Experimental Physics I
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Lecture - 24
Calculate the value of calculate the spring constant of a given spring form the recorded datas

So, in last class we have demonstrated the how to measure the spring constant of a helical spring ok.

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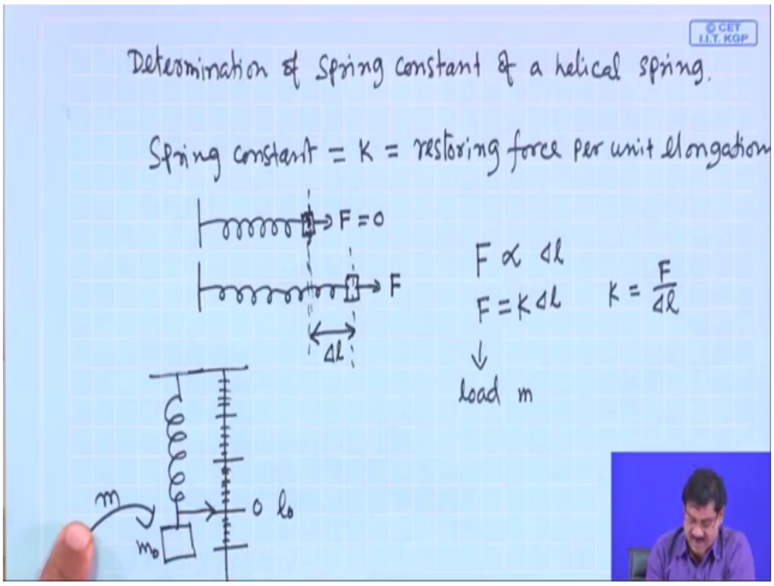

So basically determination of spring constant of a helical spring right. So, we have seen that spring and that was hang from a support. And then I told in the lab that there are two method to measure the spring constant; one is static method and another is dynamic method.

So, basically when we have used the dynamic method to find out the spring constant. So, what is spring constant? That is basically spring constant spring constant equal to say it is a K is equal to restoring force per unit elongation ok.

So, if you have a spring if you have a spring and this is the position of the spring when this force applied on the spring to elongate it. So, if it is 0; so this is the position, you can attach mass on it. So, this is basically spring mass system if just elongate it by applying force F; then its position force applied F. So, initial position there was no force and then after applying force this is the position.

So, then this we are telling this elongation of this elongation of this spring by say delta l because of applying force F. Now since it is elastic this spring is elastic; it has elastic property. So, that there will be opposite force that we tell restoring force to restore the this deformation. So, the same amount of force is applied in opposite direction ok. So, this is the internal force basically; internal this force that is called restoring force.

So, because of this force F elongation is delta l. So, this force and this elongation so is the proportional relation is proportional. So, that proportional; proportionality constant is say K delta l ok. So, this K; then you can define that F by del l means the; so F is basically this applied force and this restoring force is equal, but in opposite direction. So, restoring force per unit per unit elongation.

So, that is the definition of spring constant that in laboratory we have seen how to; how to find out. So, this two method one is static method so, in this method basically directly we apply force in terms of load; in terms of load so, if we apply m means then we have to take this spring in vertical vertically ok.

Then you attached a scale on it, you attach a scale on it; scale on it yes. So, this is basically centimetre scale millimetre scale if you and then you just, here some indicator we used here some indicator we used. So, you can see this if it is initial position before applying any load or just some initial load is there. So, because of that this; what is the initial position. So, if you adjust this, this scale it is at 0 or it can have some value also; it can have some reading also. So, this so then we tell this for some mass m 0; initial mass m 0. So, there is a reading some reading initial reading so there is the l 0 say ok.

So, then you are increasing mass and then there will be; if extension elongation of this of this spring and this then indicator will come down and you can take reading corresponding to those mass. So, here basically we will apply mass and due to this masses load, this force is basically will be mg; downwards force will be mg that is basically force downward force mg.

