22101782, Yasemin Akın

Computer Science, Physics 101 - 8

Demonstration of Conservation of Angular Momentum by Using a Spinning Wheel

1 Objective

The purpose of this experiment is to show that the angular momentum of a system remains constant unless an external force, that creates a torque on the system, is applied. The experiment consists of two parts consisting of similar applications. It is planned to reach the result with the least error by presenting the data of both parts in 3 tables. In the experiment, the first and last angular momentums of the system will be calculated and compared, and it will be checked whether they are equal. To do this, the angular momentum of each element in the system must be calculated as first and last, one by one, which requires calculating their angular velocities and moments of inertia one by one. After each change in the system, the calculation of the angular velocity should be repeated for objects other than the wheel -the angular velocity of the wheel will be almost always the same throughout the experiment, so as not to repeat the calculation continuously it will be taken as constant.

2 Theory

The main theory that I used in this experiment is about the conservation of angular momentum which says if there is no net external torque operating on the system, its angular momentum is conserved. Any object's angular momentum can be calculated and defined in one of two ways: if it's a point object in rotation, the angular momentum is equal to the radius times the linear momentum of the object,

$$1. \qquad \vec{L} = \vec{r} \times \vec{p} = \vec{r} \times m\vec{v}$$

The angular momentum of an extended object, like the earth, is determined by the moment of inertia, or the mass of the object multiplied by the distance from the center times the angular velocity,

$$2. \qquad \vec{L} = \vec{I} \times \vec{\omega}$$

But in both cases, the angular momentum before is equal to the angular momentum after a certain amount of time if there is no net force acting on it. After I experimented, I used the second equation while calculating the required data, which are angular momentums of the system's components, because, in my experiment, there was a system that rotates around its own axis, just like the earth in the example I gave.

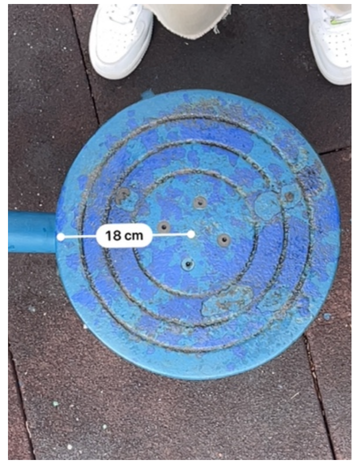
Other values that I calculated to use in the experiment were the moment of inertia and angular velocity.

$$\mathrm{I} = m \times r^2$$

$$\vec{\omega} = \frac{\theta}{t}$$

3 Procedure

The main materials I used while experimenting were the spinning wheel and the rotating platform. I also used my cellphone's chronometer in seconds, a meter in centimeters, and a precision scale in grams.



Since my assistant constantly applied the same amount of force, turned the wheel in the same direction, and in the same way every time he rotated the wheel, I assumed the wheel's angular velocity, and hence its angular momentum, to be a constant value throughout the experiment. In the beginning, I calculated the angular velocity of the wheel with the angular velocity formula I specified. my assistant turned the spinning wheel and kept a time for 5 seconds with the help of a stopwatch, so I counted how many turns the wheel had rotated during this time. We repeated the same process five times to get a more precise result and I calculated these results' average and used it as the average angular velocity of the wheel throughout the experiment. Then I measured the weights of the wheel with the help of precision scales and mine with the help of normal - daily life scales. The weight of the rotating platform was written at the bottom of it, so I did not need to measure it. Finally, I measured the radii of the rotating platform and the wheel with the help of a meter. I used all these measurements to calculate the moments of inertia one by one. While calculating my moment of inertia, I accepted my average radius concerning my axis of rotation as half of my shoulder width and I made my calculations accordingly.

In the first part, I moved the wheel from the vertical position to the horizontal position by first turning it to the right, then to the left, and calculated the angular speed of the rotating platform that I was standing on. Then I calculated the angular momentum of mine and the platform. Finally, I compared the system's last and first angular momentums and made an error analysis.

In the second part, I turned the wheel 180 degrees while it was horizontal and again observed the behavior of the rotating platform, and again at the end, I compared the first and last angular momentums and analyzed the error.

In both parts, I calculated the angular velocity of the rotating platform and therefore the angular velocity of myself, as the way I calculated the angular velocity of the wheel and using the angular velocity formula I specified. After calculating their angular velocities, this time I calculated the angular momentum of the elements in the system one by one, using the angular momentum equation I mentioned and using the moment of inertia values I calculated before, and determined their directions. Afterward, I summed the angular momentum values I found by taking their directions into account, and reached the final angular momentum values of the systems. The initial angular momentum values of the systems are already equal to the angular momentum of the wheel since the wheel is the only element that rotates in the systems before the changes are made to the system. I also used the direction chart I drew below as a direction guide while filling the tables.

