M23c: 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 disk and a hoop, both theoretically and experimentally. For the disk the moment of inertia will be determined for two spin orientations, horizontal and vertical. Also since the hoop will be resting on the disk, to determine experimentally the moment of inertia for the hoop the disk inertia in the horizontal orientation must be determined first. Once the experimental values for each moment of inertia are determined the theoretical values will also be determined and compared to the experimental result. The theoretical values for the disk will be close approximation only since the disk has several irregularities and is attached to the rotating shaft/step pulley combination during the experimental trials.

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
- Ruler
- Photogate with Computer timing system

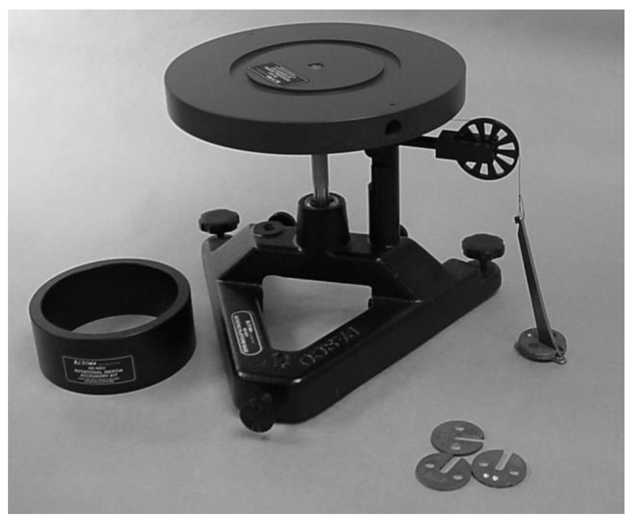

Figure 1

Procedures:

This experiment consists of several sets of trials. The first set focuses on varying the radius where the force is applied and thereby 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, in the horizontal or vertical orientation, or the disk with hoop, via the step pulley mounted underneath on the rotational shaft.

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, diameter and thickness.
3. For the thick Hoop measure its mass, the inside diameter and the outside diameter.

Varying the Torque via Changing the Radius

4. Add 40-grams to the mass hanger and measure the total mass. This mass will remain constant during this part.
5. Wind the string on the largest radius until the mass hanger is suspended close to the outside pulley.
6. Adjust the external pulley so that the string is aligned with the pulley rod.
7. 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.
8. Obtain the angular acceleration and standard deviation for each trial.
9. Repeat these steps using the other two radii.
10. Next add the hoop on top of the disk, centered, and repeat this sequence of steps.
11. Now remove the hoop and disk, turn the disk upright to mount vertically and repeat the sequence of steps 4-9.

Varying the Torque via Changing the Applied Force

12. Add 30-grams of mass to the mass hanger and measure the total mass.
13. Wind the string on the medium radius. This radius will remain constant during this part.
14. Conduct the trial as before obtaining the angular acceleration and its standard deviation.
15. Conduct four additional trials, increasing the mass by 20 grams each time.
16. 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.
17. Now again remove the hoop and disk, turn the disk upright to mount vertically and repeat the sequence of steps 12-15.

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 (horizontal) trials and graph the angular acceleration as a function of torque using Excel.
5. Utilize all of the data for the Disk (vertical) trials and graph the angular acceleration as a function of torque using Excel.
6. Utilize all of the data for the Disk with Hoop trials and graph the angular acceleration as a function of torque using Excel.
7. Obtain the statistical slope and standard deviation for each graph. Determine the experimental moment of inertia for each using the slope from the graphs.
8. Calculate the difference between the moment of inertia for Disk (horizontal) and the Disk with Hoop to determine the experimental moment of inertia for the Hoop alone.
9. Calculate the theoretical moment of inertia for the Disk (horizontal), the Disk (vertical) and the theoretical moment of inertia for the Hoop.
10. Calculate the percent error between the experimental and theoretical moment of inertia for the Hoop.
11. Calculate the percent difference between the experimental and theoretical moments for the Disk.

Experiment M23c: 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: M23c: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ DATE: _________________

Varying the Torque via Changing the Radius (measurements)

Disk (horizontal)			
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk with Hoop			
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk (vertical)			
Applied Mass	Radius	Angular Acceleration	Standard Deviation

Data Sheet 2: M23c: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ DATE: _________________

Varying the Torque via Changing the Applied Force (measurements)

Disk (horizontal)			
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk with Hoop			
Applied Mass	Radius	Angular Acceleration	Standard Deviation
Disk (vertical)			
Applied Mass	Radius	Angular Acceleration	Standard Deviation

Data Sheet 3: M23c: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ DATE: _________________

Varying the Torque via Changing the Radius (calculations)

Disk (horizontal)		
Linear Acceleration	Tension	Torque
Disk with Hoop		
Linear Acceleration	Tension	Torque
Disk (vertical)		
Linear Acceleration	Tension	Torque

Data Sheet 4: M23c: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ DATE: _________________

Varying the Torque via Changing the Applied Force (calculations)

Disk (horizontal)		
Linear Acceleration	Tension	Torque
Disk with Hoop		
Linear Acceleration	Tension	Torque
Disk (vertical)		
Linear Acceleration	Tension	Torque

Data Sheet 5: M23c: Rotational Dynamics & Determining the Moment of Inertia

NAME: ____________________________ **DATE: _________________**

Experimental Determination Moments of Inertia:

Moment of Inertia for the Disk (horizontal): __________________

Moment of Inertia for the Disk (vertical): __________________

Moment of Inertia for the Disk with Hoop: __________________

Moment of Inertia for the Hoop: __________________

Theoretical Determination:

Diameter of the Disk: __________________

Thickness of the Disk: __________________

Mass of the Disk: __________________

Theoretical Moment of Inertia of the Disk (horizontal): __________________

Percent Difference: __________________%

Theoretical Moment of Inertia of the Disk (vertical): __________________

Percent Difference: __________________%

Inside Diameter of the Hoop: __________________

Outside Diameter of the Hoop: __________________

Mass of the Hoop: __________________

Theoretical Moment of Inertia of the Hoop: __________________

Percent Error: __________________%