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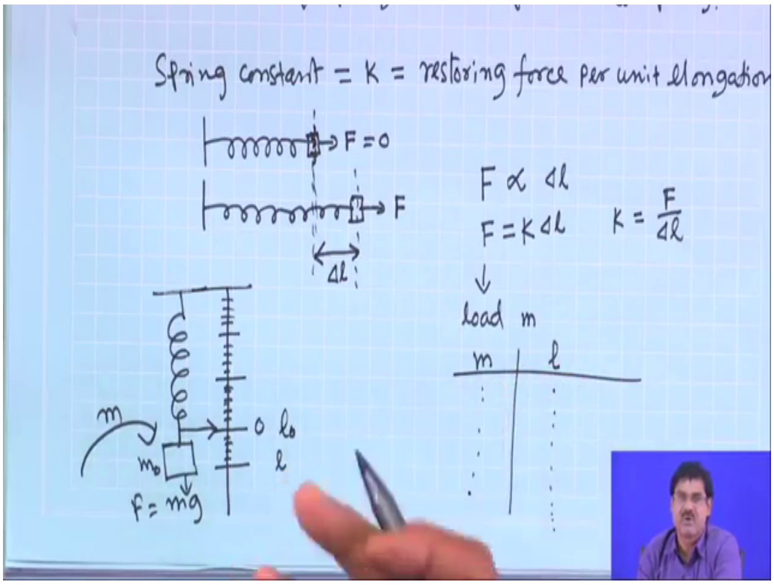

And yes it is the mg and because of that there will be; there will be if reading this integral will come down there will be reading l. So, l basically if it is 0; so this will be elongation for this mass m; for this mass m.

So, now you are varying m and taking different l; different l if it is 0; so that is the from 0. If it is not 0 some l 0, so that we have to take here. So, then basically you are getting; you are getting basically mass versus this depression l. So, you take different mass you take different mass and then take the reading l from this scale ok.

So, now in laboratory we have seen this; so what are the range of masses we are using and what are the ranges of this reading l ok. So, this change is in few centimetre or few millimetre corresponding to that mass; that depends on the spring constant K basically. So, that was the static method that just I have shown in lab. So, in static method, but I did not complete the experiment, but I have complete the experiment that dynamic method ok.

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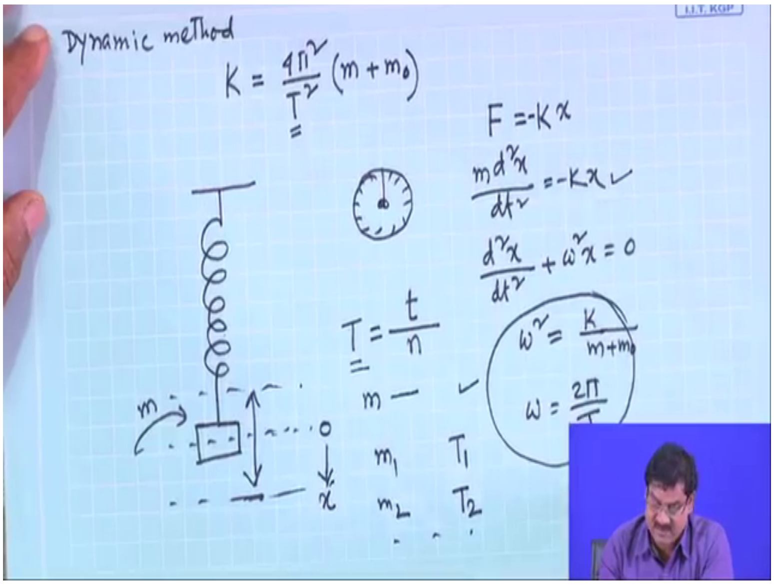

So, in dynamic method what was the working formula? That is what I just told that working formula was basically I think it was K equal to, for dynamic method dynamic method. That K equal to 4 pi square by T square and then some this mass was whatever we are varying. And then initial mass if you consider then you have to write m 0 ok.

So, how this relation came that one should understand. So, you know this F equal to actually if I write this spring constant K and then displacement instead of delta l I will write x in terms of x and then I will put negative sign.

