



# Conservation of Angular Momentum

## Physics Lab X

### Objective

In this lab, the conservation law of angular momentum will be tested experimentally.

### Equipment List

The rotary motion kit (shown on the right); a LabPro unit; a smart pulley (SP); string; a mass holder and a set of masses; a plastic ruler and a meter stick; a digital caliper; ACCULAB VI-1200 mass scale.



### Theoretical Background

Continued from the previous lab, we extend our exploration of the conservation laws to angular momentum.

### Conservation of Angular Momentum

Analogous to the translational motion, a quantity called “angular momentum” is defined in rotational motion, so is the conservation law of angular momentum. The following table shows the analogous quantities in rotational motion to translational motion used in this lab.

| Quantities in Translational Motion        | Analogous Quantities in Rotational Motion          |
|---|--|
| $M$ (mass)                                | $I$ (moment of inertia)                            |
| $v$ (velocity)                            | $\omega$ (angular velocity)                        |
| $p = mv$ (linear momentum)                | $L = I\omega$ (angular momentum)                   |
| $\frac{1}{2}mv^2$ (linear kinetic energy) | $\frac{1}{2}I\omega^2$ (rotational kinetic energy) |

The conservation of angular momentum is then stated as,

$$I_i\omega_i = I_f\omega_f \quad (1)$$

In the experiment, a platter will be spun to certain angular speed, and then the second object (another platter or a metal bar) will be dropped onto the first platter, resulting in a change of the moment of inertia and the angular speed. This is analogous to a **totally inelastic collision** in linear motion. The final angular speed can then be found with Equation 1:

$$I_1\omega_i = (I_1 + I_2)\omega_f \Rightarrow \omega_f = \frac{I_1}{I_1 + I_2}\omega_i \quad (2)$$

In the equation,  $I_1$  is the moment of inertia of the first platter,  $I_2$  is the moment of inertia of the second object.  $I_1$  is calculated with  $I_1 = \frac{1}{2}M_{disk1}R_{disk1}^2$ , where  $M_{disk1}$  and  $R_{disk1}$  are the mass and radius of the first disk. If the second object is another disk, it can be estimated with

$$I_2 = \frac{1}{2}M_{disk2}R_{disk2}^2, \quad (3)$$

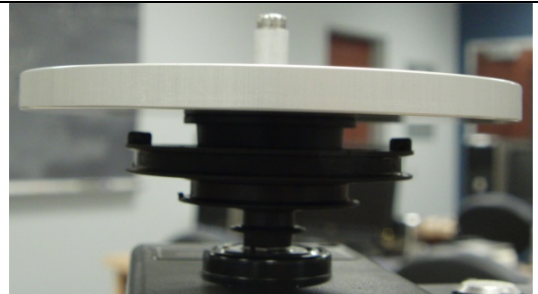
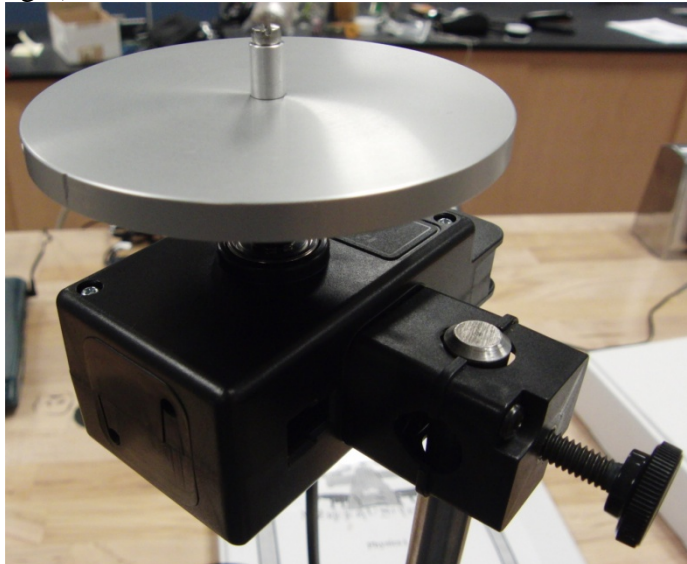
where  $R_{disk2}$  is the radius of the second disk.

## Experimental Procedure

### Conservation of Angular Momentum

In this lab, the first aluminum disk (without non-slippery pads) will be set at an initial angular speed. The second disk (with non-slippery pads) will be dropped onto the spinning platter. The angular speed will be monitored and recorded by the LoggerPro program, "**Rotational Motion.cml**", that you used in the previous lab. The operational procedure of this program can be found in the previous lab manual (Lab: Moment of Inertia & Rotational Energy).



Disk1 should be attached to the rotary motion sensor as in the previous lab. Remember to place the "hub" between the disk and the 3-step pulley (shown to the right).



Below is disk2. When dropping disk2 on disk1, the padded surface should face down.



Fig. 1 Setup of the experiment.

