Lab 7 Rotation

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Theory

- The rotational inertia of point mass m is $I = mr^2$, where r is the distance from the rotation axis. If the mass distribution is continuous, then

$$I = \int r^2 dm.$$

- For example, the rotational inertia of a rod about an axis perpendicular to the rod and through its center is

$$I_{rod} = (1/12) M_{rod} l_{rod}^2,$$

where M_{rod} is the mass of the rod and l_{rod} is the Length of the rod.

Experimental Process

Procedure for Rotation

1. You have a rotator device connected to a rotary motion sensor. The rotator device has movable masses on a rod. On the other end of the rotational motion sensor is a pulley with two wheels of different diameters.

   Check if the plug of the rotational motion is linked to the interface. In Data Studio, connect to the rotary motion sensor. Now double click on the icon of rotary motion sensor, click the "Measurements" tab, and check the box for "Angular Acceleration" and change the unit to "(rad/s/s)". Drag a graph over to the rotary motion sensor, and set it to plot angular acceleration.

2. Remove the rod and mass assembly from the sensor, and weigh the masses, the rod (without its screw), and the pulley wheel. Measure the diameters of the two pulley wheels, and convert to radii in meters. Record the information below:
   Total mass of the two movable masses, $M_{mass} =$ ______________ kg.
   Mass of the rod without its screw, $M_{rod} =$ ______________ kg.
   Total mass of the pulley wheels, $M_{pulley} =$ ______________ kg.
   Radius of small pulley, $R_{small} =$ ______________ m.
   Radius of large pulley, $R_{large} =$ ______________ m.

3. Measure the length of the rod, $l_{rod} =$ ______________ m.
   Calculate the rotational inertia of the rod, $I_{rod} = \frac{1}{12} M_{rod} l_{rod}^2 =$ ____________ $kg - m^2$.

4. Calculate the rotational inertia of the pulley wheels, $I_{pulley} = \frac{1}{2} M_{pulley} \left(\frac{R_{small}^4 + R_{large}^4}{R_{small}^2 + R_{large}^2} \right) =$ ______________ $kg - m^2$.

5. Set the masses on the rotator at the ENDS of the rod. This is the case where you can create the largest total rotational inertia. Measure the distance from the center of a movable mass to the center of the rod. $d_{long} =$ ______________ m. Calculate the largest total rotational inertia, $I_1 = I_{rod} + I_{pulley} + M_{mass} d_{long}^2$, and record your result in the chart below.

Put 100g mass on the weight hanger (so totally $m_f = 0.15kg$), and wind the string around the smaller pulley wheel. This should be the smallest angular acceleration case. Calculate the torque for this case, $\tau_1 = R_{small} m_f g$, and the theoretical angular acceleration for this case, $\alpha_{th,1} = \tau_1 / I_1$. Record your result in the chart below.

6. Click $\boxed{\text{Start}}$, let the weight fall (spinning up the rotator), and click $\boxed{\text{Stop}}$. Notice that the angular acceleration on the graph quickly jumps up and reaches an approximately constant value. You can select an area of this nearly constant value and use $\boxed{\Sigma}$ to find the mean value of angular acceleration. This is your experimental angular acceleration for the trial 1. Repeat two more times and obtain the average. Record your results.

Torque τ_1, $(m-N)$	Rotational Inertia, I_1 $(kg-m^2)$	Theoretical Angular Acceleration, $\alpha_{th,1}$ (rad/s^2)	Trial	Experimental Angular Acceleration, α_{exp} (rad/s^2)	Average	Error
			1			
			2			
			3			

7. Set the masses on the rotator close to the center of the rod. This is the case where you can create the smallest total rotational inertia. Measure the distance from the center of a mass to the center of the rod. $d_{short} =$ ____________m. Calculate the smallest total rotational inertia, $I_2 = I_{rod} + I_{pulley} + M_{mass} d_{short}^2$, and record your result in the chart below.

   Put 100g mass on the weight hanger (so totally $m_f = 0.15kg$), and wind the string around the larger pulley wheel. This should be the largest angular acceleration case. Calculate the torque for this case, $\tau_2 = R_{large} m_f g$, and the theoretical angular acceleration for this case, $\alpha_{th,2} = \tau_2 / I_2$. Record your result in the chart below.

8. Find the experimental angular acceleration for three trials. Obtain the average and record your results.

Torque τ_2, $(m-N)$	Rotational Inertia, I_2 $(kg-m^2)$	Theoretical Angular Acceleration, $\alpha_{th,2}$ (rad/s^2)	Trial	Experimental Angular Acceleration, α_{exp} (rad/s^2)	Average	Error
			1			
			2			
			3			

Precession of Gyroscope

1. Skip this part.