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

Lecture – 11
Basic Analysis (Contd.)

In last class we are discussing about the data collection procedure right. So, we will continue that discussion. So, I was telling that this that procedures 1 case was that, repeat the measurement and take the average that we have discussed, and then second point we are discussing that choose appropriate steps of X variable and note down Y variable right. So, in that case I told that this how to choose the step of s variable that will depend on the relation between the Y and X right.

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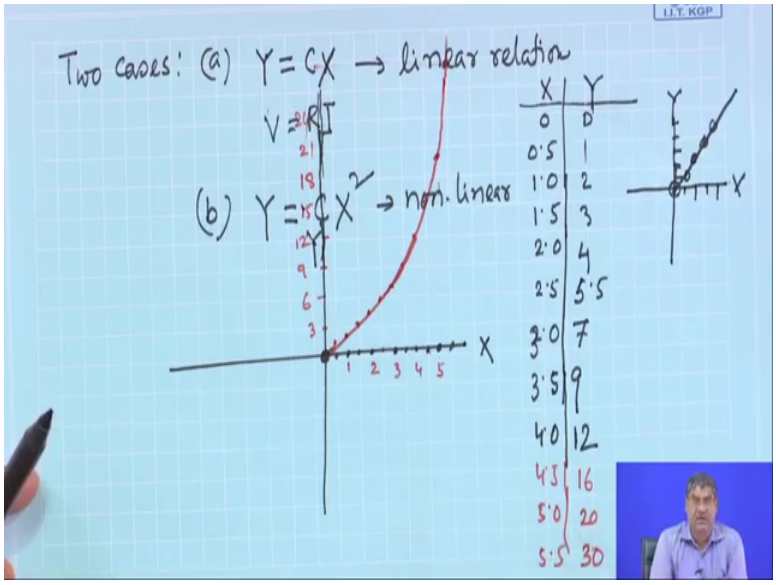

So, cases 1 is 2 cases basically, 1 is Y on X if they are their relation is linear case CX. So, if relation is linear relation ok. So, then we generally the way we take the reading in laboratory that is fine. That means, just we take equal step in X we just take equal step in X right say 0, 0.5, 1.0, 1.5, 2.0 and then corresponding dependent variable Y so, that we note down. So, that was a 0 then 1, 2, 3, 4 right. So, example as a example I told you this when this Ohms law in case of Ohms law. So, similar relation is V equal to oh RI right. So, varying I we note down the voltage we note down the voltage V.

So, in this case now generally what we do, by taking this data generally we plot we plot graph right Y and this is X right. And so we plot we choose the scale here right we choose the scale here and this. So, this is the 0 and then say 0.5 1, then 1.5 2 etcetera right then corresponding here this. So, this depends on the unit. So, we have to choose units. So, this scale I have taken 1, 2, 3, 4, 5 like this right. So, this 0 this will be the 1 point and then second point for 0.5 0.5. So, this is the point then for 1. So, this second point I am doing that will get ok.

So, this way I will plot it ok. There is we draw a straight line and you can find out from this slope. So, this is the average you see I am drawing line. So, data was discontinuous. Now, just average line I have drawn. So, any point on the line will satisfy. So, now, it is continuous variation of the X on the line and corresponding continuous value of Y, I can find out right.

So now, imagine this is another case that is the non-linear case if Y equal to say relation is like this, it is a non-linear relation non-linear relation. And in linear relation this is the way generally students take data, just they take equal step in X, and note down the Y whatever. So, then like, but this is not appropriate way to do for when Y and X their relation is non-linear so is the parabolic equation.

Now, see if we plot graph if we plot graph, we have taken data as a same way we have taken the data the same way and, but then its value 2.5 2 point 3.0; so this way when you are going ahead. So, what will happen? So, this value it is becoming 5.5, then it is becoming 7, then becoming 9 ok. So, if this way is varying. So, this means now change of Y axis here it was linear 0 1 2 3 4 right. So, if it is linear it should be 5, but it is becoming 5.5, then next should be 6, but it is 7, next should be 7, but it is becoming 9. So, then next 4.0 is becoming say 12 now of same change of X, this here change is higher and higher and higher ok.

