Physics 4A

Lab 10: Conservation of Angular Momentum

Objective: To measure moment of inertia and angular velocity during a collision to show that angular momentum is conserved.

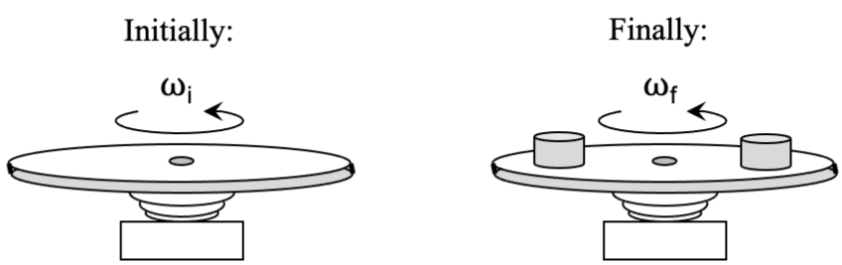
Theory:

Conservation of angular momentum states that the total angular momentum of a system is constant in both magnitude and direction if the resultant external torque on the system is zero. Assuming the system is an object rotating about a fixed axis, we can say

$$I_i\omega_i = I_f\omega_f$$

where *I* is the moment of inertia, and ω is the angular velocity.

In Lab 8 we demonstrated that linear momentum is conserved for elastic and inelastic collisions so long as no net external force was acting on the system. The same is true for collisions where the objects are rotating. In this case, angular momentum is conserved for elastic and inelastic collisions so long as no net external torque is acting on the system. In lab 10 we will focus on an inelastic collision in rotation, we will start out with a rotating turn table, then drop a pair of masses on the disk.



The moment of inertia of the system will change with the collision, therefore the angular velocity of the system will change as well.

The rotating turn table consists of an aluminum disk attached to a larger plastic disk by two screws. The moment of inertia of the rotating turn table is therefore the sum of the moment of inertia of each component:

$$I_{turn\ table} = I_{plastic} + I_{aluminum} + I_{screws}$$

where $I_{plastic} = \frac{1}{2}m_p r_p^2$, $I_{aluminum} = \frac{1}{2}m_a r_a^2$, $I_{screws} = m_s r_a^2$. The mass of the plastic, aluminum, and screws is given by m_p, m_a and m_s respectfully. The radius of the plastic is given by r_p aluminum, and the radius of the aluminum and screws are the same, given by r_a. As the turn table is the only object in motion initially, $I_{initial} = I_{turn\ table}$.

Because the pair of masses dropped on the turn table are not point masses, their moment of inertia is given by the parallel axis theorem:

$$I = I_{CM} + mD^2$$

where D is the distance away from the rotational axis. For the pair of masses,

$$I_{brass} = \frac{1}{2}mr_b^2 + mD^2$$

where r_b is the radius of the brass masses.

As the turn table and masses are both rotating at the end, $I_{final} = I_{turn\ table} + I_{brass}$.

If we take our initial equation,

$$I_i\omega_i = I_f\omega_f$$

and rearrange, we obtain

$$\omega_f = \frac{I_i}{I_f}\omega_i.$$

Therefore, when ω_i is plotted vs. ω_f, the slope of the line is equal to I_i/I_f.

Procedure:

1.1. Introduction

Watch the following video to learn about the apparatus and experiment:
https://youtu.be/K0ZWPPS-fQw

1.2. Data

To get the mass and diameter measurements, watch the following video:
https://youtu.be/33qIkVCBbsI

Record the mass and diameter of the plastic disk, aluminum disk, screws, and brass weights in Excel. Note: the mass of the brass weights is 100 g.

Calculate the radius of the plastic disk, aluminum disk, and brass weights.

For each of the 3 trials, the distance between the brass weights is different. For each trial, 7 runs occurred with varying initial angular velocities. Watch the following videos to obtain data for the initial and final angular velocities, and record them in Excel:

Trial 1: https://youtu.be/D6TEpjHG5RI
Trial 2: https://youtu.be/KXkI-wxgoJs:
Trial 3: https://youtu.be/BKZnG3GHLQQ

For each trial, indicate the distance between the brass weights *L*.

1.3. Graphs

Highlight ω_i and ω_f for Trial 1, and create a scatterplot of the data. Include axis labels, a legend, and give the graph a title. Find the slope of the line as well.

On the same graph, add data from Trial 2 and Trial 3. Include the linear curve fit, and move the equations around so it is clear which curve fit belongs to which line. Change the axis of the graph so the data fills most of the graph.

1.4. Calculations

Calculate the initial moment of inertia of the system.

Enter the distance between the masses *L* next to each trial. Calculate the distance from the mass to the rotational axis, *D*.

Calculate the final moment of inertia of the system.

Calculate the expected slope of the line.

Input the measured slope of each line into the table.

Calculate the % error between the expected slope and measured slope. Percent errors should be less than 5%. If you obtain errors larger than this, ask me (your instructor) for help.

1.5. Lab Report

Submit a lab report, where the results section answers the questions below. For the data section, refer the reader to the excel spreadsheet, and submit the excel spreadsheet as well. Details on how to write a lab report are given in Lab 2.

Questions:

1. It was stated in the video that the angular velocity of the turn table decreases over time due to friction. However, in our calculations, we do not include a term for friction. Why are we able to ignore friction in the experiment?
2. When we were dropping the brass masses on the turn table, they generally fell so the string connecting them was no longer straight. In other words, the masses did not fall exactly as expected, therefore the distance between them was not exactly as measured. Which trial did this systematic error effect the most? Why did it affect that trial the most?