Experimental Physics I
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Lecture - 10
Basic analysis

So, today I will discuss about the Basic analysis in the laboratory. So, when you will go to laboratory for doing some experiment; so, we need to be familiar with some tools and apparatus; that I have discussed; now you are going to do experiment.

So, there is a setup of the experimental setup. Now, what you want to measure basically when we are going when we are telling that we are going to do experiment means you have aim to find out some parameter. It may be verification of ohms law; it may be this to find out the Young modulus of a rectangular bar or of a material in form of rectangular bar right.

So, it may be this find out the density of water, find out the density of the material. So, whatever; so we are going to do experiment and in that experiment only you will not measure only one parameter you may need to measure few parameters the your this those parameters basically is related with the parameter; which you want to report what you want to measure us as for example, as I told this Young modulus.

So, Young modulus that is related with the length of the bar, thickness of the bar width of the bar it. So, then it depends on the deflection of the bar when you are putting weight on the bar. So; that means, when you are going to measure Young modulus; Young modulus depends on variables few parameters and you have to measure each parameter and then you can calculate Young modulus using those parameters right.

So, today I will discuss that now you are going to do experiment now how to start the experiment that ok. So, first thing; so you have to take data. So, there are some there are you see many experiments many parameters involves and you will measure them and collect the data. So now, how to collect the data what is the procedure of collection of the data?

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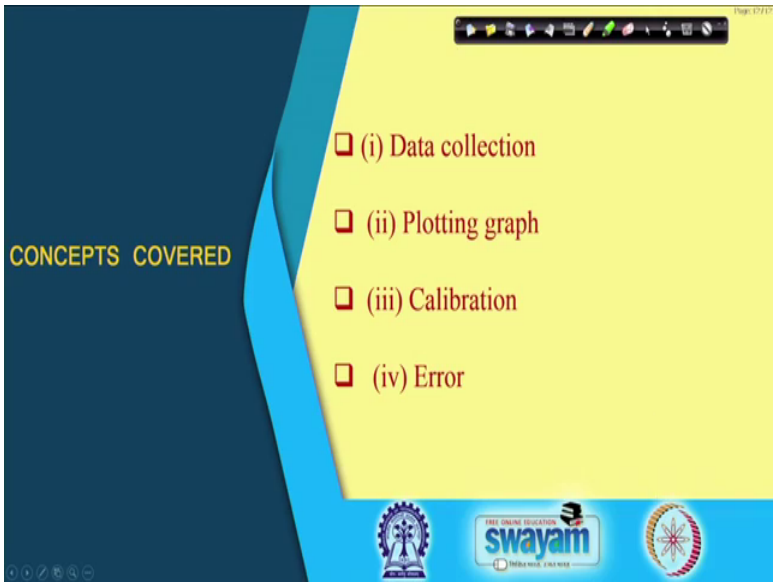

So, there are some I will discuss there are some; some important facts when you are going to do experiment. So, this I am telling this basic analysis. So, this first thing is that this data collection. So, I will discuss in general; so how to collect data and where you have to be very careful, where you can do some mistake. So, this type of discussion we will we will do in this case.

Second after collecting data in most of the cases generally we need to plot data we need to plot data. So, we use graph paper nowadays you can plot in computer there are many software, but in software also they; so, whatever manually we are doing. So, the same thing is done writing program ok. So, there is basically software someone has done for you and you will use this software to plot data.

But manually you should know how to plot it; you use computer software you have to use there is no problem, but you should know the what is the in which way you should plot data. So, manually if you know; so that you can implement you can apply in computer also ok. Because, there are some important facts that I will discuss and then other important things is that calibration.

So, when you are going to lab and measuring something; so, you may not get directly that parameter ok; you can get that parameter in terms of some other parameter, but these two parameters have relation. So, how they are related they are related linearly or there are they are non-linear they have non-linear relation.

So, you have to basically do calibration as for example, if you want to vary the magnetic field and with magnetic field some parameter say resistance of a material. So, how resistance varies with magnetic field? So, what you will do? So, you will put the material in magnetic field. So, magnetic fields means there is say electromagnet which can this magnetic field you can vary.

