M23a: Rotational Dynamics & Determining the Moment of Inertia

Introduction:

This experiment examines Rotational Dynamics and the properties of moment of Inertia. In its linear form Newton's Second Law establishes the relationship between mass, net force and the resulting acceleration. For rotation Newton's Second Law in its rotational form establishes the same kind of relationship between the moment of inertia, net torque and angular acceleration. The moment of Inertia expresses not only how much mass an object has but also how this mass is distributed with respect to the axis of rotation.

The main purpose of this experiment is to determine the moment of Inertia of a hoop both theoretically and experimentally. Since the hoop will be resting on a disk, it will be necessary to first know the moment of Inertia for the disk. But given the irregularities in the disk's surface and how its mounted on a rotating shaft this cannot be accurately calculated with a formula and it becomes necessary to obtain it experimentally. Once the experimental moment of Inertia of the disk is known, the experimental moment of Inertia of the hoop can be obtained. This value will be compared against the theoretical moment of Inertia for the hoop, which can be calculated with a formula.

Apparatus:

- Height-adjustable stand with a bearing mounted rotating shaft and attached step pulley
- Disk and Hoop
- Rod mounted Pulley
- Mass Hanger, Masses and String
- Mass Scale
- Digital Caliper
- Photogate with Computer timing system

Figure 1

Procedures:

This experiment consists of several sets of trials. The first set focuses on varying the radius where the force is applied and there by varying the applied torque. The second set of trials focuses on varying the applied force in order to again vary the applied torque. In all cases the torque is being applied to either the disk (which includes the axis, step pulley and bearings) or the disk with the hoop added.

1. The step pulley *under* the disk has three different radii. Measure the diameter of each step where the string will be wound and then calculate each radius.
2. For the large Disk measure its mass and its diameter.
3. For the thick Hoop measure both the inside and the outside diameter as well as its mass.

Varying the Torque via Changing the Radius

1. Wind the string on the largest radius until the mass hanger is suspended close to the outside pulley.
2. Adjust the external pulley so that the string is aligned with the pulley rod.
3. Add 40-grams to the mass hanger and measure the total mass. This mass will remain constant during this part.
4. Follow the provided computer instructions to begin the computer data collection. The computer will graph angular velocity over time. Obtain the *regression line* to find the *angular acceleration* for each trial. Note: start collecting data first and then release the mass.
5. Obtain the angular acceleration and standard deviation for each trial.
6. Repeat these steps using the other two radii.
7. Next add the hoop on top of the disk, centered, and repeat this sequence of steps.

Varying the Torque via Changing the Applied Force

1. Wind the string on the medium radius. This radius will remain constant during this part.
2. Add 30-grams of mass to the mass hanger and measure the total mass. Conduct the trial as before obtaining the angular acceleration and its standard deviation.
3. Conduct four additional trials, increasing the mass by 20 grams each time.
4. Next add the hoop on top of the disk, centered, and again repeat the sequence of steps to collect the angular accelerations for each trial.

Analyses:

1. Calculate the linear acceleration, also may be referred to as the tangential acceleration using the angular accelerations collected.
2. Calculate the tension in the string applied to the step pulley for each trial.
3. Calculate the torque for each trial.
4. Utilize all of the data for the Disk trials and graph the angular acceleration as a function of torque using Excel.
5. Utilize all of the data for the Disk with Hoop trials and graph the angular acceleration as a function of torque using Excel.
6. Obtain the statistical slope and standard deviation for each graph. Determine the experimental moment of inertia for each using the slope from the graphs.
7. Calculate the difference between the moment of inertia for Disk and the Disk with Hoop to determine the experimental moment of inertia for the Hoop alone.
8. Calculate the theoretical moment of inertia for the Disk and the theoretical moment of inertia for the Hoop.
9. Calculate the percent error between the experimental and theoretical moment of inertia for each.

Experiment M23a: Rotational Dynamics & Determining the Moment of Inertia

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor______________________________________

Experiment Start Date__________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheet 1: M23a: Rotational Dynamics & Determining the Moment of Inertia

NAME: ______________________________ DATE: __________________

Disk	**Varying the Torque via Changing the Radius**		
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk with Hoop	**Varying the Torque via Changing the Radius**		
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk	**Varying the Torque via Changing the Applied Force**		
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk with Hoop	**Varying the Torque via Changing the Applied Force**		
Applied Mass	Radius	Angular Acceleration	Standard Deviation

Data Sheet 2: M23a: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ DATE: _________________

Disk	**Varying the Torque via Changing the Radius**	
Linear Acceleration	Tension	Torque
Disk with Hoop	**Varying the Torque via Changing the Radius**	
Linear Acceleration	Tension	Torque
Disk	**Varying the Torque via Changing the Applied Force**	
Linear Acceleration	Tension	Torque
Disk with Hoop	**Varying the Torque via Changing the Applied Force**	
Linear Acceleration	Tension	Torque

Data Sheet 3: M23a: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________   DATE: _________________

Experimental Determination Moments of Inertia:

Moment of Inertia for the Disk: ___________________

Moment of Inertia for Disk with Hoop: ___________________

Moment of Inertia for the Hoop: ___________________

Theoretical Determination:

Diameter of the Disk: ___________________

Mass of the Disk: ___________________

Theoretical Moment of Inertia of the Disk: ___________________

Percent Error: ___________________%

Inside Diameter of the Hoop: ___________________

Outside Diameter of the Hoop: ___________________

Mass of the Hoop: ___________________

Theoretical Moment of Inertia of the Hoop: ___________________

Percent Error: ___________________%