Now, F equal to basically in differential form d 2 x by d t square then equal to minus K x. So, you are getting differential form of this spring mass system standard differential from second order differential equation. It is a; we tell it is a homogeneous equation plus omega square x equal to 0, where omega 0 basically omega not 0; omega square equal to from here you can see this K by m; K by m ok. And omega is angular frequency and omega is 2 pi by T; T is time period, time period of this spring mass oscillation. So, if it is vertical also this spring mass oscillation; so this time period of that oscillation that is T.

Now, so from here basically you are getting K equal to 4 pi square T square; m here m. So, this m if initial mass if we neglect it is a m 0 if it neglect is fine; if you do not neglect; then you should put this m 0. So, then you will get this K in this form.

Now, so here basically if it is the working formula; so we have to measure only time period T ok; so the same spring mass system that same spring is here is a mass. So, now this is the original position and now if you put change put this mass. And then if you just disturb it if you just disturb it; so these then this spring will this spring mass will this basically this mass will oscillate this mass is will oscillate; mass will oscillate. So, with respect to this position whatever the for a particular mass, whatever the position that we will take 0 position ok. And then the displacement from the 0 position; this displacement we are considering this x ok.

So, now, that is why this x whatever we have considered this x is this one and now my task is just to measure time period T. So, how to measure that we have seen; basically we count the number of oscillation. Just we displace this and just leave it and then count the displace; count the total number of oscillation. If I start at the beginning ah; not beginning not just at the here when the position is here if I start; then basically between these two position it will oscillate.

So, if I start from here then I have to take one watch; I have to take one watch right I have to take one watch. So, basically we stop watch stop clock we use and that we have seen. So, here efficiently we have to control that in one hand we have to take your stopwatch and make it ready and just after here, you see this when just you will displaced and leave it. So, you do not need to just start your stopwatch immediately. So, just you can wait; let start this start to oscillate and then you basically you start your stopwatch when this position is say here.

Now, you start this is your starting point; then now you are counting this number of oscillation 1, 2, 3, 4. So, how many times, how many number of oscillation you will take. So, that you have to decide and practically that we have seen. So, this for lower mass, for lower mass this was this time to for lower mass from here you can see mass is low. Then K is constant; so naturally T will be also low ok; means time period will be small time period. So, this frequency will be higher; so it will oscillate very fast and you will feel difficulties to count it.

So, practically in during demonstration I have shown you; when I was using this lower mass probably 100 gram or 200 gram; so, it was difficult to count it. So, higher the mass time period will be higher and it is convenient to count them. So, that way you have to we have to depending on the mass, you have to choose this how many oscillation you will take in counting.

So, generally I suggest that you fix time that ok; I will say I will take for 2 minutes or 1 minutes ok or 3 minutes. So, during that time how many numbers of oscillations will be there? So, this time as I told 2 minute, 1 minute, 3 minute this is the approximately.

So, then basically time period will be t divide by n. So, number of oscillation you see you should not fix this number of oscillation as it is 50 or 30 or 10 or 20. Because this time we will basically will be very less; when mass is very small. So, you should take reasonable time 1 minute or 2 minute or 3 minutes and then let it be there a number of oscillation, but you take this integer number of number of oscillations ok.

So, this way you for each mass at least you repeat this; this measurement two or three times two or three times and then take average of T. So for mass m 1 find out the time period T 1, average time period T 1. So, then you for mass m 2; you find out the time average T 2 etcetera.

So, practical during practical I have basically discussed all of these things ok. And we have seen; so there we have seen basically what is the realistic mass whether we use in kg or in kilogram or in gram or microgram whatever ok. And how looks this spring and how it is hang from the support etcetera.

So, here theoretically when I am speaking ok; so there here m can be any value. It can be in microgram, it can be in milligram it can be gram or kilogram ok, but in practically what is the range of mass? So, we have seen the range of mass it is in kilo it is in I think we are using in gram and then we have taken this time actually if you; I think it is the around 1 minutes; 60 second or more slightly more than 60 seconds and number of oscillation I will we are taking around basically 50, 60 oscillation.

