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

Lecture - 22
Calculate the value of young's modulus of given metallic bar form the recorded datas

In last class, we have demonstrated the measurement of Young's modulus of a material. Ah in laboratory we have seen that we have, we took a, a bar of sub material was basically brass. So, this ah, so, we have, showed how to, how to find out the young modulus, basically how to take data for this experiment.

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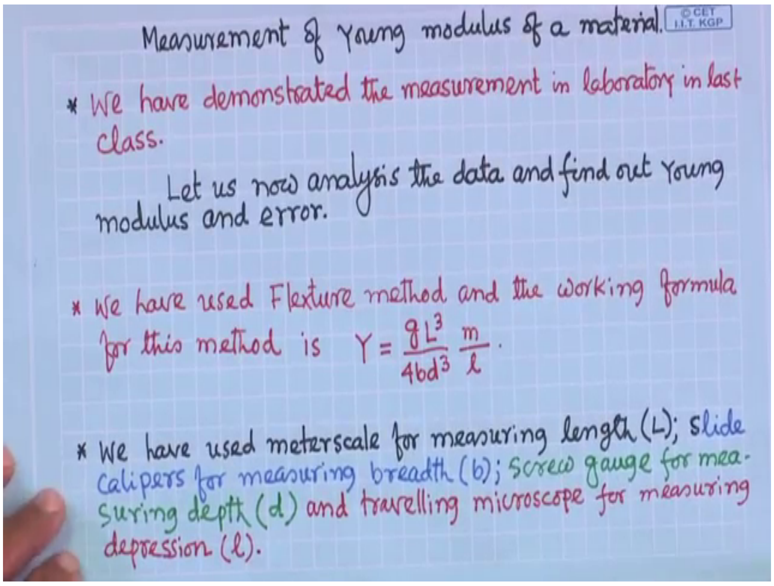

So, we have ah, we have demonstrated the measurement in laboratory. Now, let us analysis the data and find out young modulus and error on this measurement. So, we have used basically Flexture method and the working formula for this method is Y equal to g L cube by 4 b d cube m by l, right.

So, L is basically the length of the, effective length of the bar. Ah basically length between the two sharp edge, knife edge on which we kept the bar, and b is breadth, d is depth of the bar and basically m by l. So, experimentally mainly main part is to find out m by l. So, method we have used that is Flexture method, but here to find out m by l basically we take help of graph. So, we use different mass and measure corresponding depression. So, then we will plot l versus m and from that plot we will find out the slope of the curve, it will be straight line basically, because this relation is telling that it will be straight line and from that slope, that slope is basically m by l.

So,, we have to measure L bd as well as this m by l, small l. So, we used meter scale for measuring length L, slide callipers for measuring breadth b, screw gauge for measuring depth d and travelling microscope we have used for measuring depression l,, so that how to use this travelling microscope for measuring depression that we have a, showed in laboratory.

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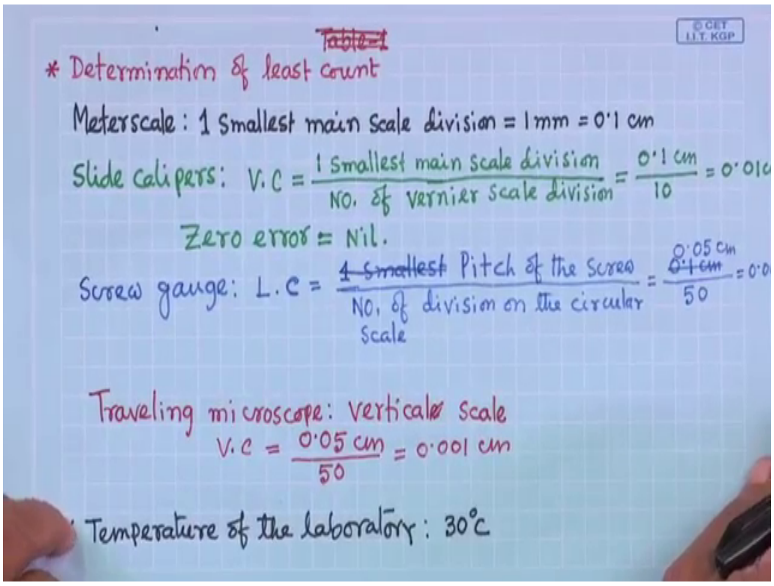

