Lab Report

Complete this report YOURSELF except DATA taking parts! This report will not be submitted (except the very last page), but you should carefully complete it as preparation for the applied exam.

Suggested Pre-Lab Questions

Q1. Explain the Parallel Axis Theorem. Give an example and apply the theorem.

1

Q2. Show dimensional analysis of Radius of gyration (k) and moment of Inertia (I).

Experiment

OBJECTIVE : To study the properties of the physical pendulum and to use the physical pendulum to determine the acceleration due to gravity.

THEORY : In simple pendulum we determined the expression for the period by solving the force equation with the assumption that the mass hanging at the end of the string is a point mass. Since we used a small ball our assumption was acceptable. When we have an object that is much larger and cannot be treated as a point particle, we can still determine the period of oscillations if we hang this object from any point and let it oscillate. In this case we should write the torque equation and solve it. Of course, we should know the moment of inertia of the object with respect to the point that the object is hung. Then the period of oscillations will be

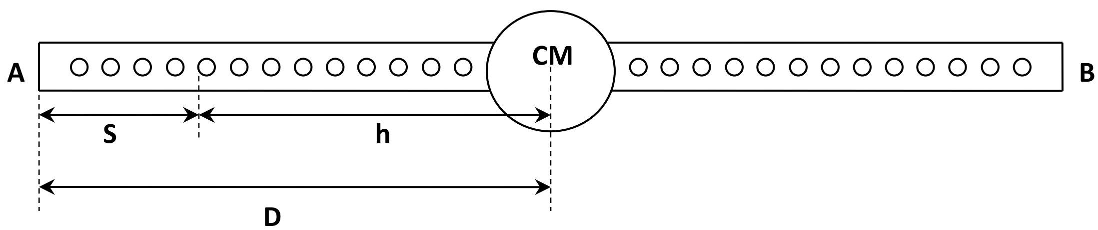


Figure 1. Physical pendulum.

$$T = 2\pi\sqrt{\frac{I}{Mgh}} \qquad (1)$$

where I is the moment of inertia about the axis of rotation or the point that the object is hung and h is the distance between this point and its center of mass. The moment of inertia about any given point can be expressed in terms of the moment of inertia about the center of mass using the parallel axis theorem:

$$I = I_{CM} + Mh^2 \qquad (2)$$

and I_{CM} can be written in terms of the radius of gyration k:

$$I_{CM} = Mk^2 \qquad (3)$$

Then combining these equations we can express the period as

$$\left(T = 2\pi\left[\frac{h^2 + k^2}{gh}\right]^{1/2} \right) \qquad (4)$$

This is equivalent to a simple pendulum with a length:

$$L = \left(h^2 + k^2\right)/h \qquad (5)$$

This simple pendulum is called "the equivalent simple pendulum" to the physical pendulum.

