

Rotational Dynamics Lab

Purpose

Using a Rotary Motion Sensor and the relationship between torque, moment of inertia, and angular acceleration, students will experimentally determine the moment of inertia of a thick ring. Data Analysis will be performed using Excel. The Moment of Inertia of the thick ring will also be determined analytically by taking physical measurements of the thick ring using a digital scale and vernier calipers. The experimental and analytical values of the ring's moment of inertia will be compared.

Part I: Basic description of the equipment and how it will be used to collect data

A Rotary Motion Sensor (RMS) is capable of collecting a multitude of data while it is spinning. In this case, the RMS will be used to collect the linear acceleration (a) of a falling mass and the angular acceleration (α) of the spinning objects. By varying the falling mass, both a and α can be varied.

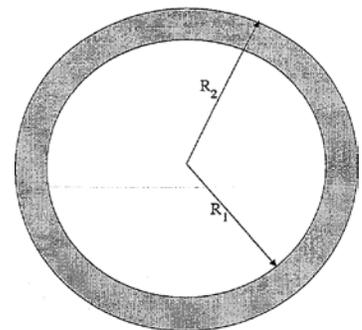
The combination of the thick ring and the RMS will be defined as the “system”, and the moment of inertia of the system will need to be determined. The RMS itself consists of a disk, axle, step pulley, etc. all of which have moments of inertias. Therefore, it is also necessary to determine the moment of inertia of just the RMS. Since the moments of inertia spinning about the same axis are additive, an expression for the moment of inertia for the system can be expressed as:

$$I_{system} = I_{RMS} + I_{ring}$$

The analytical moment of inertia of a thick ring with homogeneous density rotating about its center can be calculated using the equation below.

$$I_{Ring} = \frac{1}{2}M(R_1^2 + R_2^2)$$

Where R_1 and R_2 are the inner and outer radii of the ring as seen in the figure to the right. M is the mass of the ring.



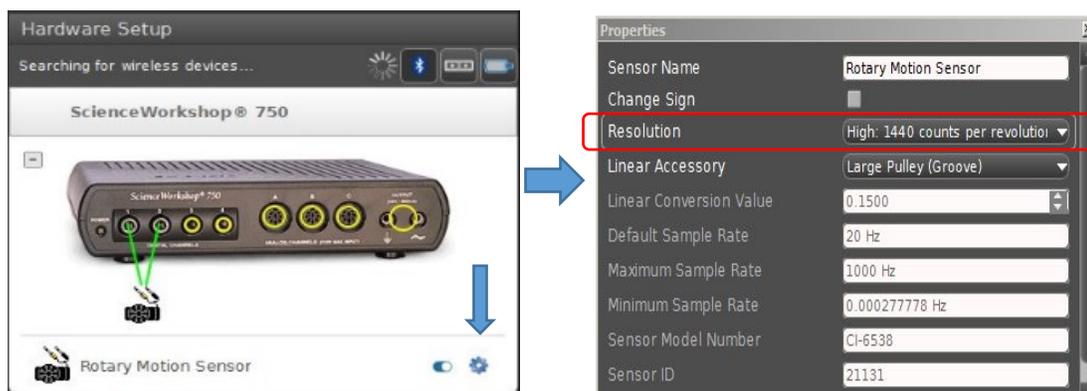
Part II: Equipment and Software Set-up

Hardware Setup

1. Make sure the interface box is turned on and connected to the computer.
2. Connect the YELLOW plug of the RMS into Digital Port 1 of the PASCO interface, and connect the BLACK plug into Digital Port 2.
3. Place the Super Pulley (spoked pulley) at an appropriate angle on the RMS such that the string will be perpendicular to the large pulley under the disk as it unwinds.
4. Place the ring on top of the disk making sure it is properly locked into place (the pegs should fit into the small holes on top of the disk).

Software Setup

1. Open the *Capstone* software by opening the “phylab folder” and double clicking “*PASCO Capstone*”
2. Once *Capstone* opens, click on the *Hardware Setup* button located on the left side of the screen. Click on Digital Port 1, and select the *Rotary Motion Sensor* from the list.
3. Click on the ‘gear’ to open the “Properties” table for the RMS, and Change the ‘Resolution’ to “High”.



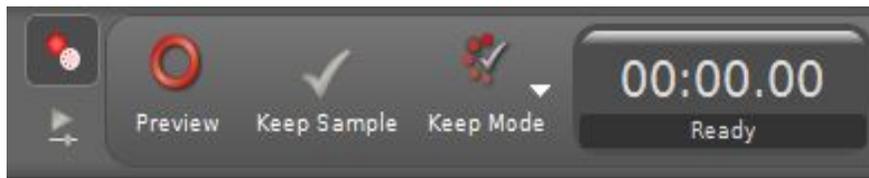
4. Next, either double click on the table icon under displays on the right side of the screen, or drag the table icon to the desired position on the display screen.
5. On the top left of the table, click on the tool bar icon to insert an empty column to the right (There should now be a table with *three* columns).
6. In the same tool bar, click the table properties (the gear symbol), then choose data options, and for Data Alignment Mode you should choose *Align by index*.
7. Now you'll want to designate what measurements you want to collect with the sensor. In the first column, click Select Measurement and choose *Acceleration*. Similarly in the second column choose *Angular Acceleration*.