So,, now, we have to proceed to analyse the data or basically in laboratory, I have shown you the instrument and describe how to take data. Now we have to note down on this data and analyse it find the result, right. So, that is what I am trying to do here. So, a fist we have to find out the least count of the instrument whatever we are using in the laboratory. So, for measuring length we have used meter scale. So, for meter scale what is the least count 1 smallest division, main division, main scale division of the meter scale. So, that is the 1 millimetre, basically whatever scale we used. So, there is 1 millimetre. So, that is 0.1 centimetre.

Then we use slide callipers. So, least count of slide callipers is basically tell Vernier constant and definition of vernier constant, you know this 1 smallest main scale division divided by number of vernier scale divisions. So, 1 smallest main scale division is 0.1 and total a vernier scale division was 10. So, your vernier constant is 0.01 centimetre. And you have to note down the ah, zero error also. So, in our case zero error, it was Nil.

So, next tools we used that is screw gauge and least count on the screw gauge is defined as the pitch of the screw. What is pitch of the screw? Now, one complete rotation of the circular scale, one complete rotation of the circular scale, seen main scale, linear scale what, what is the ah, what is the reading exposed means this circular scale and this linear scale.

So, if you rotate this circular one, so that reading basically it exposed it, it, it shows initially to was 0 then it exposed to 0.5 and then 1 millimetre, 0.5 millimetre, then 1 millimetre, then 1.5 millimetre. So, linear scales are there ah. So, that is for one complete rotation. What is the reading ah? So, that is, that is basically the pitch of the screw.

So, in our case for one complete rotation this it was 0.5 millimeter linear scale that pitch of the screw 0.5 millimetre means 0.05 centimetre and number of division was this 50, you see this you can do mistake, but you should just cleanly just cut it and right, ok.

So, do not about to about to overwrite it. So, just if any mistake, just cut it and right in a proper place. So, this screw gauge that least count is 0.001 centimetre, ok.

And then we used travelling microscope. So, it has two scale, one is vertical scale and another is horizontal scale, that I showed you. So, in this case for measuring depression, we will use basically, we have used this vertical scale. vernier constant is the basically same as slide callipers, this scale is has Vernier scale. Ah, so Vernier constant in this case smallest division was 0.5 millimetre means 0.05 centimetre and vernier division was 50. So, this vernier constant is 0.001 centimetre, ok.

So, so whatever tools we used, so just we determine find out the least count, we note it down of these things. And then you should note down the temperature of the laboratory, because the young modulus this their most of the parameter depends on temperature at which temperature you are taking reading. So, it is always, it is better to write the temperature of the laboratory. So, in our laboratory it is a, it was around 30 degree centigrade.

So, now we have to measure L then bd, right. First let us measure breadth and width, first breadth and width. Let us measure breadth and width, ok.

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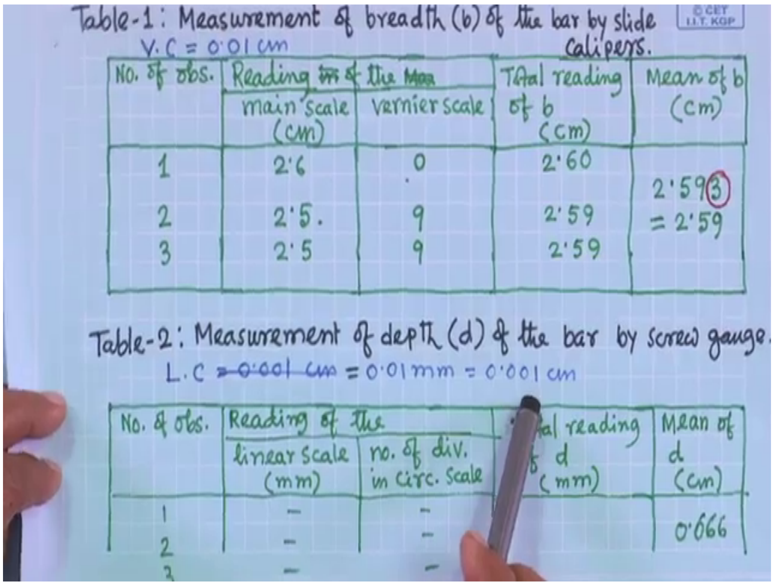

