Physics Laboratory Report

Lab number and Title: Lab 121 – Rotational Static Equilibrium - Forces on a Strut

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Date of Experiment: 11/30/2023 **Date of Report Submission: 12/07/2023**

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

In this experiment we worked more closely with balancing forces and the torque on an object to achieve a "static equilibrium" state, whereby the object is not moving. This adds onto the story that we have worked on for several weeks in the realm of rotational bodies. In this lab, we were given three experiments to do, where we calculated what the torques were in order to the system to remain stationary. We were provided with a rod and two masses (which were set at their locations throughout all experiments), and then between each experiment changed the angle between the rod and the horizontal plane (parallel to the ground). The results and calculations are in this report, and a draft report was also submitted in class to the instructor.

1.2 Theoretical background

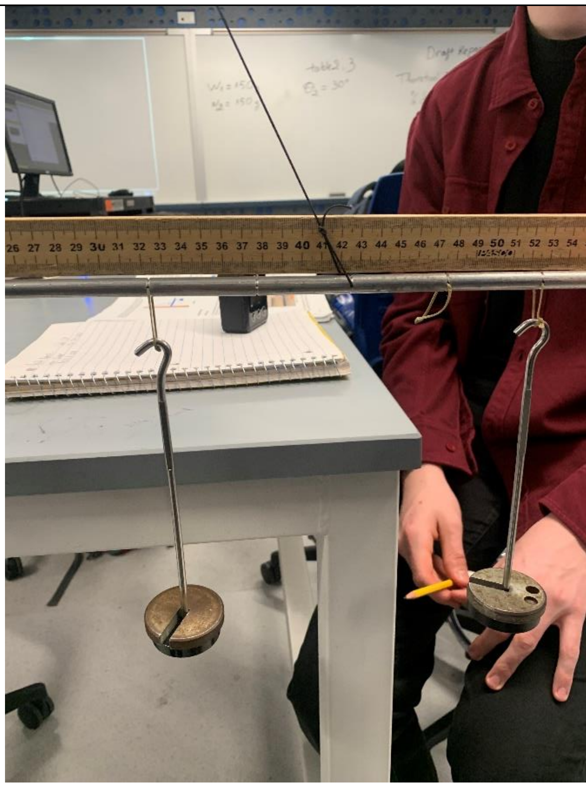
There are two important formulas in order to properly use static equilibrium. The first equation, $\Sigma T = 0$ and $\Sigma F = 0$. Note that for the forces equation there is both the x vector and the y vector which can have their own forces. However, in this experiment, considering that there is only forces in one plane (the y-plane), we do not need to worry about this. Last thing to note is when dealing with the angled platforms (experiments two and three), we have to use cos(θ), and not the magnitude of the value since not all of it is being used to provide torque to the rod.

2 EXPERIMENTAL PROCEDURE

Values of Masses

Mass of Rod = 0.11kg

<table>
<tr>
<td>

Length of Rod (0.575m)</td>
<td>
Distance of Hanging Masses
(L1 = 0.324m)
(L2 = 0.425m)
(L3 = 0.475m)</td>
</tr>
</table>

 Hanging Mass 1 (0.1498kg)	 Hanging Mass 2 (0.1495kg)

These values were used in all experiments

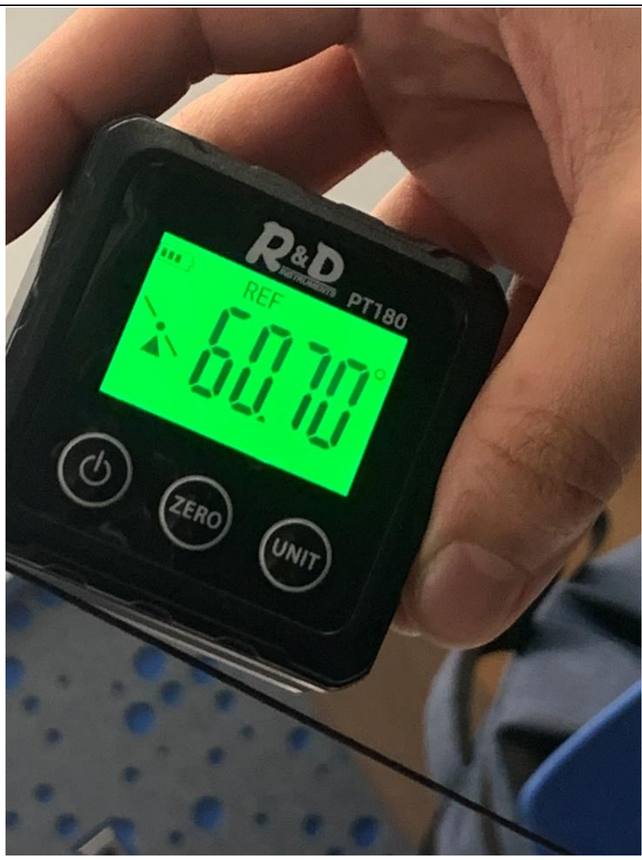
Experiment One

Experiment with the rod at no angle. This is the base experiment, and the other experiments deviate from this standard position. Put simply, we measured the values of the angles to calculate for the theoretical, and then relate that to the actual measured value from the sensor.

