Physics Laboratory Report

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

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Course & Section Number: PHYS 111A - 011 **Instructor's Name: Professor Thuan Nguyen**

Partners' Names: Logan Chappel, Jose Tabuena, Connor Nguyen

1. INTRODUCTION

1.1 Objectives

Lab 9a1 was adding onto the topic that we have been discussing last week, including what the moment of inertia is, and how it relates to our previously learned angular velocity/acceleration. In this lab, we learned about how different objects have different moments of inertia, how to calculate the center of mass of an object, what the parallel axis theorem is, and how total kinetic energy of an object is calculated. This lab consisted of four experiments (we were exempted from the fifth in class due to time constraints) whereby we were given a rotating platform and we had to calculate the changes in inertia and how it affected time and speed. A draft report was also submitted in class which contains the data we collected in class.

1.2 Theoretical background

The moment of inertia represents an object's resistance to rotational motion and is calculated based on an object's shape. Different shapes, as explained using the race test, have different moments of inertia, and that changes how hard it is to move them. For example, a ring has double the moment of inertia in comparison to a uniform cylinder, because the coefficient for the uniform cylinder is ½ whereas for the ring it is just 1. Inertia (I) is calculated using the formula $\Sigma I = \Sigma i\ mi\ ri^2$. This means that the moments of inertia add onto one another, a concept that was important to remember for the lab. The other important theorem to understand was the Parallel-Axis Theorem, which is for objects not rotating at the axis at rotation. This was used in experiment four. The formula for the parallel axis theorem is $I_p = I_{cm} + md^2$. Lastly, there were several formulas for the moments of inertia for the shapes, although this was provided during class and is provided in our main physics class as well.

2 EXPERIMENTAL PROCEDURE

We followed all procedures in the lab manual but skipped experiment five (the one with the ring) as instructed in class.

Masses

Used in all of the experiments.

Mass of Rotating Platform (0.6202kg)

Hanging Mass (0.1500kg)

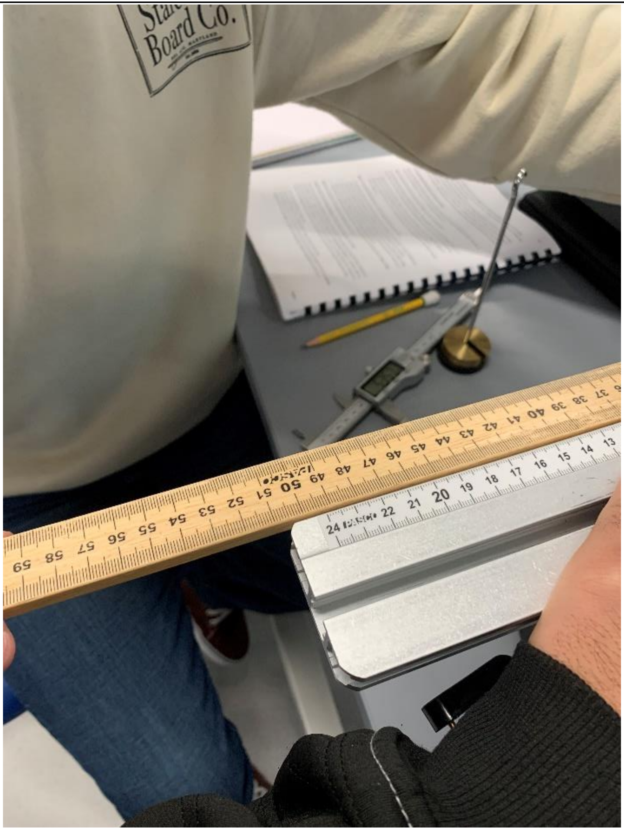
Block Masses (0.5565kg)

Note this is for both blocks

Disc (1.433kg)

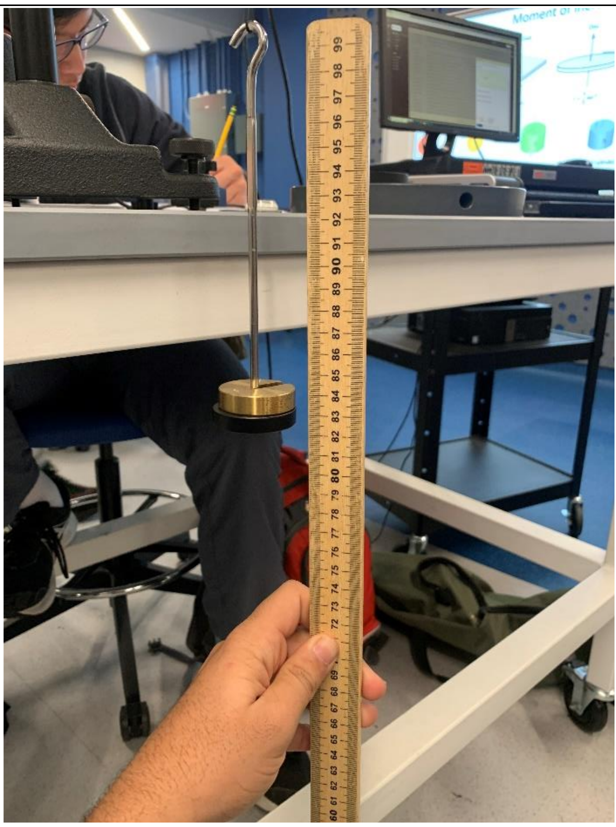
Experiment One

Measured the rotating platform



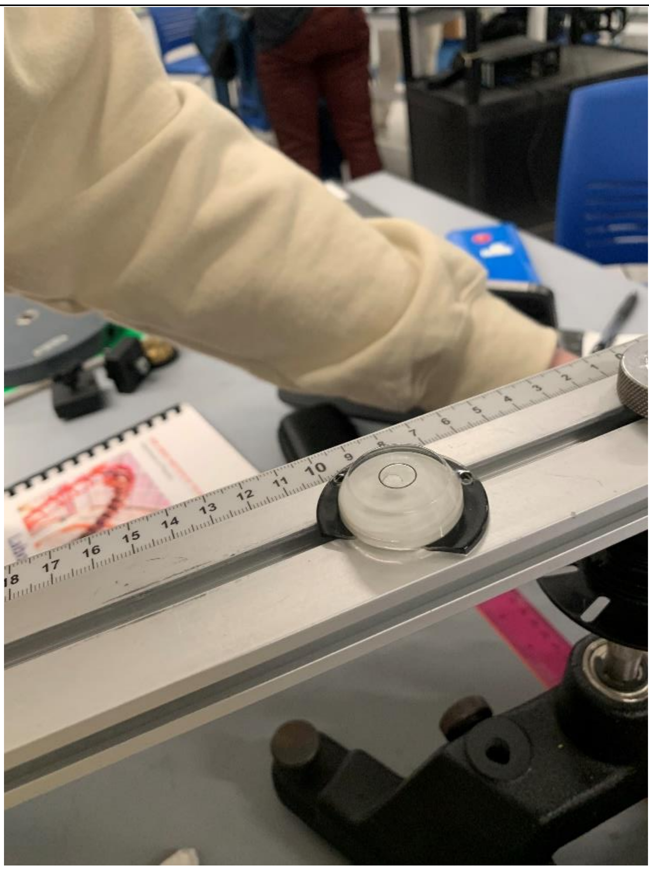
Length of Platform (0.5m)