So, Table 1, we are noting down the breadth of the bar by measured by slide callipers. So, on the top of the table, we should write the vernier constant of the slide callipers. So, already we have calculated and there is a 0.01 centimetre. And then number of the table uh, you should make it like this number of observation, reading of the main scale and vernier scale.

Here I have retained this in bracket this unit, if you write here on top of table means ah, here. So, we do not need to write 2.6 centimetre, 2.5 centimetre, 2.5 centimetre. So, it is not looks good also and to avoid writing repeatedly. So, if you write on top of it, so then it means that this readings is in centimetre.

Then total reading of the means main scale reading plus Vernier scale, Vernier scale into vernier scale reading into the vernier constant. So, data is should be available here vernier constant. So, you are writing a total reading of b and then you are finding out the mean value of b, ok. So, here as I told in laboratory that you should take few reading, not just one reading. So, the always repetition of the measurement repetition it is the, reduces the statistical error, ok. It helps to reduce the statistical error. So, instead of measuring just ones generally we take few times. So, it can be 3 to 5 times.

So, an another reason also this scale is length is around 1 meter, 100 centimetre. So, it's breadth may not be perfectly uniformly high. So, that is why we, we should take in 2, 3, 4 places and then take average, ok. So, that is the reason also here, we have taken 3 observation. So, this is the main scale and this is the vernier scale reading and this total here if you take average of this so, it is a 2.593, ok.

Now, you should not write 2.593, because here, you can demand accuracy only up to two digit after decimal point. So, that is why you have to keep up to two decimal point. So, here we have written this should is basically 2.59, ok. So, you know on this how to write the significant digit, as we described, ok.

So, here it, it should be 2.59 not 2.60, ok, because it just 3, if it is 5 or above 5 then only it could be 2.60. Ah, so, then second table is for measurement of depth of the bar by screw gauge. So, least count of screw gauge, you should note down. And then again this in 3 4 places, you should take reading. And here same way this reading of the linear scale number of division in circular scale, total reading and then mean reading.

So, I have not just here, just written the reading, but just I have written the here average or mean value of the d it is a in our breadth. So, it is 0.666. So, three digit, we have taken, because here we have three digit after this value. So, three significant digit of course. So, this is the mean value of the d.

And then now ah, so again in working formula, you have seen that we have basically four parameters one is length capital L, then breadth, then depth bd and then depression l small l for different mass, ok. So, whenever we have scope always we should take more than one set of data. So, we have taken bar now among L bd these three parameters whether we can vary one parameter or not that, whether that that possibility is there or not in the experimental setup that we should find out.

So, in this in the procedure, we have seen in the laboratory that b and d, we cannot vary for a particular bar, but we have scope to vary the length capital L. So, that is why so, we will take, we will do the experiment for more than one length. So, then we take three length, so and then for each length, we have to now ah, we have to find out m versus l, ok. So, for different mass, we have to find out different length.

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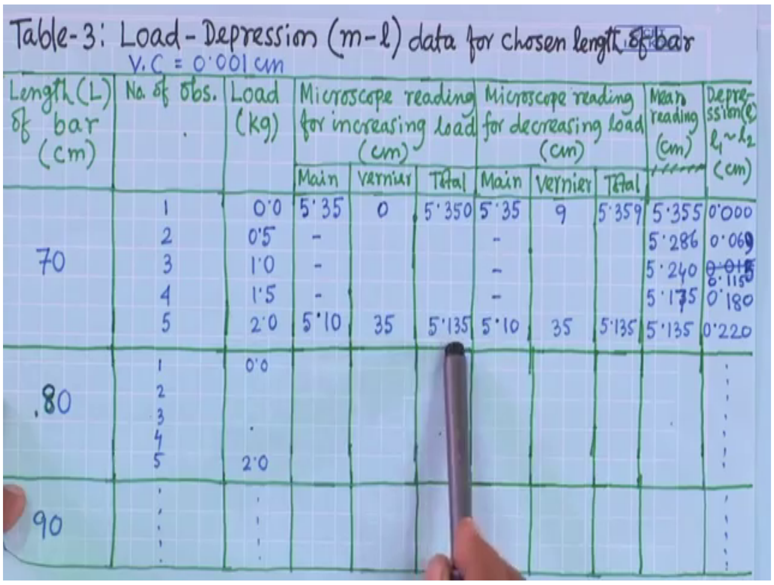

