Physics 1050
Experiment 6

Moment of Inertia

Prelab Questions

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

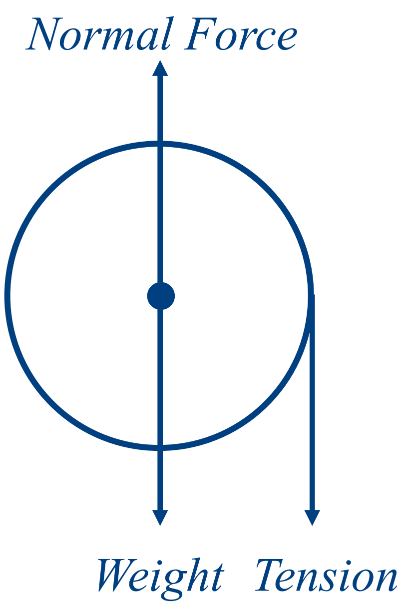
Prelab 1

Sketch a graph illustrating the relationship 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 center, which of the forces apply a non-zero torque? Explain.



Prelab 3: Write, in a sentence or two, the objective of this experiment.

Introduction

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

We will do this by applying a known force to the edge of an aluminum disk and measure the resulting acceleration. To do so, we will require a bit of background theory.

Introduction

Newton's second law for rotating objects states that the net **torque** on an object equals the **moment of inertia of the object** multiplied by its **angular acceleration**

$$\Sigma\vec{\tau} = I\vec{\alpha}\,.$$

In this expression, $\vec{\tau}$ is the torque, I the moment of inertia, and $\vec{\alpha}$ the angular acceleration.

The **moment of inertia**, I, of a rigid body depends on the mass of the body as well as how the mass is distributed around the rotation axis. Mass distribution is calculated based on the shape of the object. For example, the moment of inertia for a solid cylinder or disk about an axis through its centre of mass is

$$I = \frac{1}{2}MR^2$$

where M is the mass of the disk, and R the radius.

Introduction

When a force is applied to rotate an object about some axis, we produce a torque defined as

$$\vec{\tau} = \vec{r} \times \vec{F}$$

where $\vec{r}$ is the position vector from the rotation axis to the point where the force is applied. The magnitude of the torque vector is given by

$$\tau = rF\,sin\,\theta$$

where θ is the angle between the force and position vector $\vec{r}$. The torque is usually defined as **positive** for *counter-clockwise* rotation and **negative** for *clockwise*.

The angular acceleration, α may be calculated as

$$\alpha = \frac{a_t}{R}\ ,$$

where a_t is the **tangential acceleration** of a point on the outer edge of the object.

Part I: Experimental Apparatus

You have been provided with the following:

- rotating metal disk
- bar tape
- photogate
- mass set
- clamp

Part I: Experimental Apparatus

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

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

!

You will need a counter weight when using the balance.
Safety precaution: The disk is heavy and can result in injury if dropped.

