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**Lab 8: Rotational Motion and Moments of Inertia**

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PHYS 261 – 005

With:

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and

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**Objective**

The objective of this lab is for us to familiarize ourselves with the differences between the mechanics of rational motion versus linear motion. We will be able to calculate the moment of inertia of a disk experimentally and see the parallels of these calculations to traditional linear motion.

**Theory**

The theory being tested is that an object’s rotation will accelerate by a factor of *α* when a torque *τ* is applied. This is a rotational equivalent of Newton’s second law and can be written as follows given the rotational inertia *I* of an object.

Eq. 8-1

The moment of inertia is the object’s resistance to angular acceleration, which makes it the rotational analogue of the mass of an object.

In the experiment, we are supplied with a rope-and-pulley setup in which a hanging mass *m* applies tension *T* to an inner pulley on top of a larger disk. When the mass drops, the pulley unwinds, causing rotation of the large disk. We can find the rate at which the rotation accelerates by relating it to the linear acceleration *a* experienced by the hanging mass. We do that using the equation

Eq. 8-2

Acceleration of the hanging mass must match the linear acceleration at the edge of the pulley, and that acceleration defined the rotational acceleration of the disc with radius *r* via the equation a=rα. Thus

Eq. 8-3

**Procedure**

The procedures in the lab involved using the photogate sensor and the 10-spoke pulley to measure the acceleration of the hanging mass/disc system. The string attached to the hanging mass was wound around the step pulley, and the mass was released after collection began. The collection period started when the photogate detected motion from the 10 spoke pulley and ended when the velocity graph from the LoggerPro started showing oscillating bumps. Procedure A involved using only one disc, which was the one that had the step pulley attached to it. Procedure B was a rerun of Procedure A with an extra disc added.

**Data**

Below is the simple attributes of the pieces of the experiment, such as the masses of the disks and the radii of the components.

|  |  |  |
| --- | --- | --- |
| Disk A | 0.9475 | kg |
| Disk B | 0.8718 | kg |
|  |  |  |
| r | 0.0164145 | m |
| R | 0.125 | m |

**Table 8-1.** The simple measurements taken for the componentry within the procedures.

Here is the data collected from the Procedure A runs

|  |  |  |
| --- | --- | --- |
| **PROC A** |  |  |
| # | a (m/s2) | I (kg·m2) |
| 1 | 0.02857 | 0.009224 |
| 2 | 0.02882 | 0.009144 |
| 3 | 0.02797 | 0.009422 |
| 4 | 0.0291 | 0.009055 |
| 5 | 0.02933 | 0.008984 |

**Table 8-2.** The average accelerations for each run during the portion where the disk was unwinding.

And Procedure B

|  |  |  |
| --- | --- | --- |
| **PROC B** |  |  |
| # | a (m/s2) | I (kg·m2) |
| 1 | 0.01422 | 0.018559 |
| 2 | 0.01368 | 0.019293 |
| 3 | 0.01394 | 0.018933 |
| 4 | 0.01486 | 0.017759 |
| 5 | 0.01466 | 0.018001 |

**Table 8-3.** The corresponding information from the Procedure B runs.

**Analysis**

Using the momenta of inertia in Tables 8-2 and 8-3 we can find the average and uncertainties for both procedures. Doing so produces the following information:

|  |  |  |
| --- | --- | --- |
| Procedure | A | B |
| Iaverage (kg·m2) | 0.009166 | 0.018509 |
| σI | 0.000169 | 0.000636 |

**Table 8-4.** The average and standard deviation on the compiled moments of inertia from Procedures A and B.

This information will be compared to theoretical values for the moments of inertia, which we will calculate using the following equation

Eq. 8-4

Along with the information presented in Table 8-1. Making the calculation of the theoretical moments of inertia and comparting them with the values in Table 8-4 produces:

|  |  |  |
| --- | --- | --- |
| Procedure | A | B |
| Itheoretical (kg·m2) | 0.007402 | 0.014213 |
| %error | 19.23988 | 23.20851 |

**Table 8-5.** The theoretical moments of inertia for the disk configurations in Procedures A and B, and the percent error discrepancies between the values here and those of Table 8-4.

**Conclusions**

Looking over the results of the experiment, it is easy to see the relationships between linear acceleration and rotational acceleration. It is also easy to see how the difference in configurations between the two procedures, namely the additional disk in Procedure B, effects the moment of inertia of the cylinder on the table. However, there is a concerning discrepancy between the calculated theoretical moment of inertia in both procedures, and the average moment of inertia calculated experimentally in the lab. Reasoning for this is highly speculative, as the lab procedures were executed without hindrance. Possible sources of this percent error are a lack of attention paid to friction on the photogate pulley, the step pulley, and the axel that the disks were spinning on. Another thing to consider is that the disks may not have been level, which would affect the way the disks accelerated. Regardless, the results of the experiment match the expectations of the theory in terms of how we expected the hanging mass to affect the disks, and the difference between the moments of inertia was not a major surprise considering the state of the equipment. Thus, I believe that these results uphold the theory presented, and the objective of the lab has been achieved.