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

Lecture – 36
Demonstration on the experiment of compound pendulum

So, today we will demonstrate how to measure acceleration due to gravity using compound pendulum.

(Refer Slide Time: 00:31)

So, this is a very simple set up for computer pendulum compound pendulum. So, it is a rod and with having many holes. So, you know this simple pendulum here I can show, you we have used simple pendulum a mass basically a mass is hanged by a thread.

(Refer Slide Time: 01:02)

So, here main assumption is that this all mass is concentrated in this in this bow and the mass of this thread is negligible ok.

(Refer Slide Time: 01:16)

So, sent; so this simple pendulum here you have thread and you have mass and it is hanged from a; from a support right. Now the system is oscillating right; actually here this mass is oscillating and with that this thread is also oscillating. So, this; so to find out the time pivot actually what we do this basically we have to take the oscillation; we have to take the distance of the center of mass of your system from the from the support ok.

So, since this mass is negligible. So, center of mass it is expected that it will be the center of this of this of this mass. So, distance effective length of this pendulum we take from here to this center of this one; so this is the l ok. So, then we time period we tell this t equal to 2 pi square root of l by g; l is this one. So, what is l? l is basically this from where this is the axis of is rotation ok. So, this is the axis of rotation with respect to this axis of rotation as if it is rotating.

So, this is the axis of rotation we can tell; so with respect to. So, here is the oscillation is the rotation. So, moment of inertia is important the moment of inertia is mass into distance. So, here this distance is basically from here for axis of rotation to this center of this mass; so this is m l square ok. Now, imagine that it is not now is not a mass less, it has mass now when it is oscillating not only this mass is oscillating; each part, so this mass is distributed over this length and each mass is oscillating each mass is oscillating. Now moment of inertia of this system of this set up will be different ok.

So, because now center of mass of this system will not be this one; it will be somewhere some other places ok. So, we have to find out the center of mass of this when mass is distributed; we have to find out the center of mass. And this center of mass now the center of mass is basically the oscillating ok; so that distance we have to take from here to this center of mass that distance we have to take. So, this is the; so if only if it all mass is concentrated in the center of mass here ok; then it is oscillating.

So, what is the; what is the moment of inertia of this of this system. So, that is basically we express in terms of it is called this I will tell you that radius of gyration; that is that after which distance this all if you concentrate all masses ok. So, if only that much is oscillating; so whatever the moment of inertia now for the whole system the moment of inertia there is the same as that one. So, then that distance is called radius of gyration right.

So, that we have to take care in this in the case of compound pendulum. So, compound pendulum is basically this it, what is this? This is basically this equivalent to simple pendulum only difference is that this thread is not mass less; it has mass ok. So, now, let me show you. So, this I can take this is a; this I can take as a compound pendulum ok. So, I have to find out first the center of mass of this of this of this rod; here we have taken rod you can take any shape it is not necessary that we have to take this regular shape, you can take of any shape, but we have to find out first center of mass ok.

Now, of to find out the center of mass; so we have some arrangements here.

(Refer Slide Time: 07:04)

So, we will put it on a sharp edge; we will put on a sharp edge to and then get the balance point get the balance point just you can check it. So, efficiently one has to do; so I think let me try to make ok. So, it is a more or less this is the center of mass of this of this rod this is the center of mass of this rod more or less, but more precisely you can do it; more precisely you can do it. So, you have to just try you have to just try; now it has gone yes. So, this is the center of mass; I have to mark it I have to mark it more or less I think, but that is; anyway I think it is one has to try and get this position one has to more or less I got it.