LW

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

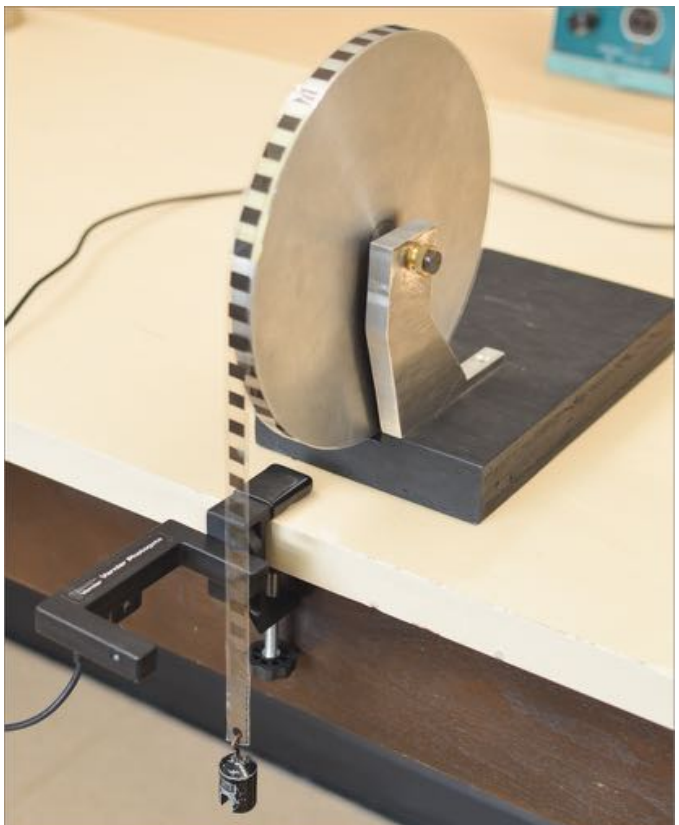
Q

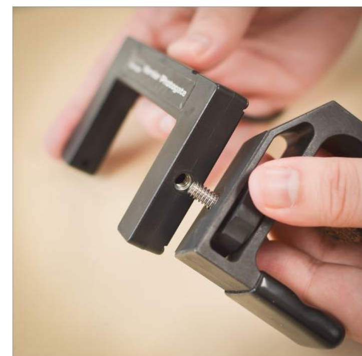
QUESTION 1: From the measured values, calculate the moment of inertia of the disk. Include uncertainty.

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

Experimental Set-up

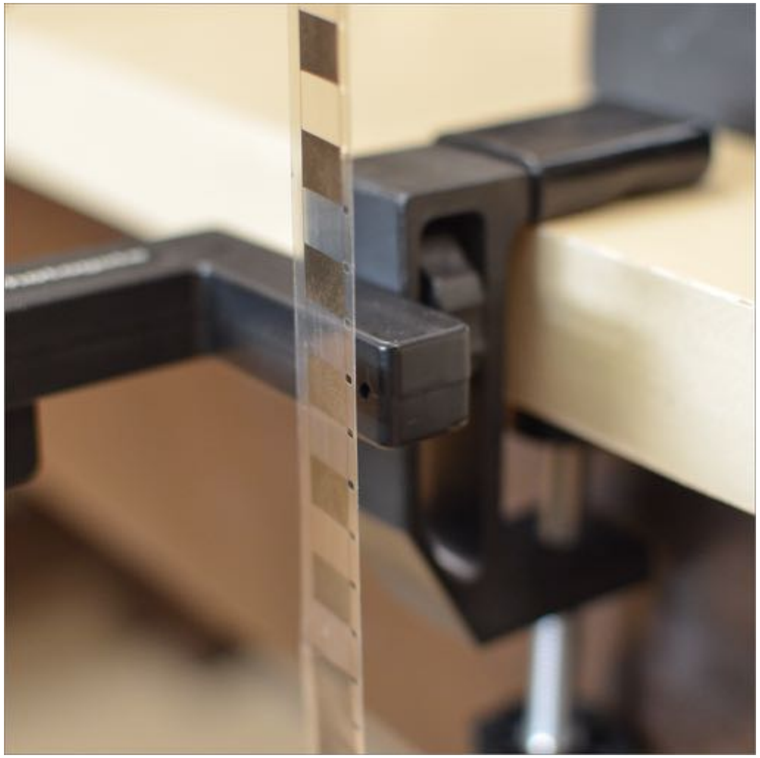
We wish to exert a known force to rotate the wheel and measure the resulting acceleration. To do so, attach bar tape to the wheel with a piece of masking tape such that a mass can be attached to the end of the tape.





Experimental Set-up

The path of the bar tape must pass directly in front of the sensor inside the photogate while ensuring that the tape can travel freely without touching the frame of the wheel. As the mass falls, the disk will rotate.



As the mass falls, the wheel is rotated and the bar tape's motion can be detected by the photogate.

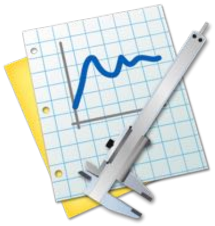
Data Acquisition

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

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

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

Click the icon to launch Logger Pro.



