Name____________________ Pd_____

Rotational Dynamics

INTRODUCTION

When you studied Newtonian dynamics you learned that when an object underwent some form of translational motion (whether in a straight line, parabolic, or circular path), the net force applied to the object is proportional to the acceleration. The constant of proportionality is the mass of the accelerating object. When a torque (the rotational analogue to force), is applied to an object that is free to rotate, the object will undergo rotational acceleration. In this experiment, you will investigate the relationship between torque and angular acceleration.

OBJECTIVES

In this experiment, you will

- Collect angular acceleration data for objects subjected to a torque.
- Determine an expression for the torque applied to a rotating system.
- Determine the relationship between torque and angular acceleration.
- Relate the slope of a linearized graph to system parameters.
- Make and test predictions of the effect of changes in system parameters on the constant of proportionality.

MATERIALS

Vernier data-collection interface
Logger *Pro* or LabQuest App
ring stand
lightweight mass hanger
string
Vernier Rotary Motion Sensor
Vernier Rotary Motion Accessory kit
balance
drilled or slotted masses

PROCEDURE

1. Connect the Ultra Pulley to the Swivel Mount and then to the Rotary Motion Sensor, as shown in Figure 1. Attach the sensor to a ring stand and position it so that a weight tied to the edge of the large pulley on the sensor and hanging over the Ultra Pulley can hang freely without touching the floor.

Figure 1

Part 1

2. Find the mass of one of the solid aluminum disks, then attach it to the 3-step pulley on the sensor. Record the radius of the pulley.

3. Open a new file in the data-collection program. The default data-collection rate is fine, but reduce the length of the experiment to five seconds.

4. Place the lightest mass available on the hanger, then wind the string onto the largest pulley on the Rotary Motion Sensor.

5. Start data collection, then release the hanging weight. Catch the hanger when the string has completely unwound.

6. To determine the angular acceleration of the disk, perform a linear fit on the appropriate portion of the angular velocity *vs.* time graph. Record this value in your lab notebook, along with the mass of the hanger and weight for each value you use.

7. Repeat Steps 4–6, increasing the mass of the hanging weight, until you have at least eight different values of angular acceleration.

Part 2

8. Find the mass of the second solid aluminum disk. Using the longer machine screw and sleeve, attach both disks to the 3-step pulley on the sensor. Repeat Steps 3–7.

Part 3

9. Remove the disks from the sensor. Find the mass of each of the weights and the rod in the accessory kit. Attach each of the weights to opposite sides of the rod at a distance recommended by your instructor. SEE MRS. DRAUGHON FOR YOUR DISTANCE. Record this distance.

10. Attach the rod and weights to the sensor as shown in Figure 2. Repeat Steps 3–7 as you did in Parts 1 and 2.

Figure 2

DATA

Data for One Rotating Aluminum Disk					
Mass of Aluminum Disk:			Radius of Rotary Sensor Device:		
Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)	Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)
1			5		
2			6		
3			7		
4			8		

Data for Two Rotating Aluminum Disks					
Mass of BOTH Aluminum Disks:			Radius of Rotary Sensor Device:		
Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)	Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)
1			5		
2			6		
3			7		
4			8		

Data for Rotating Masses on Rod					
Mass of Rod: Radius of Rotary Sensor Device:			Mass of Each Knob: Distance of Knobs from Pivot:		
Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)	Trials for Different Hanging Masses	Hanging Mass (kg)	Angular Acceleration (rad/s^2)
1			5		
2			6		
3			7		
4			8		

EVALUATION OF DATA

In order to find a relationship between torque and angular acceleration, you need to know the value of the net torque acting on the system in each of the trials you performed. Since you were not able to measure the torque directly, you must derive an expression you can use to determine the torque from quantities that you *could* measure.   We will do this in class.

Calculated Data for One Rotating Aluminum Disk			
Mass of Aluminum Disk:		Radius of Rotary Sensor Device:	
Data Point	Average Angular Acceleration (rad/s^2)	Calculated Tension (N)	Calculated Net Torque (Nm)
1			
2			
3			
4			
5			
6			
7			
8			

Calculated Data for Two Rotating Aluminum Disks			
Mass of BOTH Aluminum Disks:		Radius of Rotary Sensor Device:	
Data Point	Average Angular Acceleration (rad/s^2)	Calculated Tension (N)	Calculated Net Torque (Nm)
1			
2			
3			
4			
5			
6			
7			
8			

Data for Rotating Masses on Rod			
Mass of Rod: Radius of Rotary Sensor Device:		Mass of Each Knob: Distance of Knobs from Pivot:	
Data Point	Average Angular Acceleration (rad/s^2)	Calculated Tension (N)	Calculated Net Torque (Nm)
1			
2			
3			
4			
5			
6			
7			
8			

<u>Example Calculations</u>: Show one example of each type of calculation performed in the above tables of calculated data.

Part 1 – One Rotating Disk

1. Plot a graph of net torque, τ, *vs*. angular acceleration, α.

2. If the relationship between net torque and angular acceleration appears to be linear, fit a straight line to your data.

3. Write a statement that describes the relationship between the net torque acting on the disk and its angular acceleration. Write this statement below the graph in a document. Make sure the graph has an appropriate title and labeled axes with units.

4. Write the equation that represents the relationship between the net torque, τ, acting on the disk and its angular acceleration, α. Write this below the graph, following the statement of the relationship. Be sure to label this data set with the value of the mass of the disk.

Part 2 – Two Rotating Disks

5. Choose New Data Set from the Data menu.

6. Plot a graph of net torque, τ, *vs*. angular acceleration, α. If the relationship between net torque and angular acceleration appears to be linear, fit a straight line to your data. Both data sets should appear on the same graph. Write a statement that describes the relationship between the net torque acting on the disk and its angular acceleration. Write this statement below the graph in a document.

7. Write the equation that represents the relationship between the net torque, τ, acting on the pair of disks and their angular acceleration, α. Write this below the graph, following the statement of the relationship. Be sure to label this data set with the value of the mass of the disk.

Part 3 – Rotating Masses on Rod

12. Choose New Data Set from the Data menu. Plot a graph of net torque, τ, *vs.* angular acceleration, α. If the relationship between net torque and angular acceleration appears to be linear, fit a straight line to your data.

13. Write a statement that describes the relationship between the net torque acting on the disk and its angular acceleration. Write this statement below the graph in a document. This is a separate graph from Parts 1 and 2. Write the equation that represents the relationship between the net torque, τ, acting on the rod and weights and their angular acceleration, α.

CONCLUSION

What does the slope and y-intercept of each of these graphs represent? What meaning can you extract from the different slopes you see on the 3 graphs?

Attach the 2 graphs (1 graph has 2 lines and the other has 1) to this lab before turning it in.