

Experimental Physics I
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Lecture - 23

Experimental demonstration to calculate the spring constant of a given spring

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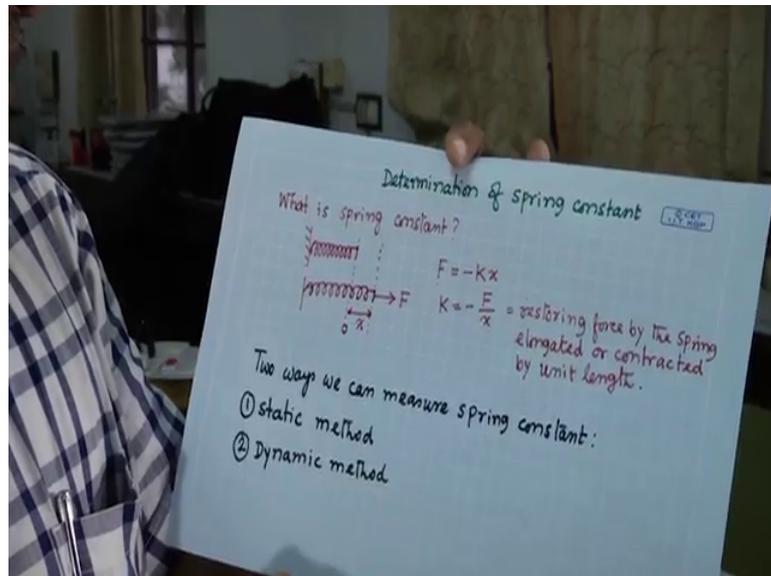
So, we will discuss about the experiment, that is determination of spring constant. So, this is the experimental setup for determination of spring constant. So, this is the spring and what is the spring constant of this spring? That is what we will find out ok, so this very simple experiment so, this one end of the spring is attached with a solid say stand and other end is basically used to put the weight and we will increase the weight and find out the extension of this spring and what for. So, basically for different mass what will be the extension of the spring? So, that is what we have to measure.

So, for measuring that is extension of the spring, we have a, here this scale, we have a scale so, this meter scale basically, it is the 0 to 50 centimetre and this least count of this scale is basically 1 millimetre. So, this is the pointer, which basically we will take reading of this pointer.

So, as I discussed that there is a two method, we use in laboratory to find out the spring constant. So, this one is static method and another is dynamic method. So, what is static method? Static method as you know this free for spring mass system it follows the

Hooke's law it follows the Hooke's law.

(Refer Slide Time: 02:29)



So, in this case, this we will apply different force on the spring, if this force is F then if extension of the spring, elongation of the spring or contraction of the spring is x . So, the relation between the force and this elongation or contraction of the spring that x , they are basically proportional, so then F equal to Kx . So, K is proportionately constant and this K is called spring constant right and minus sign here. This is basically in elasticity all always we conceived the restoring force. So, this applied force and restoring force is basically equal. So, if we apply force and there will be deformation of the body and body also just it apply just opposite force equal to the applied force that force is, we tell this is a restoring force.

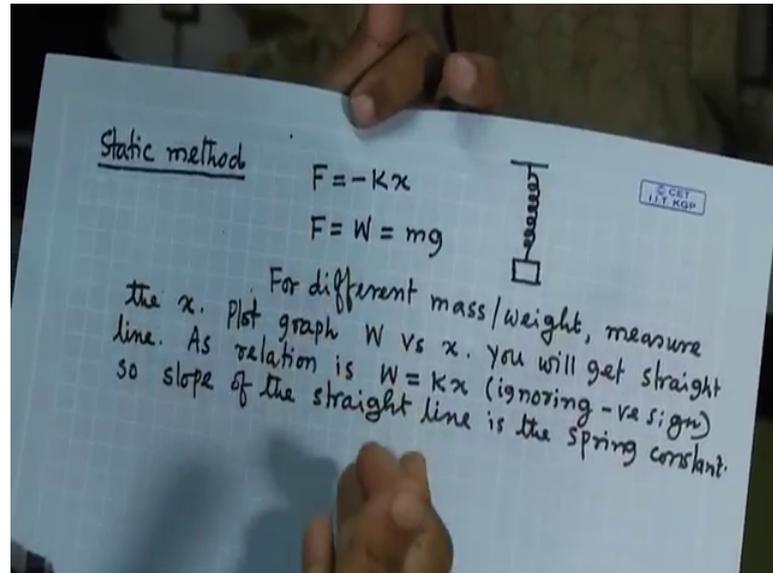
So, in this case this restoring force F and this elongation x , there in opposite direction, that is why this minus sign comes ok. So, we want to find out the K spring constant ok. So, this spring constant K is then equal to equal to minus F by x . So this, let us ignore this minus sign. So, just then just because this minus come, because of the direction of the force and the force and the elongation.