1. Measure and record the masses and diameters of disk1 and disk2.
2. Set up the experiment as shown in Figure 1.
3. To set disk1 at an initial angular speed, simply spin the platter with your hands. **DO NOT** spin it violently.
4. You should have "**Rotational Motion.cml**" opened by now. Click , then you should see the motion of disk1 shown on the graph.
5. Now as the disk1 is spinning steadily, drop disk2 right on top of disk1. Let the combined disks spin for another few seconds, until the program stops by itself. If the default data collection time is too long (or short), click  to change the setting for data collection. Identify the initial and final angular speeds ( $\omega_{i,exp}$  and  $\omega_{f,exp}$ ) from the graph as indicated in Figure 2, and estimate the uncertainties of  $\omega_{i,exp}$  and  $\omega_{f,exp}$ .
6. Export the data in "\*.csv" format for your own record keeping.
7. Repeat step 3~6 for 4 other different initial speeds (totally 5 initial speeds) set by different spins you provide.

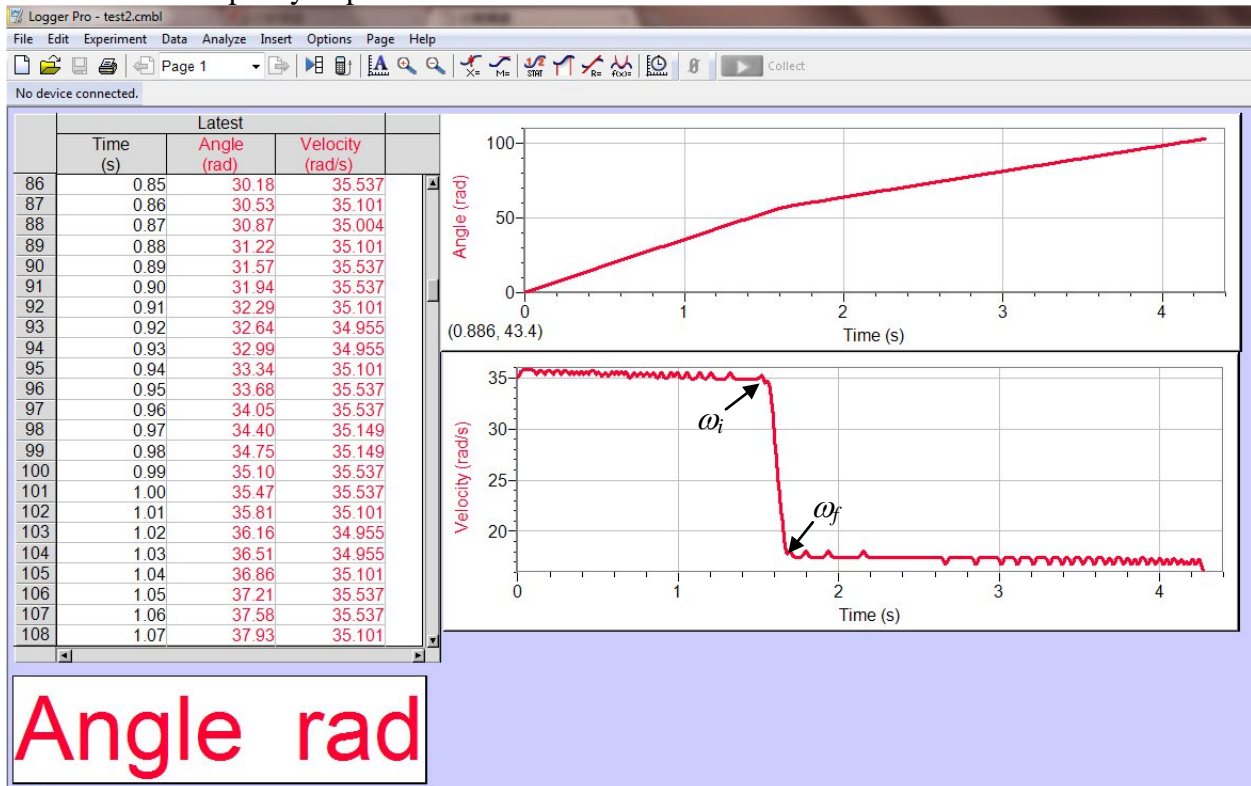


Fig. 2 Example of the collision data. Arrows indicate the moments before and after the collision. Read the  $\omega_i$  and  $\omega_f$  from the data and estimate the uncertainties of your reading.

## Data Analysis

### Conservation of Angular Momentum

1. Calculate the moment of inertia for both disks,  $I_1$  and  $I_2$ , using Equation 3.
2. Use Equation 2 and  $\omega_{i,exp}$  to calculate the theoretical values of the final angular speed,  $\omega_{f,theo}$ .

3. Calculate the % Difference between  $\omega_{f,exp}$  and  $\omega_{f,theo}$ .

4. Calculate the initial angular momentum  $L_i$ .

$$L_i = I_1 \omega_{i,exp}$$

5. Calculate the final angular momentum  $L_f$ .

$$L_f = (I_1 + I_2) \omega_{f,exp}$$

6. Calculate the ratio  $L_f / L_i$ .

Plot  $L_f$  as a function of  $L_i$ , and determine the slope and y-intercept from the plot.

## Selected Questions

1. In this experiment, the presence of friction was not taken into consideration. How would the presence of friction affect the experiment? Is the angular momentum still conserved? Is this a source of random or systematic error? Why?
2. The pads on disk2 are to prevent slipping during collisions. Assuming that the axle is truly frictionless, will the final angular speed (at which disk1 and disk2 ultimately rotate together) be different if disk2 did not have those pads? Why?