Width of Platform (0.05344m)



Original Height of Hanging Mass (0.84m)

Final Height of Hanging Mass (0.47m)



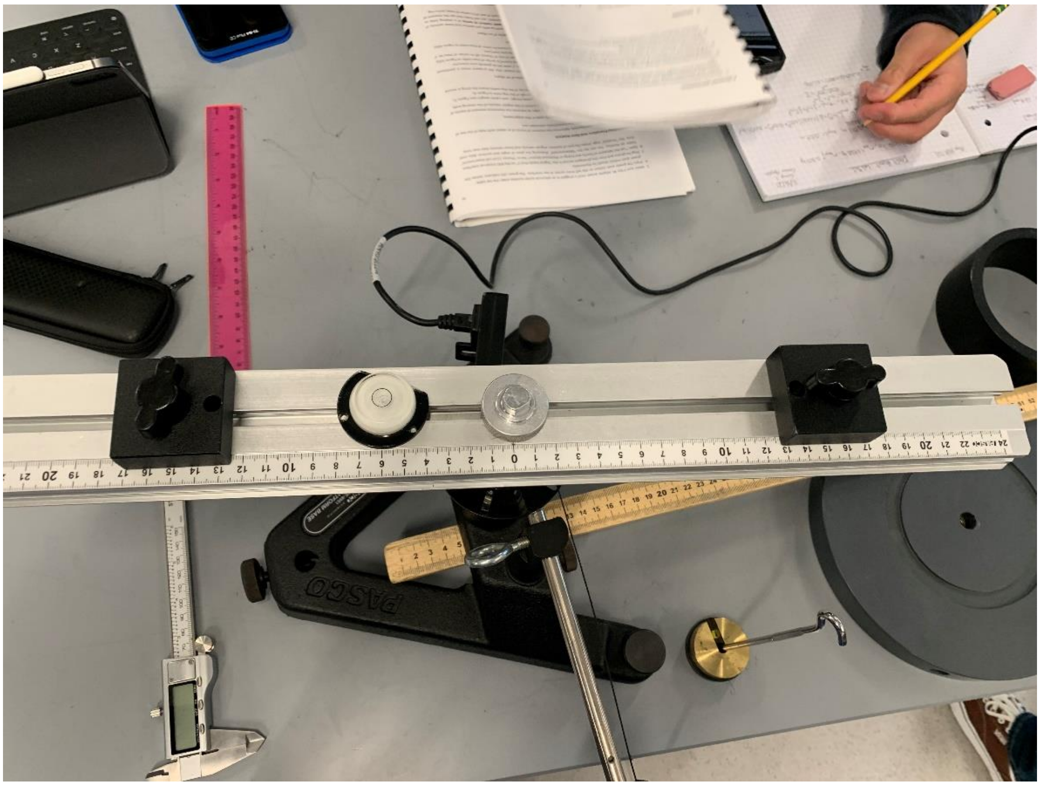
Leveling

Experimental Setup

Variables:

- Mass of Platform (m_p)
- Length of Platform (L)
- Width of Platform (W)
- Distance from Center of Mass (r)
- Initial Height of Hanging Mass (h_0)
- Final Height of Hanging Mass (h_f)

Experiment Two



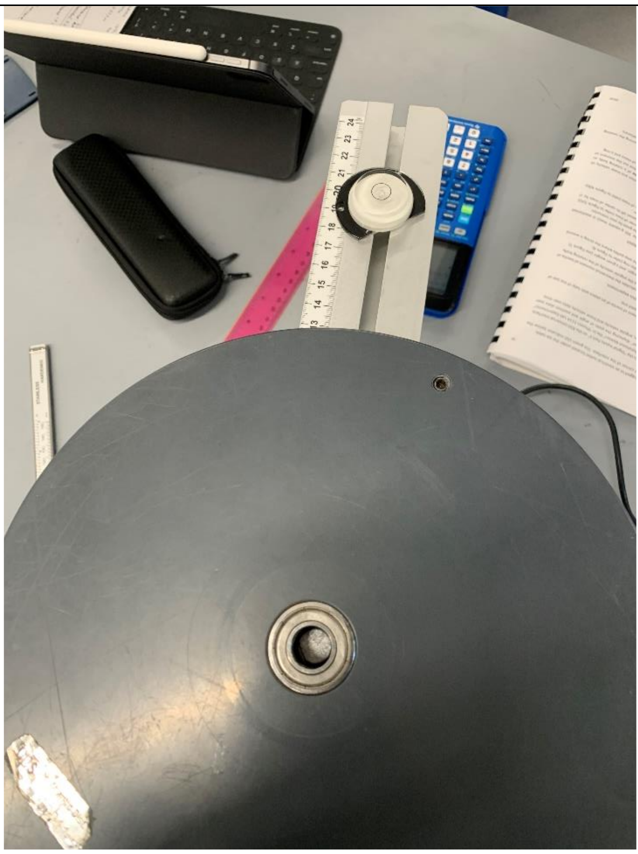
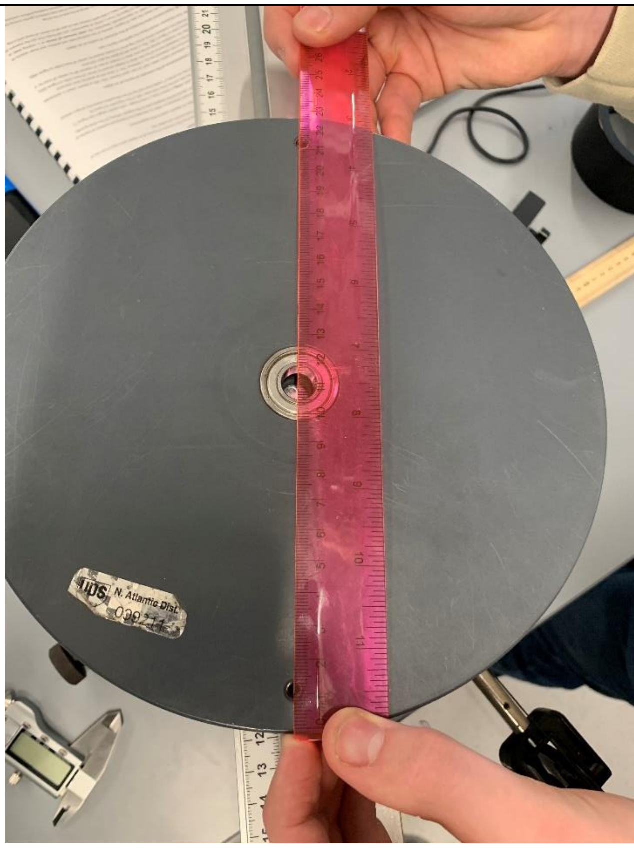
Experimental Setup Part Two

