Lab 9a1: Moment of Inertia and Energy in Rotational Motion

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Date of Experiment: 11/13/2018 Date of Report Submission: 11/27/2018
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1. OBJECTIVE

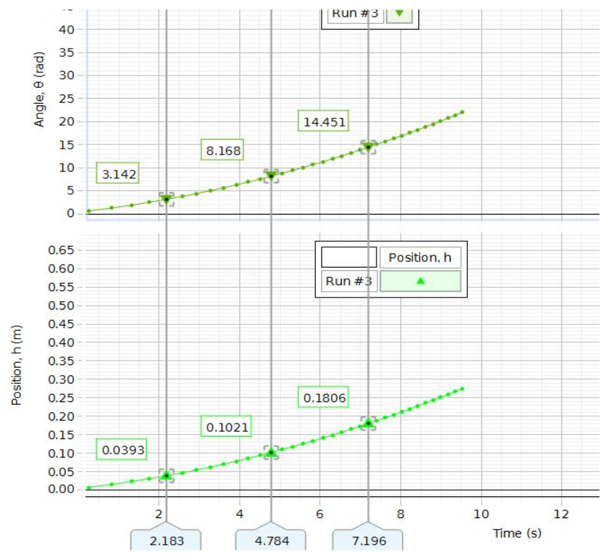
The objective of Lab 9a1 is to explore the rotational motion of rigid bodies with respect to angular position and angular velocity at a constant angular acceleration. Additionally, another objective is to evaluate the relation of those angular quantities to the linear position and linear velocity in a system with a bound motion including translational and rotational motion. Furthermore, a third objective of this lab was to experimentally determine the moment of inertia of an object and compare top the calculated one. The final objective of this lab was to demonstrate the conservation of energy in a system involving a rotational motion. Throughout conducting the lab, we kept in mind that average angular velocity, ω_{avg}, is $\frac{\Delta\theta}{\Delta t}$, average angular acceleration, α_{avg}, is $\frac{\Delta\omega}{\Delta t}$, moment of inertia, I, is $\sum_i m_i r_i^2$. We also kept in mind that the Parallel-Axis Theorem can be expressed as $I_P = I_{COM} + Md^2$ and gravitational potential energy in relation to inertia can be expressed as $mgh_i = \frac{1}{2}mv_i^2 + \frac{1}{2}I_{total}\omega_i^2$.

2. EXPERIMENTAL PROCEDURE

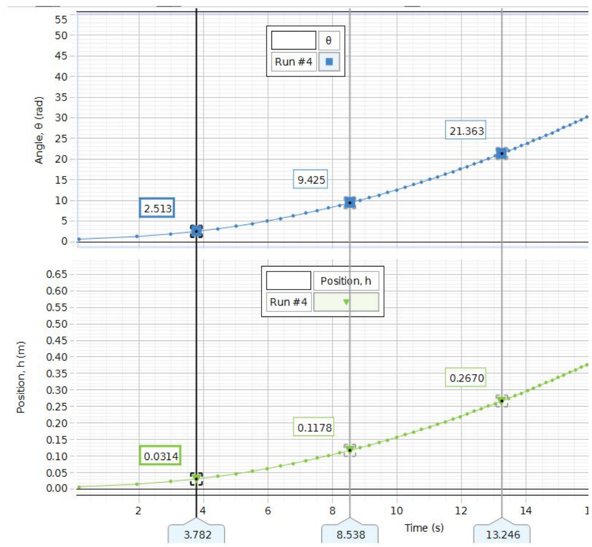
The lab started out with us setting up the equipment properly and logging onto the computer, opening up the file "Lab 9a1 Moment of Inertia and Energy in Rotational Motion" file in the "Physics 111A Experiments" folder. Part I of the lab required us to measure the masses of the disk, ring, square mass, mass hanger, and given weights. After that we had to measure the radius of the disk and the inner and outer radii of the ring as well as measure the radius of the rim of the 2nd pulley from the top of the step-pulley where the string is wound. In Part II of the lab, we had to calculate the rotational inertia when each of two point masses is positioned equally apart from the rotational axis by a set distance. We had to calculate the rotational inertia of the disk when it rotates around its center of mass and when it rotates at axis of rotation off its center of mass by a set distance. After this we calculated the rotational inertia of the ring when it rotates around its center of mass. In Part III we had to obtain the data of angular velocity of the rotating body and position and linear velocity of the hanging mass in order to experimentally determine the total moment of inertia of a rotating body. After handing the mass hanger with a weight at the end of the string we wind the string around the rim of the second pulley from the top of the step pulley by gently turning the rotating platform until the mass hanger is close to the spoke pulley.

