PHY1002 Physics Laboratory (2022-2023 Term 2)
Short Report

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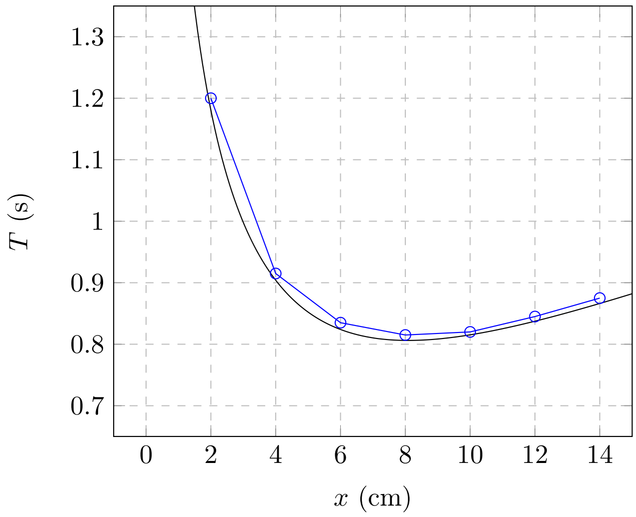
Experiment 5. Rotational Inertia (Physical Pendulum)

1. For the rectangular bar pendulum, plot the x (the distance between the pivot point and the center of gravity) vs. T (period of a physical pendulum).

Distance between the pivot point and the center of gravity vs. Period of a physical pendulum



Distance from Pivot (cm)	Measured Period (s)
2	1.200
4	0.915
6	0.835
8	0.815
10	0.820
12	0.845
14	0.875

(a) Determine the x that gives the minimum T.

The above graph shows a measurement of the period of oscillation of a simple pendulum as a function of the distance from the pivot point. Based on the summarized experiment data above, we can notice that $x = 8$ cm gives the minimum value of $T = 0.815$ s.

(b) Compare the experimental results from (a) with the theoretical values.

Theoretically, the value of T when $x = 8$ cm and $L = 28$ cm is given by:

$$T = 2\pi\sqrt{\frac{\frac{L^2}{12}+x^2}{gx}} \approx 0.806 \text{ s (rounded to 3 decimal places)}$$

Comparing the experimental value of $T = 0.815$ s for $x = 8$ cm with this theoretical value, we notice that both values are still relatively close. This small difference, which is approximated to be $\frac{|0.815-0.806|}{0.806} \times 100\% \approx 1.1\%$ error, may occur due to experimental error and the rotary motion sensor that has a record limitation within 0.005 s precision value. The fact that the experimental value is close to the theoretical value suggests that the theoretical model is a reasonable approximation and that the experiment was conducted with sufficient accuracy.

2. Calculate the rotational inertia at the center of mass for a disk sample with the M, T, and d measured in the experiment. And compared with the theoretical value from the equation: $I = \frac{1}{2}MR^2$

   The obtained experimental measurements were as follows:

   - Average period of oscillations: $T = 0.492$ s
   - Mass: $M = 0.08971$ kg
   - Distance from pivot: $d = 0.040$ m

   To calculate the rotational inertia at the center of mass for a disk, the derived formula is shown below:

$$I_{cm} = I_{pivot} - Md^2 = \frac{T^2 Mgd}{4\pi^2} - Md^2$$

   Using the formula above, we calculated the rotational inertia at the center of mass for a disk to be:

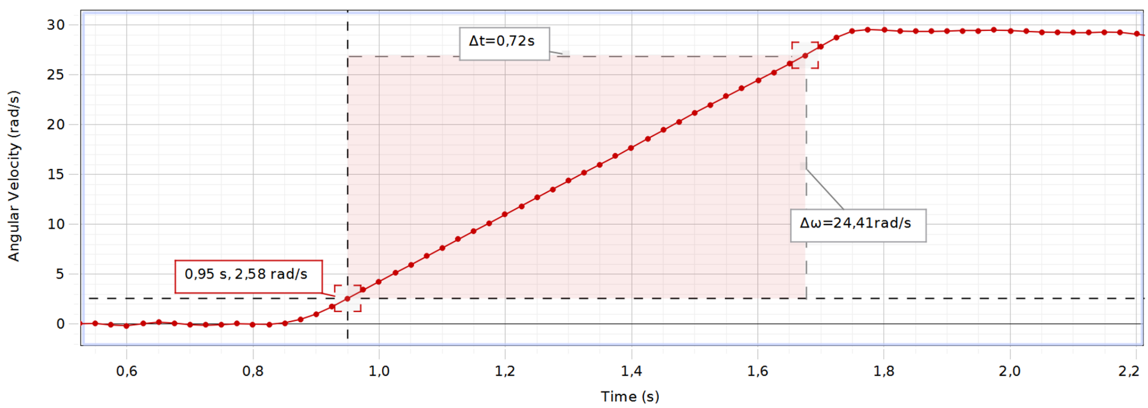
$$I_{cm} = \frac{0.492^2 \times 0.08971 \times g \times 0.040}{4\pi^2} - 0.08971 \times 0.040^2 \ \frac{\textbf{kg}}{\textbf{m}^2} \approx 7.25 \times 10^{-5} \frac{\textbf{kg}}{\textbf{m}^2}$$

