

Disclaimer: This lab write-up is *not* to be copied, in whole or in part, unless a proper reference is made as to the source. (It is strongly recommended that you use this document *only* to generate ideas, or as a reference to explain complex physics necessary for completion of your work.) Copying of the contents of this web site and turning in the material as “original material” is *plagiarism* and will result in serious consequences as determined by your instructor. These consequences may include a failing grade for the particular lab write-up or a failing grade for the entire semester, at the discretion of your instructor.

Anything included in this report in RED (with the exception of the equations which are in black) was added by me (Bill) and represents the data obtained when the experiment was run. *Use your own data you collected and perform the calculations for your own data!*

Newton's Laws II

Name _____

PES 1150 Report

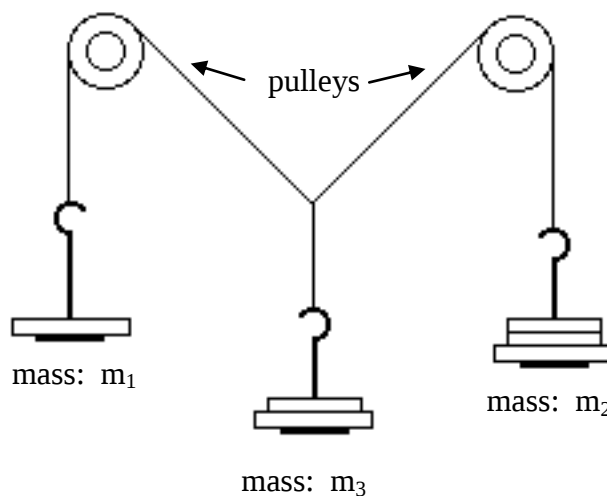
Objective

The purpose of this lab is to examine and analyze static and dynamic systems using Newton's Laws. A static system is one where the total acceleration is zero and there is no motion occurring. A dynamic system is one where the total acceleration is non-zero and the components of the system move. Furthermore, we will determine if Newton's Laws are applicable based upon the measurements recorded and results obtained via the experimental process.

Data and Calculations

Part A Force boards

- The experiment should be set up as follows:



To get the forces F_1 , F_2 , and F_3 attach the mass m_1 , m_2 , and m_3 respectively.

Figure 1: Experimental setup of a static system used to prove the validity of Newton's Laws

- Experimentally it is difficult to measure the angles θ_1 , θ_2 and θ_3 .

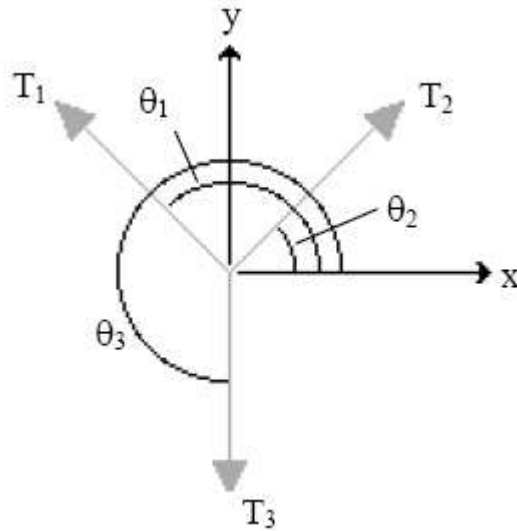


Figure 2: Analytical orientation of angles at the center of the static system in a polar coordinate frame for the experimental setup

- The problem arises when we try to measure these angles relative to the horizontal axis, which only exists on paper. So, we need to find something else. How about measuring the angles made between the strings, ϕ_A , ϕ_B , and ϕ_C .