Angle of Rod θ_2 (0.0 degrees)

Angle of Rod θ_1 (63.1 degrees)

Angle of Rod θ_1 (61.1 degrees)



Angle of Rod θ_1 (60.7 degrees)

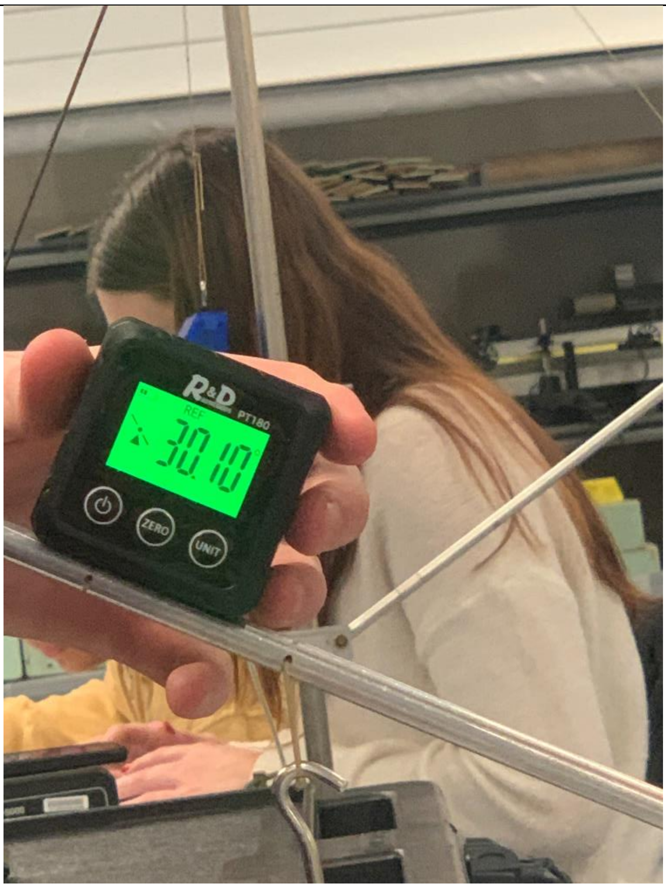
Experimental Setup

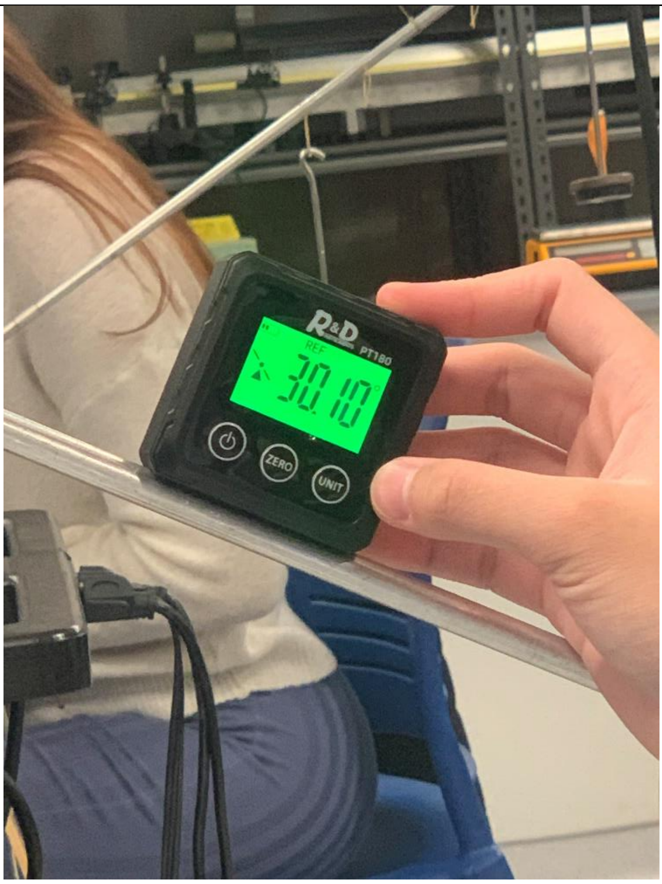
Variables:

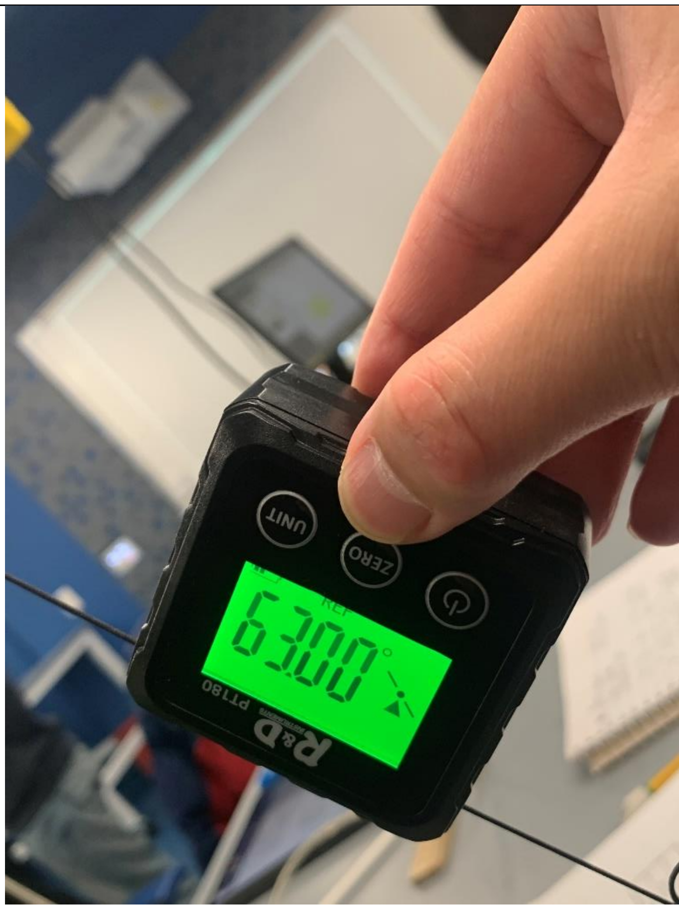
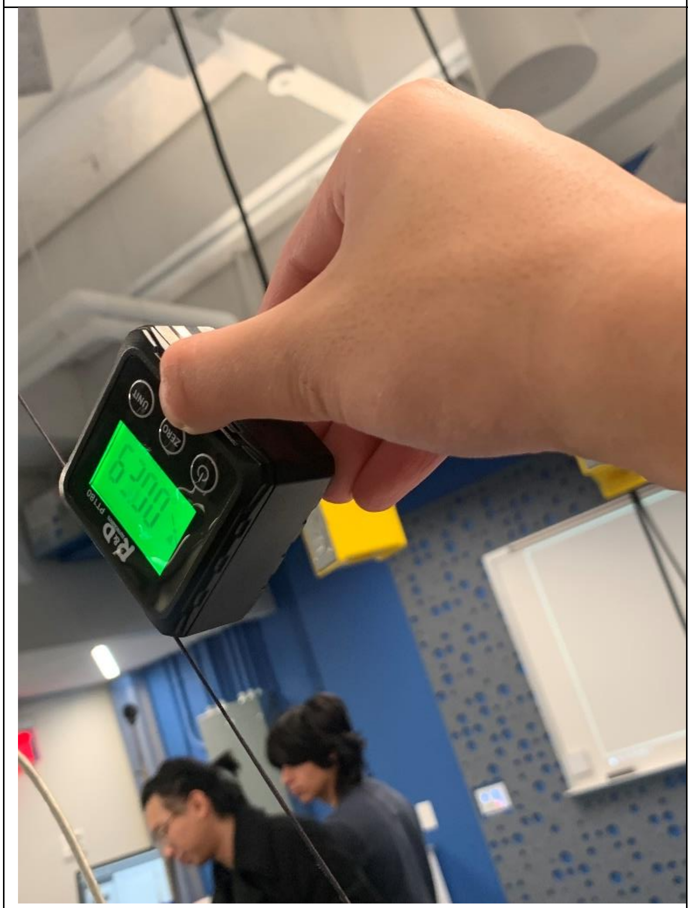
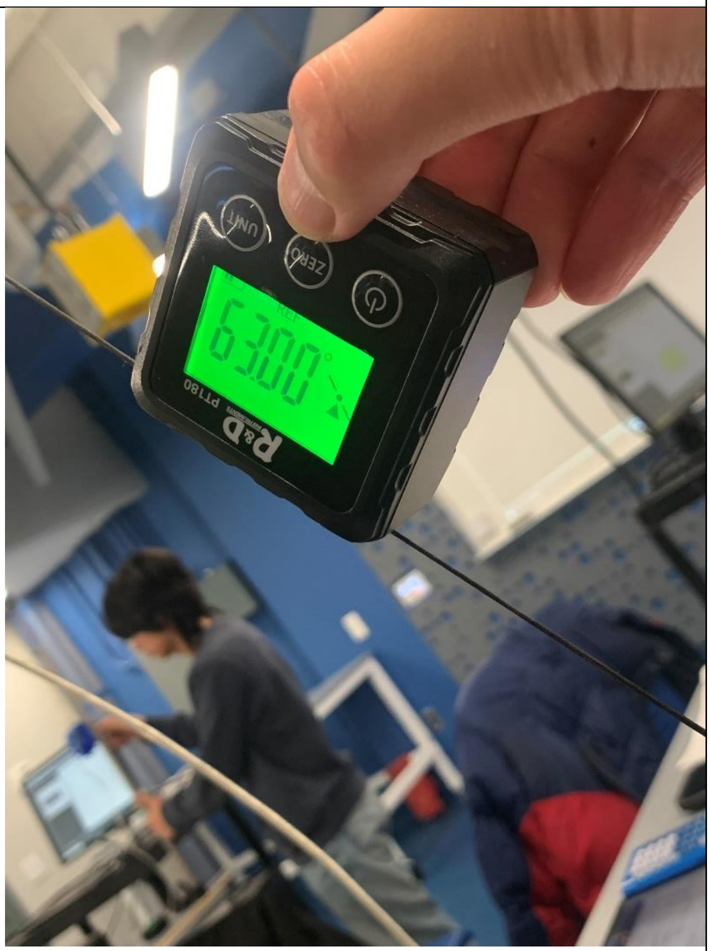
- Angle of Rod (θ_2)
- Angle of String (θ_1)
- Weight of Mass 1 (W_1)
- Weight of Mass 2 (W_2)
- Weight of Rod (W_R)
- Distance of Mass 1 (L_1)
- Distance of String (L_2)
- Distance of Mass 2 (L_3)
- Total Length of Rod (L_R)
    - Divided by 2 and used for the torque of the center of mass of the rod
- Magnitude of Tension Force (Ft)

