**Physics Laboratory Report**

**Lab number and Title: Lab 127 – Torque and Rotational Inertia**

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**Date of Experiment: 11/21/2023** **Date of Report Submission: 11/30/2023**

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

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

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## 1. INTRODUCTION

### *1.1 Objectives*

Today's lab, Lab 127, continues the story on rotating objects, now introducing torque and forces into the main equation. This experiment was very similar to one of our previous labs, but this time the objective was for us to calculate for the new variables such as torque, rotational inertia, tension force, and acceleration (both angular and linear). The lab consists of four different experiments, where in each the object that's on the rotating hinge changes. Using this, we find different masses and moments of inertia for each, which affects the torque and acceleration of the objects. A draft report was also submitted in class which contains the data we collected in class.

### *1.2 Theoretical background*

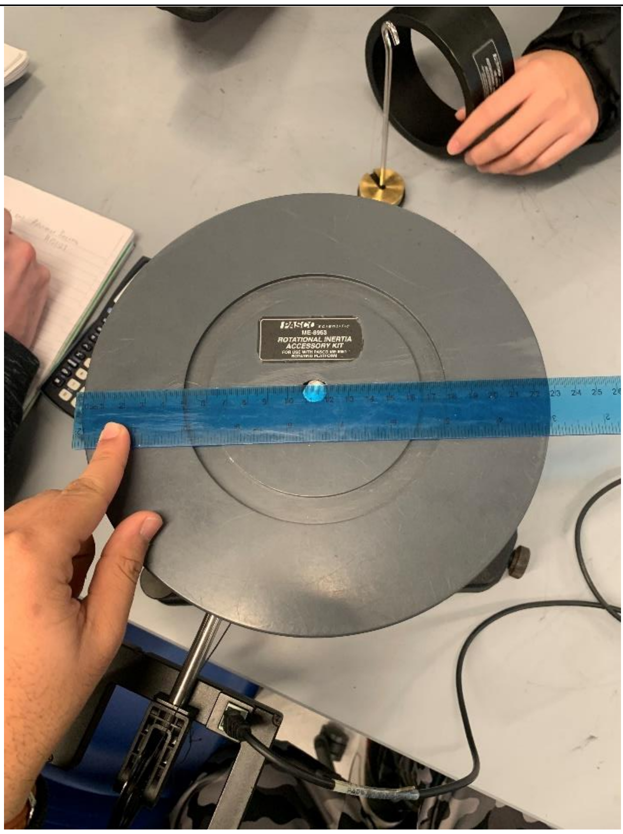
In class we were introduced to torque, which is the force acting on a rotating body to change the rate of angular acceleration for that object. This is given in the formula $T = I\alpha$, where T is the torque, "I" is moment of inertia of the object, and $\alpha$ is the angular acceleration. We also know that torque can also be $T = Fr\sin(\theta)$, where T is the torque, F is the force being applied rotationally, r is the radius (the distance from the axis of rotation) and θ is the angle formed between F and r. It is important to remember that r is the radius, not the diameter, and in our experimentation, we had to ensure that we did not accidently use the diameter in the equation, but instead dividing the value by two to get the actual value. We also reviewed the equations from the last two weeks, being for angular velocity, angular acceleration, the moment of inertia, and the parallel axis theorem.

## 2 EXPERIMENTAL PROCEDURE (10 points)

We followed all instructions as in the lab manual.

**Experiment One**

Uses the disk horizontally.



Radius of Disk (0.114m)


Disk Leveling


Mass of Disk (1.443kg)


Mass of Hanging Mass (0.150kg)

Experimental Setup

Variables:

- Mass of Object (m)
- Radius (r)
- Moment of Inertia (I)
- Tension Force (T)
- Torque (t)
- Angular Acceleration (α)
- Linear Acceleration (a)

**Experiment Two**

This experiment does not use anything but the ring itself. The mass is not 150g but just 50g.


Radius of Ring (0.00125m)


Mass of Hanging Mass (0.0501kg)

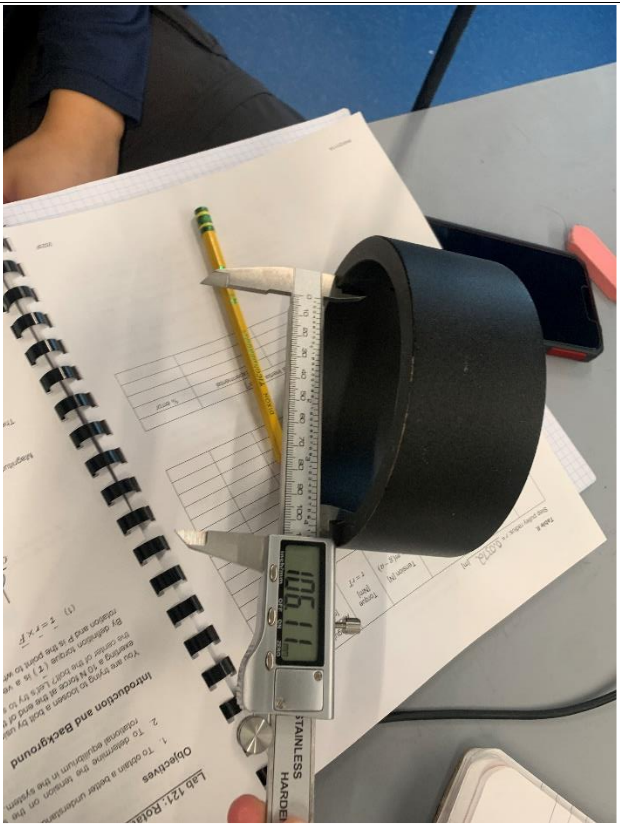
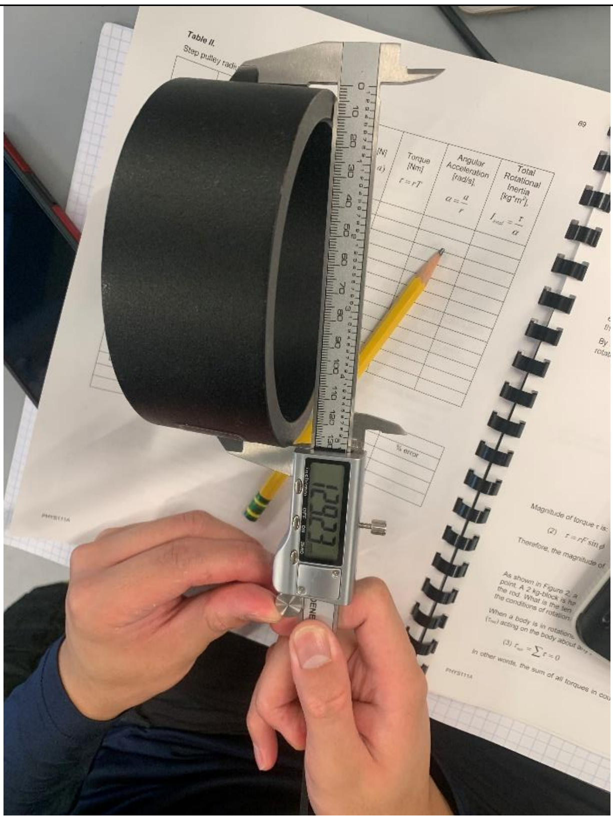
Variables:

- Radius (r)
- Moment of Inertia (I)
- Tension Force (T)
- Torque (t)

- Angular Acceleration (α)
- Linear Acceleration (a)

**Experiment Three**

Uses the disk and a ring on top of the disk.

| | |
|---|---|
|  |  |
| Inside Ring Radius (0.0531m) | Outside Ring Radius (0.0646m) |


Mass of Disk and Ring (2.871kg)


Mass of Hanging Mass (0.150kg)


Experimental Setup

Variables:

- Mass of Object (m)
- Radius (r)
- Moment of Inertia (I)
- Tension Force (T)
- Torque (t)
- Angular Acceleration (α)
- Linear Acceleration (a)

**Experiment Four**

Uses the disk in a vertical position. Many of the details are the same as for experiment one.