So, in electromagnet between two 4 pieces you will put the sample. Now, electrical connections you have taken right i v measurement mainly you have to do at different magnetic field. So, now, you are varying magnetic field in electromagnet; how you are varying? Basically, you are changing current in the coil and then due to this change of current magnetic field between 4 pieces will change right.

So, in your a meter ok; there basically you are changing current and that current how much current you are changing that you can see the reading you can take. But actually your sample is seeing the magnetic field it will not see the current and that is not I need also. So, a different magnetic field I want to measure the resistance I want to measure the yes resistance. So, it is basically by i v measure, but you have to do.

So, you are taking reading or you are varying the current and that reading you can get this from meter ok, but your sample is seeing the magnetic field. So, now, basically this magnetic field is coming due to the change of current. Now, this magnetic field and current they are they have relation. So, for 1 ampere current what is the magnetic field? For 2 ampere current what is the magnetic field? For 3 ampere current what is the magnetic field right?

So, when you are doing experiment you are not getting reading of the magnetic field directly right; you are getting reading directly that is the current. So, now, that is you need calibration this is i versus h. So, that calibration you have to do first. So, then you know this for this current what will be the magnetic field then I can from current reading itself I can convert to the magnetic field right.

So, for calibration you have to use some another instrument which will measure the magnetic field between the 4 pieces. So, that is the basically hall proof kind of things. So, I will put this proof near the sample position. So, this time I do not need sample just I will take out sample; I will proof put the proof there. Now, I will vary the current and then this proof this is called gauss meter. So, it will give me a reading of magnetic fields.

So, I will vary the current and that is my variable and result I am getting the magnetic field that reading; so, this a i versus h is that reading I will take ok.

And plotting the graph I can find out the average is called basically average I think if it is linear this fine; if it is linear then fine. So, you will get plot this linear curve. So, from there curve basically there is you will find out the gradient. So, that gradient will be the basically calibration factors ok.

So, that; so, this is the calibration and another example I can give you this say this you are we are going to measure temperature using thermocouple. So, when you are using thermocouple; so actually you are measuring the voltage. So, when temperature is change then voltage is change that signal basically you measure your meter will give this with the change of voltage due to the change of temperature.

Now, change of voltage and the change of temperatures they have relation. So, I am getting actually this voltage not temperature, but temperature have relation with this voltage. Now, I have to scaled it I have to calibrate it means this for change of 10 degree temperature what is the change of the voltage right. So, I have to take few readings and then I have to plot it and find out if linear.

So, fine if non-linear also region wise or we have to fit with some polynomial and find out this constant say temperature t equal to say a of a V plus V b square. So, this kind of polynomial fits this data and from this fitting you will get this constant value a and b if you know the a and b for that thermocouple. So, now for any voltage you can calculate the temperature. So, that is the calibration temperature versus voltage. So, this very important this factor in the laboratory this calibration of the instrument and then error analysis.

So, whenever you will do measurement you are measuring some parameter using some instruments; so, you have to your measurement cannot be very perfect. So, there will be error and this error this is systematic error, random error etcetera. There are not of analysis, but I will not discuss in details; but whatever the main error comes in laboratory and we calculate to tell this percentage error in our measurement ok.

So, see in simple way I will discuss that one. So, if you importance of this error analysis that; you will know this what are the sources of error. Then you will be careful in

measurement of this of the parameters to minimize the error you cannot nullify the error, but you can minimize the error. So, how we can minimize the error? So, that I will discuss here. So, let me tell you about the data collection procedure. So, when you are going to lab you have to basically collect data right.

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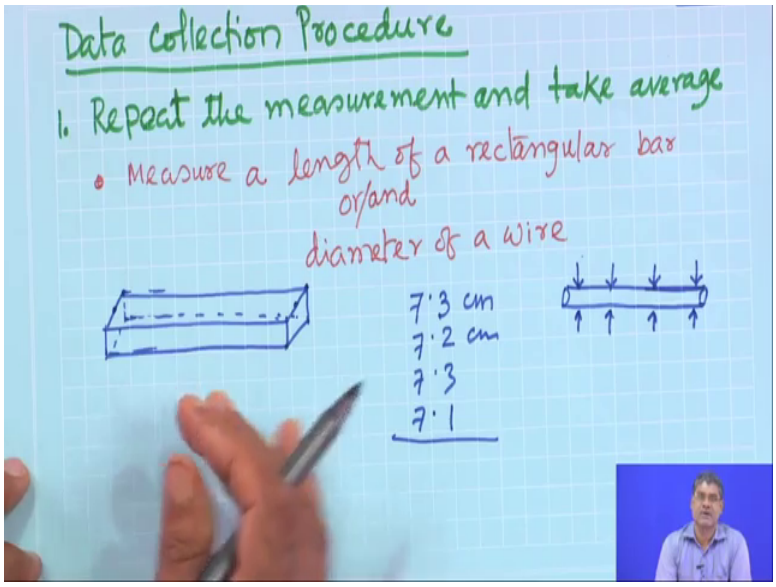

