Experimental Physics - II
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Lecture - 02
Summary of Experimental Physics-I

You are welcome to the 2nd lecture of Experimental Physics II. In the first lecture, mainly I have discussed: what is the aim of this course. Also, I have shown you the broad syllabus for this experimental physics II. Today let us just look back to the Experimental Physics I: what we have learned there. Let me summarize the experimental physics I.

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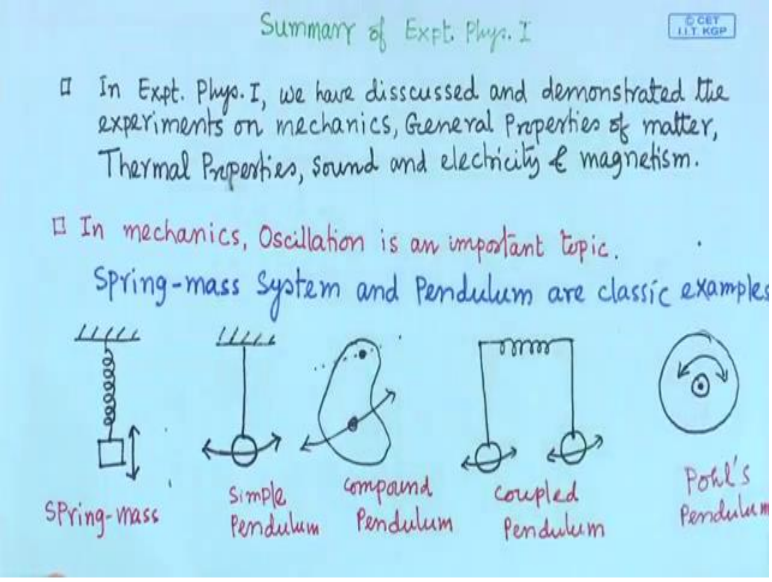

In experimental physics I, we have discussed and demonstrated the experiments on mechanics, general properties of matter, thermal properties of matter, sound and electricity and magnetism. There were many experiments which have been demonstrated in the laboratory.

In mechanics, oscillation is an important topic and we have done some experiments on spring-mass system and pendulum; because spring mass system and pendulum are classic examples in mechanics. Say, this is the spring and one mass is hanged from this spring. It can be vertical or it can be horizontal. So this is a spring mass system.

And this is a simple pendulum where a mass is hanged from a thread; it will oscillate; this is basically simple pendulum. If we take a body of any shape and then if you displace this body at this point; then leave; this body can oscillate.

This type of object is called compound pendulum; this type of object when oscillates, this will be called as a compound pendulum. These are two pendulums; when they are coupled with a spring, then we tell this is a coupled pendulum. So, its oscillation is slightly different from the single pendulum.

Also this is Pohl's pendulum; About Pohl's pendulum we have learnt that a metal disc is oscillating in a magnetic field. It is a classic example of free oscillation, damped oscillation, and forced oscillation. So this is the beauty of the Pohl's pendulum. All of them we have discussed in experimental physics I. What we have learned about these things let us summarize it.

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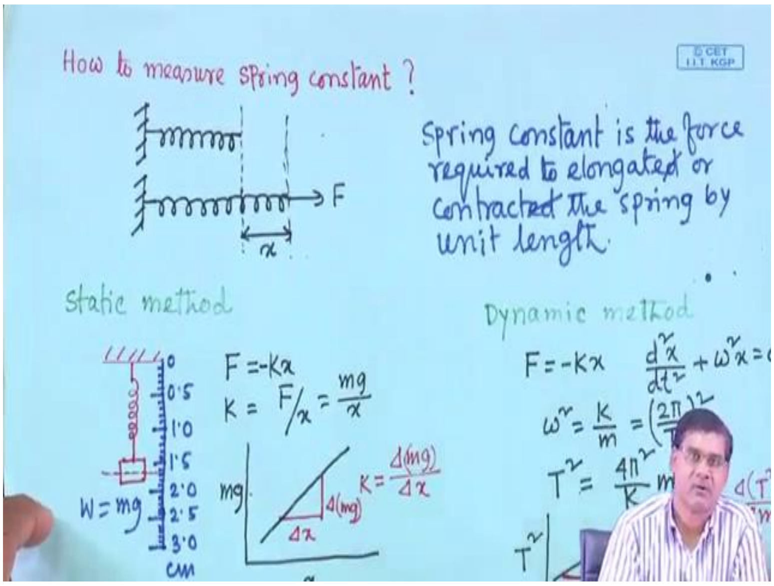

How to measure the spring constant? We have a spring; now this spring is elongated after applying a force F and it is elongated by x. So, what is the spring constant? Spring constant is the force required to elongate or compress or contract by unit length, ok. So, spring constant is F by x when F is proportional to x.

