MOMENT OF INERTIA

OBJECTIVE:

The objective of this experiment is to find the moment of inertia of a disk and a ring experimentally and to become familiar with the concepts of angular velocity, angular acceleration and torque, and to verify experimental values that correspond to the calculated theoretical values.

APPARATUS:

Rotational Apparatus, Disk, Ring, Vernier Caliper, Meter Stick, Weight, Balance, Computer, Smart Pulley, DataStudio program and Interfaces.

THOERY:

A net torque τ acting on a body free to rotate about a fixed axis causes angular acceleration give by:

$$\alpha = \frac{\tau}{I}$$

where **I** is the **moment of inertia**. The moment of inertia depends on the mass of the body and its distribution. For a solid disk of mass M and radius R rotating about its cylinder axis, the moment of inertia is given by:

$$I = \frac{1}{2} MR^2 \qquad (1)$$

The moment of inertia for a ring with mass M, an inner radius R_1, and an outer radius R_2 is given by:

$$I = \frac{1}{2} M(R_1^2 + R_2^2) \qquad (2)$$

The moment of inertia may also be determined by the Newton's Law. Figure 1 shows the experimental setup. As the mass m falls from rest, it will cause the object to rotate. Applying Newton's Law for the hanging mass m, gives

$$mg - T = ma \qquad (3)$$

where T is the tension in the string when the apparatus is rotating.

Applying Newton's Law for the object, gives

$$\tau = I\,\alpha \tag{4}$$

The relationship between the linear acceleration a of mass and the angular acceleration α of object is

$$\alpha = \frac{a}{r} \tag{5}$$

where r is the radius of the drum.

and $$\tau = rT \tag{6}$$

Combining equations (3), (4), (5) and (6), gives

$$I = mr^2\,\frac{(g-a)}{a} \tag{7}$$

The linear acceleration of mass is determined; the moment of inertia of object can be calculated from equation (7).

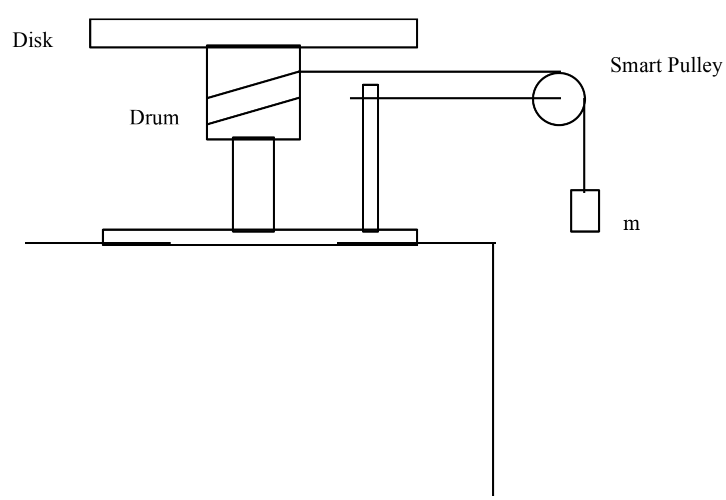

Figure 1

PROCEDURE & CALCULATION:

1. Use a vernier caliper to measure the diameter of the drum and calculate the radius r (m).

2. Measure the hanging mass m and record it.

3. Pass the string over the smart pulley and hang the mass on it. Carefully wind string on the drum as figure 1.

4. To find the acceleration a, use **DataStudio program** as follows.

   a. Drag the “Smart Pulley” from Sensors list to digital channel 1.

   b. Release the mass from rest and click the **Start** button to record the data. Before the mass touches the floor, click **Stop** button to stop the data recording.

   c. Drag the recorded data from Data list to “graph display”. The graph is shown the velocities vs. time. Click “Fit” button on menu bar, and then select “Linear Fit”. The statistics area will show the slope for the line of ‘best fit’ for your data. The slope is the acceleration of the mass.

5. Use Eq. (7) to calculate the moment of inertia of Disk I_{disk} (kgm^2).

6. Place the ring on the disk. Repeat step 4. Use Eq. (7) to calculate the moment of inertia I. This I is the combined moment of inertia of the disk and ring. Thus moment of inertia of ring $I_{ring} = I - I_{disk}$.

7. Measure the mass of disk M and the diameter of the disk. Calculate the radius R. Use Eq. (1) to calculate the theoretical moment of inertia of disk.

8. Measure the mass of ring M and determine the inner radius R_1 and outer radius R_2. Calculate the theoretical moment of inertia of ring using Eq. (2).

9. Calculate the % error in the measured moment of inertia using the theoretical value as the standard value.

QUESTIONS:

1. What was the angular acceleration of the disk in the step 6? If the hanging mass fall h = 0.85 m to the floor determine the angular velocity of disk when the mass hits the floor and determine how long the disk will continue to rotate after mass hits the floor if the torque of friction is $9 \times 10^{-4} (N \cdot m)$.

2. Friction is neglected in Eq. (7). Is the moment of inertia calculated from Eq. (7) too large or too small if friction is present? Explain.

DATA ORGANIZATION SHEET
EXP. MOMENT of INERTIA

mass of disk $M =$ ______ (kg) radius $R =$ _____ (m)

mass of ring $M =$ ______ (kg) inner radius $R_1 =$ ____ (m)

outer radius $R_2 =$ ____ (m)

hanging mass $m =$ _____ (kg)

radius of the drum $r =$ ____ (m)

1. Theoretical Value: $I_{\text{disk}} = \frac{1}{2}MR^2 =$ __________ (kgm^2)

$I_{\text{ring}} = \frac{1}{2}M(R_1^2 + R_2^2) =$ _________ (kgm^2)

2. Measured Value:

Moment of Inertia of Disk

	a	I_{disk}	$\bar{I}_{\text{disk}}$	% of diff.
1				
2				
3				

Moment of Inertia of Ring

	a	I_{combined}	$\bar{I}_{\text{combined}}$	I_{ring}	% of diff.
1					
2					
3					