This will have a relation this change is not this is, because the relation is non-linear and for slight change of X variation of Y y square of it ok. So, when this value of X will be higher and higher, this change Y change will be I think faster and faster right. So, a clear this is if you plot this 1 if you plot this one then what will happen? If you plot this one let us take only positive value of X positive value of X, this value write for negative value of X also this is Y right. So, you are plotting you are plotting this way.

So, X is 0 Y is 0 fine Y 0 Y 0. So, this I think I will choose another color. So, this is the ok. So, then next for 0.5, you are getting here 1. So, I have to do this because I have to go up to 12. So, I think this I can take as a 3, this I can take 3 this 6, this 9 this 12. So, here 1 one means one-third of it, one-third of this scale so one-third of it.

So, point here I can put a point here I can put a point then second one is 2. So, point will be I think 2 and point will be here, point will be here and then third one 3 1.5 3. So, point will be here. So, point will be here then next two that will be 4, next it will be like this, it will be like this, this is more or less linear relation here and then its becoming 5.5 next one 5.5.

So, it is close to 6 close to 6. And then next I am getting 7; that means, 6 and then one more one more that will be 7; then next I am getting 9, next I am getting 9 then next I am getting 12. So, 12 we write right. So, then it will be more and more higher you know then next for this, for this, for this, for this ok. So, here for this 1 it will be you see now curve, if you just draw the curve this following this variation this will be like this right. So, this is the basically hyperbola parabola. So, now, see if I continue this measurement next and then if I extend this scale. So, this is 12, then this is this basically 15 and then this is 18, then this is 21 and then this is 24.

So, next step here I think this one. This one will be this is 1 2 3 4 this is the 4.5, this 5. So, 4.5 here data if you take 4.5. Then from here you can tell that what will be the reading this will be the 16; it will be around 16 then if you go this 5.

So, it will be here point will be here, it will be around 19 or 20 it will be around 20 for 5.0 ok. Then if you go this is 5 5.5, 4 this is 5 no this is 5 yes then 5.5 this part. So, it is here it is here 5.5 you see it will be more here. So, it will be here this point will be you see here it will be around 30 it will be around 30 for 5.5; and for 6 now see for 6 it will be I think even 50.

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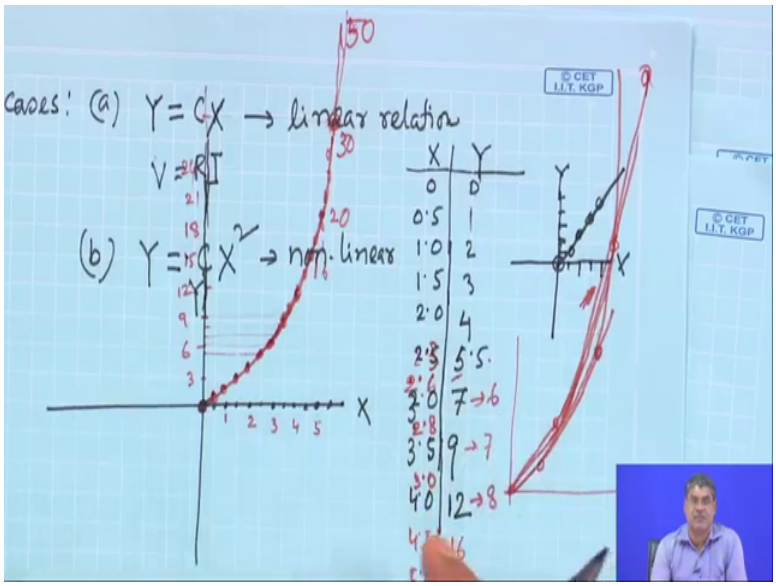

For 6 it will be 50. So, you will face problem in this region you know where slight change of X is giving very very high change of Y. So, here up to this it is fine up to this it is fine. But above 3 or 3.5, now the change point here then, here then, here then, here then. Here now see the in this case for equal step of equal step of X in this region.

So, here the change was 1. Now this change equals for equal step of this X 0.5 that is step, here change is increasing is a 1.5 then 2 then 4, then 10 then 15. So that means, on the graph you will get this value say 30, and then this value you are getting 20.