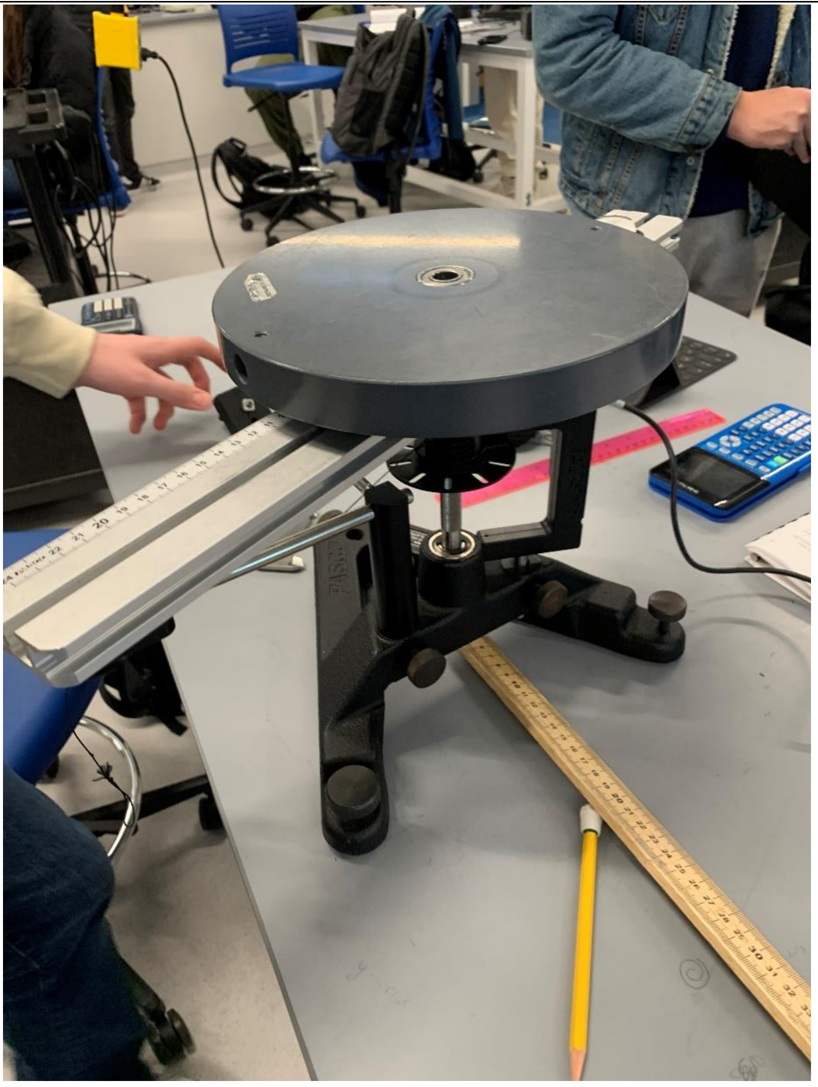
Distance between block to axis of rotation: 0.15m

Variables:

- Moment of Inertia of Platform (I_p)
- Moment of Inertia at Center of Mass (I_{cm})
- Mass of Block (m_b)
- Distance from Block to AOR (r)

Experiment Three

	
Leveling	Radius of Disc (0.112m)

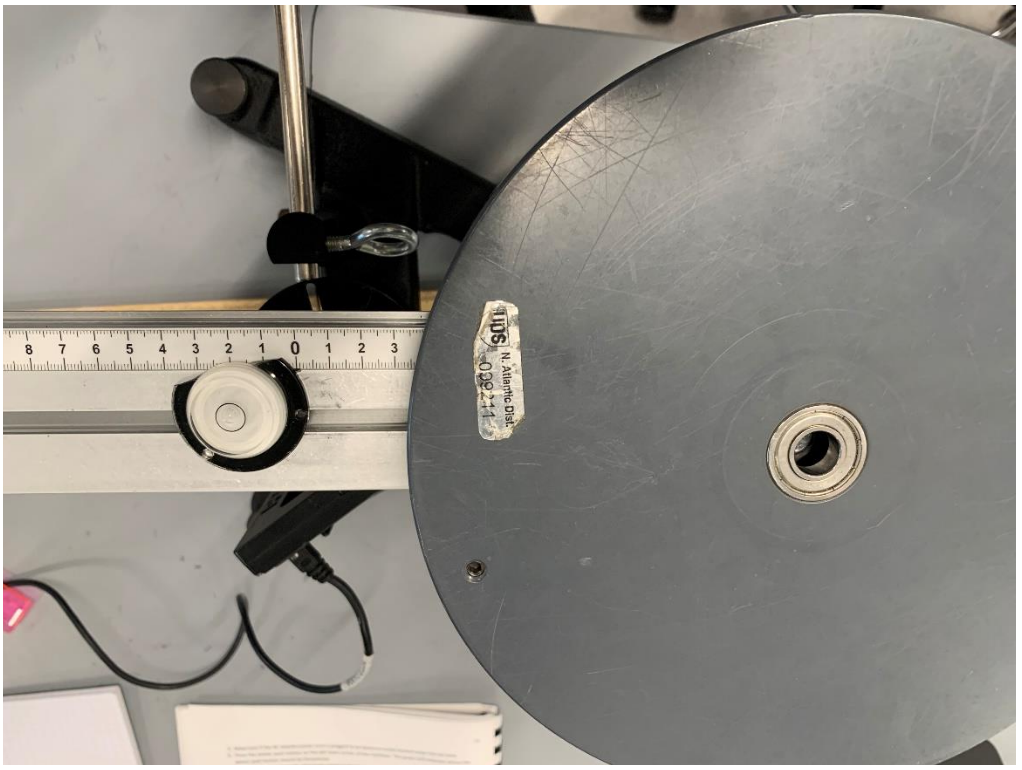


Experimental Setup

Variables:

- Moment of Inertia of Platform (I_p)
- Radius of Disc (r)
- Distance from AOR (0)
- Mass of Disc (m)

Experiment Four



Experiment Setup

Distance from AOR: 0.15m

Variables:

- Moment of Inertia of Platform (I_p)
- Radius of Disc (r)
- Distance from AOR (d)
- Mass of Disc (m)

3 RESULTS

Experiment One

Mass: 0.6202kg

W = 0.0535m

L = 0.509m

Calculated Inertia	Measured Inertia (Average)	Error Percentage
0.0135 kg*m^2	0.0120 kg*m^2	11.1%