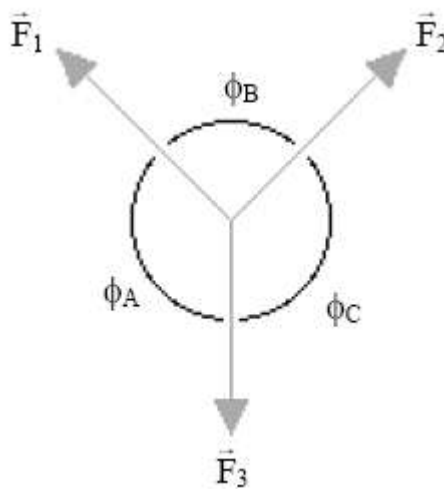


Figure 3: Analytical orientation of angles at the center of the static system in a non-discriminate coordinate frame for ease of measurement

Measured values for three separate trials: **ALL THESE VALUES HAVE A +/- 0.5**

<u>Trial Number</u>	m_1	m_2	m_3	ϕ_A	ϕ_B	ϕ_C
<u>1</u>	<u>0.0883 kg</u>	<u>0.0884 kg</u>	<u>0.1227 kg</u>	<u>133°</u>	<u>92°</u>	<u>135°</u>
<u>2</u>	<u>0.1235 kg</u>	<u>0.0884 kg</u>	<u>0.1596 kg</u>	<u>146°</u>	<u>84°</u>	<u>130°</u>
<u>3</u>	<u>0.1227 kg</u>	<u>0.1235 kg</u>	<u>0.0884 kg</u>	<u>110°</u>	<u>137°</u>	<u>113°</u>

Calculated values for the three different force board configurations:

<u>Trial Number</u>	F_1	F_2	F_3	θ_1	θ_2	θ_3
<u>1</u>	<u>0.8662 N</u>	<u>0.8672 N</u>	<u>1.2037 N</u>	<u>137°</u>	<u>45°</u>	<u>270°</u>
<u>2</u>	<u>1.2115 N</u>	<u>0.8672 N</u>	<u>1.5657 N</u>	<u>124°</u>	<u>40°</u>	<u>270°</u>
<u>3</u>	<u>1.2037 N</u>	<u>1.2115 N</u>	<u>0.8672 N</u>	<u>160°</u>	<u>23°</u>	<u>270°</u>

Show one example of each of the pervious calculations

- We used the following method to calculate the Forces acting at the masses:

$$F_1 = m_1 g = (0.0883 \text{ kg}) \left(9.81 \frac{\text{m}}{\text{s}^2} \right)$$

$$F_1 = 0.8662 \text{ N}$$

- We used the following method to calculate the Theta 3:

$$\theta_3 = 270^\circ$$

(No calculation necessary.)

- We used the following method to calculate the Theta 2:

$$\theta_2 = \phi_C - 90^\circ$$

$$\theta_2 = 135^\circ - 90^\circ = 45^\circ$$

- We used the following method to calculate the Theta 1:

$$\theta_1 = \phi_B + \theta_2 = \phi_B + \phi_C - 90^\circ$$

$$\theta_1 = (92^\circ + 135^\circ) - 90^\circ = 137^\circ$$

- We would now like to test Newton's law. You have direct measurements and an equation that relates them.

For the horizontal case:

$$F_1 \cos \theta_1 = -F_2 \cos \theta_2$$

For the vertical case:

$$F_3 = F_1 \sin \theta_1 + F_2 \sin \theta_2$$

- Fill in both halves of these equations with the measurements you have taken. How does Newton's law hold up? If both sides are equal then Newton's law is valid.

Trial 1:

For the horizontal case:

$$\begin{aligned} F_1 \cos \theta_1 &= -F_2 \cos \theta_2 \\ (0.8662 \text{ N}) \cos(137^\circ) &= -(0.8672 \text{ N}) \cos(45^\circ) \\ \underline{\underline{-0.6335 \text{ N} \cong -0.6132 \text{ N}}} \end{aligned}$$

With consideration of reasonable error introduced by human measurements, angle and mass rounding, the fact that the strings are not massless, and the fact that the pulleys are not frictionless – these values are almost identical. So, Newton's Law for Forces in the x-direction appears to hold true for trial 1.

For the vertical case:

$$\begin{aligned} F_3 &= F_1 \sin \theta_1 + F_2 \sin \theta_2 \\ (1.2037 \text{ N}) &= (0.8662 \text{ N}) \sin(137^\circ) + (0.8672 \text{ N}) \sin(45^\circ) \\ \underline{\underline{1.2037 \text{ N} \cong 1.20395 \text{ N}}} \end{aligned}$$

Again, with consideration of reasonable error introduced by human measurements, angle and mass rounding, the fact that the strings are not massless, and the fact that the pulleys are not frictionless – these values are almost identical. So, Newton's Law for Forces in the y-direction appears to hold true for trial 1.

