**Experiment**

**3**

The Atwood Machine

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# Introduction

To understand motion, one must introduce the concept of force. A detailed quantitative understanding also requires Newton's 2nd law and an organized analysis generally involving a "free-body diagram". In this second laboratory exercise, you will apply such an approach to an Atwood Machine in the form of a Smart Pulley. This interesting and useful instrument interfaces with a computer to provide automatic measurement and data collection as well as data analysis.

# Objectives

Experimental:

To verify Newton's 2nd law.

Learning:

1) To become more familiar with Newton's 2nd law and free-body analysis.

2) To learn how to use the Smart Pulley.

3) To understand the Atwood Machine.

**NOTE: You will need to upload the Capstone file of your collected data into Canvas to get credit for the lab report (no emailed files accepted). The data in the Capstone file must match the data in your report. You will need to include one sample graph for each part of the lab.**

# Theory

Newton's 2nd law states that the net force (vector sum of all forces acting on a particular object) is equal to the mass of the object times the resulting acceleration. In the case of two masses suspended from an Atwood Machine, the application of this statement can lead to and expression relating the acceleration to measurable and known quantities. By calculating the acceleration from this expression and comparing it to the experimentally measured acceleration (using kinematic expressions), Newton's important law can be verified. In the space below, show a detailed free-body analysis of this motion and derive the following expression for the magnitude of the acceleration (4 points).

**a = [(m1-m2) / (m1+m2)]g** , where m1 ≥ m2

Free Body Diagram –

Atwood Machine

Jonathon Delemos

** Apparatus**

M2G

M1

M2

M1G

M2G

M1G

(m2 – m1) g = F\_net

1. PASCO Interface 850.
2. Smart Pulley.
3. Ring stands, table clamps and right-angle utility clamps.
4. 1.5 m of string and two mass hangers.
5. A set of numbered masses
6. PASCO Capstone.

# Procedure

1. Locate the Atwood Machine file on the desktop and open it.
2. Using the top-loading electronic balance, measure and record the total mass of **M1** and **M2**.
3. Put **M1** on one side of the pulley and **M2** on other side connected with a string.
4. Move a numbered 2-, 5-, 10-, 20- grams mass (as assigned by the instructor) from **M2** to **M1**. Record the mass of M1 and M2 in the table below.
5. Raise **M1**up, dampen any movement, click **RECORD,** release, and monitor the velocity, and then click **STOP.** You should see a linear graph with a positive slope.
6. Perform a linear curve fit to the velocity vs. time graph. The slope of the fitted data yields the acceleration of the cart. Record this value in Table I along with the uncertainty.

***Caution:*** *To report the measured acceleration in a manner that is consistent with its uncertainty, you might need to modify the display of the fitting parameter for each run. To change the display of the fitting parameters, follow the instruction below:*

* *Click the curve fit display box, right click within this box, and select “Curve Fitting Properties.”*
* *Choose “Numerical Format.”*
* *Click the upside-down triangle next to “Coefficients” and select “Fixed Decimal” from the drop-down menu next to “Number Style.”*
* *Choose a number greater than 4 from the drop-down menu “Number of Decimal Places” and click the upside-down triangle next to “Coefficients.”*
* *Click the upside-down triangle next to “Coefficient Uncertainties” and select “Fixed Decimal” from the drop-down menu next to “Number Style.”*
* *Choose a number greater than 4 in the drop-down menu “Number of Decimal Places” and click the upside-down triangle next to “Coefficient Uncertainties.”*
* *Click “OK” located at the bottom right of the “Properties” window.*

1. Repeat steps 4-6 until all numbered masses have been moved from **M2** to **M1**. Keep the numbered masses in order when you move it.