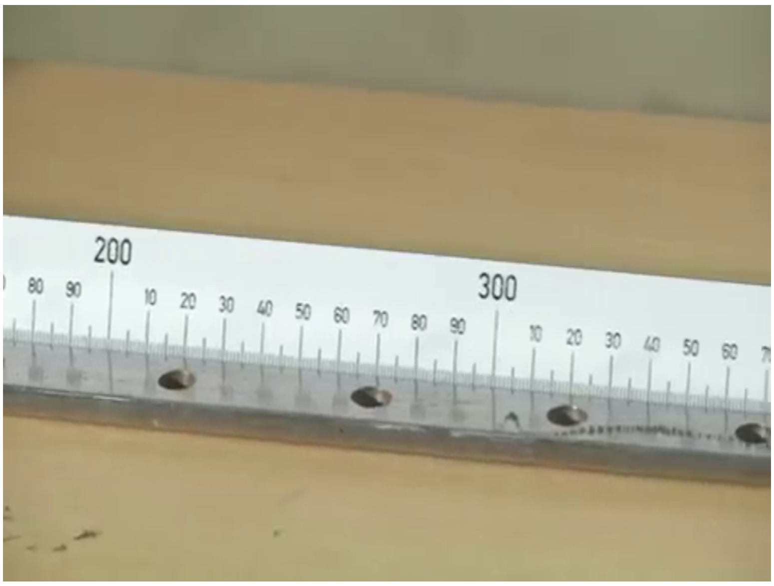
More or less I got it ok. So, this is the position this is the position for the center of mass ok. So, then I will mark it with marker I will mark it with marker.

(Refer Slide Time: 11:24)

So, I think I take a scale and mark it with marker. So, I have marked it I have marked it; so this is the center of mass of this rod ok; so to find out after finding out the center of mass; so I just hang it. So, this is the basically we will take as a axis of rotation or oscillation. So this; so we have arrangement to hang it, we have arrangement to ok. So, we have arrangement to hang it; so I have hanged it.

So, here I think I could just showed you once more. So, this total length this total length of this rod is basically this exactly 1 meter; exactly 1 meter.

(Refer Slide Time: 12:51)

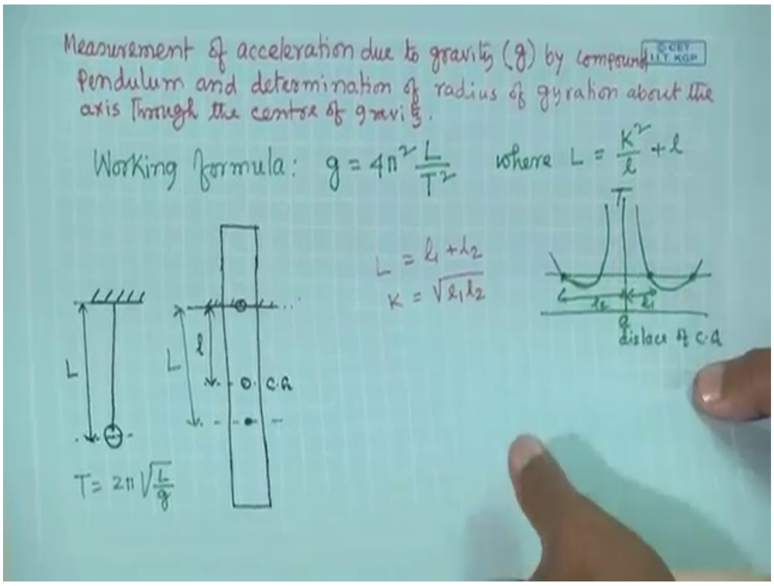


So, this is the; this scale is you see they see millimeter 100 millimeter means 10 centimeters. So, up to 9; 900 millimeter means 90 centimeter; so this is the 1 meter. So, the scale this length of this rod is 1 meter 100 centimeter and you see that just center of this inch hole. So, from here this is the 2 centimeter, from here it is also 2 centimeter and center to center of each hole is 5 centimeter. Here you see this is a it is a 80 millimeter and here it is 30 millimeter, it is a 50 millimeter means 5 centimeter.

So, this each hole defines between this each hole is basically the 5 centimeter and from this end it is 2 centimeter and my centers is more or less you see at the middle is 50 centimeter. So, this is; so if it is a 50 centimeter. So, when I will hang this one from this point from this point. So, from the axis of rotation the distance of this center of mass is 50 minus; this 2 is the 48 centimeter ok.

So, that how we can just we will just we will take different distance of the center of mass from the axis of rotation. So, just initially it will be 48, then minus 5 means 43, then 38. So, this is for different length of center of mass from the axis of rotation we will we will measure the; of time pivot. So, of then with time pivot what are the parameter related that I will I tell you; already we have disused in previous class what are the theory or working formula for this experiment and there; there I have showed you that this working formula.