So, this is the 30 this is the 20 and next this is the 16, next you will get this 50, next you will get this 50 right now you have to draw the graph you have to draw the graph how you will draw? Because you have a point and you have to you have to. So, you have to take you have to draw average curve which will go through the point or actually if graphic plot in such a way that equal number of points will be on this side equal number of point will be other side roughly, and it will pass to the most of the points.

So, it may not pass to any points that is. So, there this some calculation is (Refer Time: 15:04) is list of (Refer Time: 15:06) some calculation is there, but I am not going to discuss that one. So, we will see later on, but here importance is that this actually I am drawing curve means I am not connecting point to point, but I am drawing the line in such a way seeing the distribution seeing the distribution of points. So, my curve will be

such that this points will be distributed around this curve uniformly right. So, if distribution of the points is not uniform with variation of X.

So, then in this region I will face problem to draw the graph of curve in this region I will face problem to the draw the curve ok. So, since I have drawn this curve from the beginning. So, that is why its a difficult to understand here. Now if you have something these point like this variation. So, one point is here, one point is here, one point is here, one point is here one point is here. So, if this way points are distributed when you will draw curve. So, how will draw? So, average curve will try to draw this way.

So, this is possible if all the variation is like this it is possible if more or less these points on the curve are uniformly distributed, but if say if say these points you will not there and variation is coming here and this is another is here, another is here. So now, here we will draw the curve like this, you will draw the curve like this ok. So, we will draw the curve like this.

So, we will draw the curve that this way ok. So, it will be difficult here to draw the curves because I do not have initial distribution of the points on the curves ok. So, that is the problem. So, here to choose appropriate step of X variable and note down the Y variable. So, that is important in the sense in case of linear this we take throughout the measurement we take the uniform step in X axis, but it is not correct approach actually we have to change X in such way that this change of Y should be more or less uniform. So here one, here one; so in this case is coming 4 and then 4.5.

So, then what I have to do? To keep it around 5 instead of 5.5; so here I have to take not 2.5 say I have to take 2.3 I have to take 2.3. So, then to take it get it around 6. So, I have to I think this will not be next step X, I will not vary up to 2.3, I will vary may be its 2 point 2.6 say then for this next 1 this for 7, I have to take here this say 2.8 then for getting this 8 I have to here probably I have to come at 3.0. So now, look at it. So, if I do this way. So, here I will draw graph. So, here this change here I am getting this one point I will get at say its a one point I will get at 5, then I will get point at 6, then I will get point at 7, 8 9 ok.

So, whatever the way here I am getting here this change. So, I will get. So, this way if I continue I will get many lines. So, this points. So, where this points are almost uniformly distributing from the curve. So, important is that we have to look at the variation of Y.

So, variation of Y that it should be more or less equal if in this case it is not necessary all the time it is one, but it can be just near out 1 can be 1.2, this variation or 1.5 variation when it will be this change is very sharp, so this way.

So, approach is appropriate it in case of linear also finds if it is linear then fine, this 1 this here this equals the width equals if you go here. So, I will look at the equal step variation in Y. So, I will maintain the equal step. So, I will change this one in such a way I will not take uniform step ok. I will change this step in such a way. So, that the here this change or are initial.

So, in case of non-linear relation, this is very important in case of linear also you can follow the same way. So, whatever generally you practice our student generally follow, just we take equal step of X and look down the Y. So, approach is not that one approach is that take. So, look at the variation of Y try to maintain the equal change in each step in each step ok. So, for that whatever the initially you choose 1 step now next one, you will choose the same step of different. So, that you decide depending on the change of Y rate of change of Y.

So, you take this step in such a way so, that here this change will be whatever here change over. So, here this change also should be around 1, should be around 1 ok; so this way. So, this will not be uniform step. So, I do not bother, but I need this more or less Y change should be uniform. So, that way one has to take data.

So, in non linear case it is very important otherwise there will be here we will get very few points and you will feel difficult to this draw the curve or to feed the curve. So, there will be error in the result. So, this very importance a how to choose step of X variable and Y variable next important thing is that, this when you are going to do experiment. So, say let me tell you one example that if you want to find out the density of density of water.