So simply we can write this K equal to F by x means K is nothing, but the spring elongation the force by the spring. No I think it is the restoring force by the spring elongated or contracted by unit area, so for unit change of length of the spring, how much force we need to apply? So, equal amount of force will be the restoring force. So,

that is basically that force amount of force per unit length that is the spring constant.

So, we can measure the spring constant in two ways, as I told this static method and dynamic method ok. So, static method is let us just discuss the static method.

(Refer Slide Time: 05:27)



So, our force equation here is F equal to minus Kx . So, F as I told, I will ignore the minus sign. So, F in this case F force, so we can use the gravitational force so; that means, if I put weight on it then this load, if we apply load. So, for mass m this force will be mg , gravitational force will be mg for mg force. So, what will be the elongation of the spring that is what we have to find out.

So, basically if I vary the force means if I vary the load, if I vary the mass so, for different mass I will get different elongation and that elongation I will measure using the scale and this pointer and then. So, then we will make a table where load versus the spring elongation. So, if we measure that one, so then you can plot the graph W or mg versus x ; that is what these two we are measuring and then it will be the straight line and the slope of the straight line will be basically, constant K

So, how we will measure that? I will just show you how we will measure the elongation for different mass that I will show you.

(Refer Slide Time: 07:09)



So, I have here mass; I have here mass so, this is the 100 gram mass and this also 100 gram so, this force are 100 grams and this rest of the mass is 50 gram, it is there 50 gram. So, initially I kept without any mass or whatever this initial, this mass is there. So, I have kept this indicator so, needlepoint at 0, needlepoint at 0 right.

Now, this is my initial reading. Now, I will put say let me put 100 gram first, let me put 100 gram first ok; let me put 100 gram first and then just let it be stable it is vibrating so, then I have to take reading. So, what is the reading? So, from here you can take this, reading is 1.2 centimetre, the reading is 1.2 centimetre.

So, then I will note down for mass, this is the 100 gram and the this extension that x reading is 1.2 centimeter ok. So, then I will put another mass say, another 100 gram, I will put now this for that is for 200 gram it is now, I think it is some is it is touching this side. So, I think this 200 is too much.

So, let us vary with 50 gram. So, 100 gram is there, then I will put this 50 gram; I will put this 50 gram ok; I will put this 50 gram and then reading, I will take the reading ok. So, it is around 2.2 it seems it is 2.2 it seems. So, this slightly I have to rotate it seems slightly I can, I slightly, I have to that me. So, then I have increase mass by 50 grams so, now, it is 150 gram. So, for 150 gram what is the reading? We have to take it is the is let it be stable it is fluctuating just give it time, right time is ok. So, it is it between the 2.2.1

So, let us take this, it is vibrating, I think with respect to 2 so, it is reading, we will take 22.0 ok. So, this way I will just increase by 50 gram, I will put another 50 gram then I will take this reading. So, I will put another 50 gram then I will take this reading. So, this way I will take at least 5 to 6 reading; at least 5 to 6 reading and then I can repeat this reading when I will reduce the mass so; that means, whatever the maximum for 5 6 mass we have put here so, each mass is 50 gram initial one was 100 gram.

(Refer Slide Time: 10:41)



So, now, I will reduce the, so for this mass, what is the reading that is that I will take now, I am reducing the mass. So, during increasing the mass, I will take the reading and again during reducing the mass, during reducing the mass I will take the reading.