(Refer Slide Time: 15:17)



So, for this experiment basically we will find out the acceleration due to gravity; that is g by compound pendulum and determination of radius of gyration about the axis passing through the center of gravity ok; radius of gyration about the passes. So, or about the axis passing through the center of gravity. So, center of gravity is there this one. So, axis passing through the center of gravity that axis also is parallel to the axis of rotation; this is the axis of rotation.

So, this parallel and passing through the; so basically this radiation of gyration is this coming that from there as I told this; whatever the; so, this is the center of mass. If whole mass is concentrated here and this other things we can think this there is the mass like; it is threaded with is the, is the thread like thread like things mass less. So, then this should be the just it's; the moment of inertia would be this total mass concentrated here that into this distance l square.

But since mass is distributed mass is distributed. So, then this radius of gyration that concept comes as well as this. So, there basically this mass at the center of concentrate the center of mass this into the distance square that is plus it is a basically following the parallel axis theorem plus the moment of inertia of passing of the body; passing through the center of ma center of gravity the axis passing through the center of gravity with respect to that what is the moment of inertia of this system.

So, that as well as the distance from the distance from the axis of rotation to the center of mass that is square of that and mass of this system. So, this together will be basically the total moment of inertia of for this system. So, this compound pendulum and simple pendulum this in compound pendulum this in moment of inertia 2 parts ok.

One is one is just like simple pendulum ok; all masses is concentrated at center of mass and this other part is weight less mass less ok. So, that is that part is there and plus another part will be there; that is mass is distributed over the length ok. So, that is covered by the by the radius of gyration from the concept of radius of gyration ok.

So, that is what this T equal to 2 pi square root of L by g; so that is the simple pendulum. And in case of compound pendulum; this working formula basically it comes. So, from here you can find out this g equal to g equal to basically 4 pi square 4 pi square of L by t square 4 pi square L by t square ok; g equal to 4 pi square l by t square ok. So, this is also compound pendulum this same formula we use.

Now as I told the effective length; this L is effective length of the; of the equivalent simple pendulum equivalent simple pendulum. So, this length is not just length of the center of mass from the support from the axis of rotation; it is the, it is the as I told this there will be two parts. One is one is this mass the one is that distance of the center of mass of this system into this square of the distance into this mass of this body plus another part this coming from as I told this radius of gyration ok.

So, this effective length L is not the length of the center of mass; it is basically this length will be like this. So, here this length L is basically this l plus k square by l. So, how this terms that I already in previous class I have described. So, L is basically effective length of the pendulum which is equivalent to simple pendulum. So, effective length will be the length of the center of mass plus k square by l. So, this k is radius of gyration; now this is a quadratic equation of l ok. And if you solve it; so it is come L equal to l 1 plus l 2 and k will be equal to square root of l 1, l 2 ok.

So, as I told you earlier in previous class that basically in this experiment we have to; we have to measure time period T and effective length L. So, effect to get the effective length L actually this will be equal to l 1 plus l 2 and thereafter if you want to find out the radius of gyrations; this is the square root of l 1, l 2.

So, basically we have to find out l 1 and l 2 as well as time period. So, here whatever plot I have shown you; so this is the distance of center of distance of center of gravity from the axis of rotation. So, if you vary the distance of rotation, distance of this center of gravity from the axis of rotation at different distance.

If you measure the time period and if you plot in both side when increasing or other side also; both side if you measure and if you plot it time period versus this distance of the center of gravity from the axis of rotation, then you will get this type of curve symmetric curve with respect to this center of gravity. And if you just take a parallel line of this x axis; so it will cut this 4 points it will cut this 4 points.

So, l 1 basically from the; this is the line at the center of gravity. So, from the center of gravity this first point; these are basically l 1 and from center of gravity the second point distance is the this is the of l 2 or other side also l 1, l 2. So, generally what we do? We measure this divided by 2 that will be l 1 and this distance between these two points divided by 2 that will be l 2.

So, if; so from this job basically, we will find out l 1 and l 2 and from there we can calculate a capital L; which is epic effective length of the effective length of the pendulum and then radius of gyration of course, you can calculate taking square root of l 1, l 2.