Experimental Setup

Variables:

- Mass of Object (m)
- Radius (r)
- Moment of Inertia (I)
- Tension Force (T)
- Torque (t)
- Angular Acceleration (α)
- Linear Acceleration (a)

## 3 RESULTS

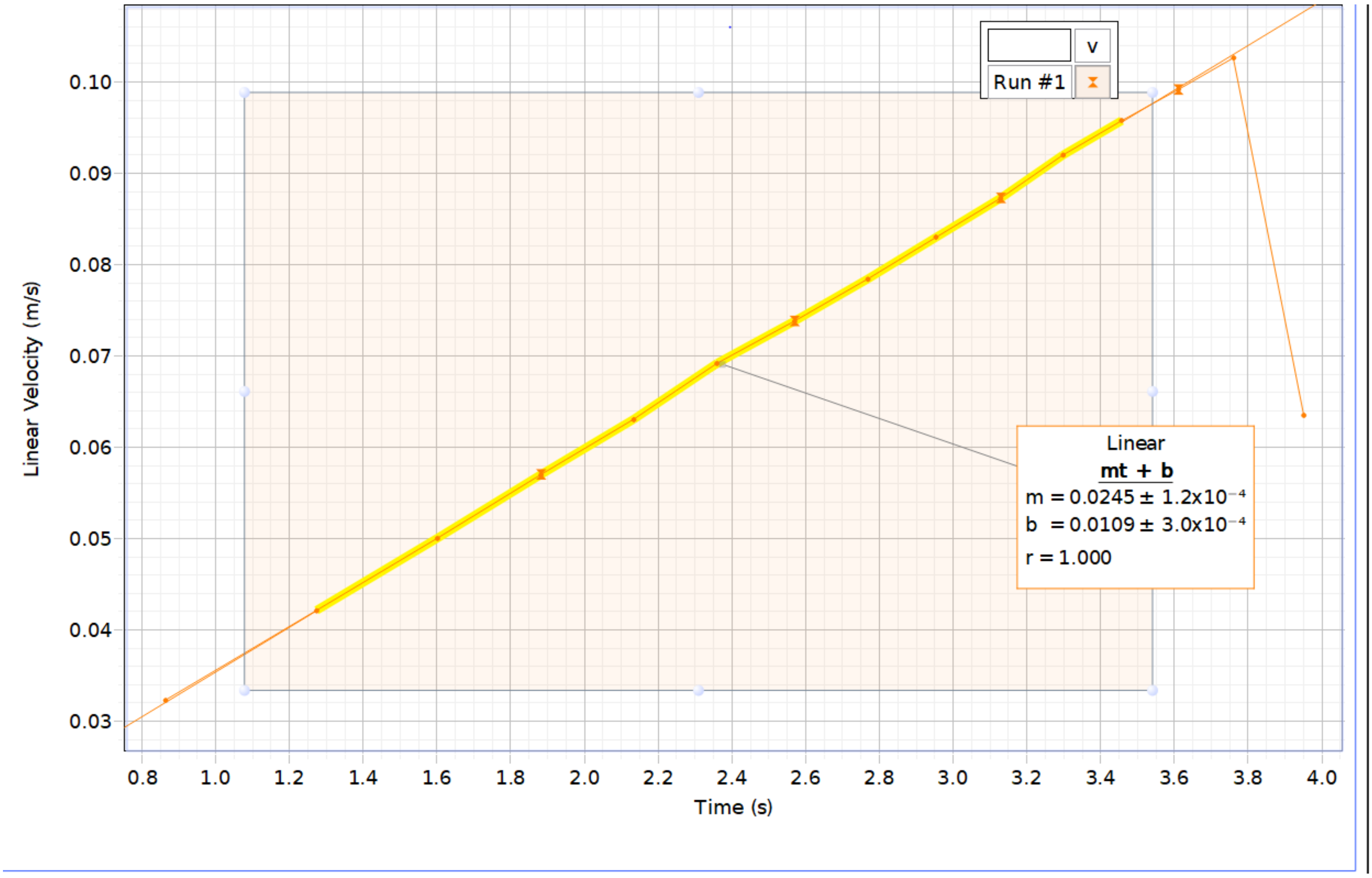
No calculations since we used a calculator in-class. Formulas were provided in the lab manual.

**Table 1.**

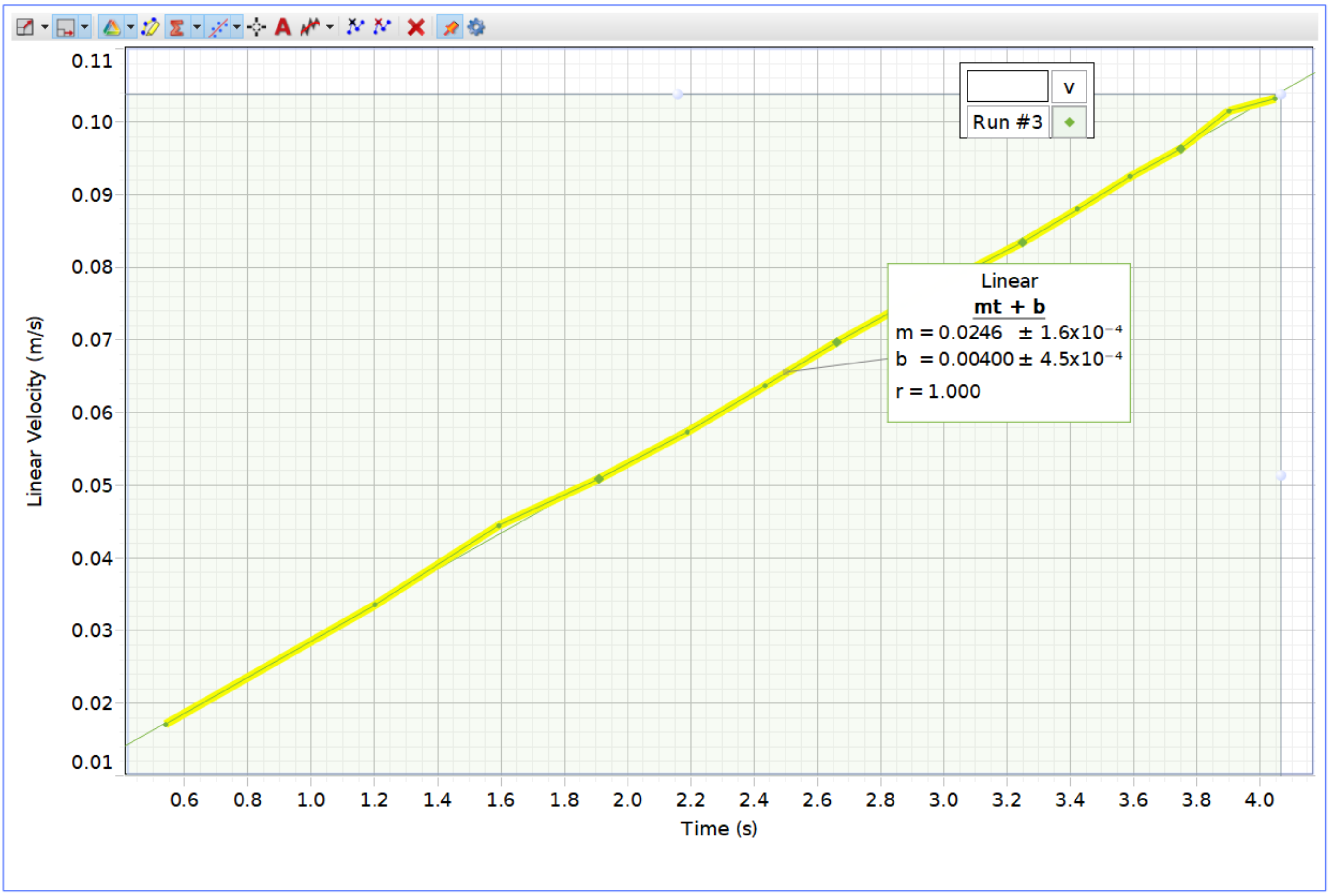
| Object | Mass [kg] | Radius [m] | Rotational Inertia [kg*m$^2$] |
|---|---|---|---|
| Disk | 1.4429 | 0.114 | Through cm: 0.093<br>Through diameter: 0.047 |
| Ring | 1.4278 | Inner: 0.053<br>Outer: 0.065 | 0.0502 |