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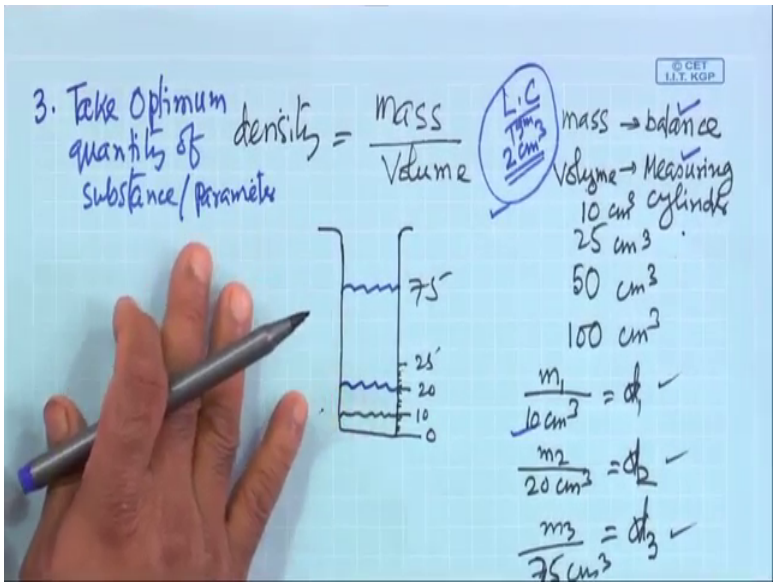

So, density of water means mass density of water or any things. So, basically mass divide by volume right. So, basically I have to measure mass and volume of water from there, I can get the density right.

So, it is very simple experiment I will use balance to measure the mass I will use balance to measure the mass this fine nice. And I will use this for measuring volume of this mass I will use this same measuring cylinder measuring cylinder; scale cylinder is available cylinder right measuring cylinders. So, I will measure volume.

So, take a cylinder put water, and take up to say some levels 50 cc we tell 50 cc or 25 cc or 100 cc or 10 cc; cc means cm cube cm cube centimeter cube. So, this is measuring cylinder have this scale and all 100 cm cube this scaling are there. So, 0 0 0 cm cube ok. So, this scalings are there. So, we have you have this cylinder measuring cylinder.

Now in this cylinder there is a scale 0, then 10, 20, 25 in between some scales are there ok. Now question is that someone some student will mistaking this may take this much water some student can take this much water. Some students can take this much water right. So, that student has to decide that who is doing experiment he has to decide how much amount of water he will take and then after taking measuring the volume. So, he may take the mass of this water using the balance right then find out the density. So, if you take 10 cm cube waters and corresponding mass you will get, you can find volume right. So, someone can take this 20 cc water 20 cm cube and measure the mass, and find

out the volume right someone has taken this 75 cm cube ok. 75 cm cube 75 cm cube then find out the volume right. Now everyone sorry it is a density 1, 2 density 3.

So, now everyone is correct right. So, I have taken I have measured the volume of the water and taken the corresponding mass and find out the density ok. Now here that is what I this rule is there. So, take optimum third rule, I am telling this take optimum quantity of substance of substance or of in general the sum whatever the parameter you all want to measure. So, take optimum quantity parameter ok.

So, choosing the appropriate amount of this in this case in this example; choosing the appropriate amount of the water this is very important important why? Now in major when you are measuring this 1 this using balance using balance or this measuring cylinder. So, they have least count right they have least count means that, error will be induct level. Whatever least count in this case I mean.

So, in case of mass it will be milligram or it may be gram whatever depending on the balance it may be gram whatever the least count; so that in your measurement that will be the error. In case of volume this may be scaling here it is this 2 cm cube is the scaling that is step in this case 2 cm cube cm cube. So, that is the least count and say here 1 gram that is the least count. So, when you are measuring. So, this error will be in that measurement error will be in this in this range least count. So, that is given to you this cylinder is given to you that balance is given to you if you have chance to choose. So, then you have to choose better one right means (Refer Time: 30:57) least count will be better because error will be less.

