LAB 8: Moment of Inertia*

Equipment List:
the rotating platform, with disk and hoop
two pulleys (one large and one small is preferred)
one long rod and two clamps
one hanging weight set
one two-meter stick
stopwatch
digital pan balance (shared)
vernier calipers
spirit level (bubble level)

Purpose: To investigate the moment of inertia of objects of various shapes and confirm the theoretical expressions for their moments of inertia.

Introduction: In this lab, you will conduct an experiment to calculate the rotational inertia of an object (the disk or the hoop) and then compare it with a theoretical value.

As the hanging weight falls, the rotating platform starts to spin. The gravitational potential energy between the earth and hanging mass decreases and the translational kinetic energy of the hanging mass and the rotational kinetic energy of the rotating platform both increase. The total energy is conserved if there is no external work done by friction to decrease the system's energy.

Theory:
Derive an equation that gives the rotational inertia of the rotating object (that is, the rotating platform and anything else that may be resting on it) in terms of the hanging mass, the height through which it falls, the time through which it falls, and the radius of the spool of the platform where the string is wrapped around it. One way is to use the work-energy theorem and kinematics. (There are other ways, too!)

Procedure:

1. Set up the rotating platform and level it using the spirit level.
2. Measure the radius of the drum of the rotating platform using the vernier calipers.
3. Set up the support rods and pulleys as shown.
4. Measure the hanging mass with the digital balance. Use one hundred to two hundred grams, including the hanger.

*Based on the lab by Prof. Newton.

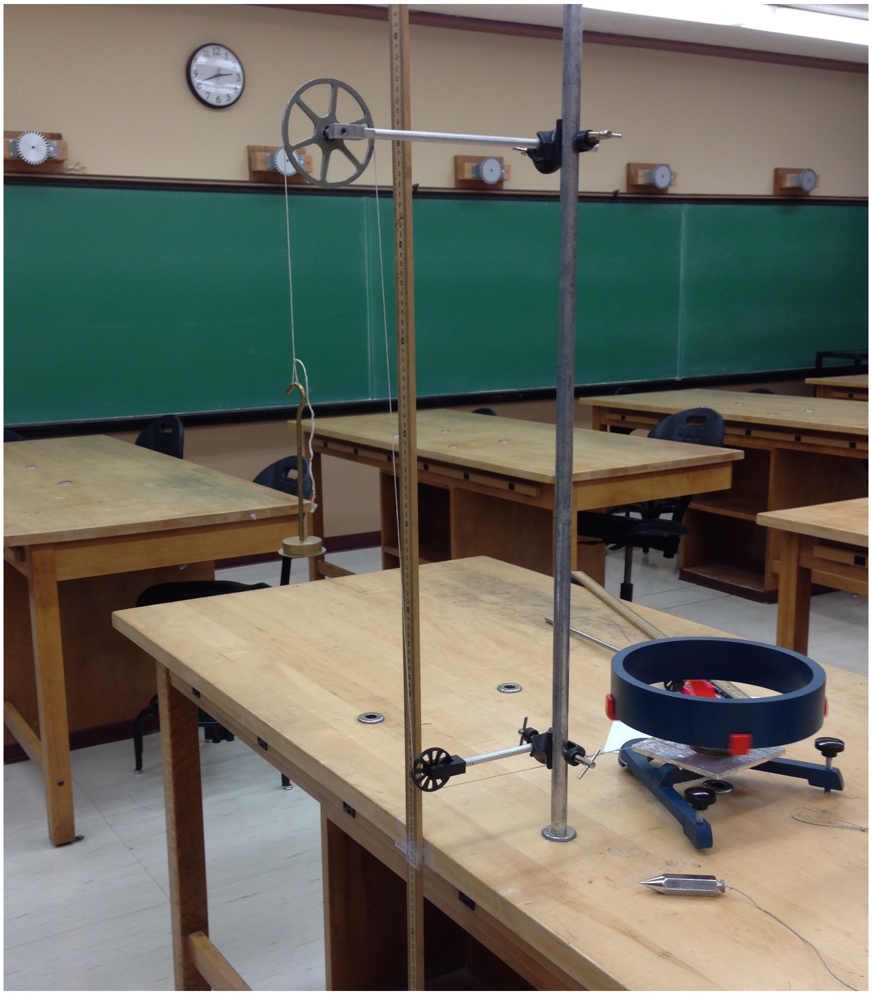

Figure 1: The rotating platform setup with pulleys and hanging mass.

5. A run will consist of letting the hanging mass fall from rest through a distance measured with the two meter stick (the distance should be as long as possible, at least one meter). Let that distance be x. Measure the time it takes to fall through this distance.

6. Do five runs with just the rotating platform alone (no disk or hoop on the platform) to calculate the total effective moment of inertia (or "rotational inertia") of the platform and the two pulleys. Find the average value of this moment of inertia and its uncertainty using the statistical method. This means you should find the standard deviation of the 5 moments of inertia ($n = 5$), one for each measured time-of-fall of the mass, and treat that as your absolute uncertainty:

$$\delta I = \sigma_I = \sqrt{\frac{\sum_{i=1}^{n}(I_i - \bar{I})^2}{n}}$$

   The average (or mean) moment of inertia, $\bar{I}$, is your best value for the rotational inertia. You can use your calculator or a spreadsheet to calculate the standard deviation, but write the formula in your lab book, and make clear notes about what you are doing.

7. Now run the experiment five more times but with the disk on the rotating platform. Calculate the rotational inertia of the disk plus the effective rotational inertia of the

platform-and-pulleys system. Use the statistical method to find the average value and its uncertainty.

8. To calculate the theoretical value of the disk's rotational inertia, you will need to measure the radius of the disk. The mass of the disk is too large to measure on the balance, so for its mass, use the value that is etched on the disk's face.

9. Go on and do the analysis section for the disk.

10. If there is time, run the experiment five more times with the hoop on the rotating platform, and repeat the calculation to find the moment of inertia of the hoop from. Again calculate a discrepancy test between the two values for the moment of inertia of the hoop.

Analysis: The experimental value of the disk's rotational inertia is calculated by subtracting the effective rotational inertia of the platform-and-pulleys from the rotational inertia of the system with the disk. Using uncertainty propagation, find the uncertainty in the experimental value. That is, since the experimental rotational inertia for the disk (or hoop) is found by a subtraction (the subtraction of the total rotational inertia of the platform and disk together by the rotational inertia of just the platform), then the uncertainty in the subtracted value is found by adding the uncertainties of the total and the platform in quadrature.

Using the well known formula for the rotational inertia of a disk (or hoop) rotating about its center of mass, calculate the theoretical value. Use uncertainty propagation to calculate its absolute uncertainty. Treat the given mass etched on the disk as exact and only use the uncertainty in your measured radius of the disk to find the uncertainty in its rotational inertia.

Compare the two values. (The one inferred from the acceleration of the mass, and the expected one using the formula for I for a disk.) Do their most probable ranges overlap? Calculate a discrepancy test between the two values for the rotational inertia. You should get less than ten percent or you might be making a mistake.

Conclusion: Knowing that systematic errors are present from dissipative forces, would you expect your experimental value to be greater or less than the theoretical because of those errors? Why? Can you think of any way to reduce the dissipative forces in this experiment?

Are there any other errors? What other experiments could you do with this equipment? In what ways could you extend your experimental investigations of rotational inertia? What else might you study?