So, if I; so, let me discuss this data collection procedure data collection procedure ok. So, first thing is that I already I have told you and many times I will tell you because we will do we will demonstrate many experiments. And I will repeat these things because these things are important case to case there are some variation, but today I will discuss in general; whatever the experiment you will going to perform. So, we have to take care of this whatever I am discussing now.

So, one thing is that first thing is that repeat the measurement and take average repeat the measurement; repeat the measurement and take average. So, that example already I have discussed; so, what is the importance of repetition of the measurement ok? So, that already I think I have mention; so let me repeat it. So, it is in general it is not for particular measurement.

So, say suppose you are going to measure a length of a rectangular bar or a diameter of a wire ok. So, the semic example I am taking that is whatever I discussed earlier. So, basically when you are going to measure a length; measure a length of a rectangular bar

right rectangular bar or and diameter, you are going to measure a diameter of a wire; this is just one example ok.

So, there you should repeat the measurement and take the average means when you are going to measure the diameter of a diameter of a wire or length of rectangular bar. So, rectangular bar means this it is this kind of rectangular bar you are taking say rectangular bar; so, you are going to measure the length.

So, just you take meter scale or slide calipers or screw gauge depending on the length, but here I think length is say higher so you take meter scale. So, then you are measuring the length; so just take one end of the scale here and another scale this is other end. So, we have to see this end where it is in which reading it is it will meet So, that I will take the reading right.

Now, so say this is 7.3 centimeter right; so measurement one sees would be sufficient, but logic is of repetition of the measurement that You see you have taken on this edge on this surface measurement. if you check the other surface you know that, it may not be perfectly this these two face these two face may not be perfectly parallel. If it is perfectly parallel; so then measuring ones it is the it is sufficient, but it may not be the case in reality. So, there may be slight change of this length on different face ok.

So, that you have to take a reality in reality; so there is the you see this theory is one and that when you are going to the going to do the experiment. So, that is basically different from this thus the theory concept in the sense that this in theory is whatever parameter; we are taking that is a we are considering this is the accurate parameter ok; we will put accurate parameter. But in case of measurement it is so when I will tell rectangular bar; so it is the in theory it is a perfect it is so, but in reality when some on have fabricated that rectangular bar right.

So, when fabricating this rectangular bar; so it may not be that perfect perfection is not 100 percent perfection. So, there may be some difference from the ideal case. So considering this reality you have to measure you have to minimize this whatever the imperfection is there in fabrication of the rectangular bar; so, that how we can minimize just repeating the measurement.

So, that is why we tell this just take the measurement along the edge; there are 4 edge this is one edge this is another edge, this is third edge and here this is the another forth edge forth edge is there ok. So, along the four edge just you measure and take the average if any imperfection in the fabrication of this rectangular bar that you are taking here because this is because any imperfection that is going to affect your result.

So, this imperfection; so to minimize this error in measurement. So, that we are repeating the; measurement and taking average so, that this we can minimize this error due to the imperfection of this of this bar ok. So, then you are taking reading of this along the different edge. So, say 7.2, 7.3; so this is a 7.1 you are getting; so, then you are taking average and write. And this I have discussed when I discussed this significant digit. So, so that context was different, but here context is why we need to repeat the measurement and take the average ok.

Similarly, this diameter of a wire; diameter of a wire I think when you are going to measure the diameter of the wire. So, this you see wire when we tell wire; so in ideal case wire it has a uniform cross section along the all along the length right. So, that is the ideal case and in theory we considered that one, but when you are going to do experiment.

