

## Experiment 12: Angular Momentum

In this lab we will study the conservation of angular momentum by studying the moment of inertias of various systems. The angular momentum,  $\vec{L}$ , of a particle with a mass  $m$  and a linear velocity  $\vec{v}$  with respect to a fixed point, typically the origin, is given as

$$\vec{L} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v}) \quad (1)$$

The  $\vec{r}$  term is once again the position vector locating the particle relative to a fixed point. Thus, we can write the magnitude of the angular momentum as  $L = rmv \sin\theta$ , where  $\theta$  is the angle between  $\vec{r}$  and  $\vec{p}$ .

The angular momentum component of a rigid body rotating about a fixed axis is given as

$$L = I\omega \quad (2)$$

where  $I$  is the moment of inertia and  $\omega$  is the angular speed. Similar to translational motion, we can write Newton's second law in angular form, that is in terms of torque and angular momentum as

$$\vec{\tau} = \frac{d\vec{L}}{dt} \quad (3)$$

Consequently, if the net external torque acting on the system is zero, the angular momentum remains constant ( $\vec{L} = \text{constant}$ ):

$$\vec{L}_{\text{initial}} = \vec{L}_{\text{final}} \quad (4)$$

This is the fundamental law of conservation of angular momentum that you will be studying in this lab. We can express this in term of the moment of inertia and angular speed as

$$I_i\omega_i = I_f\omega_f \quad (5)$$

where the final moment of inertia can be obtained using the parallel axis theorem.

### Experimental Objectives

In this lab experiment you have a rotating disk attachment, a short cylindrical tube which fits into a groove of the rotating disk attachment, a mass hanger, various masses, string, a pulley and a computer with the Scientific Workshop interface connected to the rotational measurement sensor. Using this equipment:

- Devise an experimental procedure to measure the moment of inertia of the disk attachment and the short cylindrical tube. How do these measured values agree with the expected theoretical moments of inertia as calculated using the parallel axis theorem? You can find the equations in your textbook.
- Use the measured moments of inertia to study the conservation of angular momentum in a rotational collision between the disk attachment and the cylindrical tube. You can set the initial angular speed by hand, and then, *gently and carefully*, drop the tube onto the disk.

## Conceptual Test

This part of the experiment requires no calculations, yet it may be the most difficult part to discuss in your write-up. Your skill in describing what you observe and giving a reasonable explanation of your observations using the physics involved will be tested here. CAUTION: SAFETY GLASSES MUST BE WORN FOR THIS PART OF THE EXPERIMENT.

- Set up the rotating platform to include the tilted metal ramp. Note: you must have the counter mass attached to the other end to ensure that the rotating platform is balanced.
- Display the  $\omega$  versus time graph on the computer screen.
- Place a single ball at the top end of the metal ramp.
- Give the ramp a small push so that the metal ball stays at the end of the ramp. **THE RAMP DOES NOT HAVE TO BE SPUN VERY FAST TO ACHIEVE THIS! BE VERY CAREFUL!**
- Start recording the  $\omega$  versus time graph. As the angular velocity of the ramp decreases, carefully observe what happens to the ball and how this corresponds to what you observe on the  $\omega$  versus  $t$  graph.
- After the ball rolls down the ramp, press the STOP button to stop recording.
- Be sure to print out this graph so that you may refer to it as you are writing your report. (Hint: to help you with your description and explanation, it may be beneficial to properly annotate this graph so that you may refer to parts of the graph more easily.)
- Repeat the procedure described in the above paragraph, but instead of using one ball, place three balls at the top of the ramp. The apparatus may need to be spun a little faster, but not much faster. It is important to be very cautious.
- In a clear and concise manner, describe your observations of the single ball experiment. Explain how the conservation of angular momentum can account for the behavior of the graph obtained. In the same manner, describe and explain your observation of the three-ball experiment.

A full lab report is not necessary for this lab. Answer the questions on the following page and turn it in with your signed datasheet.

## PHYS 123, Lab 12 Questions

**Name:**

**CWID:**

*Write your answers on a separate sheet and attach your signed datasheet when turning it in. You must show all of your work for full credit. Make it clear to me you understand what you're doing. Any graphs or tables should be made via computer software and attached to this handout.*

1. Answer the following questions using the data you acquired in this experiment:
  - (a) Using the parallel axis theorem, write down the equations for the moment of inertia of a short disk attachment and the short cylindrical tube. Calculate the moments of inertia using the measured values of mass and radius.
  - (b) How well do the experimental values agree with the expected theoretical moments of inertia when calculated using the parallel axis theorem?
  - (c) How well is the angular momentum conserved in the second experiment? Is this collision elastic or inelastic? Explain using energy relations.
2. In a clear and concise manner, describe your observations of the single ball experiment. Explain how the conservation of angular momentum can account for the behavior of the graph obtained. In the same manner, describe and explain your observations of the three-ball experiment.