**Experiment 10: Conservation of Angular Momentum**

**Using a Point Mass**

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OBJECTIVE**:**

The purpose of this experiment is to observe the conservation of angular momentum by predicting a new angular speed when a mass rotating in a circle is pulled in to a smaller radius.

EQUIPMENT:

* Smart Pulley Timer Program
* Rotational Inertia Accessory (ME-8953)
* Rotating Platform (ME-8951)
* Smart Pulley
* Balance

THEORY AND EQUATIONS:

When a mass on a rod is rotating in a circle, the angular momentum will be conserved regardless of the distance between the mass and the center of rotation, or the radius. The following equation illustrates the conservation of angular momentum:

**(1)**

*I* is the rotational inertia and is angular speed. For the experiment, we rearranged the equation to find the final angular speed:

**(2)**

Using the rotating platform, we could find the rotational inertia experimentally by applying a torque and measuring the angular acceleration. The following equation shows the relationship between torque (rotational inertia (*I*), and angular acceleration

**(3)**

The torque was caused by a hanging mass from the center of rotation using a thread. The thread created a tension when the apparatus was rotating. Torque relates to tension and the radius in the following way:

**(4)**

To find the tension in the string, Newton’s Second Law is applied to the hanging mass (m):

**(5)**

Thus, an equation for tension:

**(6)**

PROCEDURE:

Part I: Conservation of Angular Momentum

1. The apparatus was leveled by ensuring the platform did not rotate on its own.
2. Two stop screws were tightened on the track, one at the 5 cm mark and the other at 20 cm. The 300g mass was placed in-between the stop screws with the hole facing the center post. It was left to slide freely.
3. The pulley on the center post was placed in its lower position and the spring was removed.
4. A string was run from the mass to the pulley and up to the indicator bracket.
5. The Smart Pulley photo-gate was attached to a rod and positioned so it straddled the holes in the center-rotating shaft. The Smart Pulley Timer program was turned on.
6. Motion Timer was selected on the program.
7. The string was held just above the center post. The mass was placed against the outer stop and the track was spun. After 25 data points were taken, the string was pulled to cause the mass to slide to the inner stop. 25 more data points were taken with the mass against the inner stop. The timer was then stopped.
8. The computer graphed the rotational speed versus time. The angular velocities immediately before and after pulling the string were recorded in Table 1 in the *Data and Observations* section.
9. Steps 7 and 8 were repeated two more times.

Part II: Determining the Rotational Inertia

1. A Smart Pulley was attached with a rod to the base.
2. A thread was wound around the smaller pulley on the center shaft and then pass over the Smart Pulley.
3. To compensate for friction, a hanging mass was increased in value until the apparatus spun at a constant speed. This mass was subtracted form the sliding mass during calculations.
4. Once the velocity was constant to three significant figures, the hanging mass value was recorded in Table 2 in the *Data and Observations* section.
5. To find the acceleration, 30g was used as the hanging mass. The thread was wound up, the Motion Timer was started and then stopped just before the mass hit the floor.
6. Once the computer calculated the times, the slope of the velocity versus time graph was taken and was recorded in Table 2 in the *Data and Observations* section.
7. The distance from the center of mass of the 300g sliding mass to the center of mass of the center post and the radius of the cylinder about which the thread is wrapped were measured and recorded in Table 2 in the *Data and Observations* section.

