EXPERIMENT NO 09

CONSERVATION OF ANGULAR MOMENTUM

Objective:

The object of this experiment is to observe and analyze one-dimensional rotational collisions between two disks rotating about a common axis. You will test the law of conservation of angular momentum and determine whether or not rotational kinetic energy is conserved during the collision.

Experiment:

In this experiment both disks will rotate at different constant angular speeds. No external torque will be applied. With the drop pin in place, air is forced between the disks so both disks spin freely and independently.

When the drop pin is pulled out, air can escape through the hole and the top disk will drop onto the bottom disks. Then both will rotate at a common angular speed.

1.With the drop pin in place hold the bottom (steel) disk stationary and spin the top disk (aluminum) to a counter frequency between 300 and 400 cps. Wait a full two second count cycle after accelerating the disk before recording the rim speed and direction. Release the bottom disk at the same time you pull out the drop pin. Record the coupled speed and direction. You may use Table 1.

2. With the pin back in place, spin both disks in opposite directions. As you look down on the spinning disks, choose the one moving counterclockwise as having positive (+) direction, and the other moving in the clockwise direction as having a minus (-) direction. For reliable results keep the speeds below 700 cps. You will have to switch the optical (photocell) reader from top to bottom to obtain the two different rim speeds; keep the delay between the two readings as short as possible. Use an aluminum disk on top and a steel disk on the bottom. Pull out the pin and again record the angular (rim) speed and direction in Table 2. Note that the top three rows correspond to the initial motion and the bottom three rows correspond to the final motion.

3. Keeping the aluminum disk on top, spin the two disks in opposite directions to those chosen in part 2. Follow the same general procedure and list your rim speeds and directions in Table 3.

4. Using a steel disk on top of another steel disk, repeat part 2, listing your data in Table 4.

Analysis:

All four experiments are one-dimensional rotational collisions. The axis of rotation remains fixed throughout the experiment. Since no external torques act on the disks, the total angular momentum of the system should be conserved during the collision, that is to say, the total angular momentum before the collision should equal the total angular momentum after the collision. Letting the top disk be called disk 1 and the bottom disk be called disk 2, we can write,

$$\mathrm{I}_1\vec{\omega}_{1i} + \mathrm{I}_2\vec{\omega}_{2i} = \mathrm{I}_1\vec{\omega}_{1f} + \mathrm{I}_2\vec{\omega}_{2f}$$

$$-\mathrm{I}_1\left(\vec{\omega}_{1f} - \vec{\omega}_{1i}\right) = \mathrm{I}_2\left(\vec{\omega}_{2f} - \vec{\omega}_{2i}\right)$$

$$\frac{\mathrm{I}_1}{\mathrm{I}_2} = -\frac{\Delta\vec{\omega}_2}{\Delta\vec{\omega}_1}$$

The ratio of the change in angular velocities should equal the negative inverse ratio of the moments of inertia of the two colliding disks. Tabulate the ratios in the tables. Compute the moment of inertia for each disk. Calculate the ratio of the moments of inertia and compare the ratio to the ratio of the change in angular velocities for each experiment. What can you conclude from your comparison?

Friction between the disks caused them to change their angular velocity until they were moving at a common angular velocity. Since there is friction, one would not expect mechanical energy to be conserved. For the last case, evaluate the total rotational kinetic energy before and after the collision. Based on this is the collision elastic or inelastic?

Data:

$M_{\mathrm{al}} =$ ____________ kg

$M_{\mathrm{steel,1}} =$ ____________ kg

$M_{\mathrm{steel,2}} =$ ____________ kg

$R = R_{\mathrm{al}} = R_{\mathrm{steel,1}} = R_{\mathrm{steel,1}} =$ ______

$I_{\mathrm{al}} = \frac{1}{2} M_{\mathrm{al}} R^2 =$ __________

$I_{\mathrm{steel,1}} = \frac{1}{2} M_{\mathrm{steel,1}} R^2 =$ _______

$I_{\mathrm{steel,1}} = \frac{1}{2} M_{\mathrm{steel,1}} R^2 =$ _______

Magnitude $\left\} \ \omega\left(\mathrm{rad}/s\right) = \frac{\text{rim speed (0.002 m)}}{\text{radius of disk (m)}}\right.$; Direction $\left\} \begin{array}{l} \textit{counter-clockwise} \Rightarrow + \\ \textit{clockwise} \Rightarrow - \end{array}\right.$

Report:

In addition to the standard elements of a well written lab report described in the introduction to this manual, your report must include:

1) The four data tables

2) A conclusion in which you address the following:

a) Whether or not angular momentum was conserved.

b) Whether or not the energy of the system was conserved.

Table 1:

Initial Motion	Top Disk (aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		
Final Motion	Top Disk (aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		

$\frac{\Delta\bar{\omega}_{steel}}{\Delta\bar{\omega}_{al}} =$ $\frac{I_{al}}{I_{steel}} =$

Table 2:

Initial Motion	Top Disk (aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		
Final Motion	Top Disk (aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		

$\frac{\Delta\bar{\omega}_{steel}}{\Delta\bar{\omega}_{al}} =$ $\frac{I_{al}}{I_{steel}} =$

Table 3:

Initial Motion	Top Disk (Aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		
Final Motion	Top Disk (Aluminum)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		

$\frac{\Delta\vec{\omega}_{steel}}{\Delta\vec{\omega}_{al}} =$ $\frac{I_{al}}{I_{steel}} =$

Table 4:

Initial Motion	Top Disk (steel)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		
Final Motion	Top Disk (steel)	Bottom Disk (steel)
Direction (+ or –)		
Rim Speed (bars/sec)		
ω (rad/sec) (+ or –)		

$\frac{\Delta\vec{\omega}_{steel\ (bottom)}}{\Delta\vec{\omega}_{steel\ (top)}} =$ $\frac{I_{steel\ (top)}}{I_{steel\ (bottom)}} =$

Total Rotational KE (Before Collision)=_______________ Joules
Total Rotational KE (After Collision)=_______________ Joules
Percent difference ____________%