4 Data and Results

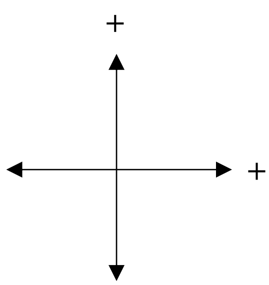


Table 1 – Initial Physical Data	mass (g)	radius (cm)	$\vec{\omega}_{avg}$ $(\frac{rad}{s})$	I $(g.cm^2)$
WHEEL	700	16	2.8	179200
VOLUNTEER (HUMAN)	57300	20	0	22920000
PLATFORM	2000	18	0	648000

Part 1

Table 2 – Rotate to Right at $t = t_1$	$\vec{\omega}_{avg}$ $(\frac{rad}{s})$	$\vec{L}$ $(g.cm^2.\frac{rad}{s})$	**Direction of Rotation and $\vec{L}$**
WHEEL	2.8	+ 501760 + 501760	At t_0: from up to down, to the volunteer's left At t_1: from right to left, to up
VOLUNTEER (HUMAN)	0.019	- 435480	At t_1: from left to right, to down
PLATFORM	0.019	- 12312	At t_1: from left to right, to down
SYSTEM at $t = t_1$	-	+ 66280	At t_1: from right to left, to up

Table 3 – Rotate to Left at $t = t_1$	$\vec{\omega}_{avg}$ $(\frac{rad}{s})$	$\vec{L}$ $(g.cm^2.\frac{rad}{s})$	**Direction of Rotation and $\vec{L}$**
WHEEL	2.8	+ 501760 -501760	At t_0: from up to down, to the volunteer's left At t_1: from left to right, to down
VOLUNTEER (HUMAN)	0.02	+458400	At t_1: from right to left, to up
PLATFORM	0.02	+ 12960	At t_1: from right to left, to up
SYSTEM at $t = t_1$	-	- 30400	At t_1: from left to right, to down

Part 2

Table 4 – Rotating Upside Down at $t = t_1$	$\vec{\omega}_{avg}$ $(\frac{rad}{s})$	$\vec{L}$ $(g.cm^2.\frac{\text{rad}}{s})$	**Direction of Rotation and $\vec{L}$**	
WHEEL	2.8	- 501760 + 501760	At t_0: from left to right, to down At t_1: from right to left, to up	At t_0: $501760 = \vec{L}$ At t_1: $-\vec{L}$
VOLUNTEER (HUMAN)	0.04	- 916800	At t_1: from left to right, to down	At t_1: $942720 \cong 2\vec{L}$
PLATFORM	0.04	- 25920	At t_1: from left to right, to down	
SYSTEM shortly after $t = t_1$	-	- 440960	At t_1: from left to right, to down	At t_1: $440960 \cong \vec{L}$

Error Analysis

Percentage Error calculation for Table 2 = $\frac{66280}{501760} \times 100 = 13.2\%$

Percentage Error calculation for Table 3 = $\frac{12960}{501760} \times 100 = 2.5\%$

Percentage Error calculation for Table 4 = $\frac{60800}{501760} \times 100 = 12.1\%$

As can be seen from my percentage error calculations, there is a slight difference between the theoretical data and my experimental data. In general, we can say that the theoretical and experimental ones show parallelism in the experiment. The reason for the small differences may be the small mistakes I made in the measurements, the fact that there is friction in real life, unlike the theoretical one, and the errors caused by the measuring instruments.

5 Conclusion

I was able to prove what I needed to prove in the experiment and that is the angular momentum of a system will be conserved as long as an externally applied force does not create a torque effect on the system. I concluded that this law is correct, thanks to the data which I collected experimentally that contain minor errors due to friction and some measurement mistakes. I tried to observe how the system adjusts itself for its angular momentum to stay the same with a few tests I made.

For the first part of the experiment, the initial angular momentum of the system was equal to the angular momentum of the wheel since the wheel was the only rotating object in the system. Later, when I brought the wheel to the horizontal position, the platform and therefore I started to turn. The reason for this was that an angular momentum had formed in a direction different from the direction of the first angular momentum that the system had, when I brought the wheel to the horizontal position, and the system wanted to balance this angular momentum formed in a different direction. As a result, the sum of the angular momentum of me and the platform was indeed almost equal to the value of the angular momentum of the wheel when it is at the horizontal position, but its direction was opposite to the wheel's angular momentum to reset the existing angular momentum in the horizontal. So, as a result, we have observed what is expected theoretically.

For the second part of the experiment, I observed once again what we observed in the first part. When I turned the wheel upside down, an angular momentum that had a different direction from the initial angular momentum of the system occurred ($\vec{\boldsymbol{L}}$), and again the system wanted to balance it, so the platform and I on it started to rotate in the opposite direction to the direction of rotation of the wheel. This time, unlike the first part, when the wheel was turned, it had an angular momentum of the same magnitude but in the opposite direction to the angular momentum that the system had at the very beginning ($-\vec{\boldsymbol{L}}$), so the magnitude of the platform's and mine total angular momentum had a value of twice this angular momentum and its direction was opposite to the wheel's angular momentum ($2\vec{\boldsymbol{L}}$) to obtain the initial angular momentum again because of the law of conservation of angular momentum.

$$2\vec{\boldsymbol{L}} - \vec{\boldsymbol{L}} = \vec{\boldsymbol{L}}$$

Thus, I achieved the aim of my experiment by concluding that angular momentum is indeed conserved.

Video Link

https://youtu.be/LEC43j7I09E