5.5: Rotational Inertia

Name: ____

Date: ______________________

Partners:____

Equipment

- *LabPro* Interface
- *Rotation* software file
- Rotary encoder
- Rotational inertia accessories
- Pulley
- Hanging masses

Introduction

Rotational inertia is a measure of the resistance of an object to changes in its angular velocity. Imagine applying a known torque to an object. While applying the torque, measure the angular acceleration. The smaller the resulting angular acceleration, the larger the object's rotational inertia. Thus, by measuring the applied torque and the resulting angular acceleration, the rotational inertia of an object can be determined.

In this activity, you will hang a known mass from the rotary encoder by means of a string wrapped around the encoder and over a pulley. The encoder will be oriented face-up to enable you to mount different objects on the encoder, and hence determine the rotational inertia of the system. When you release the mass, the string will supply a torque to the encoder, giving rise to an angular acceleration. By measuring this angular acceleration, you will be able to determine the rotational inertia of the encoder and its load.

I. Determining the Rotational Inertia of the Initial System

Open the file *Rotation.*

Orient the rotary encoder and secondary pulley as shown in the illustration above. Remove the 3-step pulley and flip it over so that the largest radius pulley is on the top. Do not yet attach the long rod with adjustable masses.

Spin the encoder to determine the positive direction. Using the small holes in the pulley to securely attach the string, wrap the string around the middle radius pulley to ensure a positive angular acceleration. Adjust the secondary pulley so that the string is horizontal between the pulleys and smoothly passes over the secondary pulley.

Attach a 5 g mass from the end of the string.

Adjust the graph to display angular acceleration vs. time, press **Collect,** and release the mass.

Question: Is the angular acceleration of the encoder approximately constant as the mass falls? Should it be constant? Explain.

Use **Analyze/Statistics** to determine the mean angular acceleration as the mass falls, and record it below. Vary the hanging mass to complete the table.

Hanging Mass (kg)	Angular Acceleration (rad/s^2)
0.005	±
0.010	±
0.015	±
0.020	±

The above data can be used to calculate the rotational inertia of the encoder system. To accomplish this requires applying Newton's second law to both the encoder and the falling mass and combining the results. You will be guided through this process step-by-step.

Question: Draw a free-body diagram for the hanging mass and apply Newton's second law. Let the direction of motion of the mass be positive.

Question: Draw a top-view free-body diagram for the encoder and apply the rotational form of Newton's second law. Let the direction of motion of the encoder be positive.

Question: Since the linear acceleration of the mass is unknown, rewrite the hanging mass equation replacing linear with angular acceleration.

Question: Since the force exerted by the string is unknown, combine your two equations to eliminate this term.

Question: Solve the resulting equation for the rotational inertia of the encoder.

You should notice that every variable in the above expression was measured and recorded in the above table, except the radius of the encoder. Measure the radius of the encoder and record it below:

radius of encoder, R = ____________ m

Using the results above, calculate the rotational inertia of the encoder for each trial and record it below.

Hanging Mass (kg)	**Angular Acceleration (rad/s^2)**	**Rotational Inertia (kg m^2)**
0.005	±	±
0.010	±	±
0.015	±	±
0.020	±	±

Question: Is the rotational inertia of the encoder the same in each trial? Should it be? Explain.

Question: What is the mean value, with uncertainty, for the rotational inertia of the encoder.

II. The Dependence of Rotational Inertia on Position

In this activity you will discover the effect that a constant mass, placed at a variable location on an object, has on the rotational inertia of the object. You will begin by placing the mass far from the axis of rotation of the object and then move the mass toward the axis of rotation.

Question: Do you believe the rotational inertia will increase, decrease or stay the same as you move the mass toward the axis of rotation? Explain.

Attach the long metal rod to the top of your encoder. Center the rod between the plastic pins on the 3-step pulley for stability. Attach the two adjustable masses to the rod, each located 16 cm from the center of the rod.

Attach 100 g to the end of the string, press **Collect**, and release the hanging mass. Record the result below. Before completing the following table, consider the question asked below.

Hanging Mass (kg)	**Mass Position (m)**	**Angular Acceleration (rad/s^2)**	**Rotational Inertia (kg m^2)**
0.100	*0.16*	±	±
0.100	*0.12*	±	±
0.100	*0.08*	±	±

0.100	*0.04*	±	±

Question: You may find that the angular acceleration becomes "less constant" as the masses move closer to the axis of rotation. Explain why this is the case and explain what portion of the angular acceleration data should be analyzed to compensate for this effect.

Create a graph of rotational inertia vs. mass position. Based on your data, select an appropriate best-fit function and display it on your graph. (Remember, your best-fit function should both match the data *and* correspond to the known physical relationship between rotational inertia and position.) Print and attach your graph to the end of this activity.

Question: Record the numerical constants in your best-fit function below. Each numerical value must have both uncertainties and units.

Question: Consider the intercept term in your best-fit function. What physical parameter of the system does this term represent? Clearly explain.

Question: Consider the other term(s) in your best-fit function. What physical parameter of the system does each term represent? If you can easily determine the actual value of this parameter, do so and compare it to your best-fit value.

III. Measuring the Rotational Inertia of the Metal Disk

In this last activity you will measure the rotational inertia of the metal disk.

Remove the metal rod from the encoder, flip the 3-step pulley over, and attach the metal disk to the 3-step pulley.

Attach 20 g to the end of the string, press **Collect**, and release the hanging mass. Record the result below.

Complete the table.

Hanging Mass (kg)	Angular Acceleration (rad/s^2)	Rotational Inertia (kg m^2)
0.020	±	±
0.030	±	±
0.040	±	±
0.050	±	±

Question: What is the mean value, with uncertainty, for the rotational inertia of the metal disk? (Hint: It is not simply the average value of the rotational inertia column above.)

Question: Measure the radius of the metal disk. Using this result, and your result from above, determine the mass of the metal disk, with units and uncertainties.

Question: Determine the actual mass of the metal disk and compare it to the value you determined above. Comment on the agreement between these values.