
PHYSICS 133 EXPERIMENT NO. 6

CONSERVATION OF ANGULAR MOMENTUM

Introduction

In this experiment, we first study the relationship between torque, moment of inertia and angular acceleration, using a rotating platform. We then test the law of conservation of angular momentum by analyzing inelastic collisions between rotating objects.

Equipment

- 1 rotating platform with photogate,
- 1 pulley with clamp,
- 1 iron disk with handle,
- 1 interface box,
- 1 computer with timing program,
- small masses,
- Vernier caliper.

Method

Observing the angular acceleration of an object, the rotating platform, under an external torque will enable us to measure the moment of inertia of the object, using the equation $\tau_{\text{external}} = I\alpha$, where τ_{external} is the net external torque, α is the angular acceleration, and I is the moment of inertia. After the moment of inertia is determined, conservation of angular momentum will be investigated by dropping a mass onto the rotating platform, and measuring the angular velocity ω before and after the "drop." The equation $I_i\omega_i = I_f\omega_f$ is an expression of the conservation of angular momentum for this system, with the subscripts i and f referring to the initial and final states. This rotational inelastic collision is completely analogous to the linear inelastic collision studied last week on the air track.

Procedure

1. Correction for Systematic Error, i.e., Friction

Unlike the motion of the glider on the air track, the rotating table does exhibit significant friction. After starting its rotation, the table will slow down and eventually stop. However, this effect can be taken into account by a preliminary experiment. Set up the computer in MOTION TIMER mode and measure the angular velocity ω of the freely turning table for 20 or 30 seconds. When the program requests the distance between timings, enter the angular distance (in radians) between the pieces of tape on the plastic ring that pass through the photogate. The velocities will then be in radians/sec.

- Q1. How does the angular velocity change as time progresses? Graph ω vs t in your lab book. If you can, fit a straight line to your data points and calculate the slope.
- Q2. Is the frictional torque dependent on the velocity?
- Q3. How does the slope relate to the angular acceleration, α ?

II. Measurement of Moment of Inertia I

Using a Vernier caliper, measure the diameter of the cylinder under the rotating table to which the string will be attached. The TA will explain its operation. Attach a mass to the free end of the string, and wind the string neatly around the cylinder. Loop the string over the pulley and record the acceleration of the table as the mass falls. You will again graph the angular velocity, ω , and determine the angular acceleration α . The moment of inertia may now be calculated from the equation

$$I = m(g - R\alpha)R/(|\alpha_{\text{fric}}| + \alpha) \quad (1)$$

where m is the mass at the end of the string and R is the cylinder radius.

- Q4. Derive equation 1. Why do we use the absolute value of α_{fric} ?

Repeat experiment with another mass m .

III. Conservation of Angular Momentum

Remove the string from the rotating table and set the table in motion. Drop the iron disk onto the rotating table from a small height (less than 1 cm) above the table so that the rim of the disk will match the rim of the table as closely as possible. **CAUTION: The disks are heavy. Serious damage to equipment and/or toes, fingers or other body parts may result if care is not taken! Be CAREFUL!** Graph the angular velocity ω during this procedure and record it just before and after the collision. Given the mass M of the iron disk and measuring its radius r calculate its moment of inertia using $I = \frac{1}{2}Mr^2$.

- Q5. What assumptions are your calculations of the moment of inertia based on?
- Q6. Compare the initial angular momentum of the table/disk system, $I_i\omega_i$, with the final angular momentum of the system after the drop, $I_f\omega_f$. Determine whether your experiment (within its error limits) confirms angular momentum conservation. Repeat for different velocities, as time permits.
- Q7. OPTIONAL. Suppose the disk drops about 1cm off-center, what effect will this have on your result? Attempt to verify your prediction experimentally.