So, that was the practical. So, that I you cannot guess from this theory class, when you are in lab. So, in lab additionally what you are learning, what is the realistic parameters we are using there ok? So, basically we are using this mass in gram and yes and this we are noting down one has to note down these readings when you are doing the experiment. So, the as I told I will discuss later on when I was doing experiment about the taking the how to note down the data when you are doing experiment.

So, I think this is the very simplest experiment and table also I think one table is enough to express this to note down this all data.

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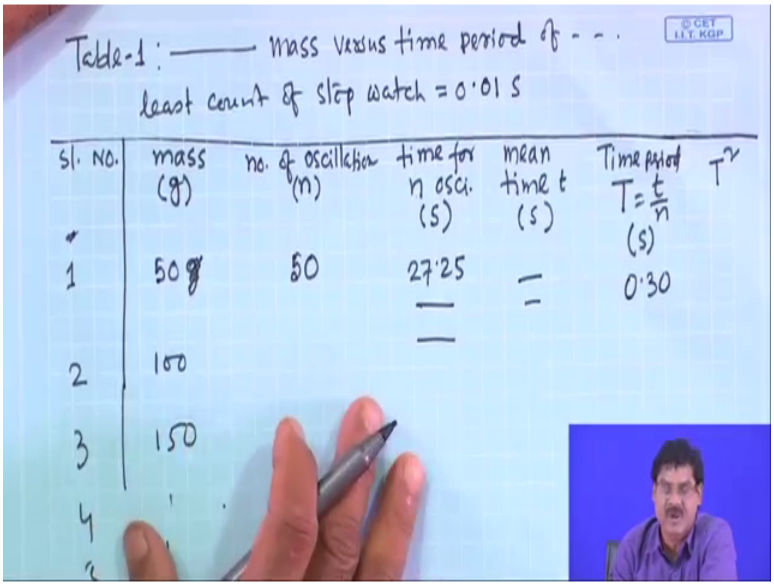

So, table 1; so only one; so I will write table 1; so in table 1 you should give heading you should give heading. So, basically mass I can give mass versus time period you know time period mass versus time period of the spring mass system; of the spring mass system spring mass system yes can be the other. So, immediately here using clock stopwatch so, least count of the stopwatch least count of stopwatch or clock, so you have to note down.

So, in our case in laboratory we have seen that is basically in second hundredth of a second. So, it is the 0.01 seconds; so that we have to note down and then if you have to make table you have to make table. So, first generally on the time we write serial number serial number means how many sets of data you are taking.

So, this can be one column and then next column will be mass; different mass we will apply and we will take reading ok. So, this mass and then you should write this you should write the; I think g or gm generally we should write g. So, for gram mass in gram and then for each mass you are counting; you are taking the number of oscillation. So, number of oscillation number of oscillation and then for this number of oscillation; what is the time? Time for number of oscillation it can be so say n ok, n number of oscillation n. And time for n oscillation time for n oscillation and then you find out for each mass.

So, here basically for each mass you should take as I told two three readings; two three readings and. So, time for n oscillation in which unit; so this is a second. So, then you should find out mean time t; mean time t so in second. So, then you find out time period; time period T equal to t by n set again it is in second ok.

Then I will find out basically; I will find out T square; why that already probably I told during demonstration. So, this will be the table ok; so just you can here mass for each mass I will take number of oscillation say; if I fix this one then time I have to. So, for different mass I think for a particular say let us say this is the serial number say 1 means first for mass I will choose say 50 gram; sorry this gram you do not need to write because already I have mentioned here.

So, number of oscillation; so mass 50 gram number of oscillation say, if you take in our system if you take 50. So, this for 50 number of oscillation this time for this 50 oscillation, it was taking this is 27.25 second. And so meantime, so basically this experiment for this 5 50 gram mass if I take 50 number of oscillation what the time is taken. So, if I take this is one reading, I should take another reading, I should take another reading.

