Physics 1050
Experiment 6

Moment of Inertia

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Prelab Questions

These questions need to be completed before entering the lab. Please show all workings.

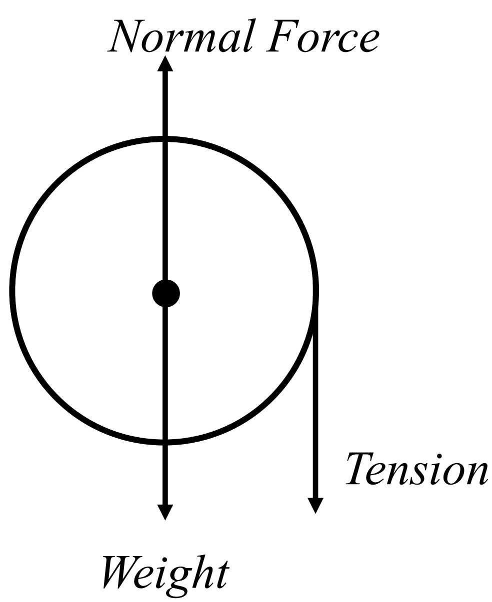
Prelab 1

Sketch a graph of torque vs angular acceleration.

Prelab 2:

The diagram shown represents a cylinder supported at its centre (at the black dot). The forces acting on the cylinder are the normal force, weight, and a tension force.

With the pivot at the centre, which of the forces apply a non-zero torque? Explain.



Contents

Introduction

In this experiment, you will determine the moment of inertia of a metal disc by studying how its angular acceleration changes with the magnitude of the torque applied to it. You will also determine the torque exerted on the disc by friction at its axis.

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Part I: Experimental Apparatus

You have been provided with

- a freely rotating metal disc
- bar tape
- photogate
- mass set
- clamp

Part I: Experimental Apparatus

Remove the disc from its stand by loosening **only one** of the screws that holds the disc in place.

Weigh it on the triple beam balance and measure the radius.

Enter the mass and radius with their uncertainties in **Table 1**.

You may need a counter weight when using the balance.
Don't drop the wheel on your feet!

QUESTION 1: From the measured values, calculate the moment of inertia of the disc. Include uncertainty and units.

Remount the disc and spin the wheel softly to ensure that it rotates well and doesn't wobble.

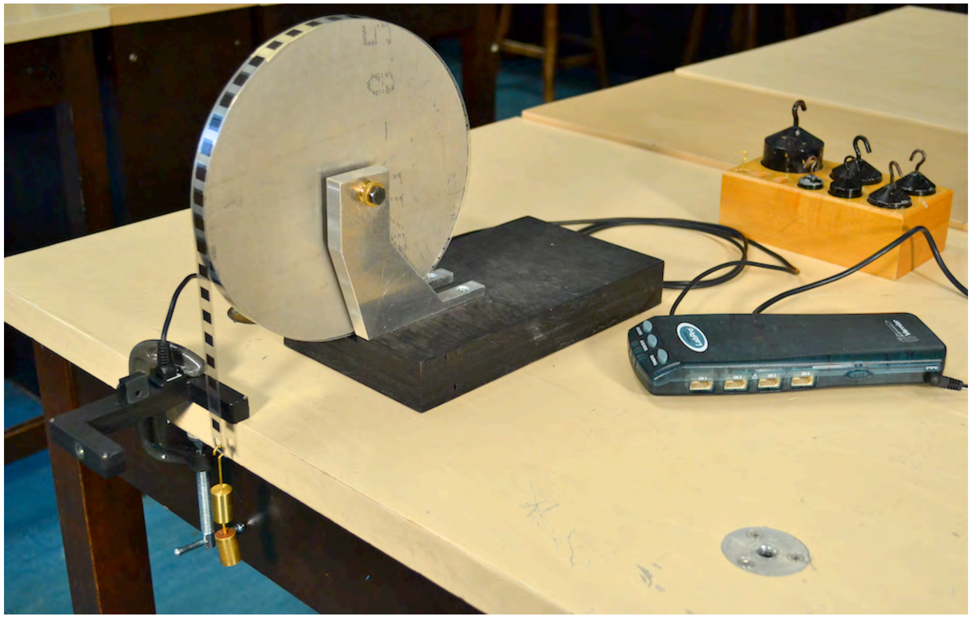
Experimental Set-up

Attach the end of the bar tape with no hole in it to the disc's edge.

Spin the disc around such that the tape winds around it.

Position your disc such that when a mass is hung freely from the tape, the tape breaks the beam of the photogate clamped to the desk.

It is sometimes easier if the tape is very close to either the light emitting diode or the sensor.



Part II: Data Acquisition

To determine the moment of inertia of the disc experimentally, we first have to measure the linear acceleration of a series of masses hung from the tape wrapped around the disc and thus find the angular acceleration of the disc for each of the hanging masses.

Accelerations will be calculated in Logger Pro using velocity versus time data obtained as the opaque bands on the moving tape break the photogate beam.

It is important that you do not adjust the screws once you have begun you data collection.