So, in theory what you are considering exactly I may not fulfill this one, but I should take action in such a way so, I can go towards that requirement; so, that towards that ideal case. So, here we assume that ok, so someone again this is a fabricated this wire right. So, they tried to make it uniform cross section, but it may not the case in reality. So, considering that one only I can minimize; I can minimize this defect or I can minimize the error in my measurement just repeating this is the measurement taking the average.

So, I assume that it may not be perfectly uniform all the along the length; so, I will take few reading. So, I will take at this near this edge I will take near the other edge and I will take say depending on the length; I will take in between this two more result or one result or three result depending on the length of the wire and then.

So, using some I think in this case is you will use screw gauge So, again I will take 3 4 5 reading depending on length. So, it is not fix that repeat 3 times, repeat 4 times, repeat 2 times; so we have to decide. So, there should be logic behind it; so if length are higher.

So, I should take at more points. So and here in case of these are; so there are 4 edges it is distributed this 4 edge. So, if I take along 4 times; so, that is a good average.

So, you will repeat the measurement 2 times or 3 times or 5 times that you have to decide there should be logic behind it is not fixed that for all measurement just take 3 reading, 3 times reading and then avenge. So, that is why in most cases two readings are doing so, but this is not the way just you have to take decision and that decision behind this decision there should be logic here why I am taking 4 in case of bar.

So, that logic I told you in case of wire why I am taking 3 times or 4 times or 5 times that is a depending on the length of the wire. So, that also all though you are measuring diameter, but fact depends on the length of the wire ok. So, that way this is the importance of the repetition of the measurement and taking the average.

Then another example also I can tell you say measure the time period of a pendulum ok. So, time period of a pendulum; so second example I can tell the measure a time period; of a time period of a pendulum right; measure a time period of a pendulum. And in this case this pendulum is basically just one mass bob ok.

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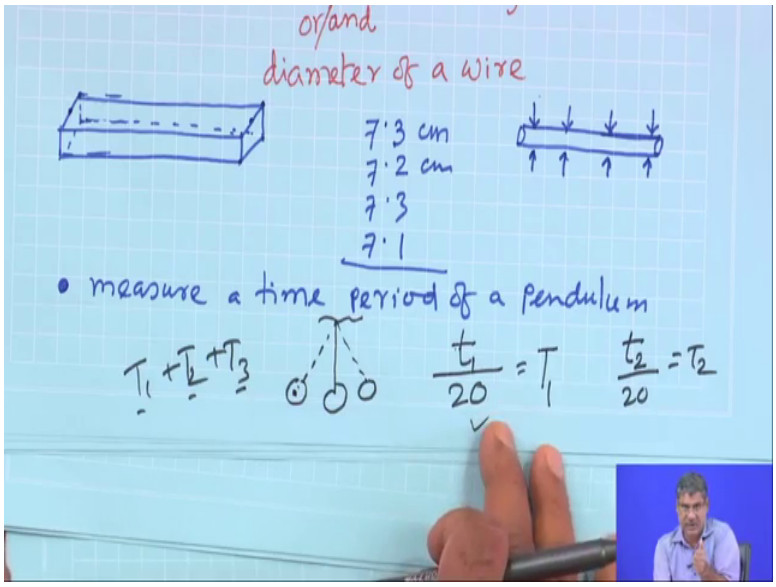

So, it is so it is hand with thread; now just it is oscillating if you disturbed once then it will oscillate it will oscillate. So, time period is the time required to complete on

oscillation starting from here going other side and coming back there is a time period I. So, I want to measure the time to period of the of this pendulum.

So, now so you can say that just once just I will start this one and just I will use my watch. So, starting from here it is going to the other end and then coming back. So, what is the time just directly I measure ok, but we tell no you repeat the measurement in this case repetition is slightly different. So, we tell that; so you are not directly measuring the time period repetition it meaning maybe that I have measure time. So, for one oscillation what is the time that I noted down this is the first reading. Second reading again I am taking another, reading again I am taking another reading, again I am taking another reading.

So, this can be the repetition of the measurement, but in this case if we follow other way means since this when it is oscillating it is amplitudly decrease with time you know this because there is a slight damping here damping. So, but time period it is amplitude will change reduce, but time period remains constant this is the fact.