**Experiment One**

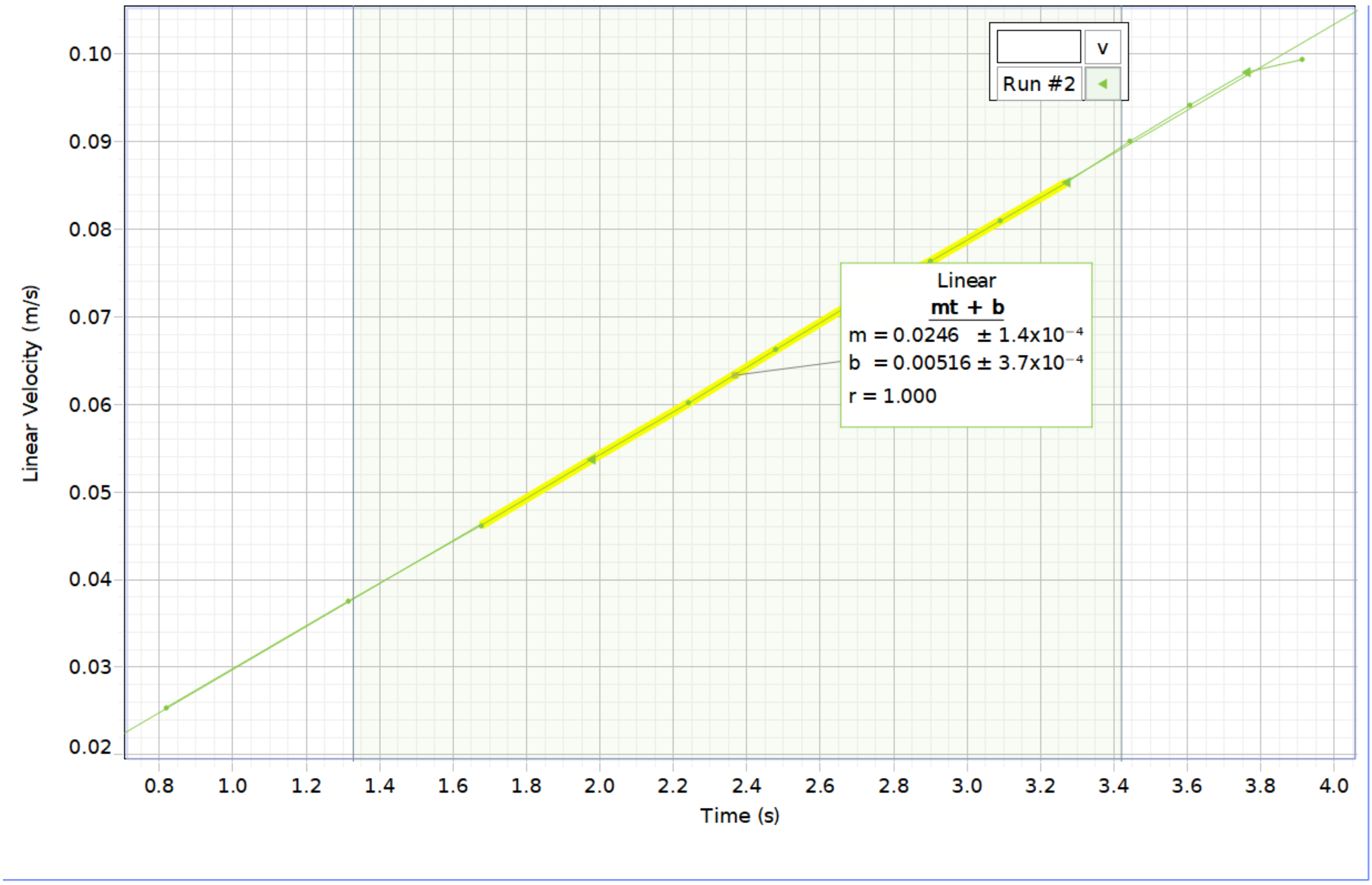
| Run | Hanging Mass [m] | Linear Acceleration [m/s$^2$] | Tension Force [N] | Torque [N*m] | Angular Acceleration [rad/s$^2$] | Inertia [kg*m$^2$] |
|---|---|---|---|---|---|---|
| 1 | 0.0150 | 0.0245 | 1.466 | 0.0183 | 1.960 | 0.0092 |
| 2 | 0.0150 | 0.0246 | 1.466 | 0.0183 | 1.968 | 0.0091 |
| 3 | 0.0150 | 0.0246 | 1.466 | 0.0183 | 1.968 | 0.0091 |



v
Run #1
Linear
mt + b
m = 0.0245 ± 1.2x10⁻⁴
b = 0.0109 ± 3.0x10⁻⁴
r = 1.000
Linear Velocity (m/s)
Time (s)