- Record all of your results and your work. Also, list any sources of error that may have contaminated these results.

Sources of error could have been from the mass values or angle values. Human error accounts for both of these things. It might have been from the mass of the weights not being properly recorded or the balance was not giving proper readings. It also could have been from not reading the protractor right.

- Repeat part A two more times using different masses

Trial 2:

<Same as above>

Trial 3:

<Same as above>

Part B Atwood Machine

- Record the value of the masses:

$$m_1 = 0.1491 \text{ kg}$$

$$m_2 = 0.1697 \text{ kg}$$

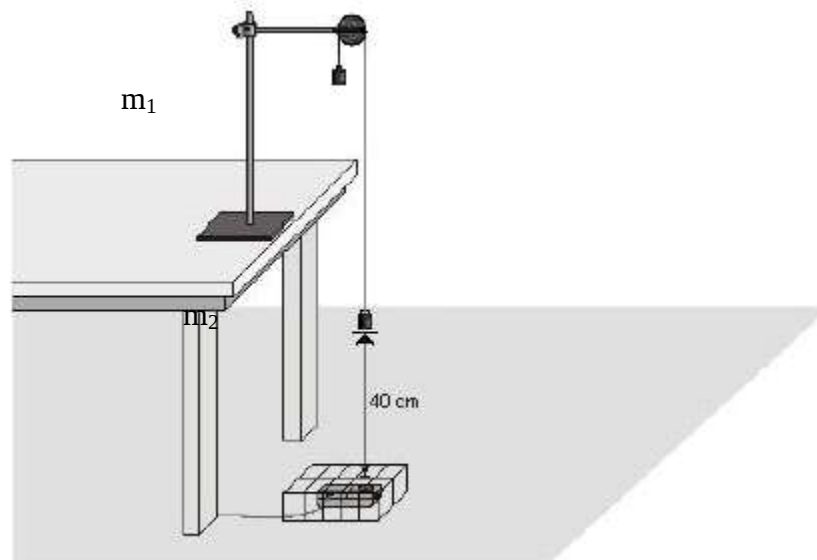


Figure 4: Experimental set-up of the Atwood Machine

- The graph of the position vs. time should be quadratic, Right?! Remember the kinematic equations, $x = \frac{1}{2} a t^2 + v_o t + x_o$. This is a quadratic equation.

- Insert a copy of just one of the graphs you made.