And for each for each length for each length we have to take the time period that is what. So, L will be available to you; now here also one can basically, so there is a graphical method, there is a graphical method to find out L by T square also that I will discuss in next class when we will analyze the data.

So, what is our task? Our task is vary will vary the distance of center of gravity and we will measure the time period ok. So, that is what we have to just experimentally we have to do it and then rest of the part we have to analyze the data. So, let us see how we will measure the of this time period for each distance. So, here at present position; so we will note down this distance of the center of gravity is 48 centimeter. Now at this length at this length I want to measure the; I want to measure the time period of the time period of the oscillation, so I just I will start just disturb it ok.

So, it is doing just twisting. So, to avoid this one basically we have to; we have to just likely other arrangement.

(Refer Slide Time: 25:56)

So, we have to use basically some nut up there curve phase yes. So, yes just I have nut I can just ok. So, we have to; so there should not be any relative motion between this axis and this one. So, this axis itself will states; I think this we have to put yes may be now it is; yes. Now nicely it is just oscillating now it is oscillating. So, again to find out time period you now this 1, 2, 3; so this why you have to you have to take time period.

(Refer Slide Time: 27:12)

So, this now, this in my stop watch it is a 0. So, this again least count of the stop watch is 0.1 second. So, I will just start 1, 2, 3, 4, 5, 6, 7; so this way intake around 30, 40, 50 oscillation and then you for that number of oscillation what is the time that to count ok. So, this is the one data for a particular length.

Then I have to I have to do for other length. So, I will put here then it will be 40 minus 5 brings length will be 43; then next one 38. So, this way I will go and you see if I just I will show you.

(Refer Slide Time: 28:23)

If I put here; it is the distance of center is a is the I think this is the 42. So, how much it will be? It will be 5 and it rather 2 by the 48 and then from their 48 and here no; so this one, 500; so if I put here. So, this 48; third 43 then 48 then this will be 33; then 28, then this will be 28 and then this will be 23 and then this will be 18 this will be 13, this will be 8, this will be 3.

So, from here the distance will be 3, the distance will be 3. So, taking these distance let me just show you one you know yes. So, if I take this one I think other side I have to take yes ok. So, now, distance; so at 48 distance we have seen now it is 3 ok. So, this it is expected that this time period will be very large; time period will be very large. So, my watch is ready, so I will start this oscillation you see ok. So, to keep it openly; yes just I am showing you method because all has to do carefully taking time.

So just slightly however if I put twisting; anyway; so one can see this one can see this time period if I just start to take it 1, 2, 3 you can see this earlier when I was counting 1, 2, 3; now I am telling 1, 2; so it is may be slow ok.

So, this side we have taken the reading for this is now what we will do we will just we will take the reading in reverse side. So, because the in graph I showed this is both side starting from the; center gravity. So, distance from this side and distance from the other side also we have to take only then you can draw this schematic curve. So, we will do the experiment from the other side.

In same way, we starting from the tough starting from the tough here other side starting from the tough; here I will do experiment ok. So, again center of mass from the other side I am taking. So, take this same way as yes. You see how fast it is and when this length was in decreasing; so it is so slow. So, that is why this graph was telling that it should be like this. So, just measure the time you have time period for 30, 40, 50 oscillation and take the time. So, you have time period t. So, total time noted down here that will be that and number of oscillation divided by number of oscillation that will give time period ok.

So, t we will find out for each length and for each length this 48, 43, 38 etcetera; so you have. So, we will plot the distance from the center of gravity 5. So, I think starting from 3 then 8 then 13, then 18 for each what is the time plot. So, we will plot the graph and we will see this schematic curve we will get and from that curve we can find out l 1 and l 2. If you find out l 1 and l 2 you will find out the effective length capital L.

And the radius of gyration k effective length capital L equal to l 1 plus l 2 small l 1 plus l 2 small l 2. And radius of gyration k will be square root of small l 1 l 2. So, l 1 and l 2 you will get from this from the curve wherever data you got; so from this measurement ok. So, this data analyze we will continue in next class.

Thank you for your attention.