So, now see who has taken 75 cm cube in that this error in that measurement this 2 cm cube that will be the. So, possibility of mistake is taken as a 2 cm cube. So, it will be over 75 cm cube. And who has taken 10 cm cube you have 10 cm cube. So, that 2 cm cube that that error will be over this 10 cm cube 10: ultimately this in this, this 2 cm cube error in 10, 2 cm cube error in 75.

So, error you can distribute this fixed error over a larger quantity; larger are how large it is etcetera. So, that will depend on your what all the instrument if it is 100 cc cylinder, maximum 100 cc you can take. So, you should take 75 will be better if you were you were given this 25 cc in them then try to take maximum around 20 5 or 20 cc water ok.

So, depending on the depending on the instrument given to you have to choose optimum quantity of the substance of this parameter which you want to measure. So, that should be optimum in the sense depending on the availability of the instrument you in this example you try to take maximum amount maximum quantity as is as possible for this for your case ok.

So, this will decrease the errors in your measurement. So, in this case 2 factors like this least count of the instrument that is may not be in your hand, whatever in laboratory is there that is you have to. But the decision of taking up amount of water whether I will take 10 cc water or 20 cc water or 75 cc water that is your decision. And obviously, here I showed you I told you that that 2 cc means cube centimeter cube centimeter basically; so that that error will be distributed over your amount quantity of this parameter or substance. So, whether it is 10, 20, 75 if it is distributed over 75 obviously, per gram your error percentage of error will be smaller than the then the case of 10 cc water. So, that 10 cc that is for 1 one gram. So, for unit means for 1 cc what will be the.

So, error one can calculate. So, that will be higher than this for 75 cc ok. So, this is another important factor. And also next I will tell you this fourth case that is now.

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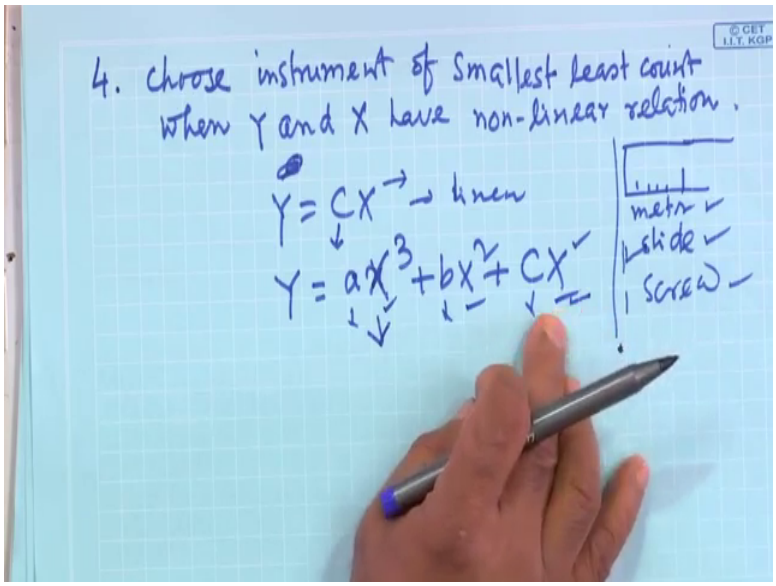

Choosing the appropriate choosing the appropriate; here next choose instrument. Choose instrument of smallest least count when Y and X that 2 parameter have non-linear relation. So, what is the meaning of this? Meaning of this is Y equal to CX is the relation.

So, you are taking reading right for X and for Y for this two instrument right not Y you say Y are not measuring X you are measuring and that is the relation with the with the Y and C say we have to move this known to you C is constant known to you.

Now you are varying the X and using this formula you are calculating Y ok. If relation is like this, then we tell is the linear now non-linear relation if it is say a a x cube relation is like this ax cube bx square and cx ok. So, these are non-linear relation. Now in this case actually Y is related with the X like this a and b some constant, and that is you are just measuring X and calculating Y right.

If this is the case now, that is what here I want to mean, choose instrument of smallest least count when Y and X have non-linear relation. It does not mean that if it is linear relation you will not choose the smallest least count, but it is very important when this relation is non-linear we have to choose, in this case if do not choose the smallest least count instrument. So, the error will not be that much, but here the error will be very high for this if you do not choose this smallest least count.