   Comparing this with the theoretical value calculated from the equation $I = \frac{1}{2}MR^2$, we obtain the rotational inertia at the center of mass for a disk to be:

$$I_{cm} = \frac{1}{2} \times 0.08971 \times 0.040^2 \frac{\textbf{kg}}{\textbf{m}^2} \approx 7.18 \times 10^{-5} \frac{\textbf{kg}}{\textbf{m}^2}$$

   The percentage difference is given by $\frac{|7.25 \times 10^-5 - 7.18 \times 10^-5|}{7.18 \times 10^-5} \approx 0.97\%$. This indicates that the experimental value is in good agreement with the theoretical value, which implies that the results support the idea of using a physical pendulum to determine the rotational inertia. Any discrepancies may be attributed to experimental errors or uncertainties. It is important to note that this percent difference is within an acceptable range for most physics experiments, and it is common for experimental values to deviate slightly from theoretical values due to experimental limitations.

3. For the irregular shape pendulum, plot the angular velocity vs. time curve and determine the constant angular acceleration. Calculate the rotational inertia at its center of mass.



   Theoretically, the rotational inertia at the center of mass is formulated to be:

$$I_{cm} = \frac{\tau}{\alpha} = \frac{rF}{\alpha} = \frac{rm(g-a)}{\alpha} = \frac{rm(g-r\alpha)}{\alpha}$$

   Throughout the experiment, we have measured that $r = 0.022$ m and $m = 0.010$ kg. Moreover, from the plotted graph above, we calculate $\alpha = \frac{\Delta\omega}{\Delta t} = \frac{24.41}{0.72} \frac{\textbf{rad}}{\textbf{s}^2} \approx 33.90 \frac{\textbf{rad}}{\textbf{s}^2}$. With this information, we have the rotational at the center of mass to be:

$$I_{cm} = \frac{0.022 \times 0.010 \times (g - 0.022 \times 33.90)}{33.90} \frac{\textbf{kg}}{\textbf{m}^2} \approx 5.88 \times 10^{-5} \frac{\textbf{kg}}{\textbf{m}^2}$$

Appendix

Attach the table in *Expt 5b* tab “Analysis 1” and “Part II”.

Table II. Pendulum Data

	Set	Set	Set	Set	Set	Set
	Pendulum Type	Avg Period (s)	Mass (kg)	Distance from Pivot (m)	Rotational Inertia Pivot (kg-m²)	Icm (kg-m²)
1	Disk	0,492	0,08971	0,040	2,16E-4	7,25E-5
2	Disk with Hole	0,552	0,10144	0,044	3,40E-4	1,44E-4
3	Thin Ring	0,570	0,02235	0,040	7,21E-5	3,63E-5
4	Thick Ring	0,526	0,05593	0,040	1,50E-4	6,05E-5
5	Irregular Shape	0,535	0,06337	0,052	2,30E-4	5,86E-5

Table III. Dimensional Data for Rotational Inertia

	Set	Set	Set	Set	Set	Set	Set
	Pendulum Type	Mass (kg)	Radius 1 (m)	Radius 2 (m)	Calculated Rotational Inertia (kg-m²)	Icm (kg-m²)	%Diff (%)
1	Disk	0,08971	0,040		7,18E-5	7,25E-5	-0,9
2	Disk with Hole	0,10144	0,047	0,023	1,45E-4	1,44E-4	1
3	Thin Ring	0,02235	0,041		3,58E-5	3,63E-5	-2
4	Thick Ring	0,05593	0,040	0,024	6,08E-5	6,05E-5	0,5
5	Irregular Shape	0,06337			5,88E-5	5,86E-5	0,3

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