Table-3: Load - Depression (m-l) data for chosen length of bar

V.C = 0.001 cm

Length (L) of bar (cm)	No. of obs.	Load (kg)	Microscope reading for increasing load (cm)			Microscope reading for decreasing load (cm)			Mean reading (cm)	Depression (l) $l_1 \sim l_2$ (cm)
			Main	Vernier	Total	Main	Vernier	Total		
70	1	0.0	5.35	0	5.350	5.35	9	5.359	5.355	0.000
	2	0.5	-			-			5.286	0.069
	3	1.0	-			-			5.240	~~0.015~~ 0.115
	4	1.5	-			-			5.175	0.180
	5	2.0	5.10	35	5.135	5.10	35	5.135	5.135	0.220
80	1	0.0								⋮
	2									
	3									
	4									
	5	2.0								
90	⋮	⋮								⋮

So, ah, so that is why here this table number 3, very important table, main table of the experiment. So, here length of the bars in centimetre. So, for length 70, 80 and 90 for 3 length, we have done experiment. So, for each length say for 70 now ah, now mass for how many mass you should take depression? So, as I told depending on the method, ok. How you want to find out the m by l that value? So, we will use graphical method that is the that we have decided. So, if you use graphical method. So, you need at least 4 to 6 readings.

So, here in our laboratory ah, we have taken for 5 mass. So, number of observation for each length of number of observation is 5, 1 2 3 4 5. So, each observation, we are taking reading of depression length this small l depression for different masses, ok. So, for basically 5 masses and then that also what are the possible that we have to find out, how we can repeat the measurement, how we can increase the set of data. So, ah, so all the time, because these are this reduces the statistical error, ok.

So, in this case again we have scope when we are increasing mass, then we are measuring the depression and then other things also, we can do that just we are decreasing mass, we are decreasing mass doing decreasing of mass. Also again, we are taking reading, then we can take the average of this of this to reading. So, thus we are increasing the number of sets of data, which all the time wherever the possibilities there. So, one should use this ah, this opportunity to reduce the, error mainly repetition of measurement, repetition of the result, ok. So, it is all the time it suggest that one should take as many as, as many as sets of data possible.

So, here within our experimental geometry. So, this is the load and for microscope, we are taking reading. So, here we have two column, one is for increasing load another is for decreasing load, ok. And then, we will take mean reading, mean reading taking average basically for from these two reading. So, here mass when mass 0, ok. We are not putting any mass. So, initial reading is 5.35 Vernier is 0, then total reading is for this mass in kg. So, this reading is 5.350. So, that 0, you have to write, because here vernier constant is 0.001 up to three decimal. So, here we have to write up to three decimal point.

So, now, what we are doing, we are increasing the weight and then taking reading for each mass. We are taking reading; we are writing yeah calculating the total reading when increasing the mass. Now here I have written see this same, same reading here basically. So, now, we are taking this is the starting point or increasing load, we took this is the starting, ok then we are increasing the mass increasing the mass taking reading. Now decreasing reading decreasing the mass so, this is the starting. Now we decrease the weight from 2 to 1.5 just the 0.5 kg. Then take reading then 1 kg, take reading then reduce again 0.5, kg. So, now it is 0.5 kg take reading, now again this 0.5 kg remove it. And then we are coming back to the 0 kg for these whatever the reading. So, this two reading are not same it is a, different in Vernier value, it should be. So, this I think measurement is very appropriate and this way also one can find out whether any mistake we have done or not during taking reading. So, that also one can cross check from this data.

