, for heating the sample, for measuring the expansion ok? So, other alternative also ok; so, those things you can write in discussion ok.

So, discussion just generally students just write few common points but it is not, discussion is not for that purpose you know it has, you can this is the place where you can put your own thought ok. So, how to improve the experiment, what can be the alternative way, what problem you face during the experiment also in precaution, you can tell different where one has to be cautious ok. So, that can mention. So, if you proceed this go this way so if you well prepare and go to the lab, then only you will enjoy the experiment ok. So, let me stop here thank you for your attention.