So, what we can do? I can take I will start my watch when it is here from here it starts to go other side ok. Then I will count number of oscillation complete oscillation 3, 4, 5, 10, 15, 20. So, for 20 complete oscillation what is the time? I will stop the watch and I will find out the time ok. So, now my average time period is what this time I total time divided by 20. So, that you will give you time period ok.

So, this way actually we are repeating the measurement instead of individual measurement repetition of this measurement; T 1 plus T 2 plus T 3 these are all time period now taking average; so that way we are not doing we are doing this way. So, another and again these things you can repeat this is say T 1 then another repetition you can do. So, this T 1, another repetition you can do again 20 oscillation here you have taken 20 oscillation you have taken; so, this is the T 2.

So, then 2 3 times you can do and then take average of T 1 plus T 2 divided by 2 ok. So, here you see this way just one oscillation I am measuring because this why? This is better that we have to know it is better. Because for this case even measuring short time you know you are using your watch and measuring time it is a very short time. Say it is 5 second this oscillation this time period is 5 second or 10 second even. So, if it is 10

second; so now error from where it will come? Error will there starting this synchronizing with this starting and the stopping or completing one oscillation.

So, starting and stopping; so it should perfectly synchronize with your oscillation and this synchronize. So, that is the so there will be error in this it is starting and stopping and this error will come over this time to a 10 second; if you measure this way. If you measure this way this starting and stopping the watch that error will come over this t 1 small t 1 ok; the time for these 2 into oscillation. So, difference between these and that here you are the starting and stopping that synchronizing that error that will be over this T 1 which is more or less 20 times higher than this capital T 1.

So, same error will be distributed over this; over this higher time whereas, in this case it will be distributed with it is lower time which is 20 times less than the other one. So, in which way we will measure? This way or that way? So; obviously, that way we will measure and why this is better than that one that we have to understand. So, again this not only repetition of the measurement how to repeat that also important that I try to tell from this example.

So, next one is basically this when you are measuring parameter. So, you have to choose; you have to choose appropriate steps of variable X variable and note down the measure actually reading you a note it down of Y variable.

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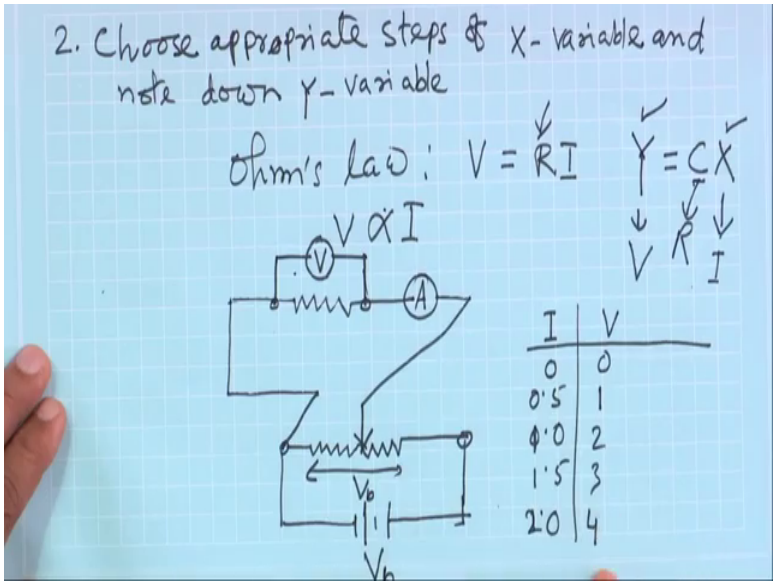

So, 2nd important thing is that choose appropriate step appropriate step steps of X variable and note down note down Y variable ok. So, what does it mean? What; why it is important that say ohms law example take Ohm's law verification ohms law. So, that is nothing, but there is a V equal to RI. So, their relation you have to verify or say you have to measure this constant. So, Ohm's law basically V is proportional to I or I is proportional to V so, then V equal to RI; so this is the proportionality constant.

So, it is like a Y equal to C X you know this relation is Y equal to C X. So, C is constant X is variable independent variable and Y is dependent variable right. So, in this case in this example that Y is basically V and X is basically I right and then this proportional this constant C it is basically R right. So, for this measurement; so you have circuit that there is a resistance and then you have put ammeter right here and then you have voltage divider basically we have to vary the voltage. So, this is a battery and so, this voltage drop across this one.

