

# Angular Momentum

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## Introduction:

Angular momentum can be observed when a figure skater is spinning and the extension or contraction of her hands reduces or increases her spinning rate. A very important physical property is being observed in this example, which is the conservation of angular momentum. Theoretically, conservation of angular momentum is valid as long as there is no external torque on the object that is rotating.

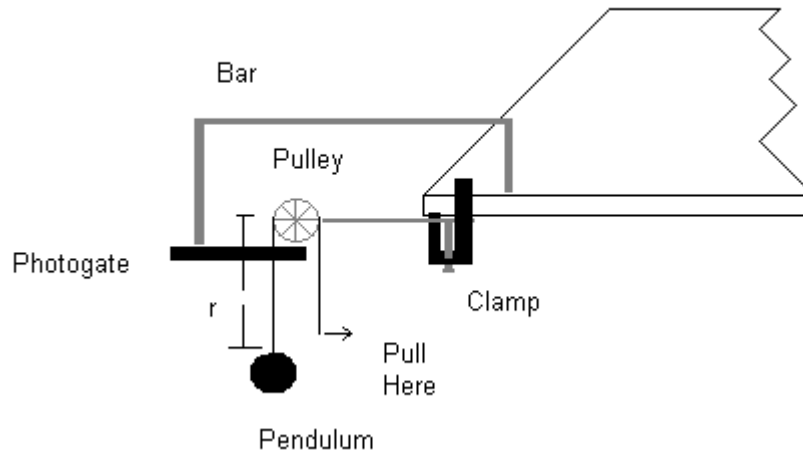
In this experiment we are going to use the concept of conservation of angular momentum to see how the rotational velocity or the angular velocity is going to change once the rotational inertia has changed. Ideally, the initial angular momentum and the final angular momentum should be equal to one another. If either value is changed the other factor will consequently change as well. This is the observation that is going to be utilized for this experiment.

## Background:

- The angular momentum in itself is an inherent property of rotation, as is every other rotational property such as angular velocity or acceleration. The definition of angular momentum can be stated in two ways:
  - $$\text{Angular Momentum} = \text{Rotational inertia} \times \text{Rotational velocity}$$
  - $$\text{Angular Momentum} = \text{Moment arm} \times \text{linear momentum}$$
- Conservation of angular momentum is the principle that the angular momentum of an object remains constant as long as no external torque, or moment, acts on that object. It can also be deduced from that statement that as long as the applied force although external does not act in the direction of the rotation then the conservation of angular momentum will still be valid.
- As seen through the setup pictured below, the photogate is going to measure the period, or the time that it takes for one full rotation, after which logger pro will calculate the frequency and the rotational velocity and display it on the digital meter and the graph. From the graph it will be seen that once the radial arm 'r' is going to increase, the angular velocity is going to decrease the inverse will be true as well.
  - The reason why the additional force that is placed does not interfere with the conservation law is because as stated previously, the force is arranged in such a way that it will not be in the direction of motion and therefore the net external torque is equal to zero.
  - The rotational inertia for a simple pendulum is calculated as follows:
 
$$I = mr^2$$
 Since we are changing the radial arm displacement and upholding the conservation principle, the rotational velocity will change as well.

- The following equation can be used to calculate the final rotational velocity if the initial rotational velocity is known:

$$\omega_{from\ sensor} = \frac{I_1}{I_2} \omega_{initial}$$



### Equipment List:

1. Vernier Photogate
2. Smart Pulley
3. Mounting Clamp
4. Pendulum
5. Vernier LabPro
6. Logger Pro

### Experimental Procedure:

1. Place the pendulum on the pulley and hold the end of the string as pictured above, and make sure that the pulley rotates freely.
2. Make sure that the photogate's LED is initially on; therefore it should initially be covered by the pendulum's string.
3. Start Logger Pro; give the pendulum an initial angle, so that it will start oscillating in the direction of the plane of the pulley. This is done to prevent any excess motion or to enforce a categorized motion.
4. Press the collect button in Logger Pro to start data collection.
5. Gently start pulling down on the string as pictured above, until the ball of the pendulum is coming in contact with the photogate.
6. Then release bit-by-bit portions of the string to increase the radial arm 'r.'
7. Stop the data collection.
8. Print the results.
9. Make sure that you print the table and the graph on separate sheets.
10. Label the portions on the graph where you've increased the length of the string and where you contracted the length of the string.

**Results:**

1. Print out the graph and the table from logger pro on separate sheets of papers.
2. Label the portions on the graph where you've increased the length of the string and where you contracted the length of the string; this will help you visualize how the angular velocity or the rotational velocity changes with the length of the rotational arm and hence rotational inertia.

**Analysis:**

1. Why does the conservation of angular momentum hold true even though we are applying an external force on it?
2. Why does the rotational inertia value change if we change the radial arm, 'r,' value?
3. Select and label two points on the graph and describe in your own words how you think the conservation of angular momentum was held constant, by describing the relationship between the variables and the equation relating the angular velocities on page 2.