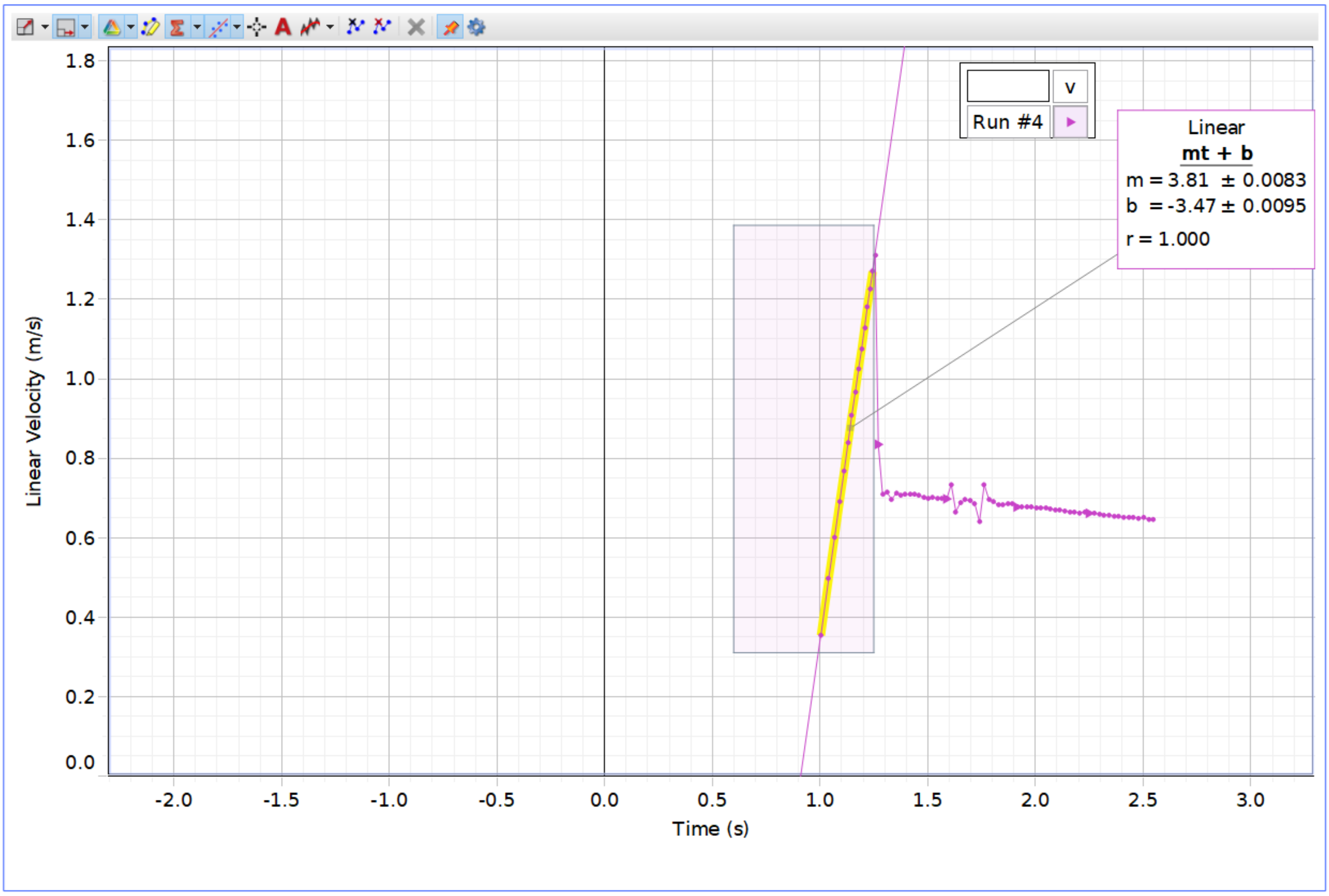
v
Run #3
Linear
mt + b
m = 0.0246 ± 1.6x10⁻⁴
b = 0.00400 ± 4.5x10⁻⁴
r = 1.000
Linear Velocity (m/s)
Time (s)



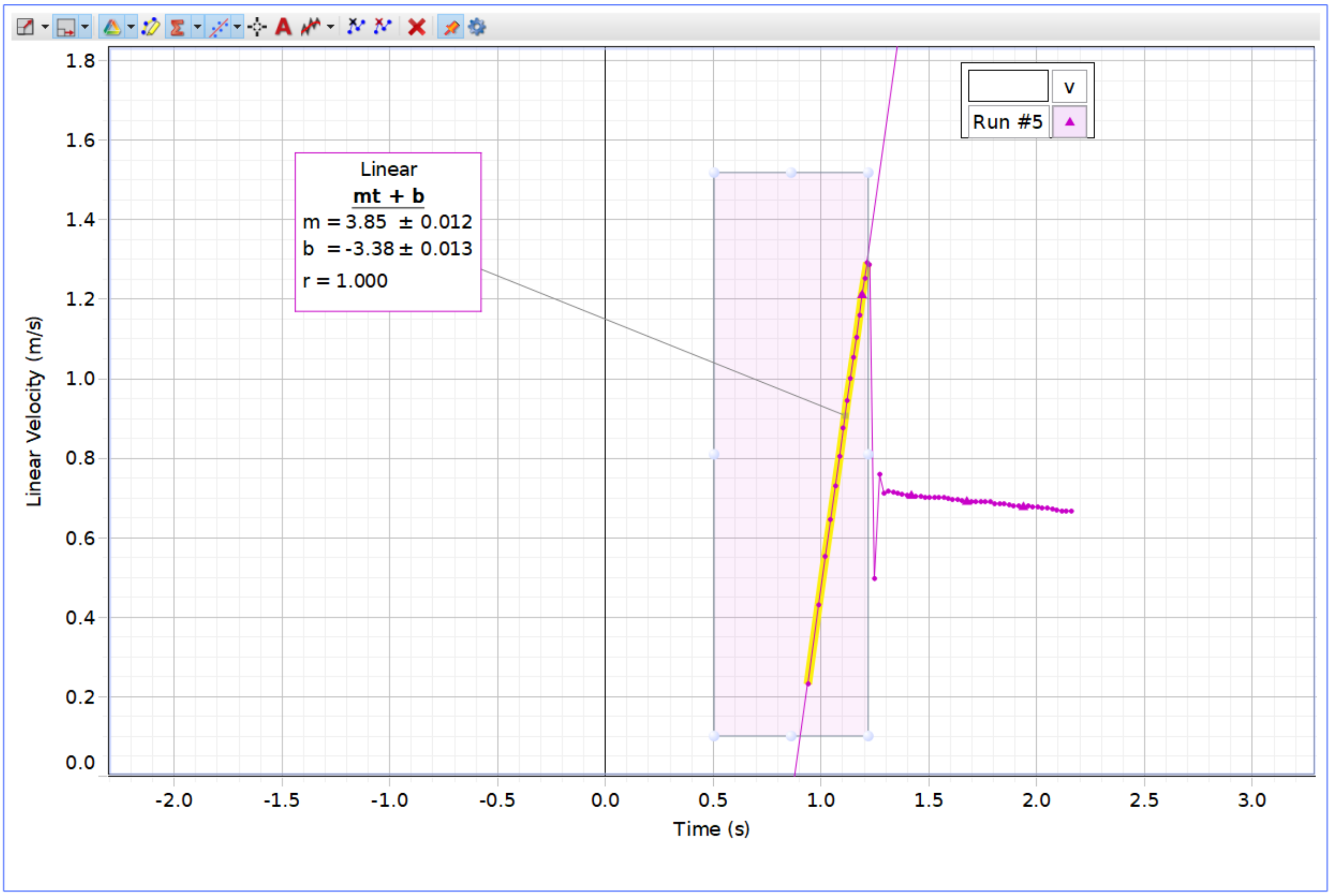

| Rotational Inertia [kg*m$^2$] | | |
|---|---|---|
| Theoretical | Experimental | % Error |
| 0.0094 (Average) | 0.0091 | 3.19% |

