Experiment
14

Conservation of Angular Momentum

INTRODUCTION

In your study of linear momentum, you learned that, in the absence of an unbalanced external force, the momentum of a system remains constant. In this experiment, you will examine how the *angular* momentum of a rotating system responds to changes in the moment of inertia, I.

OBJECTIVES

In this experiment, you will

- Collect angle *vs.* time and angular velocity *vs.* time data for rotating systems.
- Analyze the θ-t and ω-t graphs both before and after changes in the moment of inertia.
- Determine the effect of changes in the moment of inertia on the angular momentum of the system.

MATERIALS

Vernier data-collection interface
Logger *Pro* or LabQuest App
Vernier Rotary Motion Sensor
Vernier Rotary Motion Accessory Kit
ring stand or vertical support rod
balance
metric ruler

PROCEDURE

1. Mount the Rotary Motion Sensor to the vertical support rod. Place the 3-step Pulley on the rotating shaft of the sensor so that the largest pulley is on top. Measure the mass and diameter of the aluminum disk with the smaller hole. Mount this disk to the pulley using the longer machine screw sleeve (see Figure 1).

Figure 1

2. Connect the sensor to the data-collection interface and begin the data-collection program. The default data-collections settings are appropriate for this experiment.

3. Spin the aluminum disk so that it is rotating reasonably rapidly, then begin data collection. Note that the angular velocity gradually decreases during the interval in which you collected data. Consider why this occurs. Store this run (Run 1).

4. Obtain the second aluminum disk from the accessory kit; determine its mass and diameter. Position this disk (cork pads down) over the sleeve of the screw holding the first disk to the pulley. Practice dropping the second disk onto the first so as to minimize any torque you might apply to the system (see Figure 2).

5. Begin the first disk rotating rapidly as before and begin collecting data. After a few seconds, drop the second disk onto the rotating disk and observe the change in both the θ-t and ω-t graphs. Store this run (Run 2).

6. Repeat Step 5, but begin with a lower angular velocity than before. Store this run (Run 3).

7. Find the mass of the steel disk. Measure the diameter of both the central hole and the entire disk. Replace the first aluminum disk with the steel disk and hub and tighten the screw as before (see Figure 3).

8. Try to spin the steel disk about as rapidly as you did the aluminum disk in Step 3 and then begin collecting data. Store this run (Run 4).

9. Repeat Step 5, dropping the aluminum disk onto the steel disk after a few seconds. Store this run (Run 5) and save the experiment file in case you need to return to it.

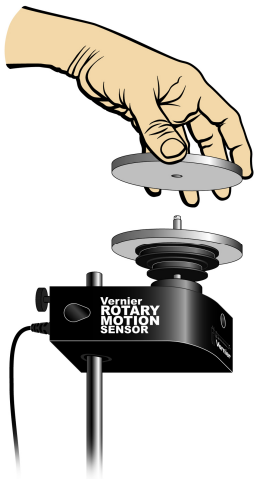

Figure 2

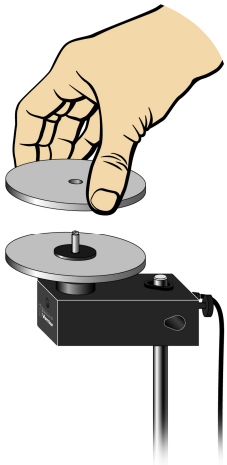

Figure 3

EVALUATION OF DATA

1. Use a text or web resource to find an expression for the moment of inertia for a disk; determine the values of I for your aluminum disks. With its large central hole, the steel disk should be treated as a cylindrical tube. Using the appropriate expression, determine the value of I for the steel disk.

2. Examine the ω-t graph for your runs with the single aluminum disk (Run1) and the steel disk (Run 4). Determine the rate of change of the angular velocity, ω, for each disk as it slowed. Account for this change in terms of any unbalanced forces that may be acting on the system. Explain the difference in the rates of change of ω (aluminum *vs.* steel) in terms of the values you calculated in Step 1.

3. Examine the ω-t graph for Run 2. Determine the rate of change of ω before you dropped the second disk onto the first. Record the angular velocity just before and just after you increased the mass of the system. Determine the time interval (Δt) between these two velocity readings.
   - In Logger *Pro*, drag-select the interval between these two readings. The Δx in the lower left corner gives the value of Δt.
   - In LabQuest App, drag and select the interval between these two readings and use the Delta function under Statistics to perform this task.
4. The angular momentum, L, of a system undergoing rotation is the product of its moment of inertia, I, and the angular velocity, ω.

   $$L = I\,\omega$$

   Determine the angular momentum of the system before and after you dropped the second aluminum disk onto the first. Calculate the percent difference between these values.
5. Use the initial rate of change in ω and the time interval between your two readings to determine $\Delta\omega$ due to friction alone. What portion of the difference in the angular momentum before and after you increased the mass can be accounted for by frictional losses?
6. Repeat the calculations in Steps 3–5 for your third and fifth runs.

EXTENSION

In this experiment, the moment of inertia of the rotating system was changed by adding mass. In what other way could one change the moment of inertia? Consider an example of how this is done outside the lab. Explain how this change in I produces a change in ω.