Calculations

Lab 9a1

Experiment 1

Theoretical Inertia

$I_{tot} = I_p \quad I_{tot} = \frac{1}{12} m (W^2 + L^2)$

$m = 0.6202 kg \quad L = 0.509 m \quad W = 0.0535 m$

$I_{tot} = \frac{1}{12}(0.6202)(0.509^2 + 0.0535^2)$

$I_{tot} = 0.0135 \text{ kg}\cdot\text{m}^2$

Measured Inertia

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

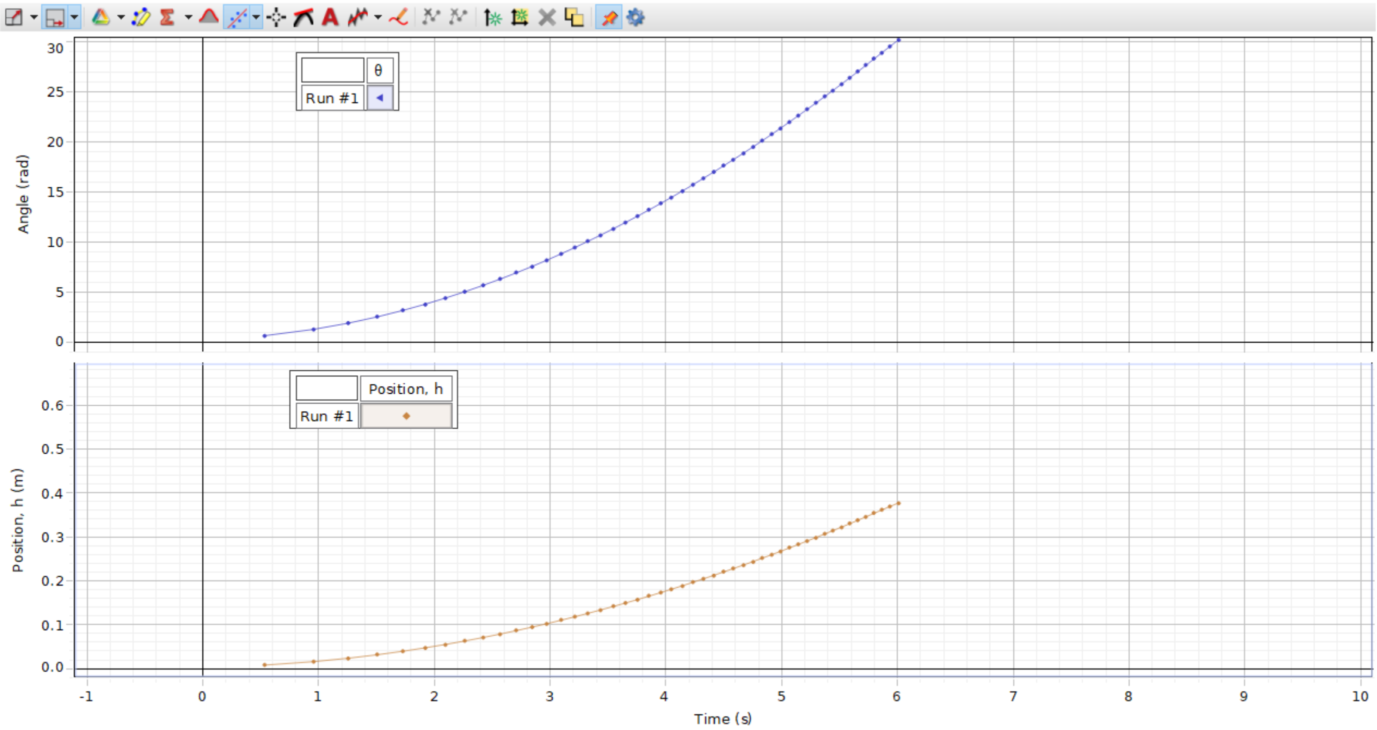
$\frac{2(mgh - \frac{1}{2}mv^2)}{\omega^2} = I$

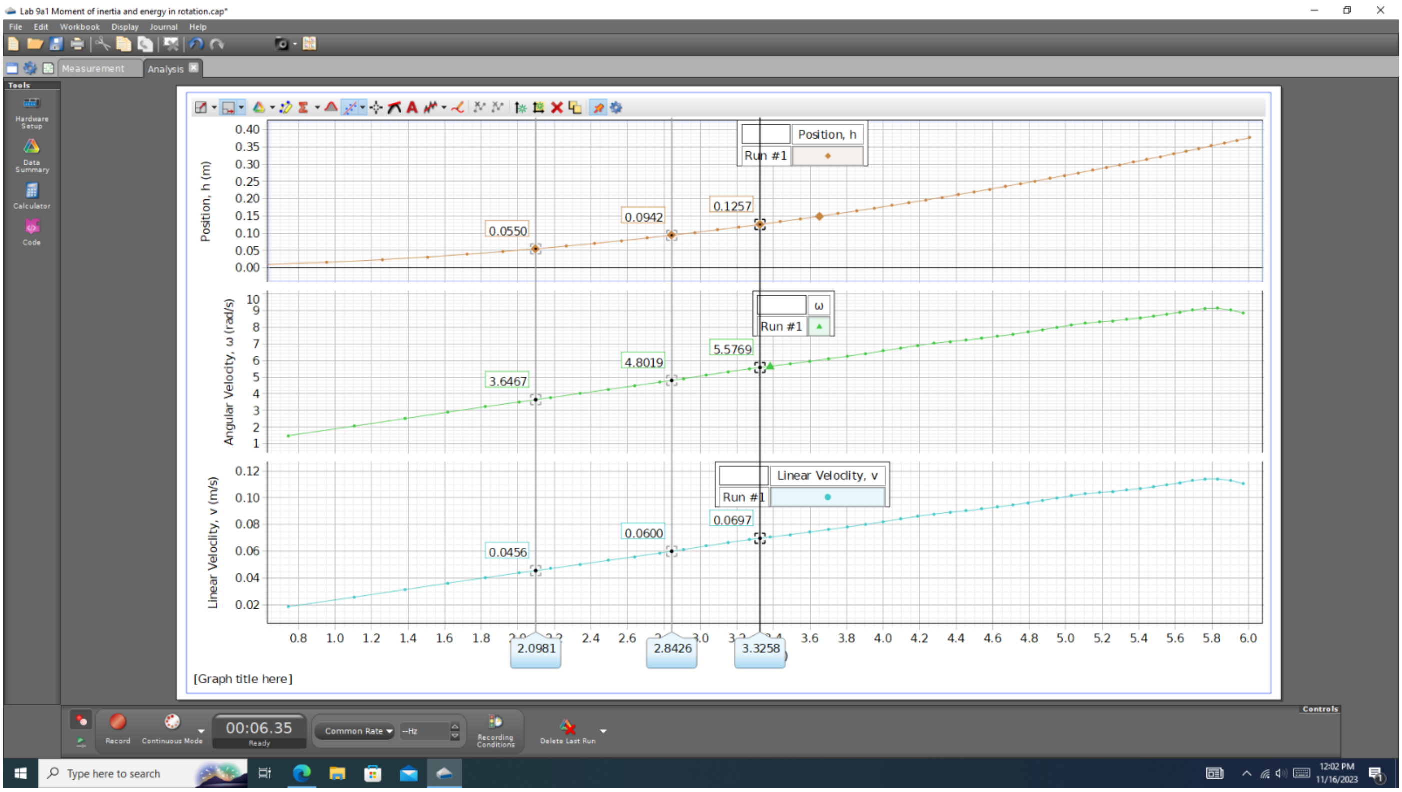
$\left.\begin{array}{l} I_1 = 0.0121 \text{ kg}\cdot\text{m}^2 \\ I_2 = 0.0119 \text{ kg}\cdot\text{m}^2 \\ I_3 = 0.0119 \text{ kg}\cdot\text{m}^2 \end{array}\right\}$ Average: $0.0120 \text{ kg}\cdot\text{m}^2$

Error Percentage:

