Physics 123
Experiment 6 : Rotational Motion

January 26, 2003

Up until now we have dealt with mostly translational motion in one dimension. Now we will focus on the dynamics of rotational motion about a fixed axis.

1 Rotational Mechanics

Rotational motion (around a single axis of rotation) is described using a polar coordinate system. All quantities familiar to you in translational motion have rotational analogues as follows:

Quantity	**Translational**	**Rotational**
position	x	θ
velocity	$v=\frac{dx}{dt}$	$\omega = \frac{d\theta}{dt}$
acceleration	$a = \frac{dv}{dt}$	$\alpha = \frac{d\omega}{dt}$
kinetic energy	$\frac{1}{2}mv^2$	$\frac{1}{2}I\omega^2$
momentum	$p = mv$	$l = I\omega$
Newton's 2^{nd} Law	$F = ma = \frac{dp}{dt}$	$\tau = I\alpha = \frac{dl}{dt}$

Of all the quantities which appear in the table, the one which will concern us in this experiment is the rotational analogue of the mass, the moment of inertia, I. In the same way as the mass for translational dynamics, the moment of inertia is intimately related to how hard it is to make a system move with the application of a particular force (torque). The larger the moment of inertia, the harder it is to rotationally accelerate a system, the more energy is stored in a rotational motion and the larger the angular momentum.

For a single point particle of mass m at a distance r from the axis of rotation, the moment of inertia is found to be

$$I = mr^2 \tag{1}$$

from a simple analysis of kinetic energy. For a system of N particles, the moment of inertia is given by:

$$I = \sum_i^N m_i r_i^2 \tag{2}$$

where r_i is the shortest distance (perpendicular distance) to the axis of rotation. For a continuous distribution of mass, this definition my be generalized to an integral over the entire mass distribution

$$I = \int r_i^2 dm \tag{3}$$

The moment of inertia of commmon objects such as cylinders, spheres, etc. is usually given in tables with the axis of rotation passing through the center of mass. To calculate the moment of inertia of the body along another parallel axis, the parallel axis theorem may be applied

$$I = I_{CM} + md^2 \tag{4}$$

where d is the shortest distance (perpendicular distance) from the center of mass to the actual axis of rotation).

2 Experimental Objectives

In the laboratory you have the rotating platform and two attachments for this in the shape of a rail and a disk, large masses which can be attached to the rotating rail, a short cylindrical tube which fits into a groove in 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:

- Calculate the inertia of the rotational platform and of the masses which can be attached to the rotating rail at various distances from the axis of rotation.
- Devise an experimental procedure to verify Newton's second law for rotational motion. First you will need to verify that torque τ is proportional to angular acceleration α for fixed inertia momentum. Then you will need to verify that for the constant torque inertia momentum is inversely proportional to angular acceleration.
- 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 moments of inertia as calculated using Equation 3 and tabulated in the 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.
- Is the above collision elastic or inelastic?

3 Conceptual Test

This part of the experiment requires no calculations, yet it may be the most difficult part to discuss in your report. Your skill in describing what you observe and giving a reasonable explanation of your observations using the physics involved will be tested. 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 ω versus t 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 ω versus t 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 ω 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 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.