F is proportional to x, so F = -Kx. So, this K is constant; it is basically called spring constant and this negative sign is for this restoring force. Because, you are applying force and the restoring force is opposite to the displacement. This F is basically, which you have applied, equal to the force acted opposite to the applied force; that is called the restoring force. It is because of the elastic property of the material.

So, this K is basically F by x if we neglect this negative sign. And, this F it can be mg; when you take this spring mass system; when you take it vertical. So, this spring and you applied mass here. So, the weight W will be mg and because of this weight it will extend this spring, right.

How much it is extended you can measure from a scale, right. Now, in experiment, we do not take only one data. When $K = mg/x$, for a particular mass and known g value, you will measure x from this scale, which is extension of this spring. Thus, you can calculate this K; but in experiment, always we take more data to reduce the error, ok. Then, we take help of graph.

We will apply different mass, we will apply different mass, ok; that means, difference weight, different force. And for that force what is the elongation that we will measure from this scale, for different mass, for different weight. Then, you can plot mg versus displacement, mg versus elongation, extension. Then you will get a straight line and you can find out the slope. This slope is nothing, but the spring constant; this slope is $\Delta mg/\Delta x$. So, this is nothing, but K and this is the K, the spring constant.

That way one can find out the spring constant and that we have demonstrated in the laboratory, ok. This is generally, we tell, this is a static method; people can use another method, that is called dynamic method. Basically, this spring, this spring mass system, just if you displace or disturb this mass or just extend it and leave it then it will oscillate.

If you can measure the time period for this oscillation, then you can calculate the spring constant. As $F = - Kx$; so, $d^2x/dt^2 + \omega^2 x = 0$; where $\omega^2 = K/m$, right and $\omega = 2\pi/T$. So, you are getting the $T^2 = (4\pi^2/K)m$; this relation you are getting. If you use different mass, for different mass if you find out the time period; square of the time period if you plot along the x axis for different mass, then you will get a straight line.

This $4\pi^2/K$ is basically slope. So, we can find out the slope; that means, $K = (4\pi^2/K)/\text{slope}$. Slope you are getting from this plot and pi value is known to you. So, you can calculate K. This is the dynamic method. So, this is the way one can find out the spring constant of a spring, ok. Now, what is the importance of spring in application of our daily life? We are quite familiar about the application of the spring.

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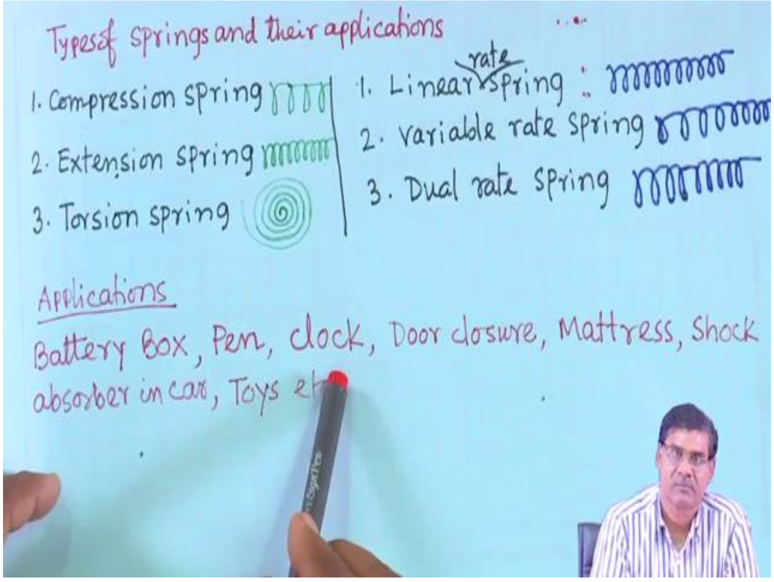

There are different kinds of, types of springs and their applications. This spring is categorized like compression spring; it can be compressed, this spring can be compressed. Extension spring: this is the spring, it can be extended; it is used for extension where you need to extend the spring for applications. This type of spring is torsion spring. This kind of spiral spring is called torsion spring, ok.

This is the way, the springs are classified. Also it is classified in other way, different way also. It is called linear rate spring; linear rate spring or constant rate spring means these patches are equidistance. This is called linear rate spring, variable rate spring. The patches distances are different. So, it is called variable rate spring; varying this distance between the successive loops. And, then also another type is dual rate spring. In dual rate springs, some portion is having, say hard spring and some portion is this type; this may be, this part is soft spring, soft part. This soft and hard, both part in a single spring. So, it is called dual rate spring.