$\frac{|\text{Measured} - \text{Theoretical}|}{\text{Theoretical}} \times 100$

$= 11.1\%$





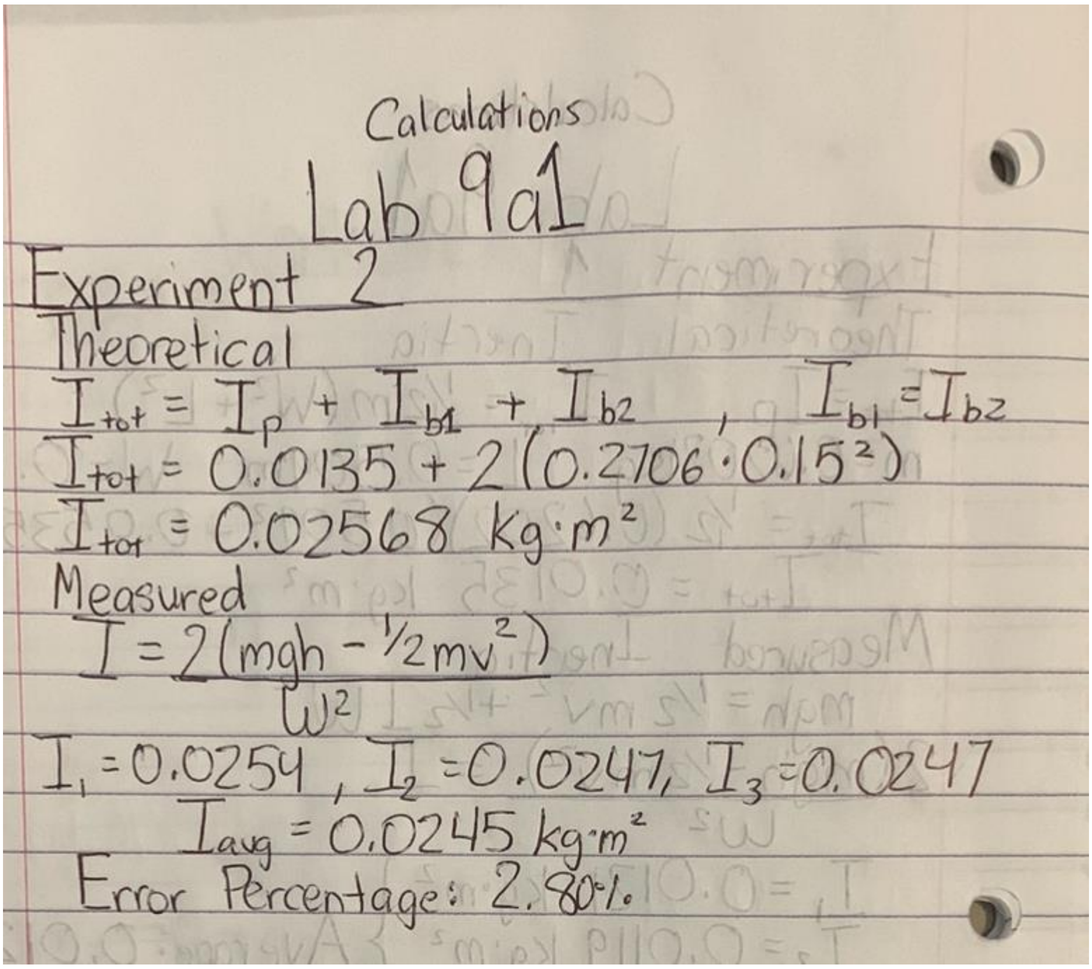
Experiment Two

Mass: 0.2706m

r = 0.15m

I_p = 0.0135 kg*m^2

Calculated Inertia	Measured Inertia (Average)	Error Percentage
0.0257 $kg*m^2$	0.245 $kg*m^2$	2.80%