So, example is this instrument is available with you. So, meter scale is there meter scale is there meter scale is there. So, then you have slide calipers slide calipers you have screw gauge meter scale. So, this 3 are available in the left, now you have to measure this all say length of a length of a rectangular bar or diameter of the wire right. So, if we use for this.

So, out of this C any one you can use for measuring this X ok. So, someone have chosen this say meter scale, someone has chosen this slide calipers someone has chosen this screw gauge for linear case also of course, for this screw gauge in this screw gauge this error will be lower that is there. But when it is non-linear now imagine that it is error will be its I see in this case error will be here whatever here error of for your major (Refer Time: 40:13) error whatever error will be in the measurement of in the on the parameter of this Y, that will be whatever error in this case, it will be 3 times higher than this one. If it depends on X cube and in this case 2 times higher in this case is more. So, this all will be added this 3 times plus 2 times of this.

So, its a 6 times higher than this error ok; so whatever error will come here. So, this is of just say this if I tell one time and then in this case if it is non-linear it will be 6 times higher. So, when I am measuring X for this case. So, one has to be careful for choosing

the meter because it is in this case this error will be will come on Y that will be 6 times of the miss of the error over the X right.

So, that is why if relation is like non-linear. So, one has to be very careful in measurement of this X parameter. So, in this case I will not use meter scale even if it is length. So, if it is within the range of the slide calipers, I will use slide calipers it may not be. So, I one can choose the meter scale as well as slide calipers. So, if it is linearly lesser. So, I may choose meter scale also ok. So, in case of meter scale; whatever error will come.

So now, if it is non-linear then using slide calipers. So, I can keep the error in the same range of this one. In this case if I use the meter scale whatever error here. So, here if I use slide calipers I can keep the error over this Y in the same range if I use meter scale. Obviously, as I told you the error will be 6 times higher than this. So, if power depending on the power of this X if it is 1 2 3. So, higher and higher error power. So, error will be higher and higher; that means, that times of this how many types times of power ok.

So, that will be the error introduced in the parameter Y. So, this is the. So, this is the data collection procedure when you are collecting data ok. So, as I told you this fourth (Refer Time: 43:39) I discussed fourth there may be other thing that this 4 are important. So, repetition of the measurement and taking average that should be logical, it is not fixed that 3 times we have to measure and take average it is not fixed ok.

So, that I discussed and then I discussed that this choose appropriate step of X variable and note down Y variable. So, I told that generally student take the equal step of X and note down the Y ok. So, that is not the correct approach, it is for the linear relation between X and Y, but in case of non-linear relation you will be travel when you plot graph. So, our aim is to have the uniformly distributed points on the curve near the curve ok. So, if this is the aim. That means the aim is to get the equal step variation in Y not in X. So, if you vary the X in such a way.

So, all the throughout the measurements do not keep the equals shape of X, initially start with some step and then when you see it is increasing or decreasing or we keep the other way also initially it is very first then it is going to our saturation ok. So, then initially you have to you have to take smaller step of X and then when it is going to our saturation,

then you can take higher step of Y sorry higher step of X. So, aim is to keep this change of Y is more or less same ok.

So, this is the important fact to choose the step of variables when you are measuring, and next I told that is in your hand to choose the amount of substance amount of length of parameter or whatever. So, this quantity of this parameter, then you should choose optimum amount of this of this parameter ok. Then you can minimize your error, and fourth point I discussed choosing instrument of lower smallest smaller least curve is very very essential when this X and Y relation is non-linear, because the power of the X is will give you the error on Y that the times that error will be the times of this power ok.

Now if X square its 2 times 2 times higher error it will give 3 power is 3 3 times higher error it will give ok. So, this Y depends on X, now that dependencies whether depends on X or X square or X cube if power is higher and higher, you need to choose better instrument to measure the parameter to optimize the error to minimize the error ok. So, that is the when you will go to lab and start experiment. So, this is the general procedure I discussed to collect data. So, that this error you can minimize for your measurement ok.

Thank you for your attention.