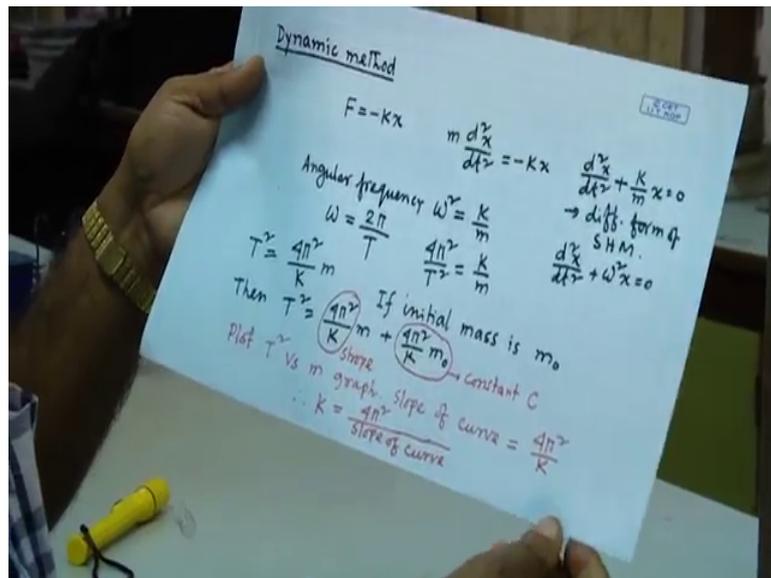
So, then I will set get two sets of reading one is when we are increasing the mass another is when we are decreasing the mass then from whatever the initial value. So, the value it was basically 0, so if it is not 0 also it is fine. So, just initial reading, we have to just minus from each reading then you will get for each mass, what is the each mass, what is the extension of the or elongation of the spring. So, now a data is ready this, your mass now multiply with g so, that will be mg . So, there is W for different load, you have this depression for during reducing mass, increasing mass and reducing mass. So, from there you have to take basically average elongation, you have to find out average elongation.

Now, we can plot the graph or this load versus the elongation and you will get a straight line and from that straight line, we can basically that the slope of the straight line, you

will be the spring constant that is what I showed you. This relation is W equal to F . So, W versus x if you plot, so this slope of the curve will be K so, this way we one can find out the spring constant so, this is the static method.

Now, there is another method galley in our lab, we prefer to do this experiment that is dynamic method ok. So, that is the dynamic method. So, what is that method?

(Refer Slide Time: 13:23)



Basically, F equal to minus Kx that we know. Now, F is m into acceleration d^2x by dt^2 square equal to minus Kx . So, this d^2x by dt^2 square plus K by m x equal to 0 so, this is the differential form of simple harmonic motion ok. So, this simple harmonic motion the differential form we write d^2x by dt^2 square plus $\omega^2 x$ is basically, the angular frequency of this spring mass system.

So, then this ω^2 is nothing, but ω^2 is nothing, but K by m . So, and again ω equal to 2π by T ; T is the time period. So, ω^2 equal to $4\pi^2$ by T^2 equal to this K by m . So, this relation is telling that if I rearrange this relation, I can write T^2 equal to $4\pi^2$ by K m ok.

So, here you can see; so, to find out the K value, to find out the K value I experimentally, I have to measure time period of oscillation for a particular mass. So, in this experiment in dynamic method we will apply, we will just load different mass and for each mass what is the time period, that we have to find out and then what we can do. So, here one

can consider the initial mass of this initial mass of this 1 ah. So, without any mass put here. So, that if it is m_0 then also there is no problem so, if it is there, if we consider this initial mass m_0 .

So, then basically m , this m will be replaced by $m + m_0$; $m + m_0$ then T^2 equal to $4\pi^2$ square by K into $m + 4\pi^2$ square by K into m_0 ok. So, this is the constant term as if it is C and this is also constant and this will be the slope right. This will be the slope I think slope so, there is a mistake. So, it will be slope slope so, then for different mass this is the variable. I will measure the T then if I plot T^2 square versus m then I will get a straight line and that is straight line will not pass through the 0, it will cut the y axis. So, this will be the intersection of the y axis ok, means T^2 square axis. So, from T^2 square versus same graph, we can find out the slope of the curve and the slope of the curve will be $4\pi^2$ square by K so, then K equal to $4\pi^2$ square by slope of the curve.

So, from curve, from plot T^2 square versus same plot we will get the slope of the curve and this is the constant, so we can calculate K ok. So, now, only experimentally, we have to measure the time period for different mass ok. So, at least 4 5 mass, we can do, because we have to plot graph. So, for this we need stopwatch; for this we need stopwatch ok.

(Refer Slide Time: 17:25)



So, this is the digital stopwatch, it has start and stop button here; it has start and stop

button here ok, if I just press it, so it started ok, it is the changing. So, it is the so it is changing second in second. So, it is we can get the reading in fraction of second also, but we do not need in fraction of second. So, here basically we will take least count as a second, so 18 19 20, it is changing ok. Now I can stop it ok, then I can read the reading ok, it is 23 second and some other 87. It is a fraction of a second in so, that we will ignore it. So, this is the reset button, I can reset it then start, stop, reset ok. So, this we will use to measure the time period.