So, basically for each mass, now we have two reading, ok we have two reading and then we have to take basically the average of these two. So, that is the mean reading, we have to take the average of these two reading. So, that is what this column, ok. So, this is in centimetre.

Now, depression here, we have written l 1 minus l 2 or l 2 minus l 1 just to keep it positive value. So, at 0 mass, so this is the reading. So, this is the initial reading basically it either l 1 or l 2 whatever you consider this one. Now from this reading since, this reading here decreasing the here reading is decreasing, here reading is decreasing so, from these actually now I will use this column. So, ah, so if you take it is a l 1 initial reading minus l 2 means this reading. So, ah, so here I have written 0.000. So, here for 0 mass basically, so we have to here basically this is the, this we have taken initial reading.

Now, if you just minus this reading. So, it is, it will be 0, so this for 0 0 0 mass, ok. So, that basically in instrument we are, we are not able to start from the 0 reading. So, here, if you just minus this initial reading so, then basically, you are calibrating with the as a 0, 0 reading. So, then next for when we are putting this 0.5 mass. So, for this what is the depression? So, this was the starting reading. Now minus this final reading or, or vice versa this reading minus this reading or this reading minus this reading. So, that is why l 1 this way, we have written it's meaning that either l 1 minus l 2 or l 2 minus l 1 depending on this which value is higher. So, here it is higher value, ok.

So, from here, so if I just minus this one l 2 it if it is l 1, so l 1 minus this l 2, so this is the reading. So, this is for 0.5 kg mass, this is the depression. Now this reading minus this reading, ok, so this will be for 1 kg. So, minus this reading, it will be for 1.5 kg minus this reading, it will be for 2 kg, ok.

So, now I have the reading l basically for different mass m here, so for length 70, ok. Similarly, now take length effective length 80, repeat the measurement in same way repeat the measurement, in same way. Take reading length 90 and repeat the measurement in same way, ok. So, now, for three length you have breadth and width of course, same for all measurement. Ah now, you have three sets of data, for each data for each set, ok. We have to draw graph, we have to draw graph l versus m. So, if you, if you draw graph.

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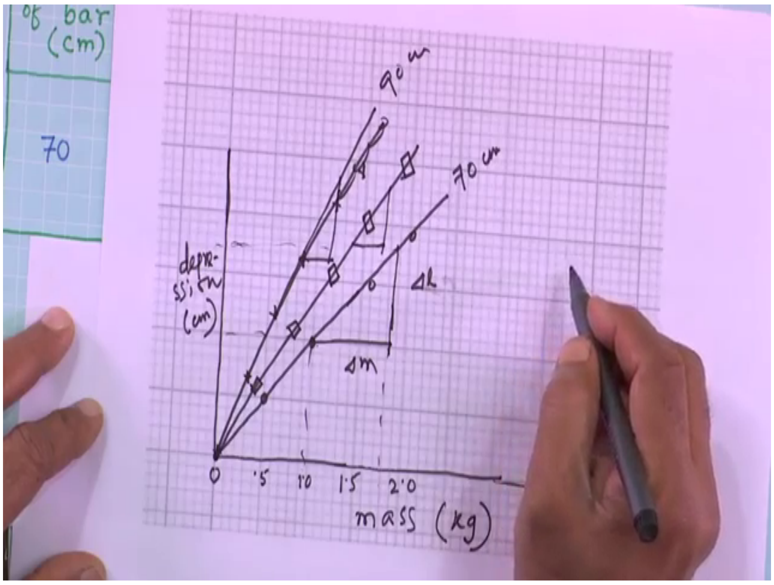

So, I have graph paper basically. So, we have to we have to draw graph. So, one scale, we have choose one scale, we have to choose. I think, this is the mass in kg or gram whatever you should write and this is the depression, depression I think, we should write say centimetre and this kg.

So, now for I have 0 0 mass then 0.5 kg, then 1 kg, then 1.5 kg, then 2 kg, ok. Now from this, from this, so here you have data for each mass you have data, right. We have data the depression l. So, that you should plot you should plot. So, this will be 1 point and this other point just you have to find out take the scale properly and you have plot. So, you will get 5 point, ok. So, find out the average graph.