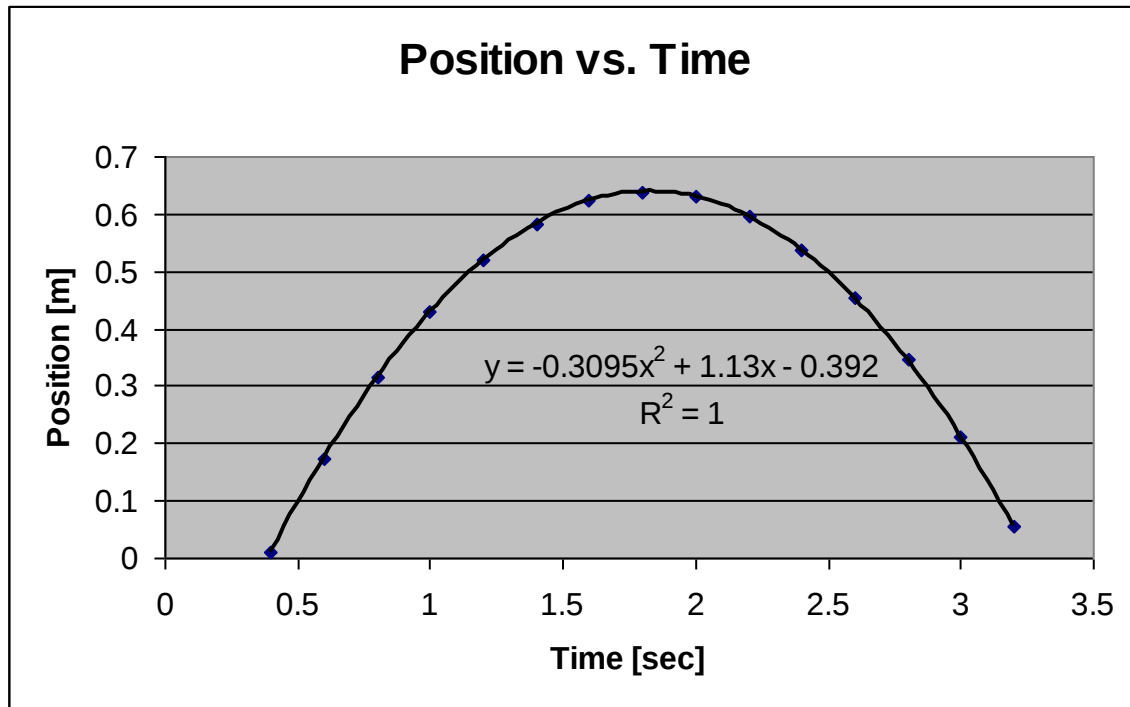


Figure 5: Graph of Experimental Data Collected of Position versus Time

- Fit the position vs. time graph to a quadratic equation using the modeling software within the Logger Pro program from this find experimental value for acceleration.

The best fit line for the data we collected was given as:

$$y = \left(-0.3095 \frac{m}{s^2} \right) t^2 + \left(1.13 \frac{m}{s} \right) t + (-0.392 m)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the “quadratic nature” of the data is extremely good.

If we compare the equation for kinematic 2D motion for the y-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$y = \frac{1}{2} a_y t^2 + v_{o,y} t + y_o$$

$$y = \left(-0.3095 \frac{m}{s^2} \right) t^2 + \left(1.13 \frac{m}{s} \right) t + (-0.392 m)$$

Thus:

a_y [m/s ²]	$v_{o,y}$ [m/s]	y_o [m]
-0.619	1.13	-0.392

Hence the “measured acceleration” is:

$$\underline{a_y = -0.619 \frac{m}{s^2}}$$

- Calculate the theoretical value of **a** using the masses involved.

$$a_y = \frac{(m_2 - m_1)}{(m_1 + m_2)} g$$
$$\underline{a_y = \frac{((149.1 \text{ g}) - (169.7 \text{ g}))}{((169.7 \text{ g}) + (149.1 \text{ g}))} \left(9.81 \frac{m}{s^2}\right)}$$

Hence the “expected acceleration” is:

$$\underline{a_y = -0.6338958 \frac{m}{s^2}}$$

- Are these two values in agreement? List all possible sources of error.

To compare the measured value with the expected value, we must do a percent difference.

$$\underline{a_{y,MEASURED} = -0.619 \frac{m}{s^2}} \quad \underline{a_{y,EXPECTED} = -0.6338958 \frac{m}{s^2}}$$

Using the percent difference, we can compare the “measured” acceleration with the “expected” acceleration.

$$\% \text{ difference} = \frac{|a_{Expected}| - |a_{Measured}|}{|a_{Expected}|} \times 100\% = \frac{\left(-0.6338958 \frac{m}{s^2}\right) - \left(-0.619 \frac{m}{s^2}\right)}{\left(-0.6338958 \frac{m}{s^2}\right)} \times 100\%$$

$$\underline{\underline{\% \text{ difference} = 2.3499\%}}$$

By examining our result of the percent difference calculation, we can see that we are not far off from the expected value of the acceleration. The value is just slightly lower (by exactly 2.3%)

than the expected value. Again, with consideration of reasonable error introduced by human measurements, mass rounding, the fact that the strings are not massless, and the fact that the pulley is not frictionless – this percent difference is well within reasonable limitations.

Conclusion

- This closing paragraph is where it is appropriate to conclude and express your opinions about the results of the experiment and all its parts. Only the final result(s) needs to be restated.

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Actual vs Assumed acceleration due to gravity (Altitude, Earth's Oblateness, see prelabs 2 and 3 for examples) [9.76 m/s^2 vs. 9.81 m/s^2]
- Technique
- Measurement
- Friction
- Drag and air resistance
- Snagging and catching
- Calibration
- Sensor limitation parameters
- Computer processor speed and reading registration
- Torque
- Sensor Alignment
- Other ...

A few of the potential errors listed above may be applicable to YOUR experiment