Calculations

Lab 9a1

Experiment 2

Theoretical

$I_{tot} = I_p + I_{b1} + I_{b2}$, $I_{b1} = I_{b2}$

$I_{tot} = 0.0135 + 2(0.2706 \cdot 0.15^2)$

$I_{tot} = 0.02568\ kg \cdot m^2$

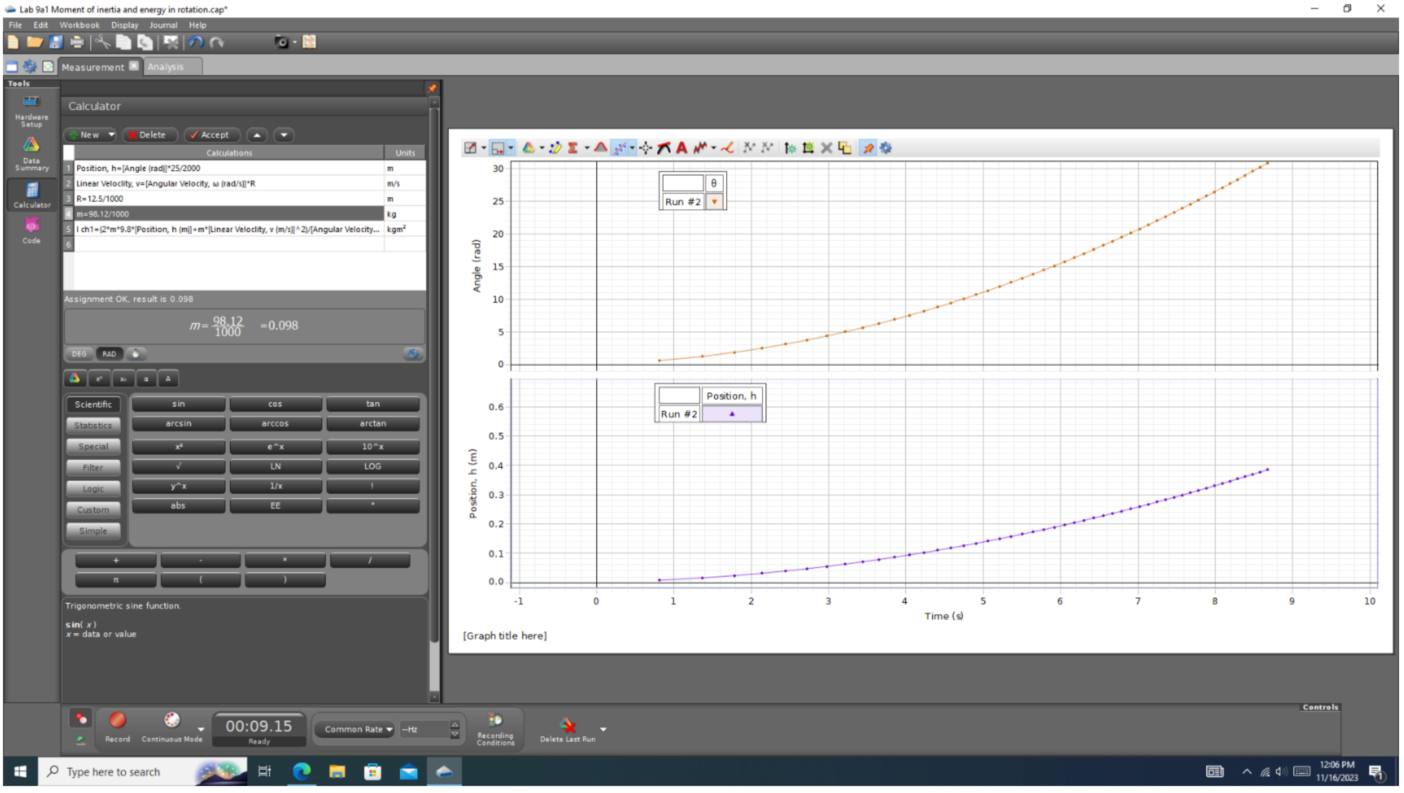
Measured

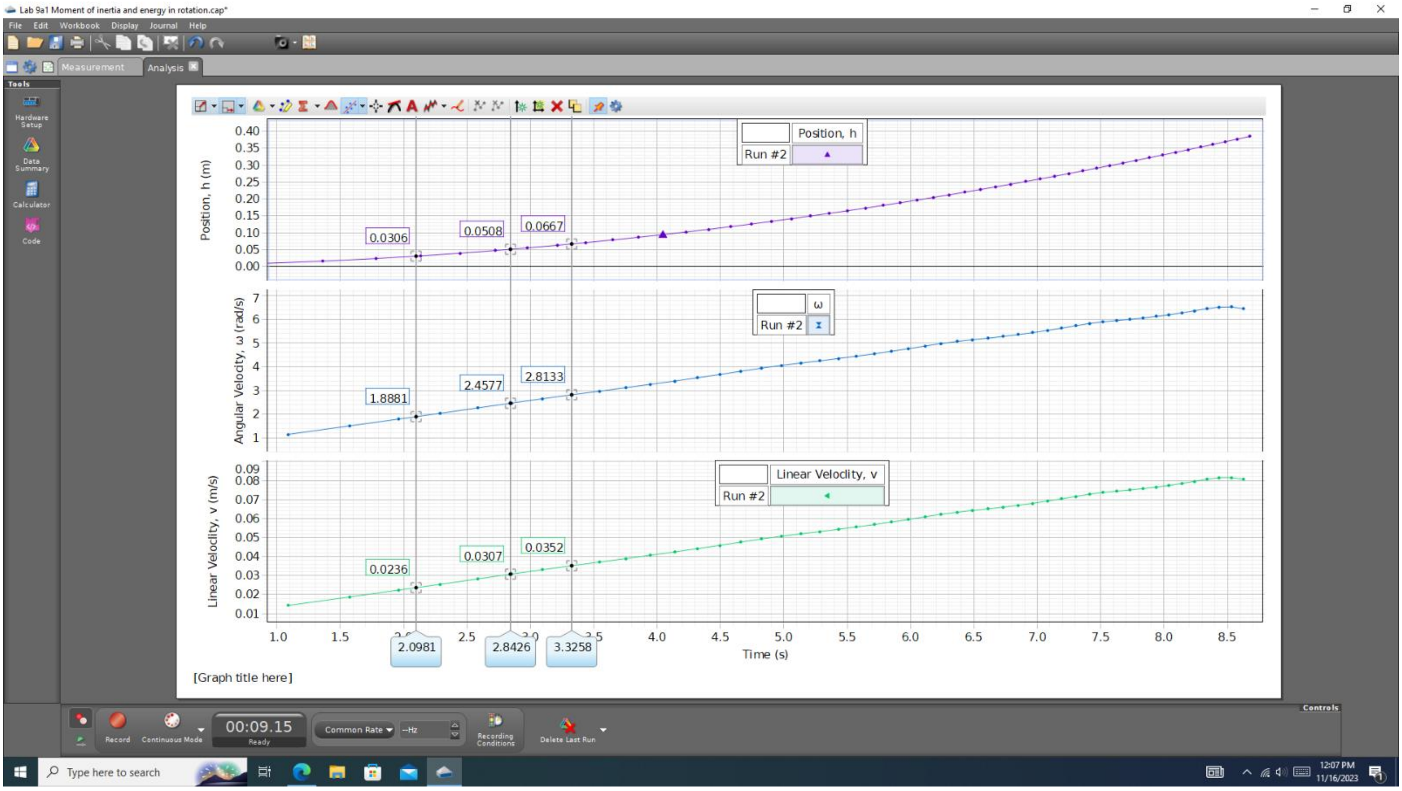
$$I = \frac{2(mgh - \frac{1}{2}mv^2)}{\omega^2}$$

$I_1 = 0.0254$, $I_2 = 0.0247$, $I_3 = 0.0247$

$I_{avg} = 0.0245\ kg \cdot m^2$

Error Percentage: 2.80%





Experiment Three

Mass: 1.432kg

r_d = 0.113m

I_p = 0.0135 kg*m^2

Calculated Inertia	Measured Inertia (Average)	Error Percentage
0.0226 kg*m^2	0.0245 kg*m^2	11.3%