Similarly, this say for 70 centimetre length. Similarly, you should draw for other length. So, other length, you have we have chosen this 80 and 90. So, for other length also you should plot in same graph or different graph also you can use. So, you should use different symbol, you should use different symbol, ok. So, you then you plot the graph. So, it is not straight line, it is, so one should use scale and I think you should, you should draw properly, you should draw properly, ok. So, for it may not pass through the 0, exactly that that would be basically error.

So, similarly for this for 90 centimetre and in between here getting for, sorry different symbol you are using different symbol, you are using, right. So, from each, just you find out the slope, you should find out the slope, ok. So, this is basically delta l and this is delta m, from here you should find out, you should find out these value, right.

So, similarly from each graph, you should find out the slope from each graph, you should find out the slope. So, you are in working formula, it was now what we should do? We should calculate the young modulus. So, for that you can make table ah. So, you make table.

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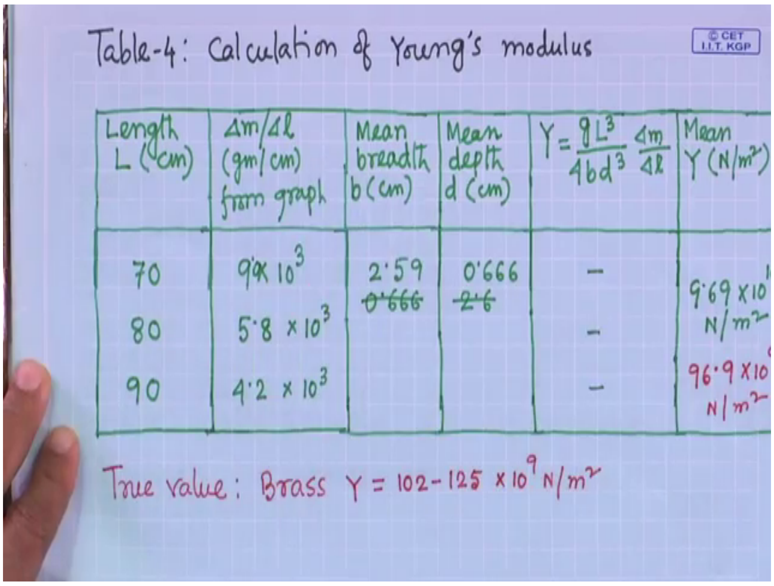

So, say table 4 calculation of young modulus. So, for each length for 70 del m by del l as I told, here del l by del m or graph whatever the way I have plotted, it will, it is slope is giving del l by del m, but just inverse also you can find out del m by del as you need in your working formula. Ah seeing the working formula, you can decide whether you will. So, slope basically del l by del m not del m by del l.

So, but in our working formula we need del m by del l. So, you should not write this is slope, it is the inverse of slope. So, you can find out the from this graph. So, this del m by del l unit, you should write gram per centimetre or whatever this is from graph. So, from graph you find out this value not breadth depth is there and then young modulus this is the formula, ok. So, you have all data now you just calculate and find out the young modulus for each for each length, ok. And then take average of this young modulus of these 3 and this average is say coming 9.69 in our case and 10 to the power 10 newton per meter. So, unit here now I have written Newton per meter although other unit is in centimetre. So, one has to convert it.

So, here I have written 96.9 into 10 to the power 9 why, because now this is a material is brass as I told you. So, just from standard data I find out from internet, I found this value for brass. What is the young modulus? Young modulus is there is a range given 102 to 125 into 10 to the power 9 Newton per meter square is also gigapascal it 10 to the power 9 Newton per meter square, you can do one gigapascal. So, people write also 102 to 125 gigapascal means gigapascal, ok. This one can write also 102 to 125 gigapascal ok.