# Data

# MTotal = \_\_\_310.36 grams\_\_\_\_\_

## Table: Acceleration

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Trial | M1(kg) | M2(kg) | Δm (kg) | Fnet  (N) | ameas±a  (m/s2) | atheory  (m/s2) | % err | MTotal (kg)  Fnet/ameas | % diff |
| 1 | 0.16001 | 0.15036 | 0.00965 | 0.09457 | 0.2840 -.0008 | 0.30470 | 6.79382 | 0.33299 | -7.04 |
| 2 | 0.16503 | 0.14533 | 0.01970 | 0.19306 | 0.596+.006 | 0.62205 | 4.04336 | 0.3234 | -4.13 |
| 3 | 0.16998 | 0.14039 | 0.02959 | 0.28998 | 0.89+.007 | 0.93431 | 4.74260 | 0.3258 | -4.86 |
| 4 | 0.17510 | 0.13527 | 0.03983 | 0.39033 | 1.193+.005 | 1.25764 | 5.13985 | 0.3272 | -5.28 |
| 5 | 0.18010 | 0.13028 | 0.04982 | 0.48824 | 1.486+.003 | 1.57303 | 5.53243 | 0.3286 | -5.70 |
| 6 | 0.18510 | 0.12528 | 0.05982 | 0.58624 | 1.82+.009 | 1.88877 | 3.64092 | 0.3221 | -3.71 |
| 7 | 0.19029 | 0.12007 | 0.07022 | 0.68816 | 2.129+.006 | 2.21728 | 3.98159 | 0.3232 | -4.06 |
| 8 | 0.19532 | 0.11502 | 0.08030 | 0.78694 | 2.434+.006 | 2.53574 | 4.01205 | 0.3233 | -4.09 |
| 9 | 0.20022 | 0.11004 | 0.09018 | 0.88376 | 3.053+.006 | 2.84846 | 7.19818 | 0.2894 | 6.98 |
| 10 | 0.20531 | 0.10505 | 0.10026 | 0.98255 | 3.184+.007 | 3.16583 | 0.57779 | 0.3086 | 0.58 |

**Use g=9.8006m/s2 (5 significant figures)**

Work Shown Analysis Part One

Acceleration Theoretical:

Mass Total:

Percent Difference:

# Analysis

1. Complete the Data Table, calculating the percent error between ameas and atheory, and percent difference between Measured MTOTAL and the column MTOT.
2. Graph Fnet vs. ameas and perform a curve fit to your data (You should only keep one significant figure for the uncertainty of the slope.). On your graph, include error bars for the acceleration. To create a graph with error bars in SciDavis,

* right click on the y-column (generally column 2) and select “Add Column,” after entering your data into SciDavis
* right click on the new column and select “Set Column As” and select “X Error”
* enter the measured uncertainties you obtained from the measurements into this column.
* highlight the last two columns, click “Plot” in the menu bar and select “Scatter”

Paste your graph below along with a percent difference with **MTOTAL** found above the Table.

**Graph MTOTAL=\_\_\_\_.310kg\_\_\_\_\_\_\_**

**δMTOTAL =\_\_\_\_\_.00003\_\_\_\_\_\_**(uncertainty from graph)

**%diff=\_\_\_\_\_\_.11\_\_\_\_(**between graph value and Measured **MTOTAL**)

Work Shown

Diagram

Description automatically generated

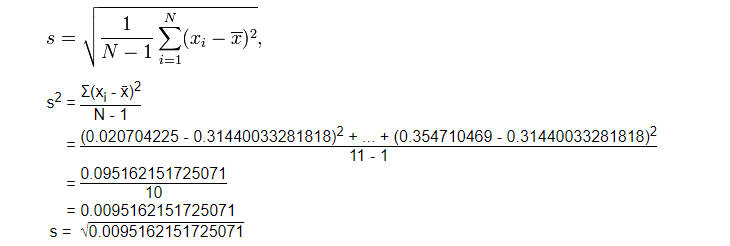
Chart, line chart

Description automatically generated

.