So, then so I am not writing or reading. So, this is from our lab this reading so it you will get it is average you will get mean time for is the mean time t will be I think it is the second. So, there will be some meantime there will be some meantime and yes one should calculate some meantime. And then from there you have now n; you have now meantime t and from there you should find out this t by n and if you calculate.

So, it will come say 0.30 the second ok. Say suppose this because this is the realistic reading from our lab, but one has to write all I am just avoiding this one; just I am telling this just. So, this serial number 2; so say 100 gram, serial number 3 say for 150 gram, 4, 5.

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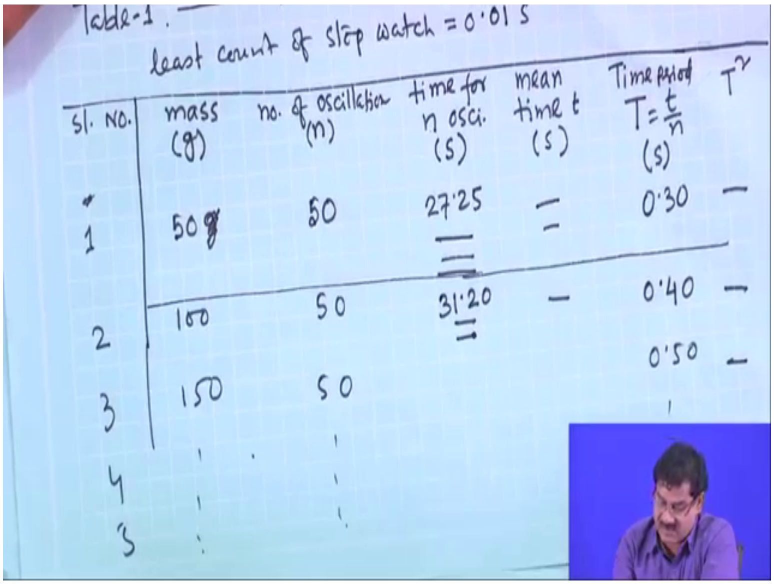

So, for this at least 5 point you need and then you either you can yeah; so mass is increase. So, I think you can keep this 50 number of oscillation; 50 number of oscillation and then for this 50 this is 3; if I think this is the one mean I think here I will draw like this. So, this is for one set another set again you take three reading.

So, here one reading is we have noted down this is the 31.20 and then other two also you should take; then find out the mean of it and then find out the it is a around this one 0 point basically 39 5; this type of calculation come so we have written 0.40. So, similarly for other one 0.50 this kind of data we got from our lab. So, if you take square of it just make it square of it.

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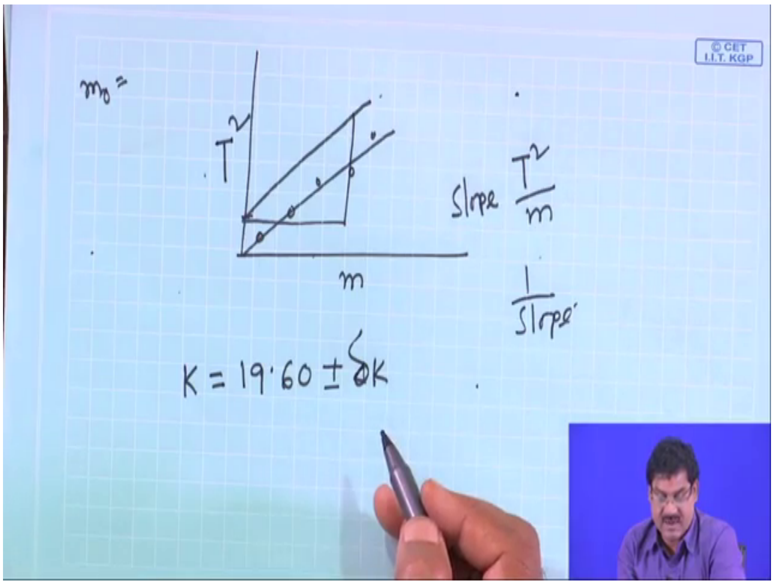

Now, just as I mentioned earlier; so you should plot the graph; you should plot the graph this you are changing mass and basically calculating the finding out the time period for different mass.