From the figure above we see that

$$h = D - S \tag{6}$$

and plugging this into the expression for the period results in

$$T = 2\pi\left(\frac{k^2 + (D-S)^2}{g(D-S)}\right)^{1/2}. \tag{7}$$

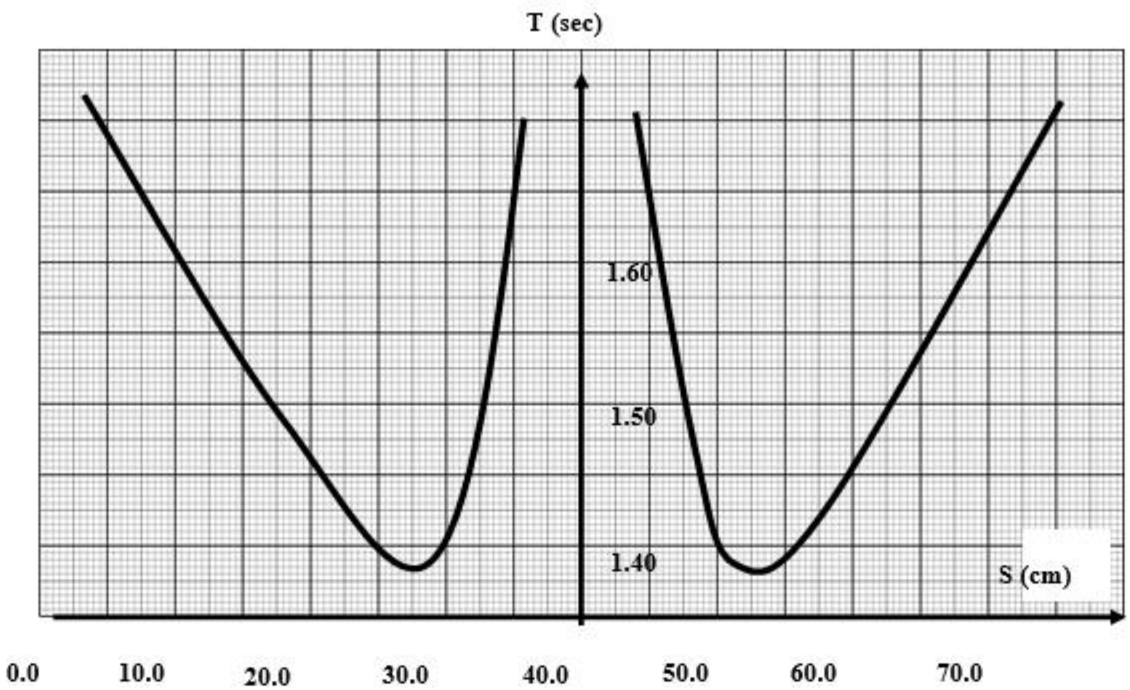


Figure 2. Plot of the period as a function of *S* (Equation (7)).

Plotting the period as a function of S will give us the graph in Figure 2. As you can see from the graph, there are four possible points for a specific period value that we can hang the pendulum. These four points collapse down to two for the minimum period. Radius of gyration is the distance at which the physical pendulum is hung to get the minimum period. We can determine the radius of gyration by measuring the period while varying the distance between the center of mass and the point that the pendulum is hung. Then we can simply read the distance corresponding to the minimum period from the graph. Radius of gyration is the distance between this point and the center of mass.

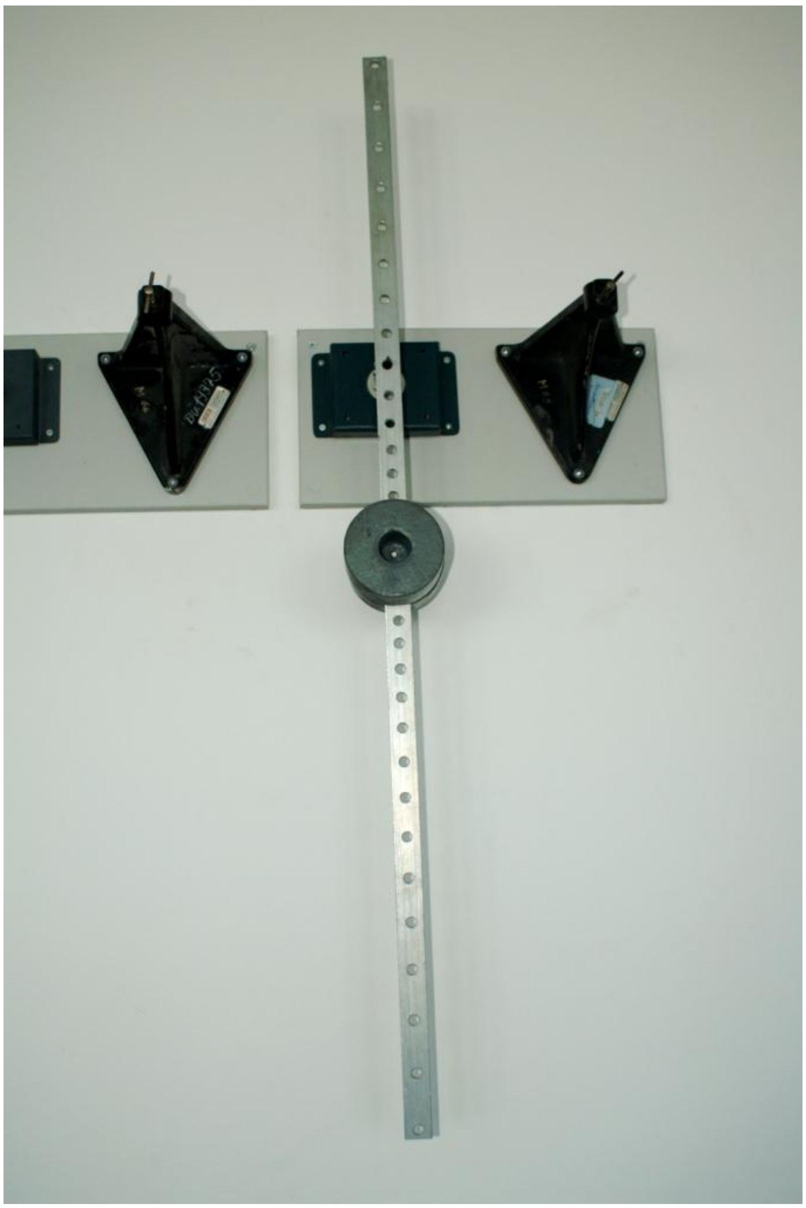
From the plot we can also see that the period of oscillations become infinite if we hang the object from its center of mass.