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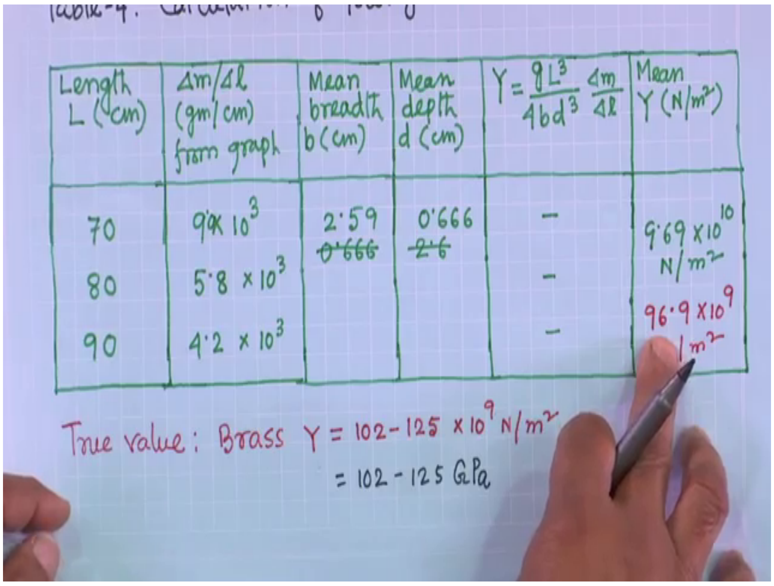

So, here, so to compare with this true value, so that is why I have written in the same format into 10 to the power 9 format. So, our result is quite good, this is 102 and this y is the one has to understand why is the range is given, because brass is that the pure material, it is the basically alloy of different material. Ah yeah, I did not remember exactly the composition of this brass, I think zinc copper ah, etcetera there. So, in which percentage is there depending on, because this is the mixture is the alloy of 2 3 materials. So, that is why depending on the percentage of this individual material pure material. So, it will have different value.

So, one have scope to adjust the composition in this brass. So, if you want higher young modulus. So, that way if you can you choose your composition such that, so, it should go towards this value 125. So, this is the reason, this range is given, because composition of individual materials in brass is not fixed one can vary. So, that is why it, it will be the in this stage.

So, our result is, is very close to these two value. So, this way one should if two values available one should compare and show this how good your result. In this here the difference is how much, difference is basically say 5, it is a 9700 to 5, 5 into 10 to 5 in this range, ok. So, 100 plus minus 5, 100 plus minus 5 ah, so this is the difference. So, this 5 percent error in the measurement, if you compare with the not in the measurement it is in here difference between the two value and this is the difference is 5 percent,ok. So, now we have to find out the error in our measurement percentage error or, or we tell the most probable error.

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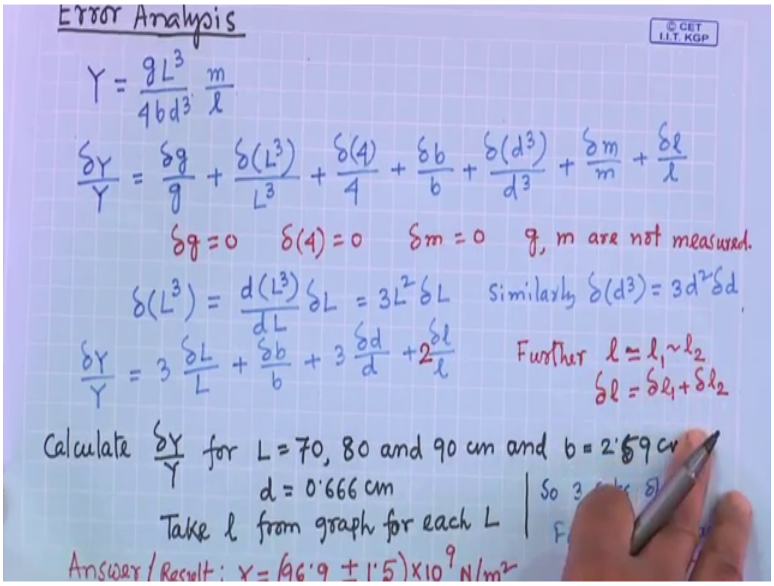

So, error analysis this is the working formula and all are in multiple division, ok. So, you know this relative error will be added. So, del Y by Y. So, del g by g, etcetera. So, for each term this will be added.

So, the following the rule I have written del g, del 4, del m, gm are not measured in our laboratory. So, error is zero on this on this parameter.