**Experiment Two**

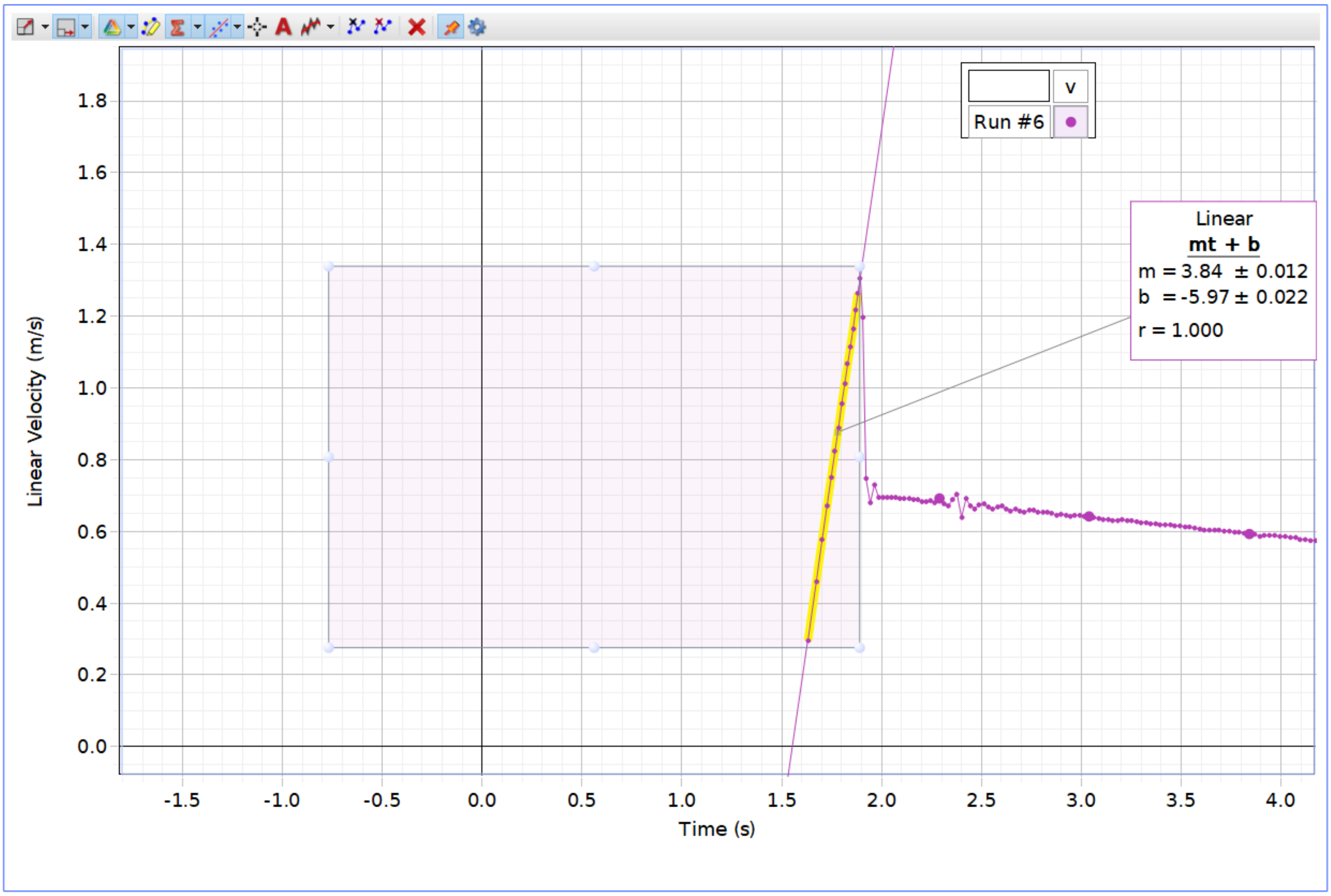
| Run | Hanging Mass [m] | Linear Acceleration [m/s$^2$] | Tension Force [N] | Torque [N*m] | Angular Acceleration [rad/s$^2$] | Inertia [kg*m$^2$] |
|---|---|---|---|---|---|---|
| 1 | 0.050 | 3.81 | 0.2995 | 0.0037 | 304.8 | 1.21e$^{-5}$ |
| 2 | 0.050 | 3.85 | 0.2995 | 0.0037 | 308.0 | 1.20e$^{-5}$ |
| 3 | 0.050 | 3.84 | 0.2980 | 0.0037 | 307.2 | 1.20e$^{-5}$ |



Linear Velocity (m/s)
Time (s)
v
Run #4
Linear
mt + b
m = 3.81 ± 0.0083
b = -3.47 ± 0.0095
r = 1.000