What about the different types of springs which are used for different purposes? Some of the applications, you are familiar. Say, battery box, in battery box when you place battery for electrical connection, this spring is used. I think, torch, if you have used torch or radio or some multi meter where you have to put battery. If you see it, that we are telling battery box, where in the instrument we put the battery.

So, there is always, you have seen, there is a spring because of two purposes for using this spring; one is: it will give electrical connection, because it is made of metal and also it will keep it tight, ok. So, in battery box we use spring; in pen we have seen we use spring; in clock this spring is used; in door closure we have seen that door closes automatically if you open the door and then leave it.

So, automatically it is closed, because this spring is used. So, in door closure, in mattresses also spring is used, and then spring is used for shock absorber, as a shock absorber in car it is used to minimize, to damp the vibration. So, this is called shock absorber in car; in toys, spring is used; different kind of toys are made using the spring.

There are many kind of applications of spring. And, spring constant is important for different application and how to measure the spring constant. So, that we have learned, it is very simple, in any laboratory easily we can measure; we have demonstrated, right.

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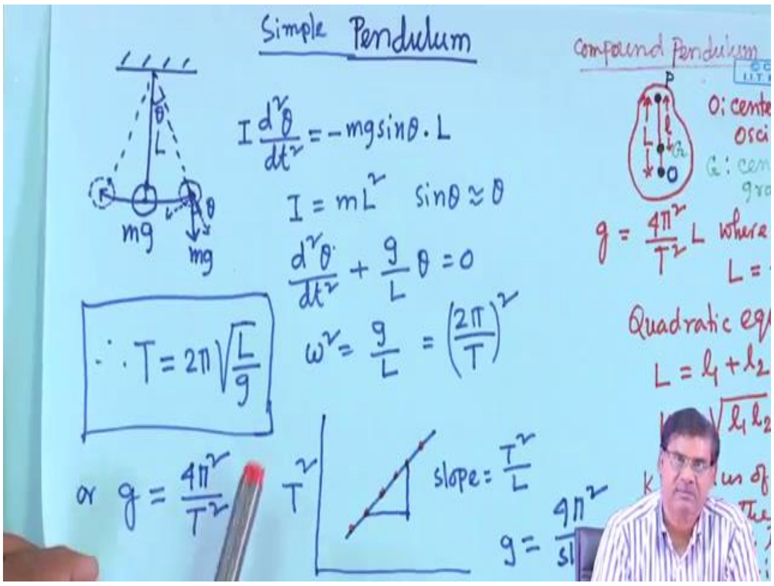

Next pendulum, simple pendulum, although we have not demonstrated these simple pendulum in a laboratory, I think most of you have done this experiment in class 12. But this simple pendulum is basically used for measuring the acceleration due to gravity that g value, ok. This is very simple experiment and is very important in the sense that using this simple experiment, one can find out the universal constant g, acceleration due to gravity, right.

Simple pendulum is basically a mass hanged from a thread. This, from this fixed wall, thread is hanged; basically mass is hanged through this thread. Length of this thread is L and mass of this bob is m right. So, force will act downwards, that is mg. Now when you will displace this bob by angle theta; at this place this force will act downwards, mg. Now, you can get two components: one is along this thread; this will be mg cos theta, because this angle is theta, right and perpendicular component will be mg sin theta.

This mg sin theta is the force which is responsible for restoring force. So, it will try to take back this bob from here to the original position, ok. Now, if you write the equation in terms of theta, like $m(d^2x/dt^2) = F$. Here basically it is not linear displacement, it is the basically rotation about this axis, ok. Then change of theta, change of angle with time, so $d^2\theta/dt^2$ and the moment of inertia, I is moment of inertia. When displacement, x is replaced by angle theta, then mass is replaced by the moment of inertia, right.

In linear motion whatever the function of mass seen, in rotational motion the same function is, it is basically represented by the moment of inertia I, right. So, $I\, d^2\theta/dt^2$ equals to, now this is not force, so equals to basically torque. Here $mg\sin\theta$, as I told, this is restoring force, ok. So, torque will be this force into distance, the distance from this point, the distance is L, ok. So, torque will be $(mg\sin\theta)L$, right. These are quite familiar equation to you.

Here moment of inertia $I = mL^2$, and if θ is very small, for $\sin\theta$, one can write θ. This is your equation: $d^2\theta/d^2t + (g/L)\theta = 0$, right. This part is ω_0^2 or ω^2. So, $\omega^2 = g/L$; $\omega^2 = (2\pi/T)^2$. Thus, you are $T = 2\pi\sqrt{(L/g)}$; this is very known formula or $g = (4\pi^2/T^2)L$, right.