Experiment 3

Theoretical

$I_{tot} = I_p + I_d \qquad I_{tot} = 0.0135 + \frac{1}{2} m r^2$

$I_{tot} = 0.0135 + \frac{1}{2}(1.432)(0.113)^2 = 0.0226 \ kg \cdot m^2$

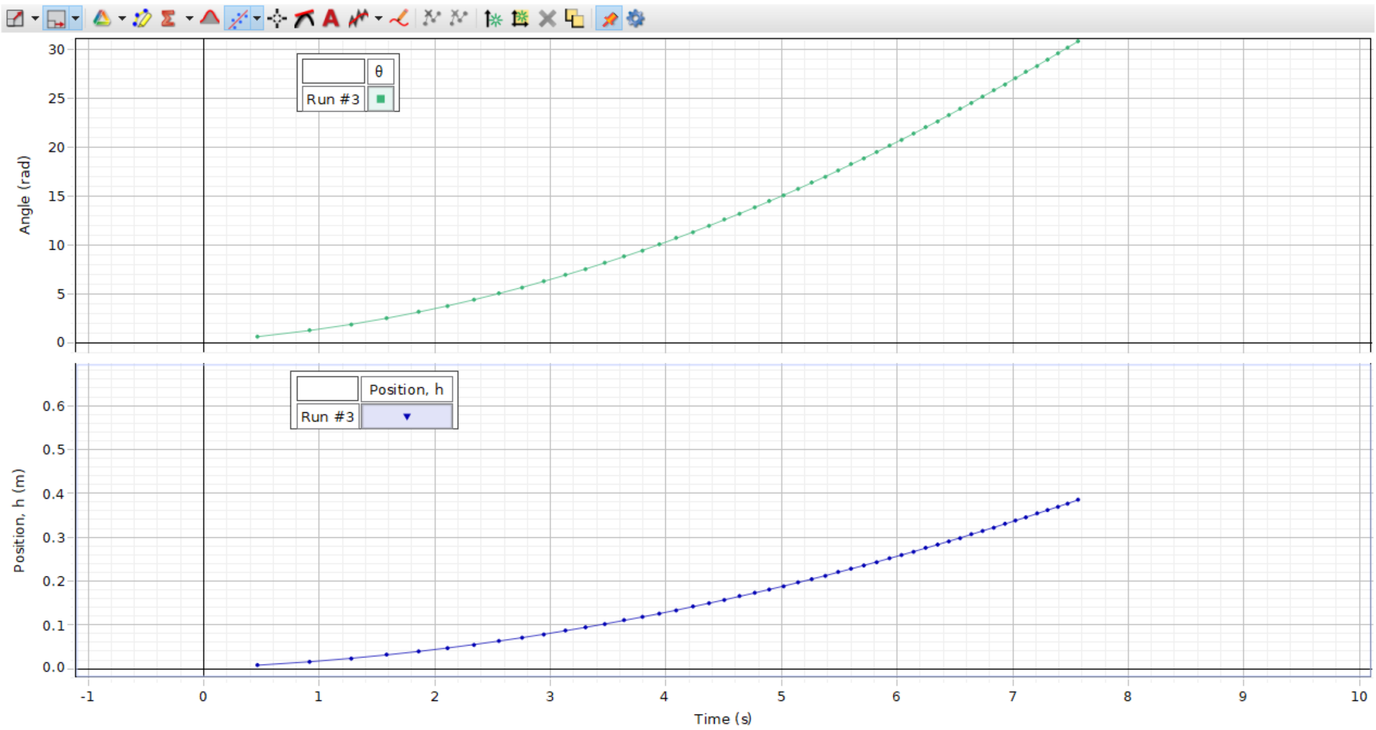
Measured

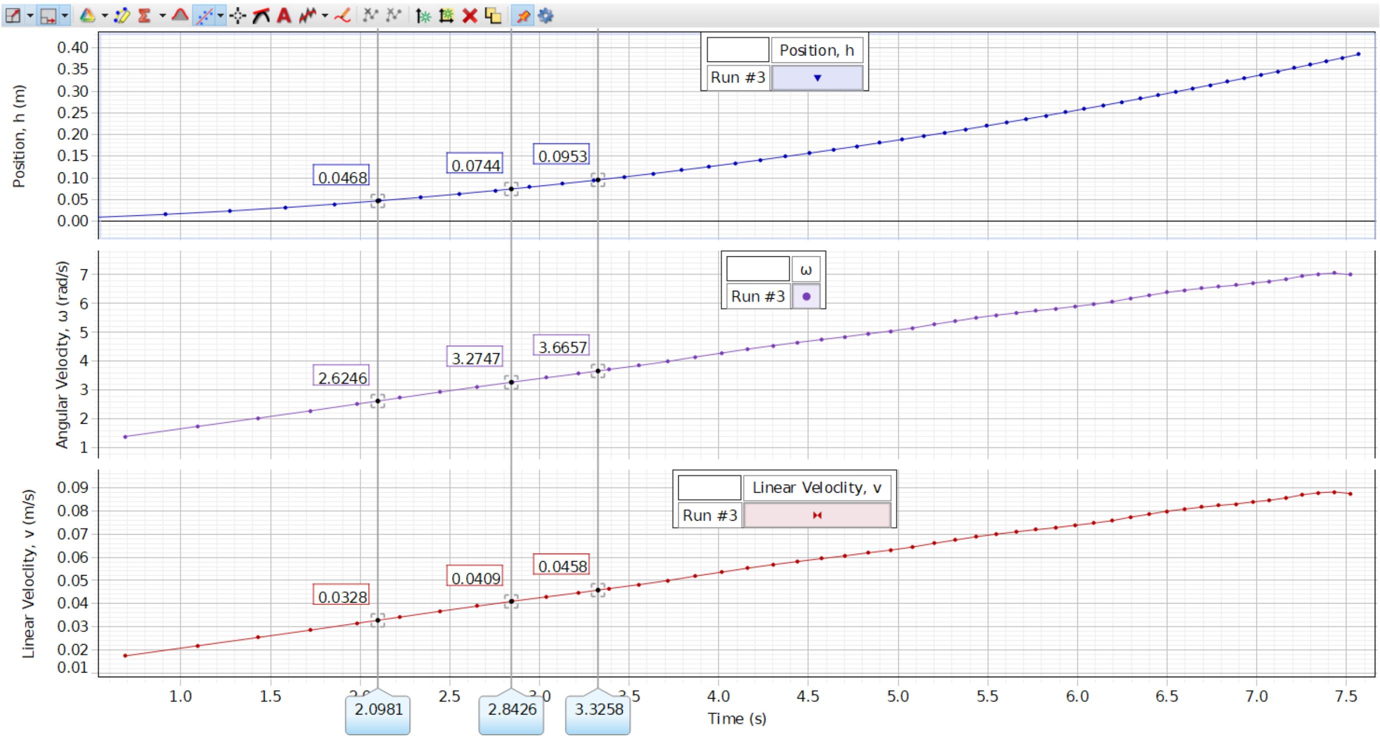
$$I = \frac{2(mgh - \frac{1}{2}mv^2)}{\omega^2}$$

$I_1 = 0.0199, \ I_2 = 0.0204, \ I_3 = 0.0208$

$I_{avg} = 0.0203 \ kg \cdot m^2$

Error Percentage: 11.3%





Experiment Four

Mass: 1.432kg

d = 0.15m

I_{p+cm} = 0.0226 kg*m^2

Calculated Inertia	Measured Inertia (Average)	Error Percentage
0.0548 kg*m^2	0.0576 kg*m^2	4.73%

Calculations

Lab 9a1

Experiment 4

Theoretical

$$I_{tot} = I_p + I_{cm} + md^2$$

$$I_{tot} = 0.0226 + (1.432)(0.15)^2$$

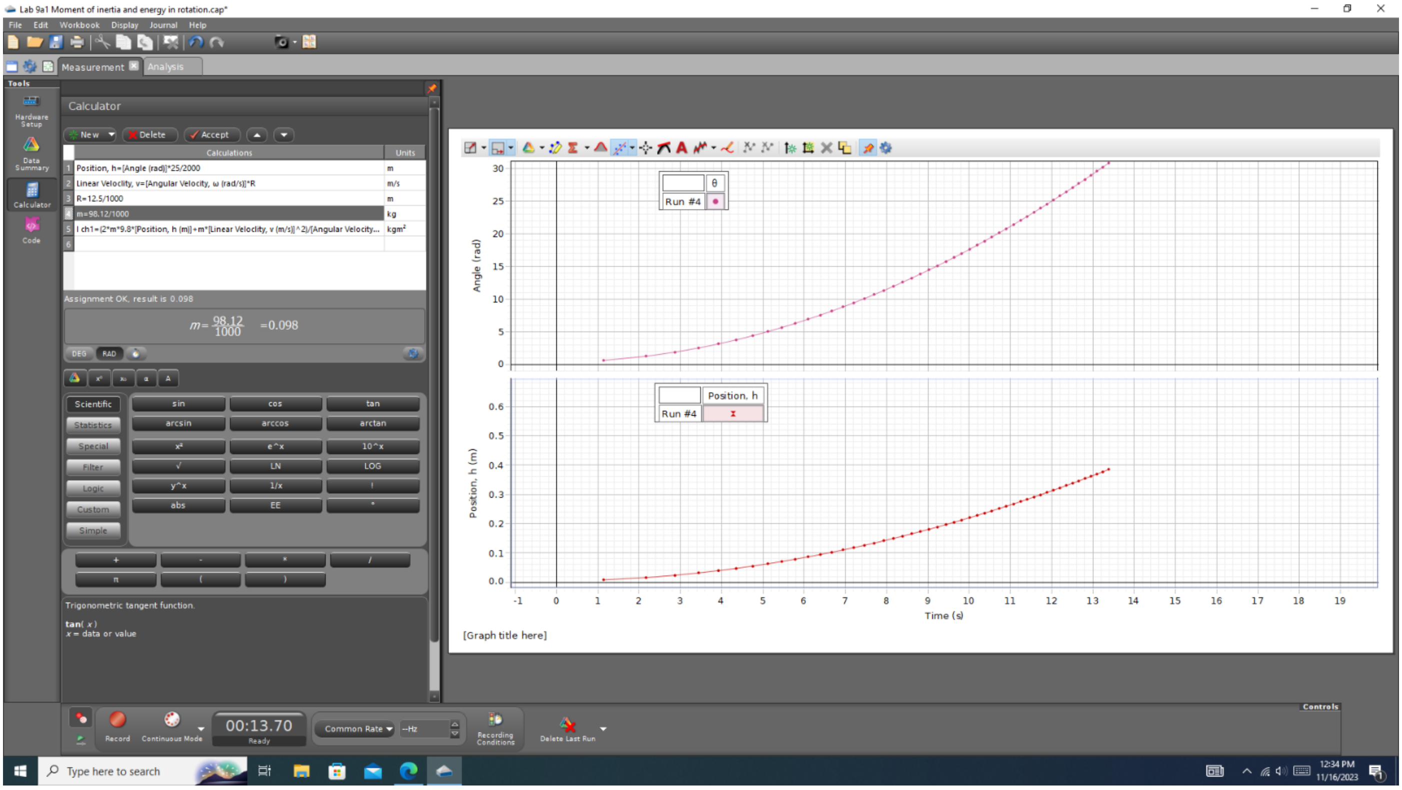
$$I_{tot} = 0.0548 \text{ kg} \cdot \text{m}^2$$