- In the last column, this time you will choose *Create New* and then *User-Entered Data*. Once that is done, it should say “UserData1” and “units”. Click on the label “UserData1” and choose Rename. You should type in *Mass* and hit enter. Then rename the units to *kg* and hit enter.

▲ Set
Mass (kg)

NOTE: You are responsible for manually entering the mass in this column correctly such that the mass correlates to the correct data.

- At the bottom of the screen you should see the data taking mode set to Continuous. This should be changed to *Keep Mode*.



Part III: Collecting Data for the System

- Hang 20 grams (0.020 kg) *{including the mass of the mass hanger}* from the end of the string and wind the string around the largest pulley of the step pulley located under the disk of the RMS by turning the disk until the mass hanger is just below the super pulley.
- Click Preview.
- Release the disk letting the mass fall and the disk spin. While the mass is falling, click the KEEP SAMPLE button to record data. If you observe negative values for your angular acceleration, it is due to the direction the string was wound around the step pulley. Stop collecting data and delete the previous data runs. The angle of the super pulley will need to be changed in order to wind the sting in the opposite direction.
- Take multiple data points with the same weight and record which mass was used in the third column of the table.
 - Note: you may be able to collect multiple data points while the mass is falling.
- Collect data in 10 g increments up to and including 60 g.
- Click the red square after all of the data has been collected.
- Print your data table.

Part IV: Data Analysis for the System

1. Excel will be used to analyze your data. Copy and paste *all* of the data from the Capstone data table into an Excel Spreadsheet. Create a column for Torque in Excel, and insert an equation to calculate the Torque for each data point collected. The radius of the large pulley of the step pulley is $r = 0.02385 \text{ m}$.
2. In order to determine the moment of inertia of the system, create a scatter plot of angular acceleration vs. Torque using Excel. After you have created the plot of α vs τ , fit the data with an appropriate trend line and display the fit equation. Make sure that the numerical coefficients of your fit equation are displayed with at least two decimal places. The plot should have an appropriate title and axis labels with units.
3. Determine the moment of inertia of the system using the appropriate coefficients from the fit equation of the scatter plot.

Part V: Data collection and Data Analysis for the RMS

1. Remove the ring from the RMS and repeat the data collection and data analysis procedure you performed for the system.
2. For this trial, begin with 10 g and end with 50 g in 10 g increments. Be sure to record the appropriate mass for each data point. The mass data from the previous run will need to be deleted.
3. Analyze the data using Excel.

Part VI: Determine the Experimental Moment of Inertia of the Ring

1. Use the information from the fit equations of your scatter plots and the idea that moments of inertia are additive to determine the ring's experimental moment of inertia.

Part VII: Analytically determine the Moment of Inertia the Ring

1. Use a pair of Vernier calipers to measure the inner and outer diameters of the ring.
2. Use the digital scale to determine the mass of the ring.

Part VIII: Compare your analytical and experimental values of the moment of inertia for the ring

1. Calculate the percent difference.

Name: _____

Banner ID: _____

Lab Group ID: _____

Number of Lab Partners: _____

Data Sheet

Rotational Dynamics Lab

Hints:

1. The plastic mass hanger has a mass of 5g.
2. When using the Vernier calipers, diameters are being measured.

Part I: Basic description of the equipment and how it will be used to collect data

Referring to Figure 1, the mass (m) will accelerate downward and apply a torque (τ) to the disc.

Draw a free body diagram, and write an expression for the torque (τ) applied to the disc in terms of m , r , a , and g . (15, 10, 5, or 0 points)

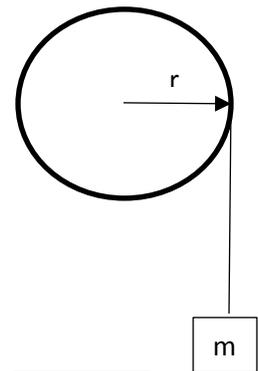


Figure 1

Part III: Collecting Data for the System

Print your table of data from Capstone and attach to report (5 points)

Part IV: Data Analysis for the System

Print the Excel table and scatter plot for the system data and attach to report (10, 5 or 0 points).

Record the value of the moment of inertia of the system.
(15, 10, or 5 points)

Part V: Data Collection and Data Analysis for the RMS

Print your table of data from Capstone and attach to report (5 points)

Print the Excel table and scatterplot for the RMS data and attach to report (5, or 0 points).

Record the value of the moment of inertia of the RMS. (10, 5, or 0 points)	
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Part VI: Determine the Experimental Moment of Inertia of the Ring

Record the value of your experimental Moment of Inertia for the Ring (5 points)	[A]
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Part VII: Determine the Analytical Moment of Inertia of the Ring

Inner Diameter of the Ring	
Outer Diameter of the Ring	
Mass of the Ring	
Show your calculation for the analytical moment of inertia for the ring.	
Analytical Moment of Inertia of the Ring (10 or 5 points)	[B]

Part VIII: Compare your analytical and experimental values of the moment of inertia for the ring

$$\text{Percent Difference} = \frac{|A - B|}{(A + B)/2} \times 100\% = \underline{\hspace{2cm}}$$

Circle the group's score

Percent Difference	<=8%	<=9%	<=11%	<15%	<=20%	>20%
Points	20	18	16	14	10	5