Rotation

Purpose

The purpose of this lab is to measure the moment of inertia of a wooden disk.

Introduction and Theory

The moment of inertia of a uniform circular disk about its axis can be calculated analytically:

$$I_{theo} = \frac{1}{2}MR^2 = \frac{1}{8}MD^2 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where M is the mass of the disk, R is its radius and D is the diameter. In this lab, we will call the above result "the theoretical moment of inertia", I_{theo}.

Another method to determine the moment of inertia of the disk is to suspend a mass m from a light string wound around the disk (Figure 1) and measure the acceleration a of the mass. You will show in your pre-lab that the moment of inertia of the disk about the rotational axis can be expressed as:

$$I_{exp} = \frac{m(g-a)D^2}{4a} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

We call this result "the experimental moment of inertia", I_{exp}.

Apparatus   Draw a labelled diagram of the apparatus (see Figure 1). List all other apparatus required, along with any identifying numbers.
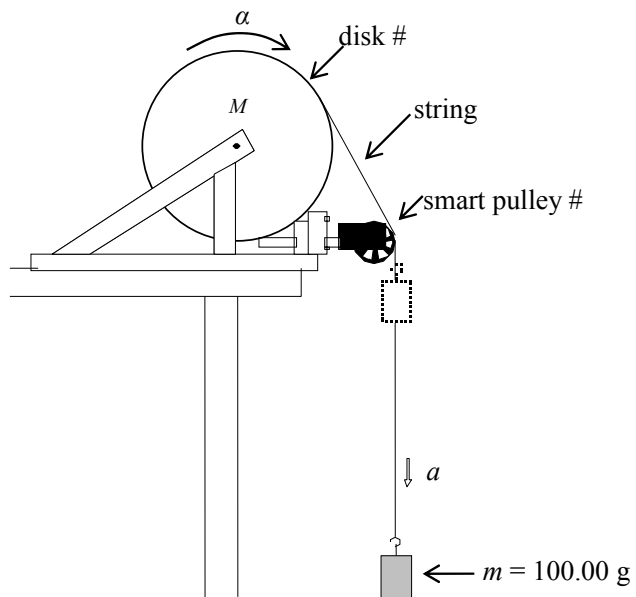

Figure 1

Rotation – Pre-lab

Give a complete derivation of Equation (2). Explain the meaning of each symbol in the equation.
Also calculate the relative uncertainty of I_{exp}.

For the hanging mass	For the wooden disk
FBD	FBD
Equation of the linear motion	Equation of the rotational motion

Based on the equations of motion, derive Eq. (2) for I_{exp} below:

Give the equation to calculate $\delta I_{exp}/I_{exp}$:

Data

1. Measure and record the appropriate quantities to determine the theoretical moment of inertia of the disk. Note that the disk is not perfectly round so one measurement of the diameter is not sufficient. Briefly explain how you choose the final uncertainty for the diameter: it is either the uncertainty of a single reading, or the uncertainty from scatter.

2. Set up the apparatus as shown in Figure 1. Make sure that the pulley is stable and well aligned by using the rubber stoppers.

3. Connect the smart pulley to the "Dig/Sonic 1" port of the computer interface. Start the Logger Pro program and open file: *Probes & Sensors\Photogates\Pulley.cmbl*.

4. Tape one end of the string to the disk and rotate the disk to wrap the string around the disk. Hang a mass $m = (100.00 \pm 0.05)$ g to the other end of the string so that the mass is suspended just below the smart pulley. Brace one hand on the iron framework to hold the disk as motionless as you can.

5. When you are ready, click on the ▶Collect button. After 2 or 3 seconds, release the disk. Press the "Stop" button after the velocity on the screen starts decreasing.

   Note: If at any time the ▶Collect button disappears from the main screen, you will probably have to close the LoggerPro program, reset the interface box and restart the program. This appears to be a result of unstable software.

6. Click on the velocity vs. time graph area. Select the region of constant acceleration (the straight-line portion of the curve). Click on the "linear fit" button to find the average acceleration. In a data table, record the variable "m" (the slope, and therefore the acceleration) and the "Correlation" value from the box that pops up. The "Correlation" variable is a measure of how well the data fits the straight line, with 1.000 being a perfect fit. If you get a trace that only occupies a small part of the graph, you can re-scale the axes.

7. To account for the non-uniformity of the wooden disk, re-tape the string so that it starts about 120° and 240° away from the first run and repeat Steps (4) to (6) two more times to get a total of 3 measurements for the acceleration. Calculate the average acceleration and its uncertainty based on the scatter of 3 accelerations. Record your results in the same data table, with a short explanation of how you calculate the uncertainty.

Calculations

Calculate the theoretical moment of inertia for your disk using Equation (1).

Calculate the experimental moment of inertia of the disk using Equation (2) and $g = 9.81 \pm 0.01$ m/s^2.

Uncertainty Analysis

Calculate the relative (percentage) and the absolute uncertainty for the theoretical moment of inertia.

Calculate the relative (percentage) and the absolute uncertainty for the experimental moment of inertia.

Conclusions

State your two results in the appropriate format.

Discussion

Does your experimental result agree within uncertainty with the theoretical result? Show the agreement/disagreement either by comparing their difference with the total uncertainty, or by a comparison graph.

List at least two possible physical factors that may have affected your results, but were ignored in your experiment. Be specific in your discussion: the word "friction" alone is not enough; you should point out it is the friction between which objects, and explain in what way you expect the friction to affect the result.

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