Experiment Two

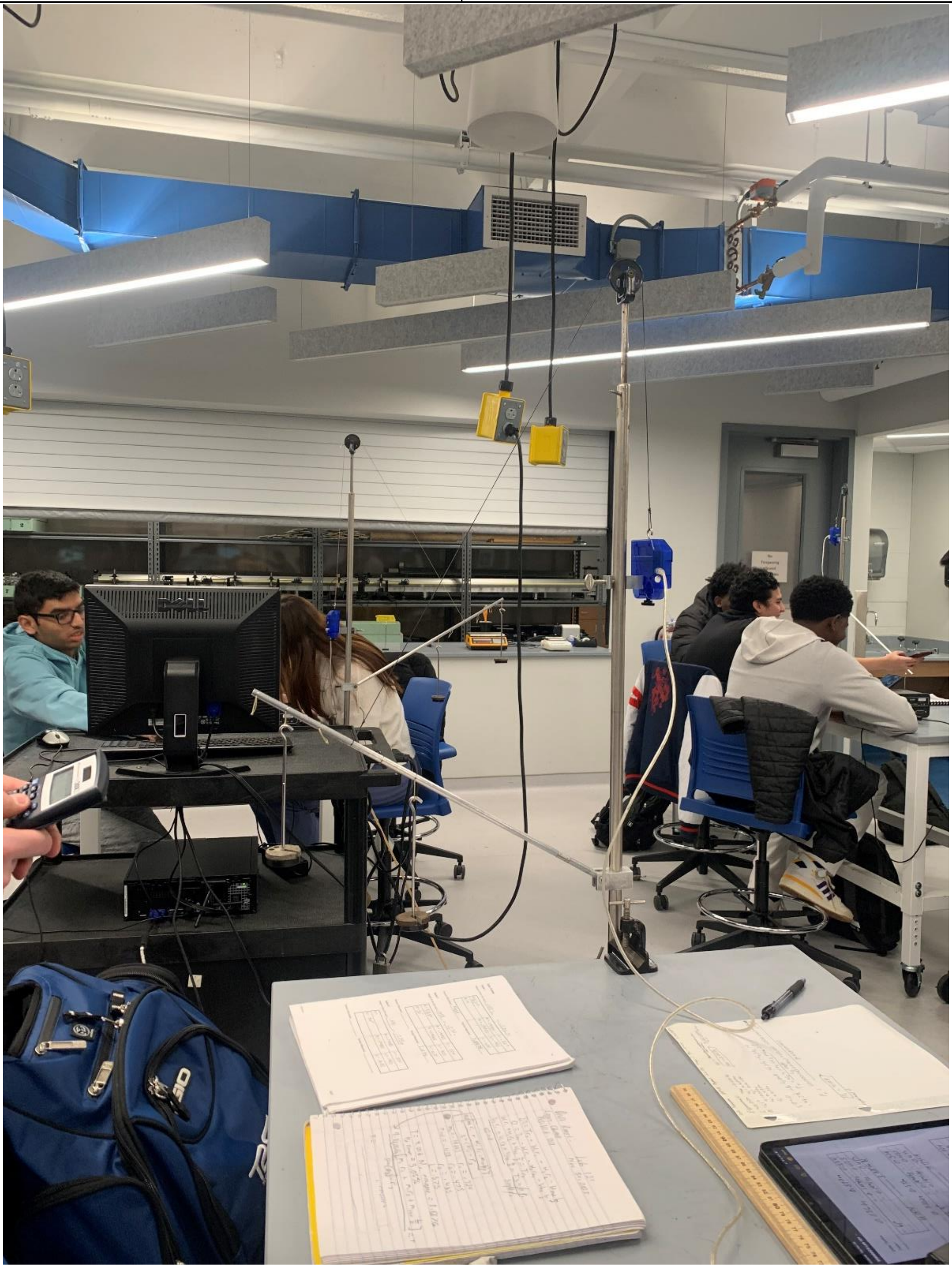
Experiment two had the rod at a 30-degree angle from the horizontal, pointing upwards. Put simply, we measured the values of the angles to calculate for the theoretical, and then relate that to the actual measured value from the sensor.





Angle of Rod θ_2 (30.1 degrees)	Angle of Rod θ_2 (30.1 degrees)
	
Angle of Rod θ_2 (29.7 degrees)	Angle of Rod θ_1 (63.0 degrees)
	
Angle of Rod θ_1 (63.0 degrees)	

	Angle of Rod θ_1 (60.7 degrees)



Experimental Setup

The values of Theta 1 do not reflect the actual values, for which we forgot to take photos for.

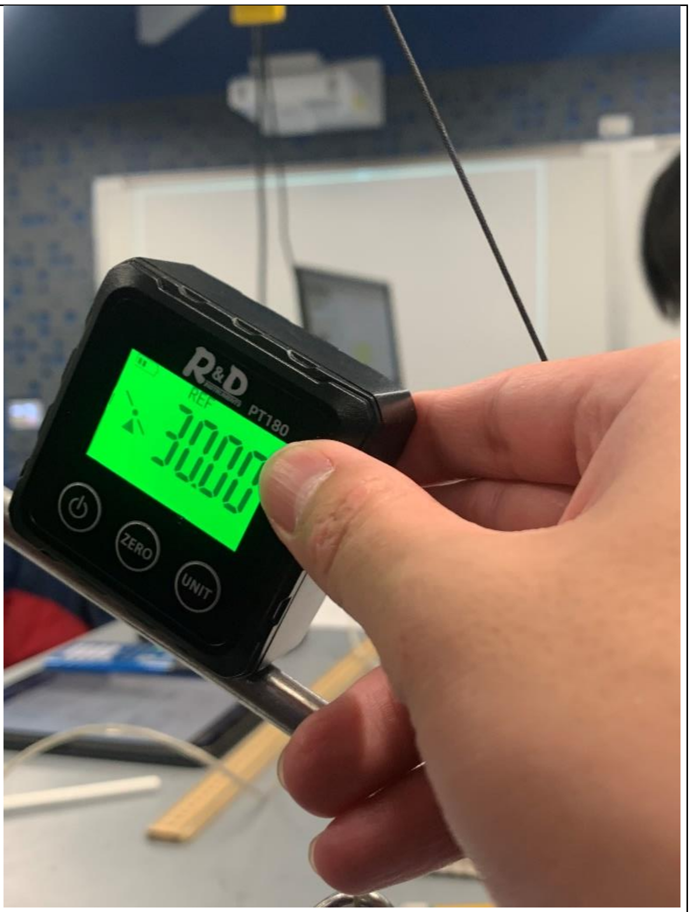
Variables:

- Angle of Rod (θ_2)
- Angle of String (θ_1)
- Weight of Mass 1 (W_1)
- Weight of Mass 2 (W_2)

- Weight of Rod (W_R)
- Distance of Mass 1 (L_1)
- Distance of String (L_2)
- Distance of Mass 2 (L_3)
- Total Length of Rod (L_R)
    - Divided by 2 and used for the torque of the center of mass of the rod
- Magnitude of Tension Force (Ft)

Experiment Three

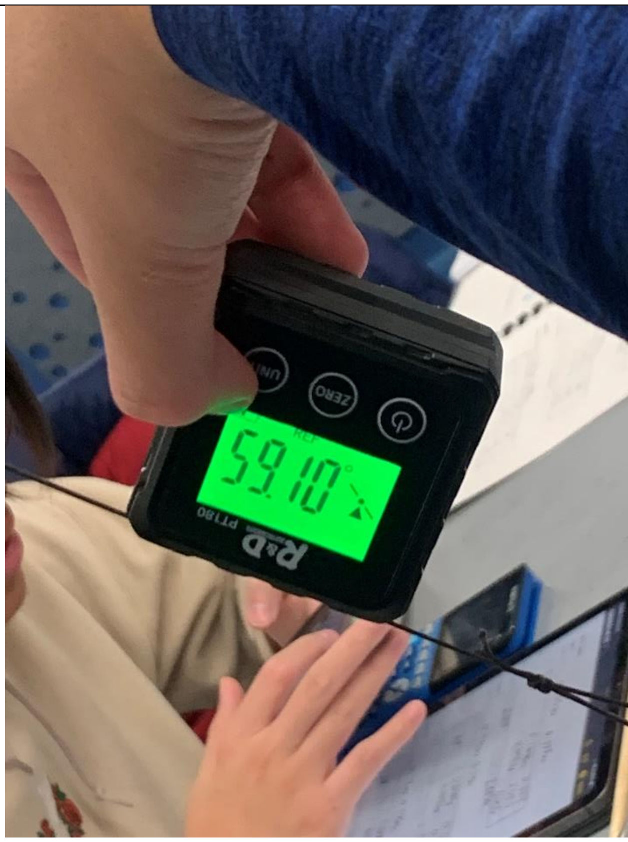
Experiment three has the rod 30 degrees downwards. Put simply, we measured the values of the angles to calculate for the theoretical, and then relate that to the actual measured value from the sensor.

	
Angle of Rod θ_2 (30.0 degrees)	Angle of Rod θ_2 (30.0 degrees)

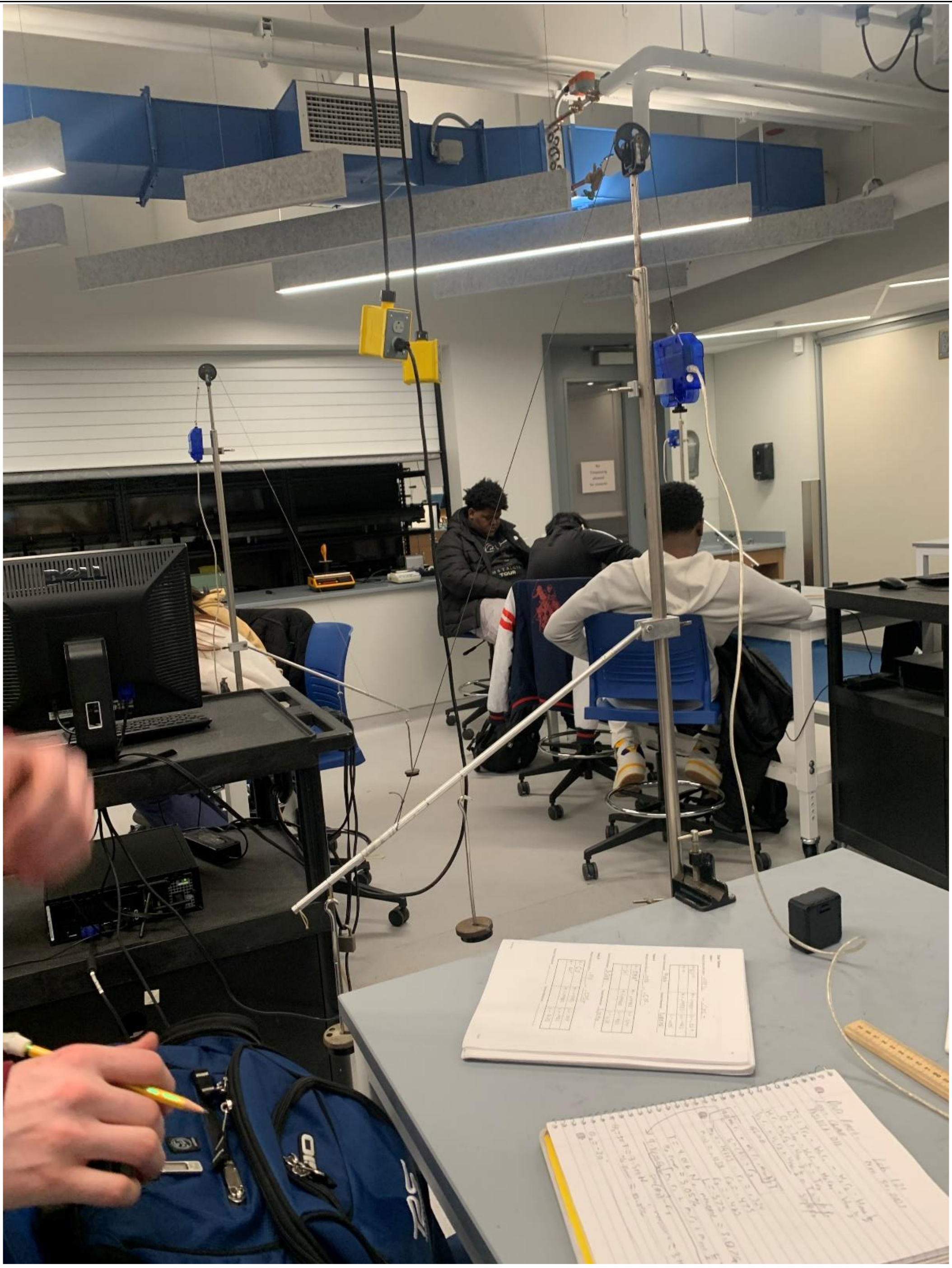
Angle of Rod θ_2 (30.0 degrees)