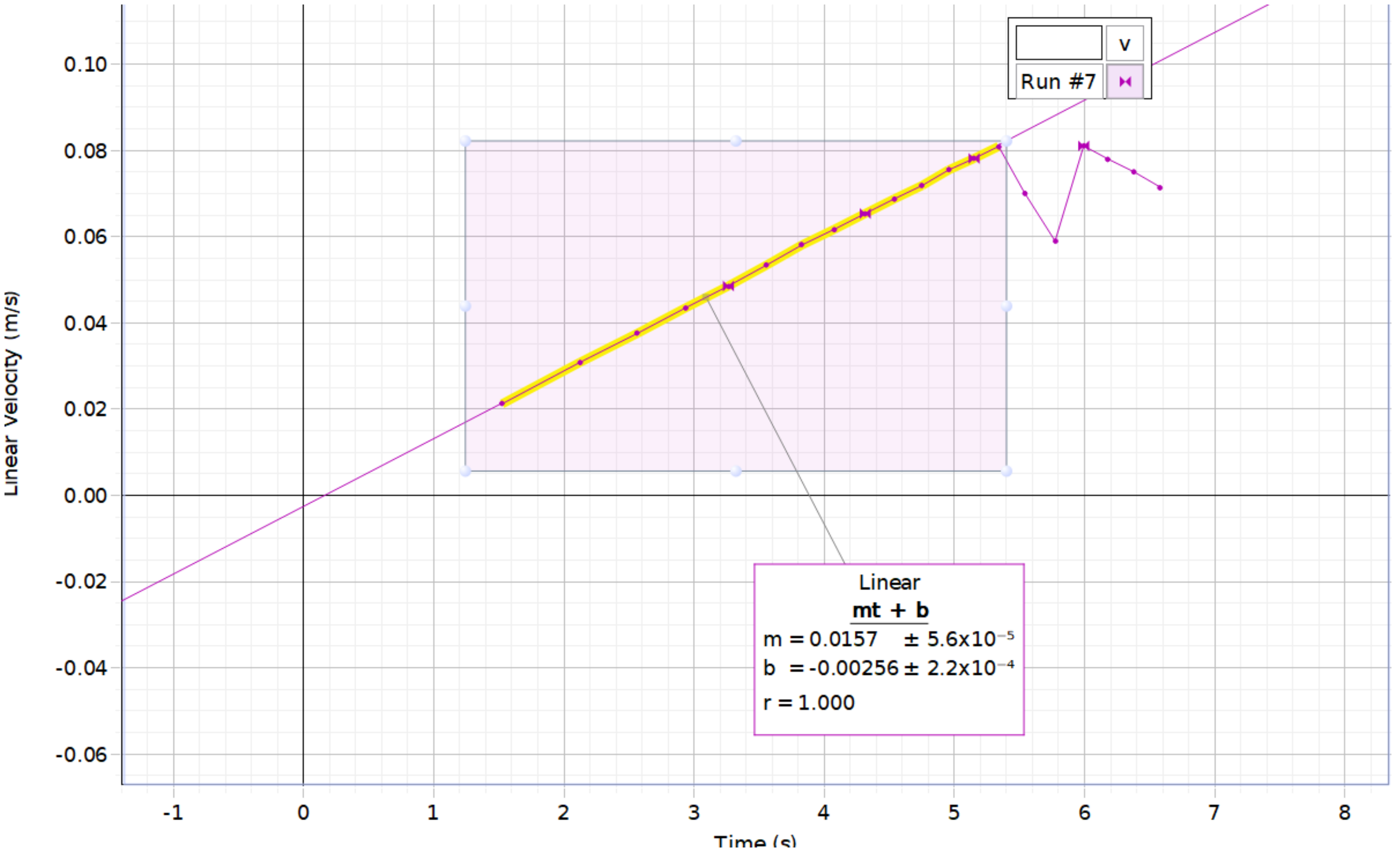



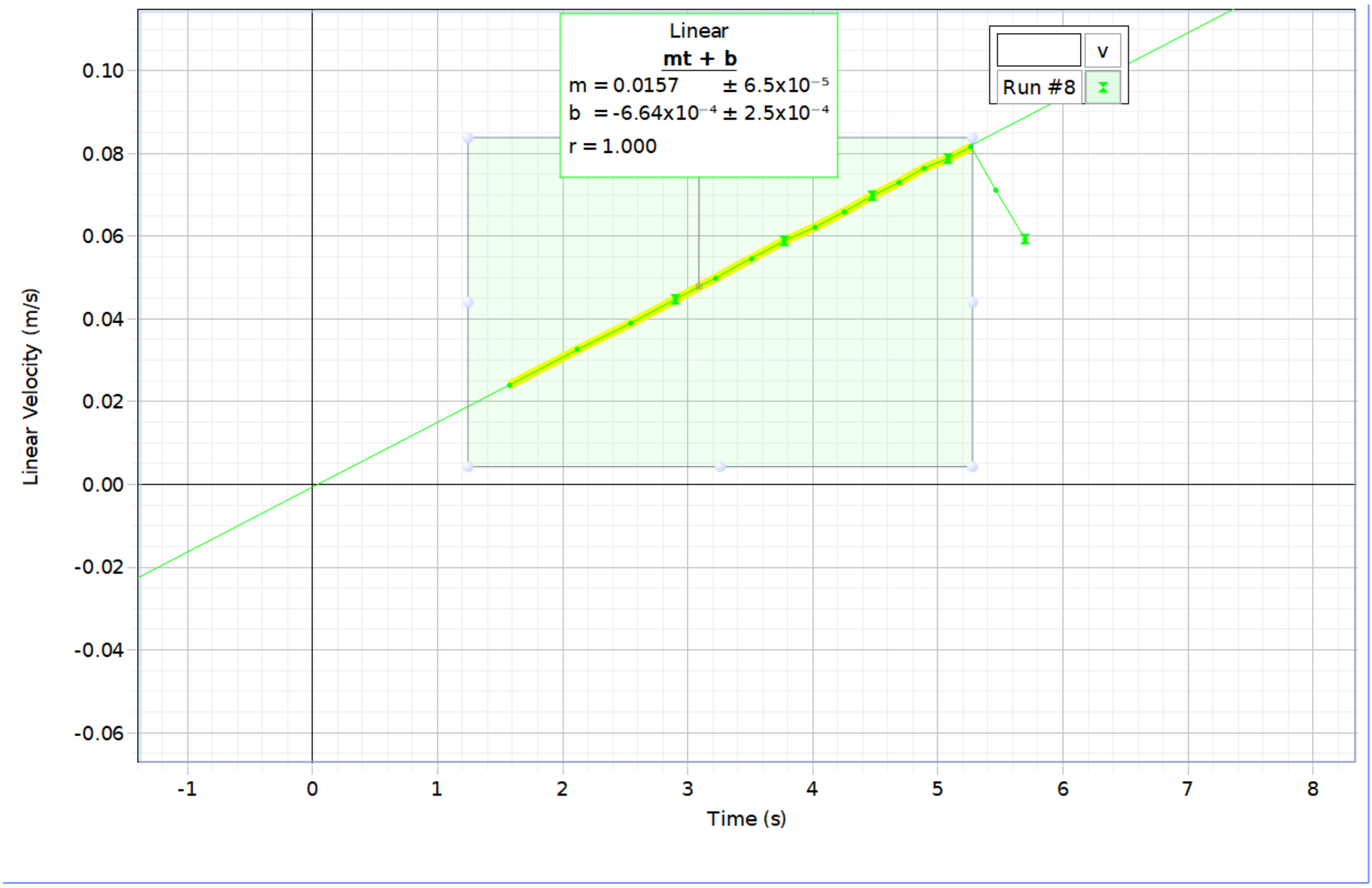
Linear Velocity (m/s)
Time (s)
v
Run #5
Linear
mt + b
m = 3.85 ± 0.012
b = -3.38 ± 0.013
r = 1.000

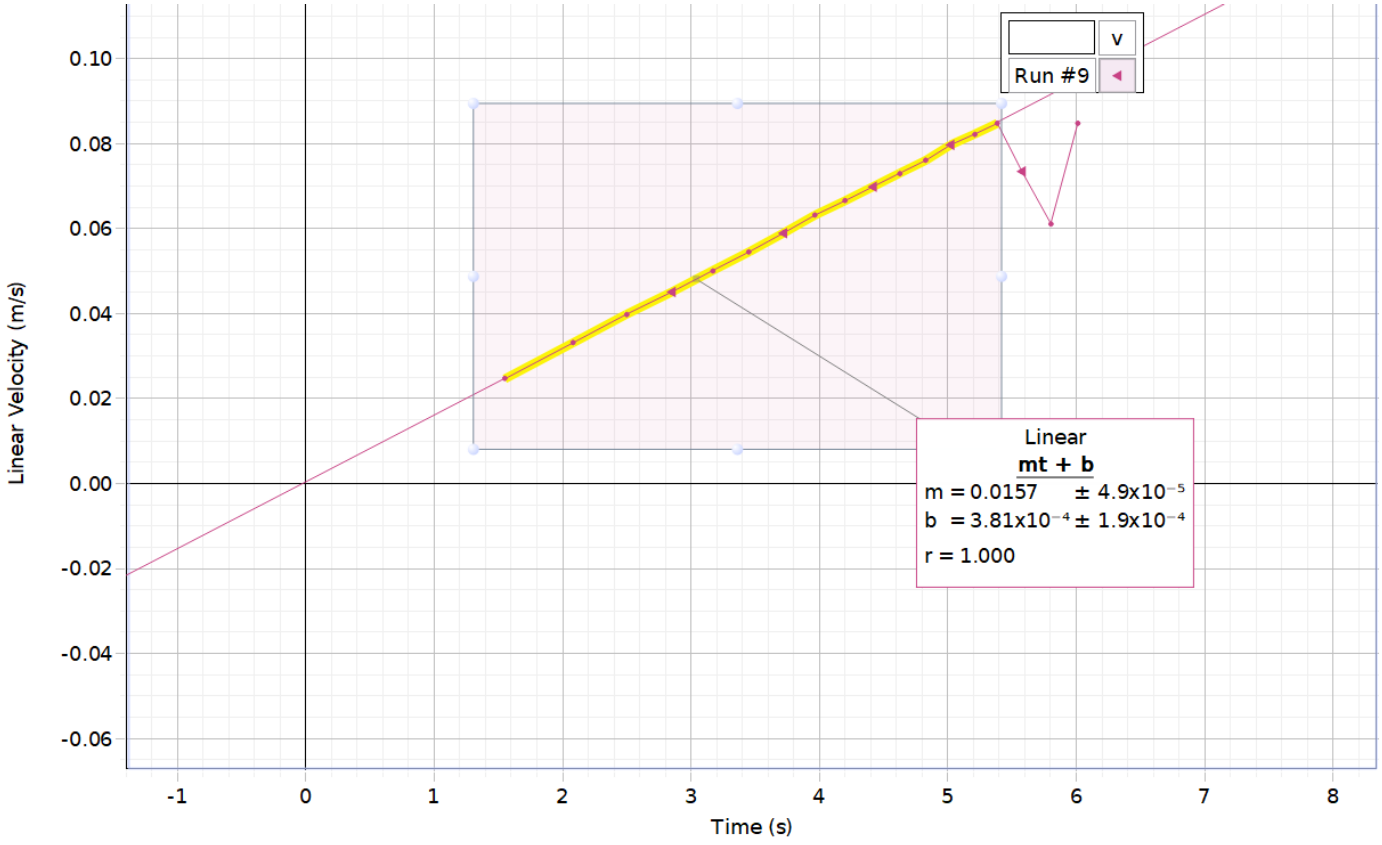



## Experiment Three

| Run | Hanging Mass [m] | Linear Acceleration [m/s$^2$] | Tension Force [N] | Torque [N*m] | Angular Acceleration [rad/s$^2$] | Inertia [kg*m$^2$] |
|---|---|---|---|---|---|---|
| 1 | 0.0150 | 0.0157 | 1.468 | 0.0184 | 1.256 | 0.0146 |
| 2 | 0.0150 | 0.0157 | 1.468 | 0.0184 | 1.256 | 0.0146 |
| 3 | 0.0150 | 0.0157 | 1.468 | 0.0184 | 1.256 | 0.0146 |