Data Acquisition

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

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

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

Release the mass and allow it to fall freely.

Click **Stop** when the mass reaches the end of the bar tape.

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 the edge of the photogate lights.

Data Acquisition

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

From the top menu, click **Analyze** then **Linear Fit** to determine the slope of the line.

LW

Enter the acceleration value of the hanging mass in **Table 2**.

!

You do not need uncertainty for the acceleration values.

CP

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

LW

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

Analysis

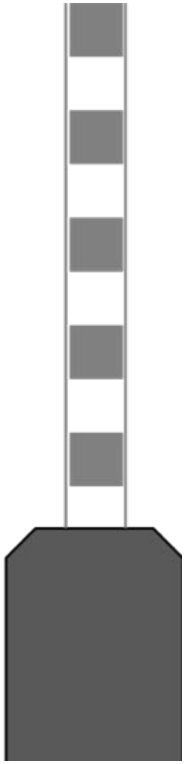
QUESTION 2:

Draw a free-body diagram for the hanging mass and apply Newtons second law to determine the expression for the tension T on the tape.

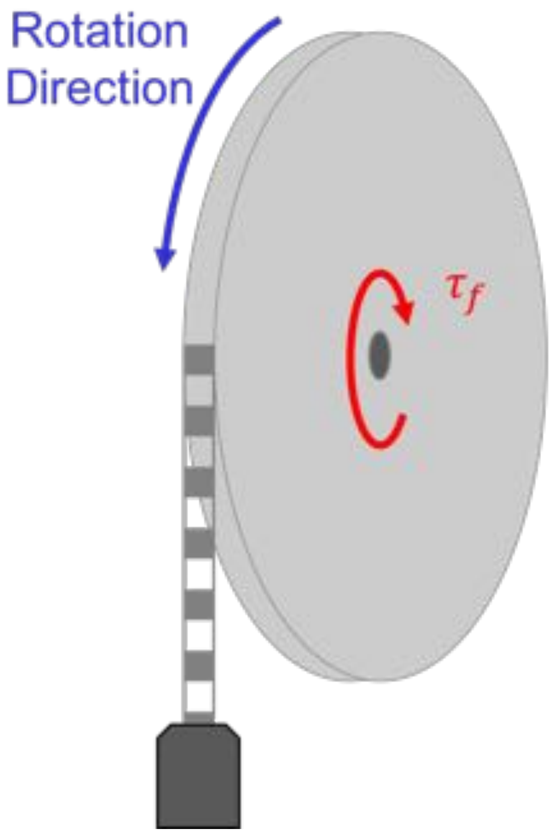
Remember, the mass is accelerating downward.

QUESTION 3:

Write the expression for the torque exerted on the wheel due to the tension τ_T. Your expression should include the m, r, g, and a.



Torque Acting on Wheel



Up to this point, we have only considered the torque due to the tension acting on the wheel, which is the torque which will make it rotate.

An important consideration in the rotation of the wheel is that some *friction may exist at the pivot point*. Even though the friction is small, it may not be negligible.

In the following questions, consider the torque provided by the tension of the hanging mass as well as the torque due to friction τ_f at the pivot.

Analysis

QUESTION 4: Given $\Sigma\vec{\tau} = I\vec{\alpha}$, write the expression for the net torque acting on the wheel in terms of τ_T, τ_f, I, and α.

QUESTION 5: What physical parameters correspond to the slope and intercept of a plot of τ_T vs. α? Show your reasoning.

QUESTION 6: Sketch a plot of τ_T vs. α. Indicate how τ_f will affect your plot based on your reasoning from Q5.

Data Analysis

To make a plot of τ_T vs α, we'll calculate these terms using the data we have collected and your answer to Question 3 and the definition of angular acceleration. We'll use *Graphical Analysis* to do this.