So, this if I plot this T square versus m. So, if m 0 I neglect; if m 0 I neglect then if you do not consider if you make m 0 is 0. So, then you will get a straight line passing through the this centre. If you, so this is your 5 point say distributed like this.

So, if you consider this m 0; so, there will be I think earlier here; I will show you where I have calculated m 0 yes here. So, here K you are plotting this m versus T square; m versus T square ok, so this part ok. And other part this 4 pi square by 4 pi square m 0 so that will be constant ok.

So, it will intersect the y axis; it will intersect the y axis when T square. So, either this curve you will get or this curve, but slope of this both curve; slope of this both curve is same. So, that is basically that is basically T square by T square by m ok. So, that will be slope of this curve; slope of this curve.

Now, so we have to find out the slope of this curve and that slope of the curve we will put in your yes in your equation here it is m by T square so, but slope you are getting T square by m. So, you have to take just inverse of it. So, you have to take inverse of it 1 by slope and put in this formula and you know pi square value so you will get the K value.

So, whatever the data we have; so we have calculated this K in generally yes we got it is K equal to 19.60 ok. Now, we have to find out the error ok; so that is plus minus some error delta K. So, generally I write this way delta K we have to find out.

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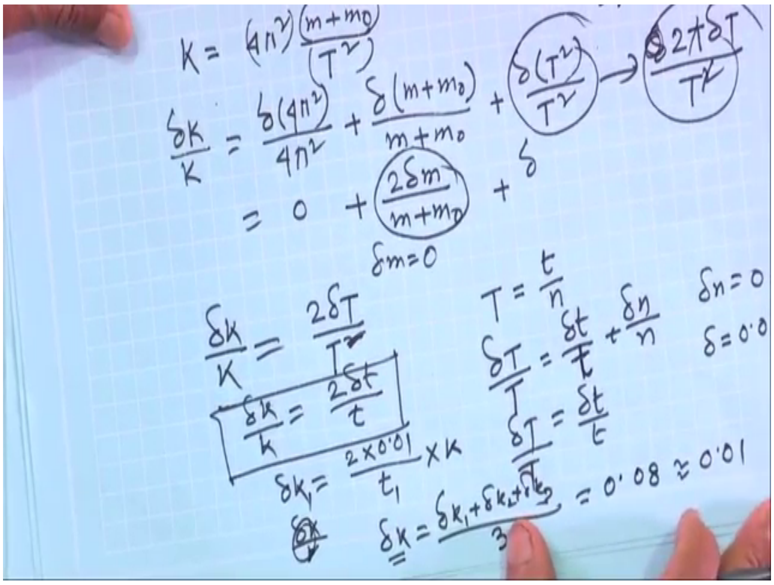

So, delta K to find out delta K; so, you know this you have to use formula K equal to 4 pi square; 4 pi square m plus m 0 divide by T square ok, so that is the formula.

So, now how to find out this error Delta K? So, this is the we can take this is the multiplication and division. So, relative error will be added for which one? So, relative error what is delta 4 pi square; this is the 4 pi square by 4 pi square plus delta this three terms multiplication and division in that format it is there plus delta T square by T square right.

So, naturally this is the constant ok so it will be 0. Now plus here; now here you can add this delta m plus m 0 summation and subtraction rules; so that is the just absolute one is added. So, it this will be basically 2 delta m; this will be basically 2 delta m divide by m by m 0. So, now delta m we are not basically measuring; so this is a, so delta m is 0, delta m is 0; delta m is 0.

So, this part also will be 0; so only this part will contribute delta T square ok. Now delta T square by T square is there delta T square; so you know this for any if this is the function of T if you consider. So, I think delta T square I can write delta T square will be so, like this y; q equal to T square ok. So, delta q equal to del q by del T delta T right; so q is T square. So, it will be delta T square delta q will be 2 T delta T; 2 T delta T and the here this T square is there.