So, now del q you know d q by d q by if q is a function of x, d q by dx delta x, ah. So, that is the rule you have learned. So, from there, you can find out this. Similarly for d also same way if you put this one here. So, I can write three del L by L del b by b plus 3 del d by d plus del l by l.

Now, here I have written 2, because this is a difference of two reading you know l equal to l 1 minus l 2. So, now, this is the l 1 minus l 2 del l. So, absolute value will be added as per rule, ok. So, delta l equal to delta l 1 plus delta l 2. So, basically the error is same on this. So, it is a twice of this error. So, that is why these two is written here.

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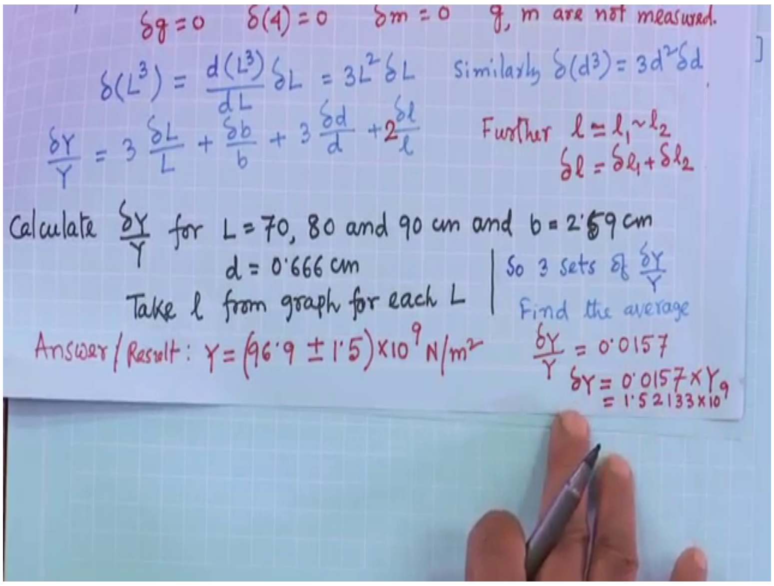

So, now just using this formula, you calculate del Y by Y so, for So 3 error you will three sets of error ah, you should calculate 1 is for 70, then 80 and 90 centimetre b and d is same and from graph ah, you just tick one depression delta l one 1 choose one l and then use that l. So, from graph we find out ah l just choose one l and that l value use for your error calculation.

So, you will have three sets of del Y by Y, find out the average. So, I have just written our result using our result. So, this is the delta average one del Y by Y is coming like this, ok. Now, del Y is multiplied with Y. So, this coming 1.5 to 133 into 10 to the power 19 9. So, answer or result you should write y equal to 96.9 plus minus here you see as I described earlier. So, you cannot write 1.52133. So, how many digit you will keep. So, here since you know result it is up to 0.9. So, here one decimal point, we have used here also we should keep one decimal point.

So, if you keep here one more decimal point. So, up to which you we you will keep here. So, actually ah, b in the b, we have used 0.01 d 0.001 and, but for L measurement, we have used 0.1, ok. So, among these, so if this is the highest possibility of the error. So, among these, so our least count is in this case. So, if you, you are multiplying during result you are multiplying all of them and when you will keep the significant figures. So, you will see, you will see basically, you know the rule this how to after multiplication of two digit two number. So, how to keep this? So, this is significant figure in the final product. So, that depends on this if it is one decimal point. So, minimum I think this out of two which is having minimum number of digit. So, that many number of digit you should keep in the product result, ok.

So, that way you, you will find out that only you can keep up to one digit after decimal ah. So, that is why you have you can keep only 1.5, 1.5. So, if it is 2 up to 2, we can write 1.52. So, here result we have to write 96.90, ok.

So, this should be after decimal, this should be same for both cases. So, here is consistently I have written. So, this is the way, one has to write answer or result.

So, from this analysis I think how to make table, how to write data, how to find out the average, keep the significant figure, how to how to calculate the value, ok. And then finally, how to find out the error. So, that is that is what you learned. So, I will stop here.

Thank you for your attention.