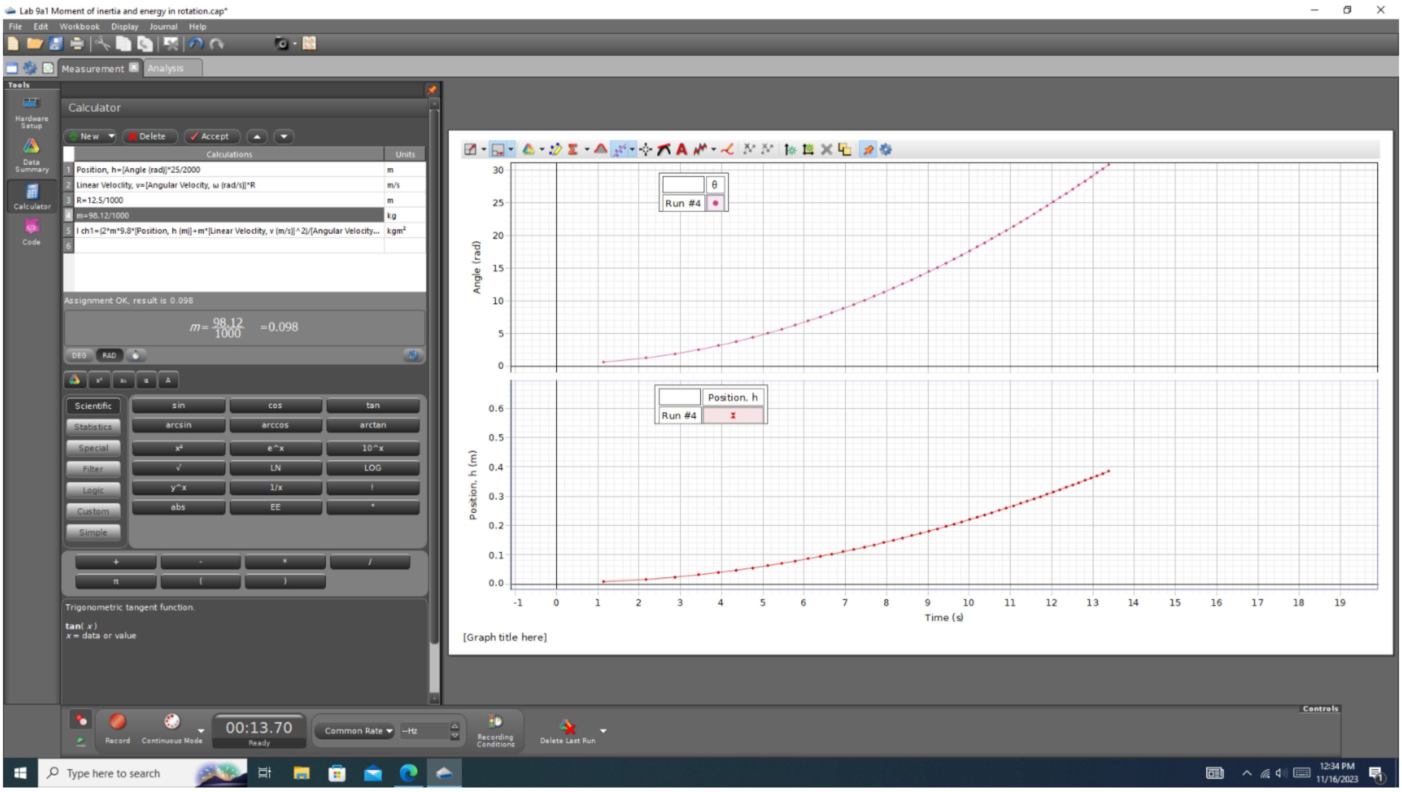
Measured

$$I = \frac{2(mgh - \tfrac{1}{2}mv^2)}{\omega^2}$$

$$\left.\begin{aligned} I_1 &= 0.058 \\ I_2 &= 0.058 \\ I_3 &= 0.057 \end{aligned}\right\} I_{avg} = 0.0576 \text{ kg} \cdot \text{m}^2$$

Error Percentage = 4.73%





4 ANALYSIS and DISCUSSION

There were four separate experiments that had us calculate and then measure the values for the moments of inertia. This determines how much resistance the object had to the hanging mass which was connected by a string. As the graphs show, the higher amounts of inertia had a longer period, and subsequently a lower angular velocity. We used our understanding of inertia, and how the different values add onto one another, to get an answer. There was a margin of error between 5-10% for all of them, which could have happened because of friction or small inaccuracies in the measured values. The amount of error is limited, however, which shows the calculations are correctly done. Because of this, I believe we met the objectives of the lab.

There were some discussion questions that should be addressed as well. Question one of the manual asks about what changes. The value for angle and velocity is increasing at an increasing rate, while the angular acceleration is a constant value. We can calculate for this if we assume a no-slip condition (which was the case for this lab). If we assume a conservation of kinetic energy, we can use the change of height of the hanging mass to determine how much translational and angular velocity is there by the end. The second question asks about the relation between angle and linear position, which does exist. This goes back to the no slip condition, which states that $S = r\theta$, for which the S would be the length of string. The r in this case would be the radius of the small cylinder that the string was wrapped around. The third question asks how friction would have changed the system. The formula would have to include a work variable, since work is the change of kinetic energy, and the only change would come from friction. The new formula would be $mgh = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2 + W$. Work is equal to F*d, d being equal to h, and F being the force of friction. As for question four, it asks about the margin of error, which was between 5-10% as stated in the last paragraph. As already stated, the difference probably came from friction, between the string and the various surfaces it was on, and significant figures of our values.

5 CONCLUSIONS

In summary, we learned to add onto our story about rotating bodies with the introduction of the moment of inertia. We learned what the definition of inertia was, how it affected different objects, and how it can still be used in many of our known equations to solve problems. I enjoyed this lab and how it connects the current material to what we learned before. Something I would love to see is how friction would play out, or if there were more than two objects (with different radius/mass) and how it would play out in the experimentation. Other than that, it was a good lab. Overall, I found this lab very insightful.