Run #7
v
Linear
mt + b
m = 0.0157 ± 5.6x10⁻⁵
b = -0.00256 ± 2.2x10⁻⁴
r = 1.000
Linear Velocity (m/s)
Time (s)
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-1
0
1
2
3
4
5
6
7
8

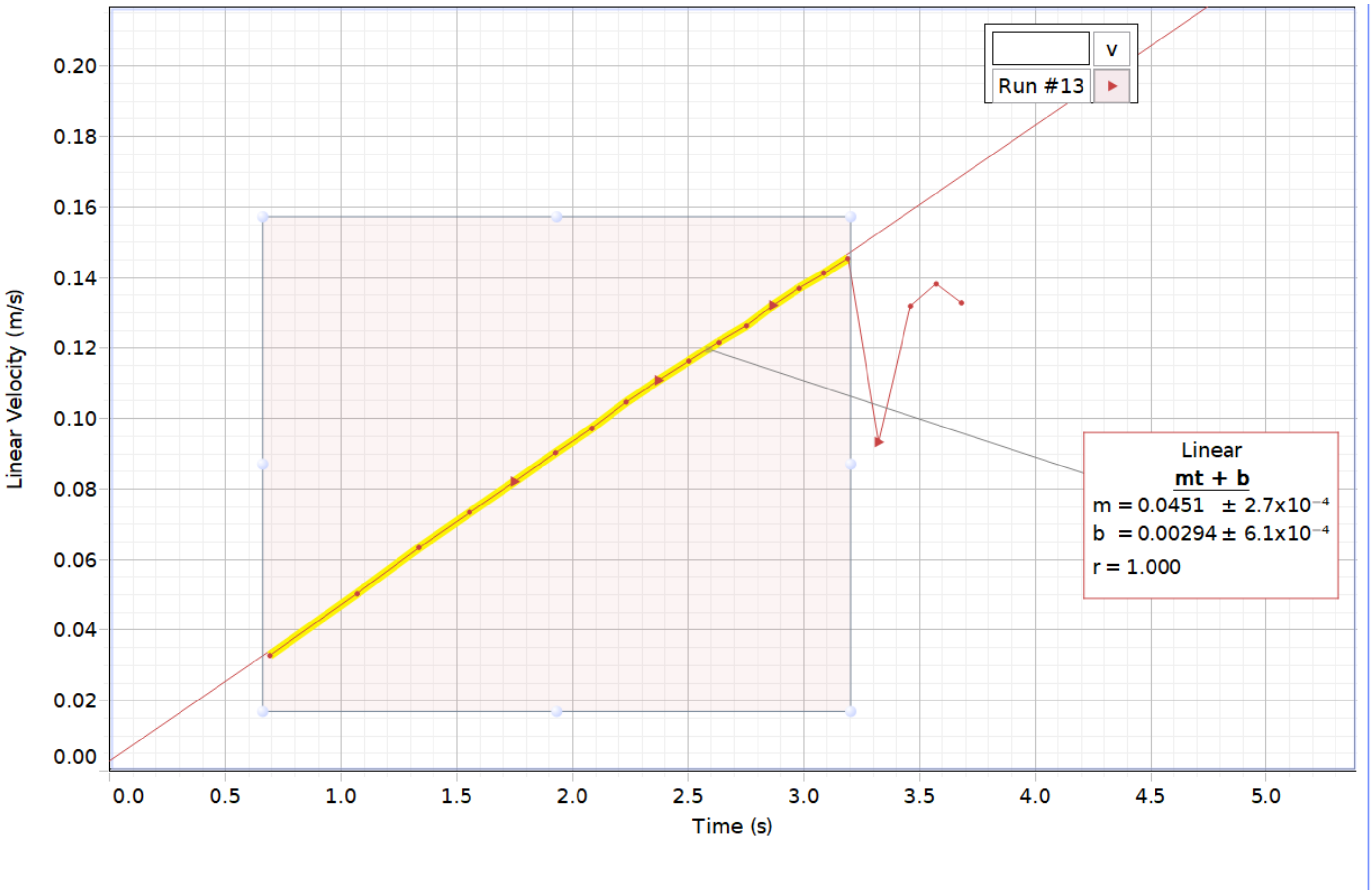

Linear
mt + b
m = 0.0157 ± 6.5x10⁻⁵
b = -6.64x10⁻⁴ ± 2.5x10⁻⁴
r = 1.000
Run #8
v
Linear Velocity (m/s)
Time (s)
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-1
0
1
2
3
4
5
6
7
8

