CONSERVATION OF ANGULAR MOMENTUM

INTRODUCTION

One of the fundamental conservation laws of physics is the law of conservation of angular momentum which states that the total angular momentum of a system is constant in both magnitude and direction if the resultant external torque acting on the system is zero . In this experiment you will not try to "prove" the law of conservation of momentum but rather you will be asked to accept this law and then investigate various experimental situations to see how well your predictions for the model of an actual piece of apparatus agree with experimental measurements.

By dropping a series of rings and cylinders onto a rotating disc you will be able to compare angular momenta before and after the "collisions".

In this experiment, data is taken using rotational motion sensors. The rotational motion sensors are interfaced to a computer and the data is analysed using the DataStudio software.

THEORY

For rigid bodies that possess axial symmetry, the angular momentum $\vec{L}$ and the angular velocity $\vec{\omega}$ are parallel and we can write $\vec{L} = I\vec{\omega}$ where I is the moment of inertia of the body about the axis of rotation. If $\vec{L}$ stands for the total angular momentum then this equation applies only to bodies that have symmetry about the rotational axis. However, if $\vec{L}$ stands for the vector component of the angular momentum along the rotational axis then this equation holds for any rigid body, symmetrical or not, that is rotating about a fixed axis. If the axis of symmetry and the axis of rotation are one and the same then one need not worry about this distinction.

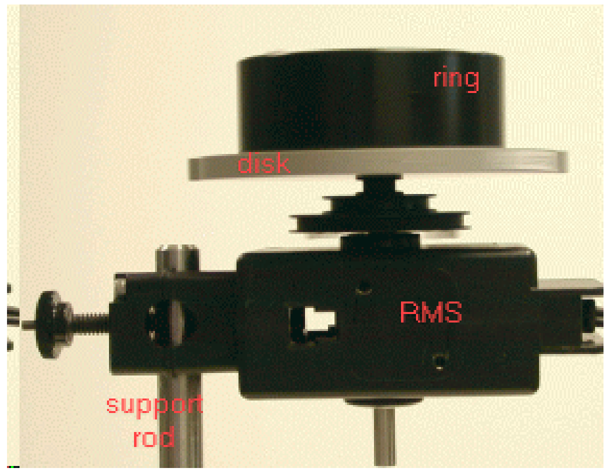
For rotation about the axis of cylindrical symmetry, the moment of inertia of a disk is $I_{disk} = \frac{1}{2}MR^2$ and the moment of inertia of a hollow cylinder of finite thickness is $I_{hollow\ cylinder} = \frac{1}{2}M\left(R_1^2 + R_2^2\right)$ where R_1 and R_2 are the inside and outside radii of the hollow cylinder.

For rotation about an axis parallel to, but not through, the axis of cylindrical symmetry, the Parallel Axis Theorem states that the moment of inertial is given by $I = I_{C.M.} + MD^2$ where D is the distance from the axis through the centre of mass to the axis of rotation.

THE EXPERIMENT

You will need to measure the masses and radii of the various disks and hollow cylinders. If the aluminum disk is attached to the rotary motion sensor you can remove it using the hex key provided. Note that the aluminum and brass hollow cylinders have about the same physical dimensions but different masses while the brass disc and hollow cylinder have about the same mass but different shape.

Mount the aluminum disk on the rotary motion sensor and attach the rotary motion sensor to the support rod near the base of the stand so that it is quite solid.



You will be dropping objects onto the rotating disk. In order to keep the objects centered on the disk you should arrange the apparatus to that you can look down on the apparatus from above. Note that the pulley between the disk and the rotary motion sensor in the diagram at the right has been removed since it isn't needed.

Place a bubble level on the aluminum disk and level the stand so that the bubble stays in the centre as you rotate the disk. This means that the axis of rotation is vertical.

In DataStudio, create an experiment with a rotary motion sensor. Click on *Setup*. Double click on the rotary motion sensor and select a *Sample Rate* from the *General* category, *Angular Velocity* (rad/s) from the *Measurement* category and 360 Division/Rotation from the *Rotary Motion Sensor* category to start. You may investigate other settings later.

WHEN YOU DROP OBJECTS ONTO THE ROTATING DISC DO NOT DROP THEM FROM A LARGE DISTANCE. THIS WILL DAMAGE THE SENSOR AND GIVE ERRONEOUS RESULTS. In fact, the closer you are to the disk when you drop the object, the better is the chance that it will be centered on the disk

Investigate the law of conservation of angular momentum by dropping a symmetrical object onto the rotating disk and measuring the angular velocities immediately before and after the "collision". Use a little double sided tape to prevent the dropped object from sliding when it "collides" with the aluminum disk. Using the circular lines on the disc as a guide, drop the objects onto the disc with their centre of rotation as close to the centre of rotation of the disk as possible. **Practice several time until you become good at it.**

After you have dropped one object, perform the calculations to determine how well your experimental results agree with conservation of angular momentum.

Measure the distance *D* for use in the parallel axis theorem. How much is the moment of inertia changed by using the parallel axis theorem?

Do the calculations immediately. Do not just take data and bring it home for analysis.

Repeat the steps above for the other symmetrical objects.

For one of your “collisions” estimate the frictional torque on the rotating disk which changes the angular momentum. How much does it contribute to a change in angular momentum during the time of the collision? Is the frictional torque the same before and after the “collision”?

Revised: November 6, 2001