3. RESULTS: (Graphs)

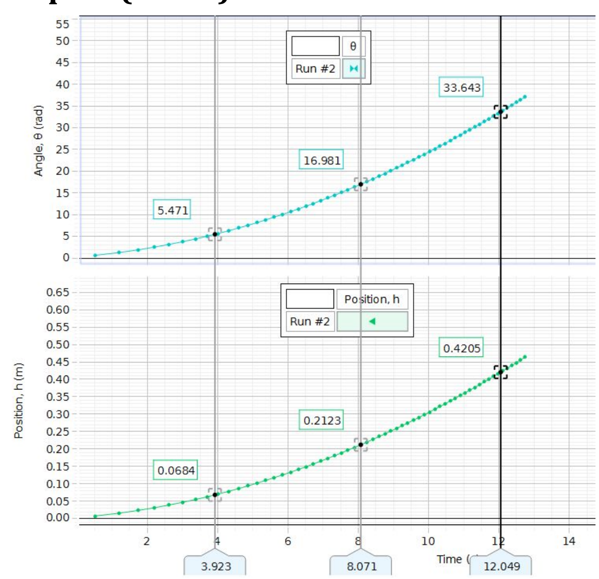
Graph 1 (Run 1):



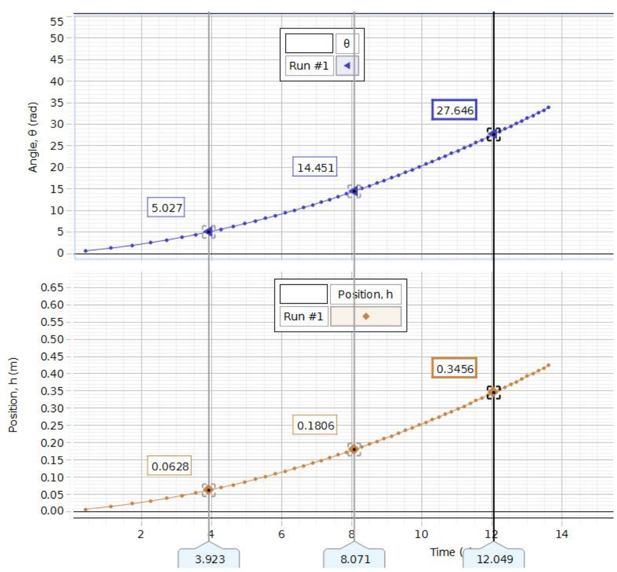
Graph 2 (Run 2):



Graph 3 (Run 3):



Graph 4 (Run 4):



All four graphs above show the relationship between angle, θ, and time as well as the relationship between position, h, and time. The graphs to trials 1 to 4 correlate to which “Run #” it has. From this data, we were able to calculate the angular velocity, ω , as well as the linear velocity

Calculations:

Table I

$\omega = \frac{\Delta\theta}{\Delta t} = \frac{8.168\ rad - 3.142\ rad}{4.784\ sec - 2.183\ sec} = 1.932$ rad/sec

$$\frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 = mgh$$

$$I = \frac{2(mgh - \frac{1}{2}mv^2)}{\omega^2} = \frac{2(0.6215kg \times 9.81m/s^2 \times 0.0393m - \frac{1}{2} \times 0.6215kg \times (0.0360m/s)^2)}{(1.439\ rad/sec)^2} = 0.231\ kg * m^2$$

Table II

$$I_{Disk} = I_{Total} - I_{platform} = 0.293kg * m^2 - 0.231kg * m^2 = 0.062\ kg * m^2$$

$$I_{Theoretical} = \frac{1}{2}MR^2 = \frac{1}{2} \times 1.4434kg \times (0.115m)^2 = 0.0095\ kg * m^2$$

$$Percent\ Error = \frac{|I_{experimental} - I_{Theoretical}|}{I_{experimental}} \times 100 = \frac{|0.062 - 0.0095|}{0.062} \times 100 = 8.5\%$$