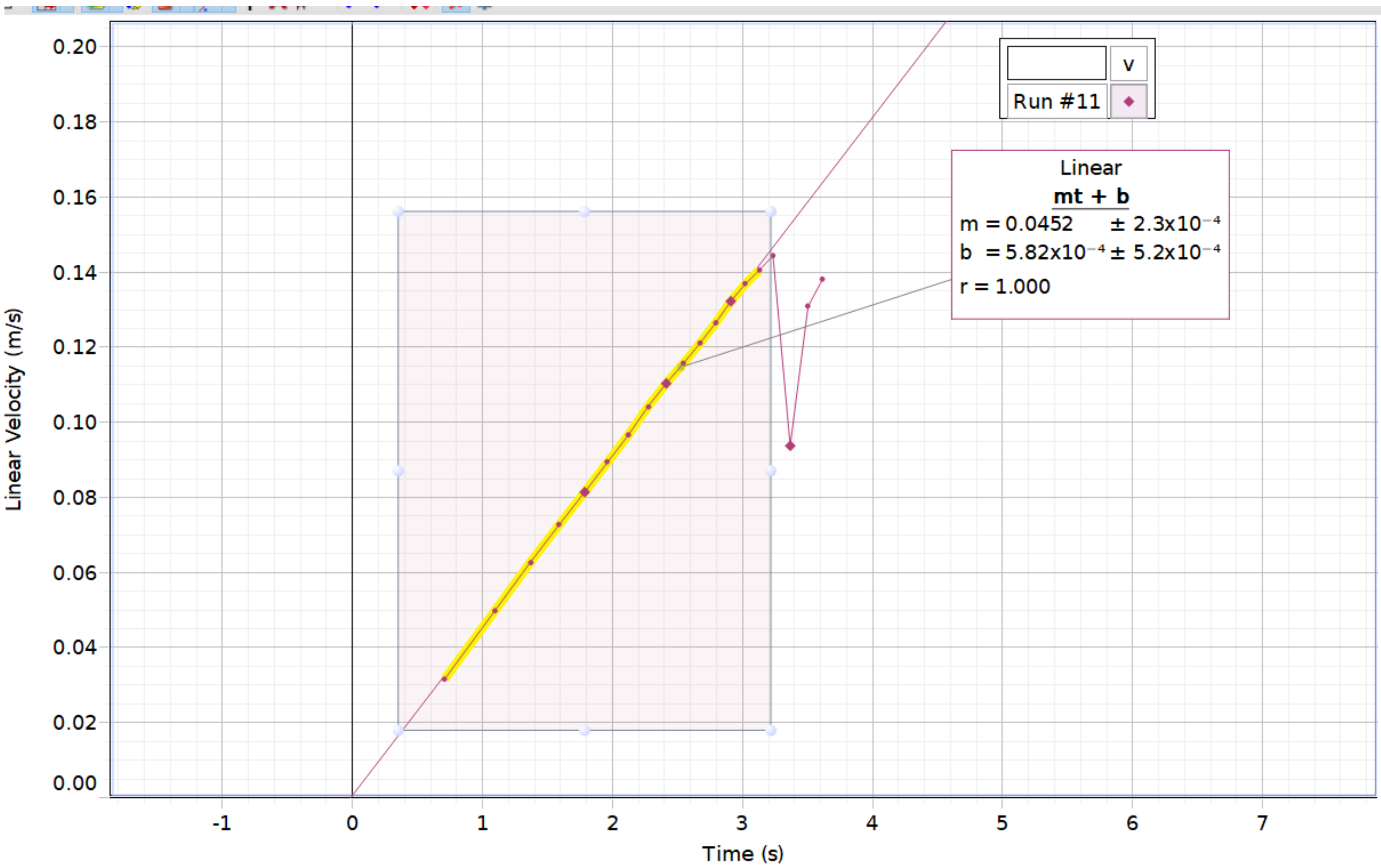


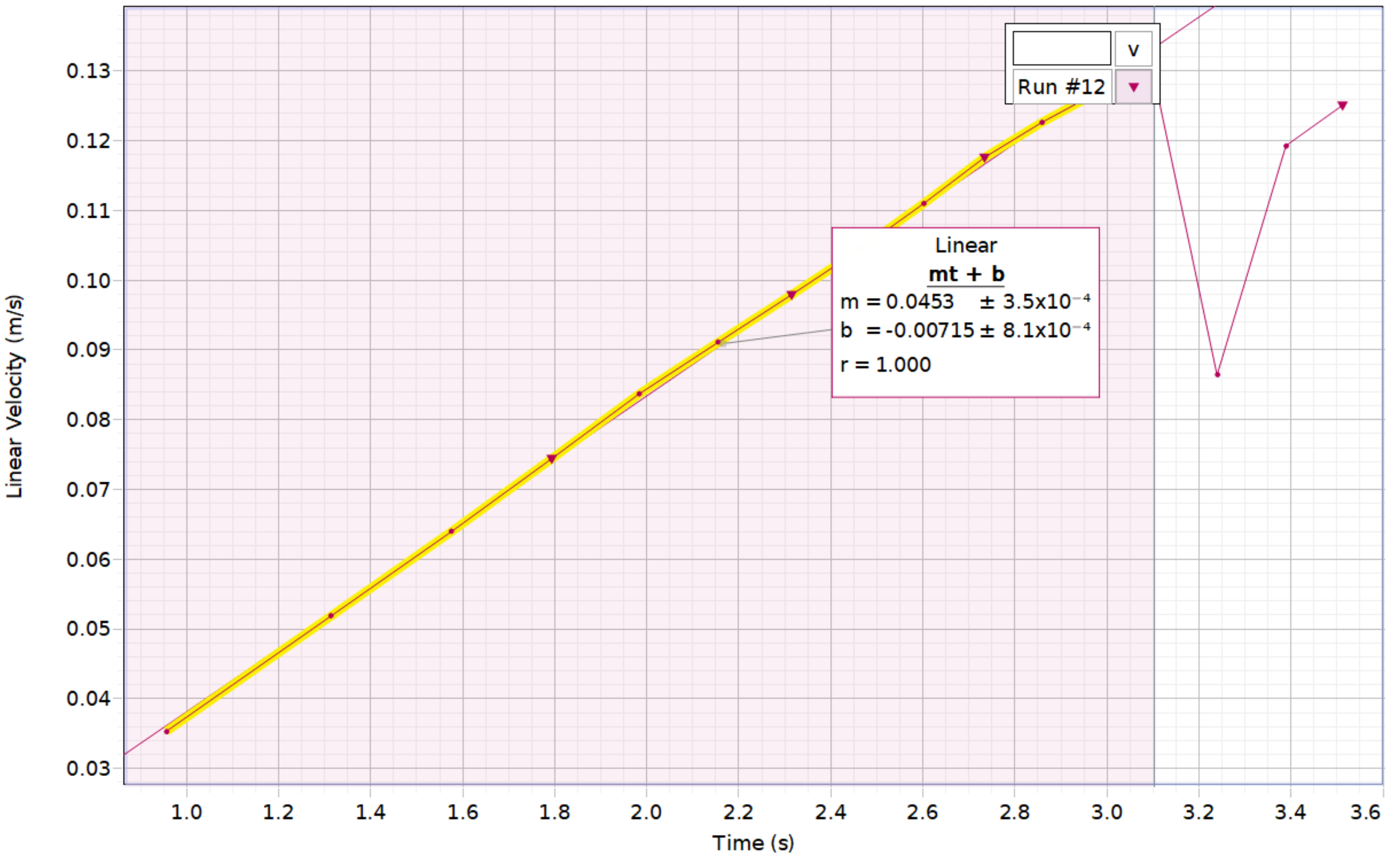

| Rotational Inertia [kg*m$^2$] | | |
|---|---|---|
| Theoretical | Experimental | % Error |
| 0.0050 (Average) | 0.0055 | 10.00% |

**Experiment Four**

| Run | Hanging Mass [m] | Linear Acceleration [m/s$^2$] | Tension Force [N] | Torque [N*m] | Angular Acceleration [rad/s$^2$] | Inertia [kg*m$^2$] |
|---|---|---|---|---|---|---|
| 1 | 0.0150 | 0.0451 | 1.463 | 0.0183 | 3.608 | 0.0051 |
| 2 | 0.0150 | 0.0452 | 1.463 | 0.0183 | 3.616 | 0.0051 |
| 3 | 0.0150 | 0.0453 | 1.463 | 0.0183 | 3.624 | 0.0050 |


Run #13
Linear
mt + b
m = 0.0451 ± 2.7x10⁻⁴
b = 0.00294 ± 6.1x10⁻⁴
r = 1.000
Linear Velocity (m/s)
Time (s)


Run #11
Linear
mt + b
m = 0.0452 ± 2.3x10⁻⁴
b = 5.82x10⁻⁴ ± 5.2x10⁻⁴
r = 1.000
Linear Velocity (m/s)
Time (s)




| Rotational Inertia [kg*m$^2$] | | |
|---|---|---|
| Theoretical | Experimental | % Error |
| 0.0047 (Average) | 0.0051 | 8.51% |

## 4 ANALYSIS and DISCUSSION

There were four separate experiments that had us calculate for a variety of different variables in order to have completed the objective of this lab. It required us to put our understanding of inertia, torque, and acceleration to get the necessary values and then see how close we get to the actual inertia. There was errors between the measured and the theoretical values of at most 10%, while the average of it being around 6%. This is a good level which means that the measured values are near accuracy, but the small margin of error could come from friction (of the string sliding against the various surfaces) or significant figures playing a role (rounding error). Either way, they have accounted for a small change in the measured and theoretical values. Because of this, I believe that the lab report meets the objectives of the lab. There was a singular discussion question which asks about how our experiment resulted in comparison to the theoretical value. This was explained earlier, but in summary there is a small change (with no specific trend of either side being bigger/smaller) that could have come about from rounding error or unaccounted friction.

## 5 CONCLUSIONS (10 points)

To conclude this lab report, we have learned more about rotating bodies and how they now can be affected by forces in a unique way. This adds onto our story about how rotation works, what inertia is, and how rotating works with translational motion. In this experiment, we saw how different objects (or the same objects in different orientations) have different accelerations depending on their moment of inertia and the amount of torque being applied (by the tension force connected to the hanging mass). The experiments did raise some questions for me. For experiment two, we noticed an acceleration of the string of around $4 m/s^2$, although gravity accounts for almost 10. Where did the rest of the acceleration dissipate if the moment of inertia for the ring was so low? Another thing is how friction would either speed up or slow down the systems. I assume it would slow down, as energy is being dissipated, but that would be good to include into the experiments. I suggest that in the future we also include another sensor capable of reading rotational acceleration rather than relying on a no-slip condition which may not always apply, especially in the case of experiment two where the string would constantly fall off. Overall, I found this lab very insightful and would love to continue the discussion on rotation.