So, basically here so this term is basically this term ok. So, basically you are getting delta K by delta K by K equal to 2 delta T by T square right. Now, T square we are not measuring directly; T again T equal to t by n righ T equal to t by n. Now again it is in difference in division form so, relative error will be added for this.

So, delta t by T plus delta n by n ok; so delta n we are we are counting. So, there is a delta n we will consider that is 0, but delta t; we will consider there is a values 0.01 ok. So, here basically you are getting delta T by T equal to delta t by its not this T; it will be this t small t ok delta t by t.

So, simply delta K by K is true delta T by here no not T square here this T and this will go; so it is a T. So, here delta T by T equal to delta t by t; so this is the form of; this is the form of error expression. So, now, easily you can find out what is this 2 into 0.01 divided by t; t see now for different mass we have calculated. So, we have to calculate error for each mass then their time period at different t 1, t 2, t 3 etcetera ok.

So, we have to put this time for different. So, we will get for each mass there is a error now we should take average of this error that will be delta K by K. I think; yes what I should do we should do. So, this delta K by K equal to this. So, this I will write delta K equal to this into K; because K value you know already we found this K value 19.60 so, I will multiply with 19.60, so I will get delta K.

So, I will get basically for different t; t 1, t 2, t 3; delta K 1, K 2, K 3. So, from there I will take average delta K equal to delta K 1 plus K 2 plus K 3 etcetera divided by this here if I take 3, this is 3 ok; so, I will get delta K. So, this delta K in with our data I have calculated it is around it is coming 0.0; I think I have calculated it is coming 0.08 ok. So, this approximately you can write 0.01 ok, you can write 0.01.

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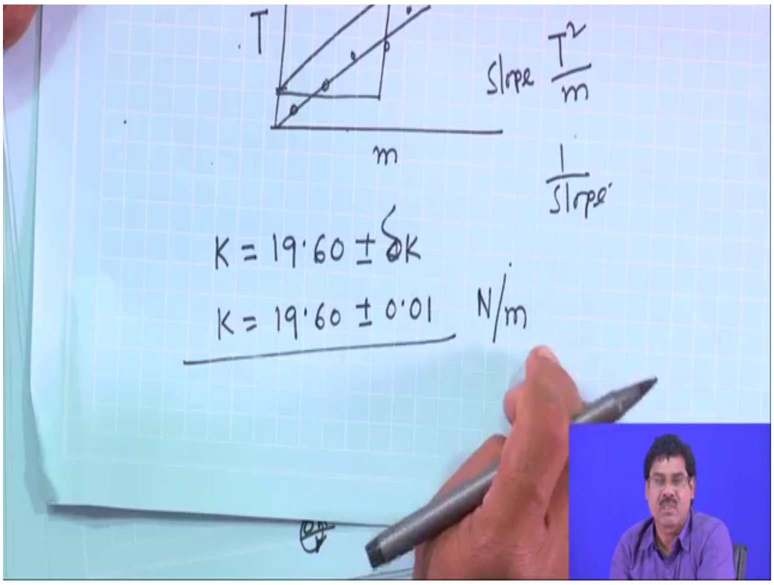

So, you result is basically we have to write K is spring constant; what you have find out, 19.60 plus minus 0.01. So, this is the result we have to report. So, this is the way after doing experiment basically you have to understand the working formula before starting experiment. And then depending on the formula you have to take data and then you have to analyse the data plotting graph calculation. And then error calculation and then final result you have to write this way.

And of course, you have to put your unit this unit whatever here. So, here basically it is Newton per meter because Newton per meter because per force per unit elongation ok. So, that the spring constant so, this is in Newton per meter ok. So, do not forget to write unit; all the time you have to write unit ok, otherwise this is the meaning. So, I think I have completed the experiment and the analysis on the determination of spring constant ok.

So thank you for your attention.