So, what is the time period? So, for a complete one oscillation what is the time it is taking. So, that is a time period. So, in this case what we will do? So, it is difficult to just take time for just one oscillation. So, if it is the starting point one complete oscillation will be, just it will go down and come back at the initial points. So, this will be one complete oscillation, then it will be repeated. So, what I will do? I will just count number of oscillation, count number of complete oscillation starting this watch and say 20 30 40 oscillation. I will take and then stop it and then I will take this. So, total time taken for this 20 30 or 40 oscillation then for one oscillation. So, this total time divide by this number of complete oscillation, I will find out that is the time period ok, so that I will repeat the experiment for different mass.

So, let us start the experiment; let us start the experiment. So, here first I have to put some weight. So, this is the initial starting point; this is the initial starting point ok; this is the initial starting point and so, in this case I do not need scale; I do not need scale. So, just I will put, so, this whatever the, it is weight, I do not bother. So, initial when it is say if it is m_0 . So, as I told, because of this we will get the intersection at y axis, but I do not bother that one. So, only now I will put weight say 100 gram, this is the 100 gram ok, 100 gram. Now, for 100 gram weight, 100 gram plus m_0 something is there for that, what is the time period that I want to find out? So, what I will do? I will just disturb it, just I will elongated it slightly and then leave it.

Then now I have to measure the time period, I have to measure the time period. So, in convenient way I will start it ok. So, it is very difficult to measure, because it is too fast, but you remember that relation between time period and this relation between the time period and the mass is basically here. You can see it is the time period and mass, it is the square of the time period is basically proportional to the mass; that means, if I increase mass, time period will increase ok. Time period will increase means for a one oscillation

it will take more time ok. So, in this case it is taking less time, so and for me it is difficult to measure, also to difficult to count it. So, from this knowledge what I will do? I will increase the mass for taking the reading.

So, let me put another mass ok; let me put another mass of 100 gram. So, this is 100 gram. So, now you will see, this is 100 gram ok, this is 100 gram ok, now it is 200 gram. Now, for 200 gram plus some initial mass, so for that you see the interestingly if I just disturb it; if I just disturb it, you see now its time period is higher. Now, I can easily count if the starting point is this ok. So, if start from the down, so 1 2 3 4 5 6 7 8 9 10 11 ok.

So, now I will start my clock ah. So, when it is down then I will start ok, start 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30. So, just I will stop it.

So, you see starting and stopping. So, at this 2 point, I think there will be some mistake. So, to distribute this mistake over this total count, so it is always better to take higher number of count. So, I have taken 30, but you can take 50, if you take 50 this is it, your result will be better. So, here I can see for 30 count so, this reading is 21 seconds. So, in 21 second this 30 oscillation. So, for one oscillation, so what is the time? So, 21 divide by 30 right. So that will be the time period. So, this way for different mass we should repeat the experiment. So, this I have done for 200 gram then I will increase by 50 gram, I think I will put this way, I will increase by 50 gram so, now, it is for 250 ok.

Now, again just I will reset it, I have to be ready. So, again for 250 gram mass I just disturb it ok. You see again this time period now becoming higher. So, it is the becoming easier to measure, here will be less in counting. So, I will start, so ok. So, when is it's down, I will start it, start 1 2 3 4 5 6 7 so, this way you take 30 40. So, this time probably 30 is good enough. So, this way I will take 30 count and stop it and take the reading right so, find out the time period.

So, what we are doing? So, at least I need 5 to 6 data point ok, because I have to plot graph and it is straight line. So, 5 to 6 point 2 2 will be good enough to draw a straight line. So, for that way I will just at the mass here and find out the time to also you can do in just reverse way, also we had decrease. So, that I do not think we need, because we are not taking reading here. So, just increase the mass and for different mass you find out the

time period ok.

So, now we will do calculation, we will find out the time period square of the time period and, versus this I think versus this mass ok. So we will plot at x axis this mass and y axis T square. So, T square versus m graph that will be straight line and now from straight line how to find out the slope. You know I will show you that calculation I will show you and how to find out this K that I will show you, but this from this graph basically, we will find out the slope.

Now, $4\pi^2$ by slope of the curve, then it will be your spring constant ok. So, I will discuss about the calculation and other this error how to calculate error in this measurements. So, that I will discuss in the in next class, so I will stop here. So, this is the very nice experiment for this for determining the spring constant.

So, thank you for your kind attention.