4. DISCUSSION

Throughout this lab, my group was exposed to many different physics theories and principles in real life. The primary principles/theories we learned in this lab was rotational inertia. Additionally, we also learned about the Parallel_Axis Theorem. When the lab was done, the percent error calculated was 8.5% and this error could have been due to countless reasons. To our ability, the lab was conducted with as near perfect conditions that we could get, however there could have been many problems. For one, there could have been a machine error of the sensors used, which seems to be only incremental, but they can have a large effect in the whole experiment. Above all, human error could have been one of the largest errors. For instance, when releasing the weight that was hanging, we tried or best to be as steady as possible, but to a certain degree there was a human error in releasing the weight, even if it was very small. Additionally, a variety of motions were involved. As the hanging mass falls a displacement , Δh , the step-pulley rotates an angular displacement, $\Delta\theta$. Since gravity accelerates the hanging mass, the linear velocity and angular speed also change with respect to time. To add to this, the linear velocity of the mass was equivalent to the tangential velocity about the pulley. This resulted in a changing of translational motion to rotational motion. As requested by the lab manual, the relationship between the change in linear and angular position can be described as the vertical position of the mass moves a distance (Δh) from to Δt the step pulley has rotated

$\Delta\theta$ from two points equivalent to the arc length change in the formula $\Delta s = R \bullet \Delta\theta$. Additionally, by using the law of conservation of energy, $PE_1 + KE_1 = PE_2 + KE_2 + KE_{rotation}$, without friction our equation looked like, $mgh_i = \frac{1}{2}mv_i^2 + \frac{1}{2}I_{total}\omega_i^2$ and with friction, you can simply add μmg to the right side of the equation.

5. CONCLUSION

Similar to the labs in the past, much has been learned from this experiment as expected. I learned about the parallel-axis-theorem and rotational inertia. However, no lab is perfect and certain things could have been improved to make it better. One thing that could have been improved was the equipment because our string was not the smoothest, but it suffice. Another thing that could have been improved were the weights because some of them had a slight rust on them or the labeling of how heavy the weight is had worn off.

6. REFERENCE

"Rotational Inertia." *Khan Academy*, Khan Academy, www.khanacademy.org/science/physics/torque-angular-momentum/torque-tutorial/a/rotational-inertia.

"The Parallel-Axis Theorem & the Moment of Inertia." *Study.com*, Study.com, study.com/academy/lesson/the-parallel-axis-theorem-the-moment-of-inertia.html.

7. ATTACHMENT OF RAW DATA

Raw Data

Moment of Inertia of Rotating Platform

$m = 0.6215$ kg $R = 0.025\ m$

Position	Height, h (m)	Angular Velocity, ω (rad/s)	Linear Velocity, v (m/s)	Moment of Inertia, I $(kg * m^2)$
1	0.0393	1.439	0.0360	0.231
2	0.1021	1.932	0.0483	0.333
3	0.1806	2.605	0.0651	0.324

Moment of Inertia of Disk off Center

$m = 0.6215$ kg $M = 1.4434$ kg R = 0.025 m $r = 0.05\ m$

Position	Height, h (m)	Angular Velocity, ω (rad/s)	Linear Velocity, v (m/s)	Total Moment of Inertia, I $(kg * m^2)$	Moment of Inertia of Disk $(kg * m^2)$
1	0.0314	0.664	0.0166	0.293	0.062
2	0.1178	1.453	0.0363	0.229	0.104
3	0.2670	2.536	0.0641	0.170	0.154

Moment of Inertia of Ring and 2 Square masses (Revolving about its center of mass)

$m_{ring} = 1.4267$ kg $m_{square\ masses} = 0.5554$ kg $R = 0.025\ m$

Position	Height, h (m)	Angular Velocity, ω (rad/s)	Linear Velocity, v (m/s)	Total Moment of Inertia, I $(kg * m^2)$	Moment of Inertia of Disk $(kg * m^2)$
1	0.0684	1.395	0.0349	0.139	0.099
2	0.2123	2.775	0.0694	0.108	0.078
3	0.4205	4.189	0.1047	0.094	0.067

Moment of Inertia of Disk and Ring (Revolving about it center of mass)

m_{disk} =1.4434 kg m_{ring} = 1.4267 kg $R = 0.025\ m$

Position	Height, h (m)	Angular Velocity, ω (rad/s)	Linear Velocity, v (m/s)	Total Moment of Inertia, I $(kg * m^2)$	Moment of Inertia of Disk $(kg * m^2)$
1	0.0628	1.281	0.0320	0.218	0.110
2	0.1806	2.272	0.0568	0.199	0.100
3	0.3456	3.317	0.0829	0.179	0.090