Because of the symmetry around the center of mass we can limit ourselves to one side of the center of mass. Equating the expressions for the two points that result in the same period:

$$2\pi\sqrt{\frac{(h_1^2+k^2)}{gh_1}} = 2\pi\sqrt{\frac{(h_2^2+k^2)}{gh_2}}, \qquad (8)$$

after simplifying we get:

$$\frac{h_1+k^2}{h_1} = \frac{h_2+k^2}{h_2}, \qquad (9)$$



and solving for *k*

$$k^2 = \frac{(h_1^2h_2 - h_2^2h_1)}{(h_1-h_2)} = h_1h_2 \qquad (10)$$

Hence, the period expression given in Equation (7) becomes

$$T = 2\pi\sqrt{\frac{(h_1+h_2)}{g}}$$

and similarly the length of the equivalent simple pendulum (Equation (5)) becomes

$$L = h_1 + h_2$$

APPARATUS: Physical pendulum, meter stick, stopwatch

PROCEDURE :

1. Support the pendulum on the knife edge at the hole nearest to one end of the bar. Observe the time for 10 full oscillations and determine the period. In the same way determine the period about an axis through each and every hole in the bar.
2. Remove the pendulum from its support and measure the distance of the various points of suspension from one end of the bar.
3. Record these values of ***S*** as a function of the corresponding values of period ***T***.
4. Plot the values of ***S*** versus period ***T*** and draw a horizontal line corresponding to any period and call this period ***T****.
5. S_0 is the S value that corresponds to the **minimum *T*** value. S_1 and S_2 (therefore h_1 and h_2) are the values that corresponds to the period ***T****, *i.e. where the curve intersects with the period line*.
6. Determine the radius of gyration, ***k***, from the graph.
7. Determine the length of the equivalent simple pendulum and calculate the gravitational acceleration using this value. Compare your result with the known value of ***g***.

DATA

Description / Symbol			**Value & Unit**
Distance from one end to the center of the pendulum	***D***	=	. . . .
Mass of of the pendulum	***M***	=	. . . .

DATA

Distance from one end of the pendulum to the suspension point ***S* ( )**	Time for 10 Period ***t* ( )**	One Period ***T* ( )**

PLOT *S* versus *T*:

Read from the Graph:

Description / Symbol			**Value & Unit**
Period (any chosen)	$\boldsymbol{T^*}$	**=**	. . . .
Minimum Period	$\boldsymbol{T_o}$	**=**	. . . .
Distance from the center to the first suspension point for T	$h_1 = D - S_1$	=	. . . .
Distance from the center to the second suspension point for T	$h_2 = D - S_2$	=	. . . .
For minimum Period:	$h_o = D - S_o$	=	. . . .
Radius of Gyration	$k = h_o$	=	. . . .

CALCULATIONS and RESULT:

Description	Symbol	Calculations (show each step)	Result
Radius of Gyration	$k = \sqrt{h_1 h_2}$	=	. . . .
Length of the Equivalent Simple Pendulum	L	=	. . . .

Description/Symbol	Calculations (show each step)	Result
Moment of Inertia about the CM $I_o = I_{CM}$ =	. . . .	. . . .
	. . . .	
Moment of Inertia Corresponding to h_1 $I_{(\text{for } T)}$ =	. . . .	. . . .
	. . . .	
Moment of Inertia Corresponding to h_2 $I_{(\text{for } T)}$ =	. . . .	. . . .
	. . . .	

Emprical value of acceleration

due to Gravity g_{EV} = ...

. . . .

Theoretical value of acceleration

due to gravity g_{TV} = ...

% Error for g = ...

Suggested Post-Lab Questions

Q1. Give a definition of radius of gyration. Explain its relationship with the physical pendulum and the simple pendulum.

Post-Lab Report

Aim of the experiment:

Suggestions for possible solutions to the problems experienced during the experiment:

Conclusion:

I have completed this experiment myself as specified in the lab sheet and as explained by the lab instructor.

Name & Surname:

Student ID:

Lab Section:

Table #:

Date:

Signature of the student

As the instructor of this Lab Section I confirm that the student has participated in and completed this experiment on time.

Stamp of the PHYS Labs and signature of the instructor

This page serves as proof of the fact that the student participated in and completed the experiment, only if it is submitted in time and accepted by the Lab instructor. The student and the instructor shall sign it along with the stamp of the Physics Laboratories.