If you are interested to find out the acceleration due to gravity g, from this equation you can see: for different length, if you can measure the time T, then we can plot T square versus L, we will get a straight line; for different length, will get different points, will get different points.

Now, if you find out the slope of this straight line, this slope will be $4\pi^2/g$. That is slope; slope will be got from this straight line. $4\pi^2$ is known. So, we can find out the g value, right.

This is the way one can find out the g value, the universal constant and one can find out this value, one can measure this value very accurately using this simple method. This is the beauty of the pendulum, simple pendulum, right.

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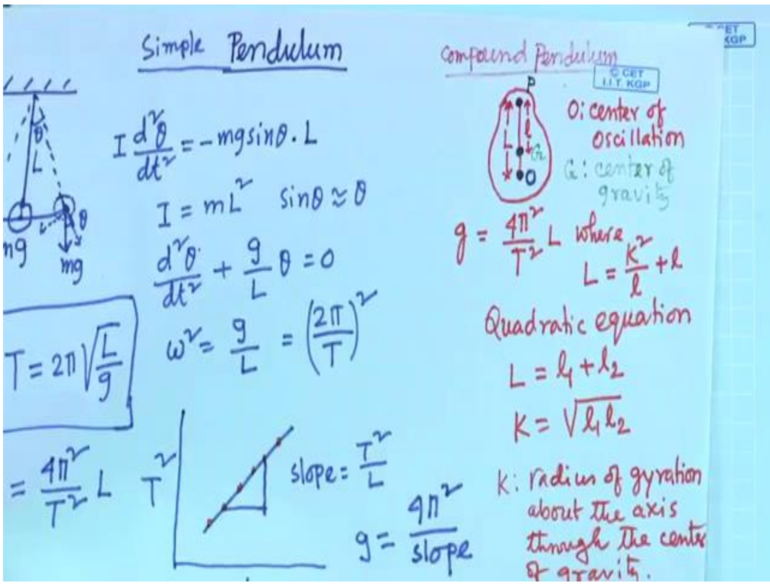

Now, compound pendulum, it is as I told, if you take an object of any shape, this object is pivoted at a point P, ok. Now, center of gravity, say it is G, and O, this point, is basically center of oscillation, center of oscillation; then the distance of G from P, if it is small l and distance of O, center of oscillation, O from P if it is capital L, one can find out that g equal to 4 pi square by T square L. This formula is nothing, but this formula, right. That means, this compound pendulum, it is just simply, simple pendulum if you think that whole mass is concentrated at a point O. And, then this mass is oscillating with respect to the point P. This O, this point O, it is called the center of oscillation, ok. If distance L, see just like a simple pendulum; this formula is for simple pendulum, it is same formula which one can use.

In principle in this case, we have converted this system for comparison to the simple pendulum and the known formula we have written, but here this L we do not know, the center of gravity one can find out, but we cannot find out this O directly, right. So, this distance L, we cannot, directly we cannot find out. So, L, it is related with other factors; it is related with L and the radius of gyration, K.

This $L = K^2/l + l$, ok. So, this is a quadratic equation of l. We will get two solutions of l: l_1 and l_2 if you solve this one. From this quadratic equation one can get this capital $L = l_1 + l_2$. And, this radius of gyration $K = \sqrt{(l_1 l_2)}$, ok.

Now what are l_1 and l_2? l_1 and l_2 are two lengths; this is l, and 2 length for same time period T. For same time period, we will get two lengths in this system, in this object, irregular shape object, we will get two lengths: l_1 and l_2 and for that, the time period will be same. So, that is the l_1 and l_2, ok.

One has to find out l_1 and l_2 and how to find out that we have discussed and also demonstrated in the laboratory. We will change length means one will change basically point P at different places; then we measure the time period T, right. If you plot the time period versus this small l which is the distance from P to G. Then you will see, you will get a curve like this; you will get a curve like this, ok. I can show you.