Now, from here I am taking voltage. So, that is the; so this I will connect here this I will connect here and this I will connect with some jockey ball is called jockey; so you can vary the position on this. So, total voltage of the whatever voltage here; so this total voltage is this one drop voltage drop across this one. So this basically whatever the current will flow through it and then whatever the resistance; so that is the; now if we divide this resistance in different parts means you are varying this one.

So, this voltage drop across this portion; so that will be the voltage across this resistance. So and now you are noting down basically you have added voltmeter here. So, in this circuit what is the current ok; that current you are varying these voltages if this volt and this volt is not same it is different.

So, let me here write voltage of battery V b voltage of battery it is a equivalent. Now, here you are measuring for different current you are measuring different what is the voltage drop across this resistance. So, basically so you are noting down you are noting down your. So, what is the current; what is the current and then for this current what is the voltage drop across this resistance that you are noting down.

So, here what I choose appropriate step of X variable means here in which step you will change? Continuously you are not changing the current and noting down the voltage; so,

generally we change it step by step. So, whether I will choose. So, some 0 voltage 0 current initially and for that; obviously, it will be 0 voltage should be ok.

And then now next step whether you will choose this variation in milli ampere or ampere or micro ampere etcetera ok; if say choose any you need say ampere. So, now next step you will change this 0.5; ampere then 0 then 1.0, then 1.5, then 1.20; so that way generally will vary. And this step I have taken 0 5 ampere step ok; so I am increasing this I value in step of 0 5 and that throughout this measurement I have maintain that step ok.

So, that is the way generally we do we do not bother about the V what will be the value of V. But we generally take equal step; equal step in X variable and we note down corresponding voltage say 1 volt, this 2 volt, 3 volt 4 volt; this is a we note down whatever that we need because, I do not have control over it I have control over it. So, I am varying this one and noting down this one.

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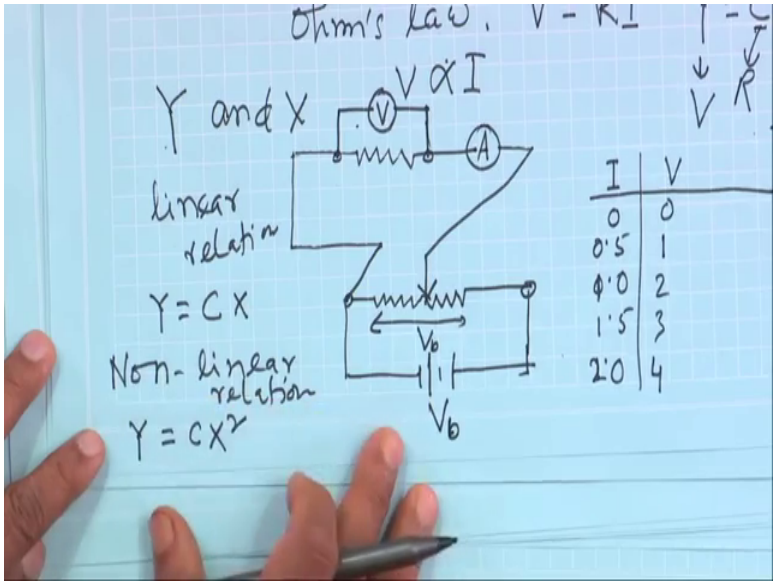

So, this is the way we do, but this is appropriate for the case where Y and X they have linear relation; they have linear relation ok. In case of non-linear relation; this is not good way to choose the step.

Like here in this case linear relation means Y equal to C X ok; there the this relation is linear relation. For non-linear relation; non-linear relation; so if say Y equal to C X

square; X cube or C X square plus V X plus d ok. So, this X and Y this relation is non-linear relation.

So, in case of non-linear relation this way; so, we have to be very careful to choose the step that is why I want to mean you are choose appropriate step of X variable and note down Y variable. So, I will continue in the next class this non-linear relation when this two parameters are related not linearly; it is a non-linear relation then how to choose the step very important for taking data. So, I will continue in next class.

Thank you very much.