DATA AND OBSERVATIONS:

**Part I**:In this part of the experiment, the values from Table 1 were obtained experimentally. The initial angular speed was when the mass was against the outer stop. The final angular speed was when the mass was against the inner stop. Three trials were done and an average was taken; values obtained are presented in the table below:

|  |  |  |
| --- | --- | --- |
|  | **Angular Speeds** | |
| **Trial Number** | **Initial (radians/sec)** | **Final (radians/sec)** |
| 1 | 7.12 | 9.97 |
| 2 | 7.24 | 10.25 |
| 3 | 8.53 | 12.06 |
| Average | 7.63 | 10.76 |

**Table 1**: Above are the values found for initial and final angular speed and the average reported in radians/sec.

**Part II**: In this part of the experiment, we obtained the friction mass, hanging mass, slope, and radius, for both the outer stop and inner stop experimentally. The rotational inertia for the outer and inner stop was calculated using the experimental data. Experimental results and calculations are presented below:

|  |  |  |
| --- | --- | --- |
|  | **Mass at Outer Stop** | **Mass at Inner Stop** |
| **Friction Mass (kg)** | 0.01 | 0.008 |
| **Hanging Mass (kg)** | 0.03 | 0.03 |
| **Slope (radians/s2)** | 0.284 | 0.398 |
| **Radius (m) cylinder** | 0.0125 | 0.0125 |
| **Rotational Inertia (kg-m2)** | 0.00864 | 0.00676 |

**Table 2**: Above are values for friction and hanging mass in kilograms, slope, radius in meters, and rotational inertia in kg-m2.

CALCULATIONS:

MR2 = m (g-αr) r / α

Rotational inertia (at outer stop)

MR2 = m (g-αr) r / α

(0.275)(0.171)2 = (0.02) (0.0125) {9.8- (0.284) (0.0125)} / (0.284)

0.00804kg-m2 = 0.00864kg-m2

Rotational inertia (at inner stop)

MR2 = m (g-αr) r / α

(0.275)(0.083)2 = (0.022) (0.0125) {9.8- (0.398) (0.0125)} / (0.398)

0.00189kg-m2 = 0.00676kg-m2

Wf = IiWi

If

Theoretical angular speed (trial 1)

Wf = IiWi

If

Wf = (0.00864) (7.12) / (0.00676)

Wf = 9.1rad/sec

Theoretical angular speed (trial 2)

Wf = IiWi

If

Wf = (0.00864)(10.25) / (0.00676)

Wf =9.25 rad/sec

Theoretical angular speed (trial 3)

Wf = IiWi

If

Wf = (0.00864)(12.06) / (0.00676)

Wf =10.9 rad/sec

% difference = |theoretical – experimental| X 100%

Theoretical

Percent Difference (Trial 1)

% difference = |theoretical – experimental| X 100%

Theoretical

% difference = | (9.1) – (9.97)| X 100%

(9.1)

% difference = 9.6%

Percent Difference (Trial 2)

% difference = |theoretical – experimental| X 100%

Theoretical

% difference = | (9.25) –(10.25)| X 100%

(9.25)

% difference = 10.8%

Percent Difference (Trial 3)

% difference = |theoretical – experimental| X 100%

Theoretical

% difference = | (10.9)–(12.06) |X 100%

(10.9)

% difference = 10.6%

RESULTS:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Trial 1** | **Trial 2** | **Trial 3** |
| **Theoretical Angular Speed** | 9.1 rad/sec | 9.25 rad/sec | 10.9 rad/sec |
| **Experimental Angular Speed** | 9.97 rads/sec | 10.25 rad/sec | 12.06 rad/sec |
| **% Difference** | 9.6% | 10.8% | 10.6% |

**Table 3**: the above table presents the theoretical angular speed for each trial and the percent difference between the theoretical and experimental value.

CONCLUSIONS:

The objective of this experiment was to observe the conservation of angular momentum by predicting a new angular speed when a mass rotating in a circle is pulled in to a smaller radius. The objective of this experiment was successfully met by following the given instructions. The differences in the experimental angular speed, found in Table 3, were fairly close. Their differences were probably due to the placement of the photo-gate and receiving a constant acceleration on the computer. The percent difference was calculated from our experimental value and the calculated value. This difference was most likely due to errors found in the values from the second part of the experiment; the theoretical angular speed was found by using the values from part two. For part two, human error played a big part in obtaining the values. Values that were subject to human error were measuring the radius, measuring the acceleration using the photo-gate.