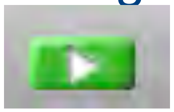
Launch Logger Pro by clicking on the icon below:

CLICK HERE → Logger Pro ← CLICK HERE

Data Acquisition

While holding the disc stationary, attach 30.0 g to the end of your tape.

Allow the masses to hang far enough from the disc so that they are below the photogate.

Reduce the swinging motion of the mass and click the **Collect** button in *Logger Pro*. 

Release the mass and allow it to fall freely.

Click **Stop**. 

If your data has a "gap" with no points, your tape probably missed the photogate for a brief period of time. Readjust your set-up and try again.

When the beam is broken, the light on top of the photogate lights up!

Data Acquisition

Acceleration from Velocity vs time Graph

In Logger Pro highlight the region of constant acceleration on the velocity vs. time graph with your mouse.

Click on **Analyze** then **Linear Fit** to to create a linear fit.

The results will appear in a pop-up box.

Double click on the pop-up box and check **Show Uncertainty**.

AL Enter the acceleration and its uncertainty (from the linear fit) of the hanging mass in **Table 2**.

CP Have an instructor check your graph and initial your lab manual.

AL Repeat the entire procedure for masses from 40 g to 100 g in increments of 10 g, entering your results in **Table 2**.

! You do not need uncertainty for the remaining rows of the table.

Part III: Data Analysis
Sample Calculation

For the sample calculation, **use data from the 30.0 g mass**.

QUESTION 2: Draw a free-body diagram for the mass and calculate the tension, T, in the tape. Include uncertainty.

You may assume $\delta m = 0.1$ g and $\delta g = 0$.

The mass is NOT in equilibrium because it is accelerating downward.

QUESTION 3: Using the **tension** in the tape and the **radius** of the disc, calculate the torque exerted on the disc by the tape, τ_T, as the 30.0 g mass attached to it is falling. Include uncertainty.

From page 39: $\tau_T = rF\sin\theta$.

Part III: Data Analysis
Sample Calculation

QUESTION 4: From the **acceleration** of the mass hanging from the tape and the **radius** of your disc, calculate the angular acceleration, α, of the disc due to this mass. Include uncertainty.

From page 39: $\alpha = a_t/r$.

QUESTION 5: Neglecting any torque exerted on the disc by friction at its axis, use the torque exerted by the tape and the resulting angular acceleration of the disc to calculate the disc's moment of inertia. Include uncertainty.

Compare it to your earlier calculation of the moment of inertia in Question 1.

If it is not the same, explain why.

Data Analysis: Finding I and τ_f

From Newton's second law (for rotation)

$$\Sigma\tau = \tau_T - \tau_f = I\alpha$$

where $\tau_T = rT = rm(g-a)$ as determined in Question 3 and $\alpha = a/r$ as determined in Question 4.

$\boldsymbol{\tau_T}$ is torque due to the tape, $\boldsymbol{\tau_f}$ is the torque due to friction, ***I*** is the moment of inertia, and $\boldsymbol{\alpha}$ is the angular acceleration

QUESTION 6: Sketch a plot of τ_T versus α. What are the slope and the intercept of this graph in terms of the physical parameters of the experiment?

Do not use data to answer this question! You may need to use equations given in the introduction.

Data Analysis

Open an Openoffice spreadsheet by clicking on the icon below.

CLICK HERE CLICK HERE

In the **blank box to the right** of the box marked "Radius", **enter the radius** (in meters and without units) of the disk.

The radius must be entered in the correct place to produce the correct results. Follow the instructions carefully!

In the column marked "Acceleration" enter the acceleration for each hanging mass (30 g to 100 g) in m/s^2 from Table 2.

The spreadsheet will automatically calculate the values of τ_T by determining *rm(g-a)* and α by determining *a/r.*

Open Graphical Analysis by clicking on the icon below.

CLICK HERE CLICK HERE

Graphical Analysis

Use the mouse to highlight the columns of α and τ_T (*a/r* and *rm(g-a))* from AppleWorks.

Select **Edit, Copy**.

In your Graphical Analysis file, click in the first empty box of the "Data Set" table and select **Edit, Paste**.

Don't select the column labels, just the numerical data!

Fit a straight line to the data by clicking **Analyze** then **Linear Fit.**

Double click on the results box and check **Show Uncertainty**.

Enter the slope and intercept of the τ_T versus α (or *rm(g-a)* vs. *a/r*) plot, including their uncertainties, in **Table 3**.

Graphical Analysis

QUESTION 7: What are values of the moment of inertia of the disc and the torque due to friction that can be determined from the graph? Include their uncertainties.

Enter your name in the Notes box on Graphical Analysis and select **File** then **Print**.

Your graph must have a title, axes labels with units, and the fit parameters displayed.

QUESTION 8: Do the three values that you have found for the moment of inertia of the disc agree within their uncertainties? If not, explain why.

Part IV: Summary

QUESTION 9: Summarize the relationships illustrated in this experiment:
How are linear and angular acceleration related?
How are torque, moment of inertia and angular acceleration related?
Comment on whether it would be a good approximation to neglect torque due to in this experiment.

Wrap it up!

- AL Check that you have completed all the **Tables**.
- Q Make sure you have answered all **Questions** completely.
- P Attach your **Graph** of *rm(g-a)* vs. *a/r* .