Angle of Rod θ_1 (60.3 degrees)

Angle of Rod θ_1 (59.5 degrees)



Angle of Rod θ_1 (59.1 degrees)



Experimental Setup

The values of Theta 1 do not reflect the actual values, for which we forgot to take photos for.

Variables:

- Angle of Rod (θ_2)
- Angle of String (θ_1)
- Weight of Mass 1 (W_1)
- Weight of Mass 2 (W_2)
- Weight of Rod (W_R)

- Distance of Mass 1 (L_1)
- Distance of String (L_2)
- Distance of Mass 2 (L_3)
- Total Length of Rod (L_R)
    - Divided by 2 and used for the torque of the center of mass of the rod.

Magnitude of Tension Force (Ft)

3 RESULTS

Experiment One

$$\sum \tau = 0$$

$$\cancel{F_t L_2 = W_1 L_1}$$

$$-W_R g L/2 + F_t L_2 \sin(\theta_1) - W_1 g L_1 - W_2 g L_2 = 0$$

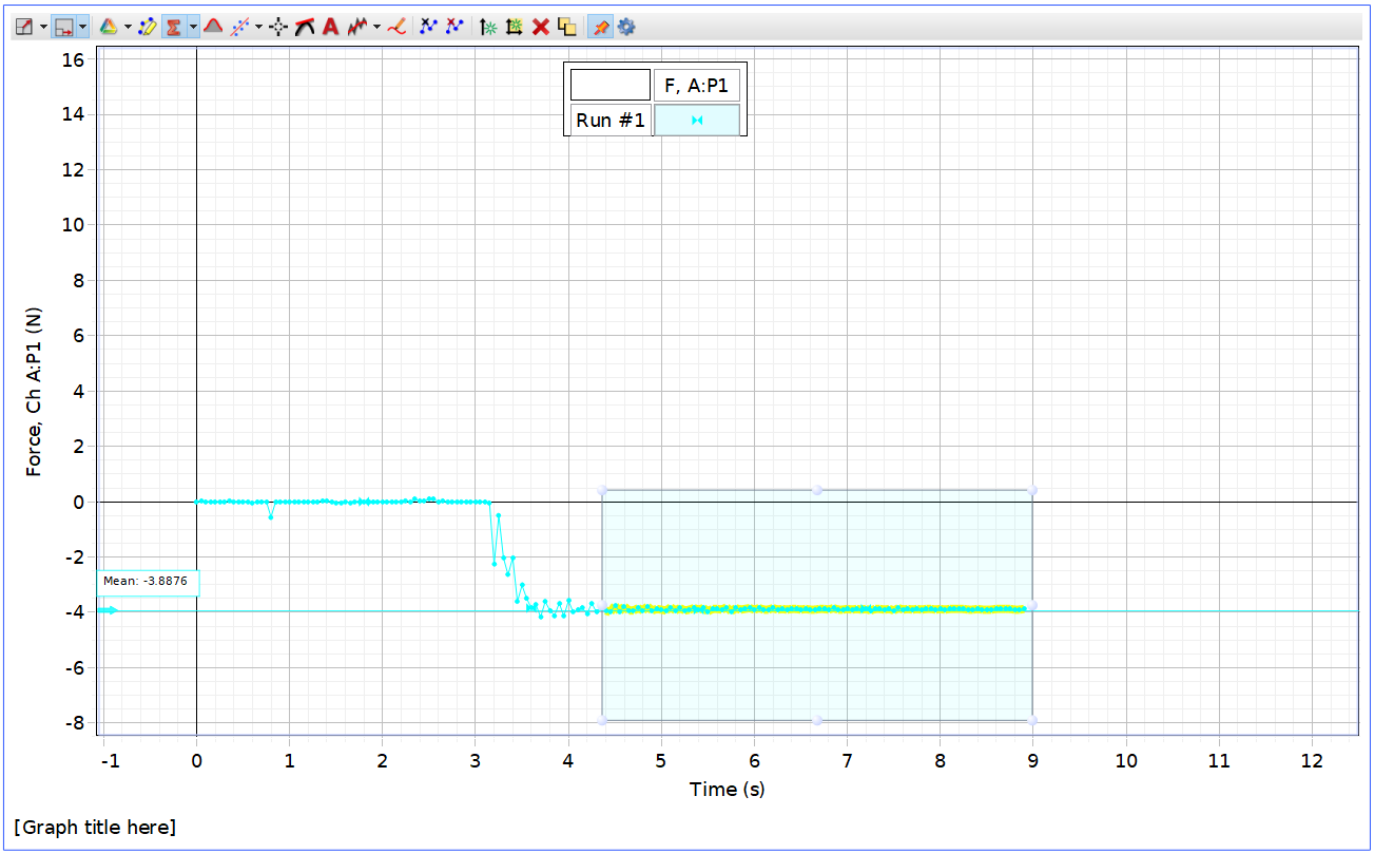
$$\rightarrow F_t = \frac{W_1 g L_1 + W_2 g L_3}{L_2 \sin(\theta)}$$