1. Calculate the average of, **MTOTAL**, its standard deviation from the mean σx, and δx ( ), the uncertainty from the data in the Table.



**** s =  0.012

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |

1. Compare the values of ameas and atheory. Does the percent error between the two values decrease as m increases? Explain.

The values for drop as the difference in mass is increased. Listed below are the values we calculated for percent error between the two values, -7.035938041

-4.126793295

-4.861017897

-5.278646354

-5.696262528

-3.714875068

-4.062466797

-4.087740456

6.980296566

0.576122658

It is quite clear to see that these values are decreasing as the difference in mass is increased. This is because there is less tension between the system and the acceleration is more easily measured as

1. Use the equation **MTOTAL=FNET/aMEAS** to derive the theoretical expression for the uncertainty in the total mass of the system, **δMTOTAL**, in terms of the measured quantities **M1**, **M2** and **aMEAS** along with estimated uncertainties **δM1**, **δM2** and **δ**aMEAS. Then derive the expression for theoretical relative uncertainty **δMTOTAL/MTOTAL**.

1. Choose the worst value of **δaMEAS/aMEAS** from your data table and calculate numerical values for the theoretical uncertainty and relative uncertainty, **δMTOTAL** and **δMTOT/MTOT**x100%, respectively (assume **δ**g=0.0001m/s2 and show your work).

=.003kg

# Conclusion

Your conclusion must include a description of the experiment and its purpose, a discussion and statement of results, a discussion of random errors and systematic errors. In addition, discuss

* whether or not the results agree with existing theory or a stated hypothesis (don’t forget to include any evidence in your discussion).
* the meaning of the y-intercept in the graph in the “Analysis” section
* the dominant source of error
* any systematic trends in the percent error and percent difference values in the table.
* the agreement of lack of agreement between the values of **MTOTAL** and **δMTOTAL** obtained from the graph and in Step 3.
* the agreement or lack of agreement between the theoretical uncertainty **δMTOTAL** and the value obtained in Step 3.

The conclusion must be in paragraph form; otherwise, ten percent of the total points will be deducted.

Conclusion:

The purpose of this lab was to improve our scientific method by following instructions and gathering instrumental data. The instructions were clear; we were to measure the acceleration of a two-weight pulley that was unevenly distributed with weight on each side. Due to the uneven distribution of weight, one of the weights would accelerate toward the floor and the other would rise while the string would facilitate the rise and fall of the system.

This is evident through this equation:

Which is derived from:

My other groupmates and I (Evan Esponisa and Diana Ravlo) were able to calculate for the net force of the system after finding the acceleration and mass with which the system was operating. Using newtons second law we found the net force acting on the system. Plotting this against acceleration we confirmed the system was operating with a mass that was very close to the measured value we knew it to be operating in.

Using the derived equation for we discovered the measured acceleration to be very close to the theoretical acceleration. Our lab group found the acceleration to differ by less than 10% of the expected acceleration throughout our time spent calculating and gathering data. The dominant source of error within our experimental group was weight of the string and oscillation of the string as it crashed toward the ground. This experiment is assuming the string is massless.

Notable systematic trends in our data are interpreted as a decrease in percent difference and percent error as the weights become more unevenly distributed. This is likely due to the reduction in the equilibrium. As one side of the pulley systems gathers more weight, it will be easier to measure the acceleration of that object. The object will get closer to a larger value of m\* g which is easier to quantify.

The agreement between the graphing of our mass system and the measured values of the mass was apparent within our uncertainty calculations. We were very confident in our gathering and assessment of the data.

Random errors did persist throughout the experiment. The device used to measure the acceleration would stop gathering data momentarily, forcing our group to reconnect the cables and restart an attempt to gather data. The string was not massless and therefore would interfere with our data.

As a group we were successful in our attempt to derive the formula for acceleration and use a curve fit graph of force versus acceleration. In this lab, we confirmed newtons second law and the existence of mass within our system.