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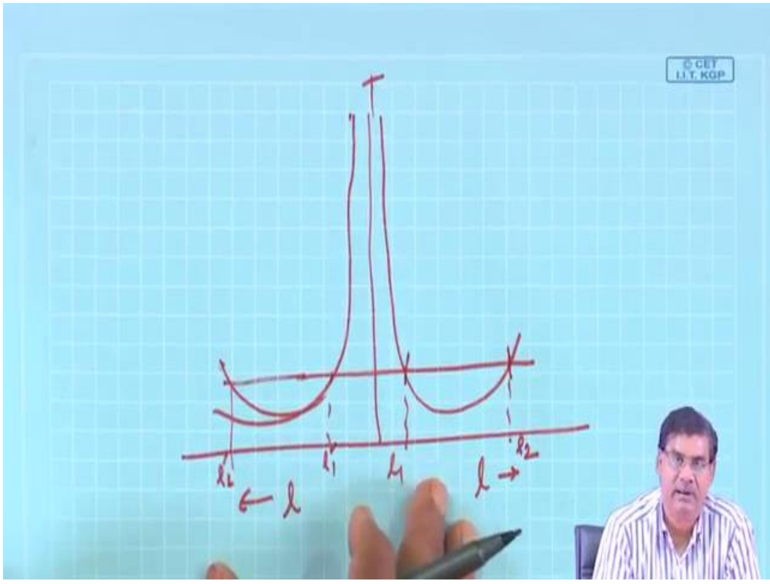

If you plot; if you plot, you will get a curve like this, ok. This is the one if you take in opposite direction; similarly you will get, you will get this way curve like this; I think this way. So, if you, for same time period, this is T and this is l for same time period, if you choose a time period, for same time period, basically you will get two l, ok; this is one, say it is l_1 and this is another, this is l_2, ok. Similarly, this in other side also l_1, l_2: you will get l_1 and l_2; then you can get l_1 dash, l_2 dash. From them one can find out or get the average 1.

We have discussed experimentally how to find out l_1 and l_2 and then basically you will see this l 1 and l 2 and you will calculate, you will get the capital L; because l_1 and l_2, you will get from curve; so, we can calculate capital L. When we will calculate capital L, then you can find out this g value. Because capital L for which T value for, as I told, for a same period you will get two length: l_1 and l_2. From the graph you will choose a time period T and for that you will find out l_1 and l_2; so from them you will get capital L. You know now capital L and T, so we can calculate the g.

Using the compound pendulum one can also find out the acceleration due to gravity g value, ok. And, also from this, from compound pendulum, one can find out the radius of gyration, radius of gyration about the axis through the center of gravity. Now, about the center of gravity G, what is the radius of gyration? In this case radius of gyration is basically about the axis passing through the center of gravity. From where it comes? It comes basically when you write this equation like this, ok, so this moment of inertia that will be there. So, that moment of inertia basically with respect to this P; because it will oscillate with respect to this P.

Using the parallel theorem, one can, this I_G, moment of inertia with respect to center of gravity, $I_G + ml^2$. So, this type of relation comes. They are basically that I_G moment of inertia about the axis passing through the center of gravity; that is I_G, ok. They are this K and I_G is basically, it is mK^2 where K is called the radius of gyration. Also one can find out from this compound pendulum experiment, one can find out the radius of gyration also apart from the acceleration due to gravity, right.

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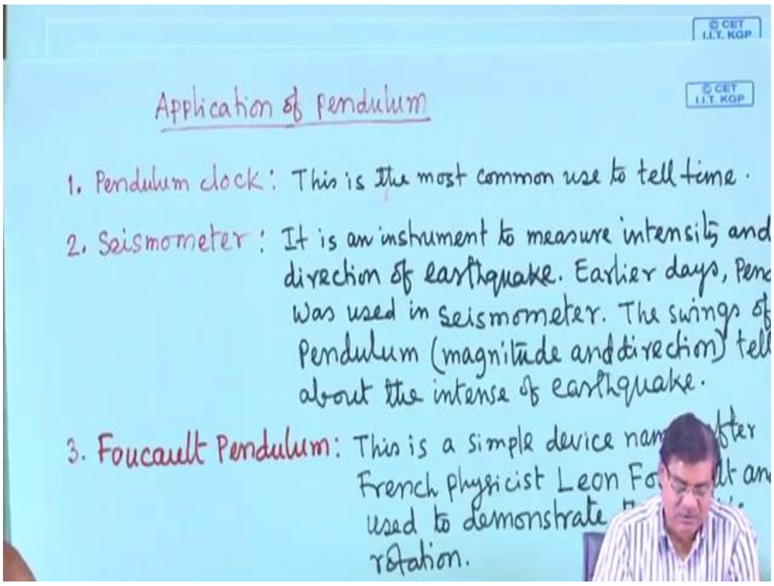

What is the application; what is the application of this pendulum? Again there are applications, common applications in our day to day life. One application, you know, all of us are familiar with the pendulum clock, right. Pendulum clock nowadays, we do not see much; but earlier days this was the most common use to know the time. This was the most common used to tell the time, ok. So, pendulum clock was the only clock in earlier days. Then seismometer: seismometer is another instrument. I will continue this discussion in next class. Let me stop here.

Thank you.