$$+9.8(0.1136)\left(\frac{0.575}{2}\right)$$

$$\rightarrow F_t = \frac{(0.1498 \cdot 9.8)(0.324) + (0.1495 \cdot 9.8)(0.475)}{(0.425)(\sin(61^\circ))}$$

$$\rightarrow \boxed{F_t = 4.01\,N}$$

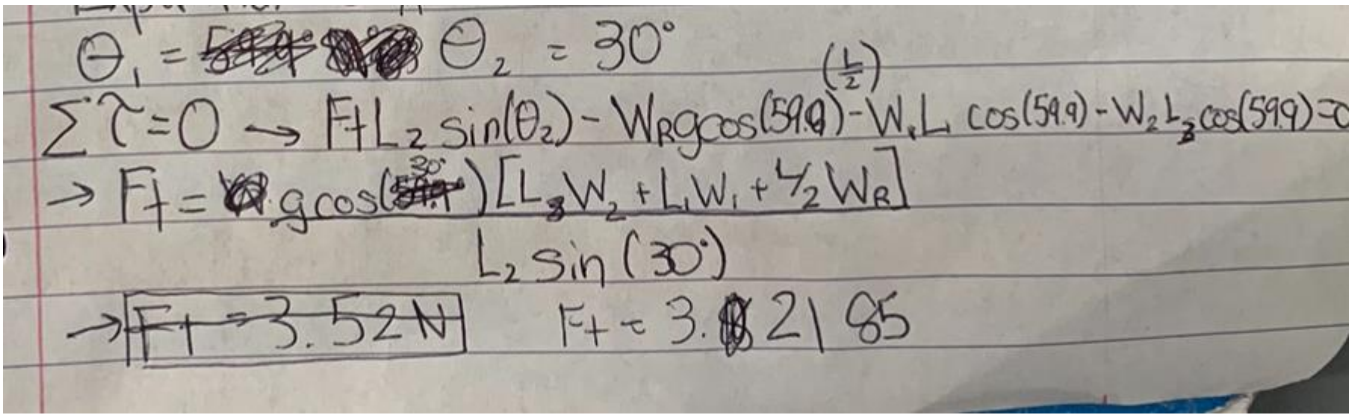
Theoretical Ft = 4.01N



Actual Ft = 3.8876N

Error Percentage: 3.05%

Experiment Two



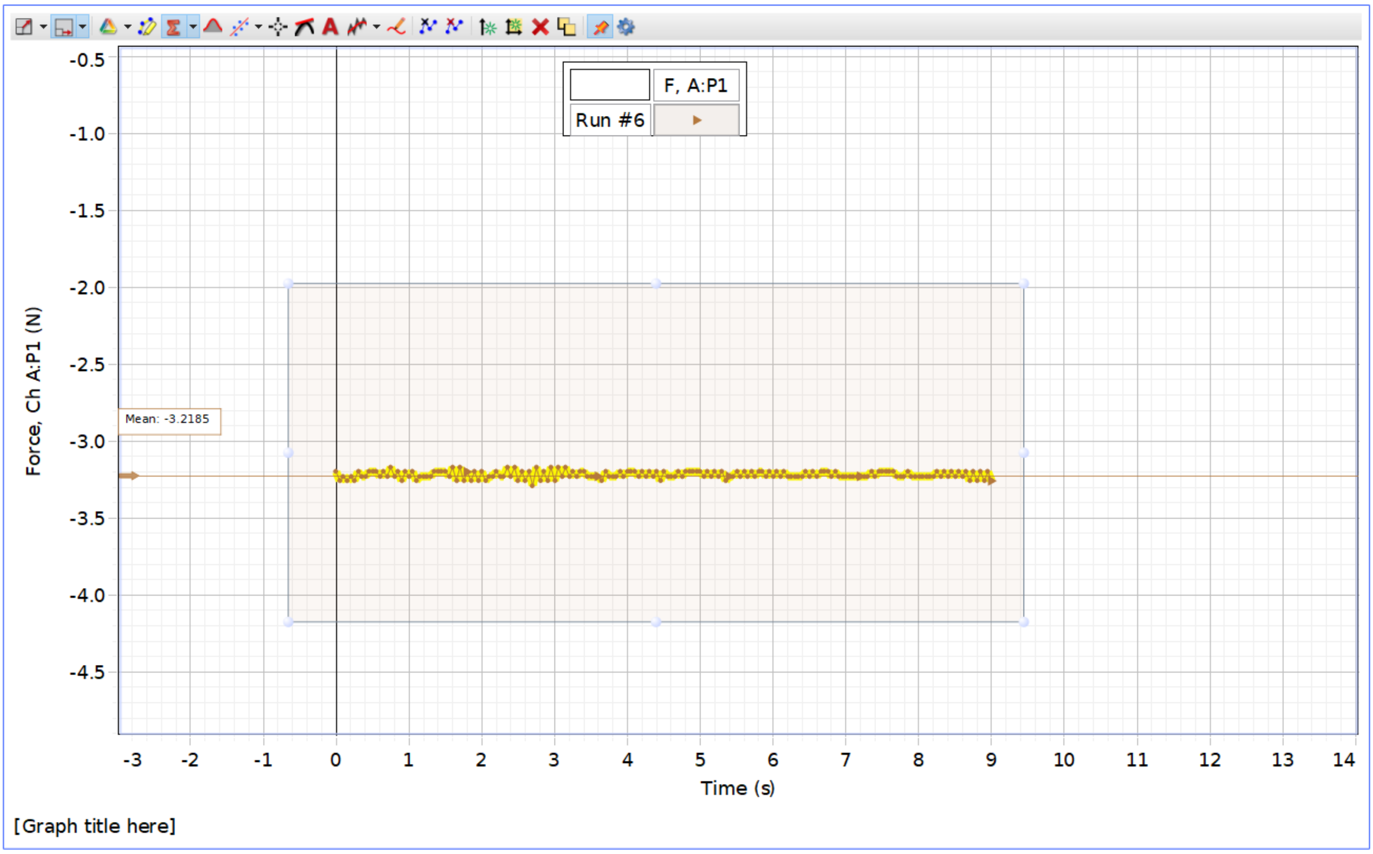
$\Theta_1 = \quad \Theta_2 = 30^\circ$

$\sum \tau = 0 \rightarrow F_t L_2 \sin(\Theta_2) - W_R g \cos(59.9)\left(\frac{L}{2}\right) - W_1 L_1 \cos(59.9) - W_2 L_3 \cos(59.9) = 0$

$\rightarrow F_t = \dfrac{g \cos(30^\circ)\left[L_3 W_2 + L_1 W_1 + \frac{1}{2} W_R\right]}{L_2 \sin(30^\circ)}$

$\rightarrow \boxed{\cancel{F_t = 3.52N}} \quad F_t = 3.2185$

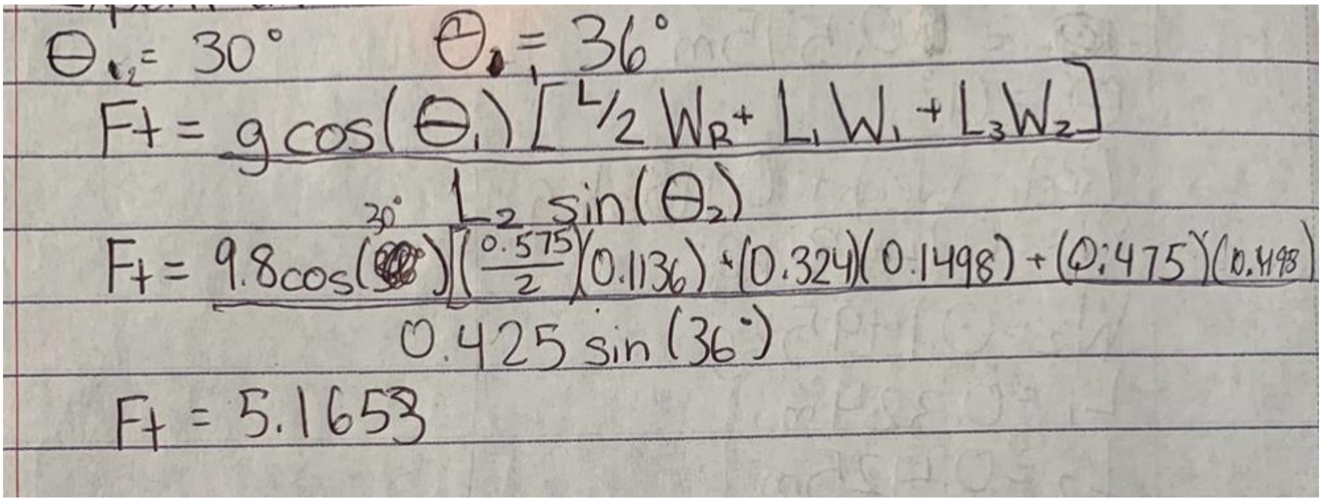
Ft = 3.2185N



Measured Ft = 3.2185N

Error Percentage: 4%

Experiment Three



$\theta_2 = 30°$ $\theta_1 = 36°$

$$F_t = \frac{g\cos(\theta_1)\left[\frac{L}{2}W_R + L_1 W_1 + L_3 W_2\right]}{L_2 \sin(\theta_2)}$$

$$F_t = \frac{9.8\cos(30°)\left[\left(\frac{0.575}{2}\right)(0.1136) + (0.324)(0.1498) + (0.475)(0.1498)\right]}{0.425\sin(36°)}$$

$F_t = 5.1653$

Ft = 5.1653N

Ft = 5.1644N

Error Percentage: 0.3%

4 ANALYSIS and DISCUSSION

There were three separate experiments that helped us calculate the tension force. The objective of the lab was to find the tension in a method that was reliable using the formulas that we provided. There were small errors at most of 4%, which represents a very accurate amount. The third experiment had the best error percentage of 0.3%, which may have been due to the redo that we had to do to get the values closer to one another. The small error values were likely due to the measurements and errors in the significant figures.

While there were no discussion questions, there was one question that was asked in class that needed to be addressed. The question asks that as we move the rod up and down, how would it affect the tension force on the string. The actual movement of the rod would not change the force, but instead change the angle which changes the force. As the rod is moved up, the angle increases (the rod is pointing downwards) and therefore the tension force increases. As it is moved down, the opposite occurs as the angle shrinks (therefore the rod starts pointing up), and less of the force is in the x vector.

5 CONCLUSIONS

To conclude this lab report, we have learned about what static equilibrium is and how it works. This applies our understanding of torque and forces to a specific scenario and using our understanding of trigonometry we solved for the experiments in class. In this experiment, we saw how the tension force had to hold up against three different forces (the two hanging masses and the gravitational pull on the rod itself), as well as how the angle changed the scenario. The experiment did raise some questions for me in how forces in the x vector would have affected it. Would an object spinning on one plane still be considered static equilibrium, or simply having equilibrium in one axis is a question I would like to answer at some point in the future. Another thing was dealing with the angles because of how the equipment worked. I would suggest that we find a new, better method of measuring the angles that is better to understand and use. Overall however, I found this lab very useful.