Click here to open Graphical Analysis

In the columns marked "Hanging Mass" and "Acceleration" enter your recorded values from Table 2 into *Graphical Analysis*.

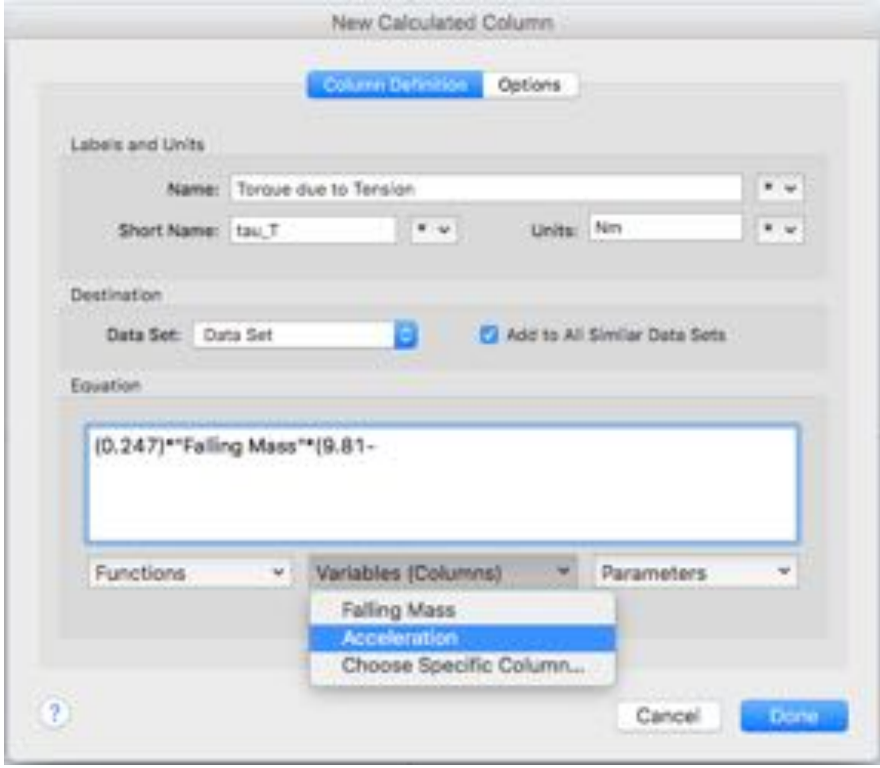
We can use *Graphical Analysis* to calculate the values of τ_T and α for each of our data values using a *Calculated Column*.

Using Calculated Columns

To create a new Calculated Column, click **Data, New Calculated Column**.

Enter the *name*, *short name*, and *units* of the new column to be created. Enter the equation for the calculation into the *Equation* text box.

When you need to use one of the data columns in your equation, select it from the **Variables (Columns)** menu.



Create Calculated columns for:

I. τ_T, *Torque due to Tension.*

II. α, *Angular Acceleration*.

Graphical Analysis

To change the variable displayed in your plot within *Graphical* Analysis click the axes label of the graph and select which you want it to display.

Apply a straight line fit by clicking **Analyze,** then **Linear Fit.**

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

LW

Enter the slope and intercept of the τ_T versus α plot, including their uncertainties, in **Table 3**.

P

Print your graph.
Include title, axes labels, and fit information.

Summary and Conclusions

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

Q **QUESTION 8:** Compare the value of moment of inertia of the disk from the plot with the value calculated from Question 1 by writing their ranges. Do these values agree within the uncertainty? Comment on any differences.

Q **QUESTION 9:** Comment on whether it's be a good approximation to neglect torque due to friction in this experiment.

Q **QUESTION 10:** List any sources of uncertainty and classify them as random or systematic.

Q **QUESTION 11:** Write a brief paragraph summarizing the experiment and your results.

Summary

Ensure that you have completed all **Tables** and answered all **Questions** completely.

Attach your printed **graph** to the appropriate page.

Submit your workbook to the appropriate shelf/box as directed.

Good luck on all your exams and enjoy the break!