Atwood Machine

Lab Report

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Course: PHYS 141

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**Abstract**

The purpose of the lab was to identify the relationship between mass and acceleration. We used an Atwood machine, performing 50 trials, changing the total mass and differences of two masses to attempt to determine if there was any correlation between acceleration and mass. In short, we have identified that to obtain a faster acceleration, the total mass is going to be fairly small or the difference between two masses is going to be very large. From there we determined that acceleration was directly proportional to the difference of two masses, and indirectly proportional to the sum of two masses.

**Introduction**

The goal for this lab is to determine the relationship between acceleration of an Atwood machine and the difference of two masses and the total mass. Our purpose is to understand how mass affects acceleration, and how can we change acceleration accordingly by changing the mass of two hangers. We also want to understand the concept of an Atwood machine and how its function helps us to identify and determine acceleration as a result of the forces of gravity, mass, and tension acting on the hangers.

**Procedure**

The lab is split into two parts, each part measuring and changing a different variable. Hence, the procedure will be split into Part I and Part II.

The general set up will be kept the same throughout the experiment, two hanger masses connected by a piece of string, hung over a pulley system that has a Smart Gate over it to record the revelations per minute which will then give us the acceleration of the masses. To record the data, set up the hangers so that Hanger 1 is on the left and Hanger 2 is on the right. Hanger 2 will always be the heavier mass and will be dropping down, giving us acceleration in the positive y direction when looking at the raw graph and data. When dropping the masses, hold them at equilibrium so that they are as level as you can get. When ready to record the data, start the record button on the software provided and release both masses at the same time. Once Hanger 2 has dropped and touched the ground, stop the recording. Collect the data in table format, and export to Excel. Once the trials have been completed, find the average acceleration for each trial, then take total average for a set. For example, if Hanger 1 had a mass of 25 grams and Hanger 2 had a mass of 45 grams, five trials of this mass would count as a set. Each trial has its own average acceleration, and the total average acceleration would take the five average accelerations from the five trials, and average those out to find the total average. This process is the same regardless of which part of the lab is being performed since our main goal is to determine the relationship between the acceleration of an Atwood machine and the sum of its masses and the difference between its two masses. Note that the values of the masses used include the weight of the hangers which are respectively each 5 grams.

Part I: Keeping the difference between the two masses the same while changing the total mass.

For Part I, determine a difference that will be kept constant throughout Part I. For example, we opted for a difference of 20 grams, keeping that the same whilst changing the weight of both hangers. If Hanger 1 had a mass of 20 grams, Hanger 2 had a mass of 40 grams. Determine five sets of masses, each set perform five trials for a total of 25 trials.

Part II: Keeping the total mass constant while changing the two masses.

In Part II, identify a total mass that will be kept constant for the entirety of Part II. We opted for a total mass of 100 grams. Similar to Part I, determine five different sets of trials and masses, with each set being performed five times, for a total of 25 trials for Part II.

**Theory**

We are given two equations to begin with, acceleration is proportional to the sum of the two masses raised to a power (1), and acceleration is proportional to the difference between the two masses raised to a power (2).

Equation (3) will help us simplify the final equation when we combine (1) and (2).

Equation (4) and (5) are equations (1) and (2) with the p and q values being substituted with actual numbers. These numbers are taken from the graphs of the total average acceleration vs the total mass or difference in two masses. For the total mass graph, we linearized the data by plotting 1/Total Mass, hence getting the power of -1. Difference in two masses was already linearized so that had a power of 1.

Plugging in (4) and (5) and setting them equal to each other, we get equation (6). And to simplify further, we substitute in (3).

…. (6)

Free Body diagram:

Diagram

Description automatically generated

**Sample Calculations and Results**

Using the equations and the data collected, we are able to obtain linearized graphs that, through Excel, we can obtain a formula for and find the constant value. For the Total mass graph, the constant we found was 0.0909, while the Difference graph had a constant of 181.22. Then to find C (Constant) we took our Total mass and Difference and divided them by the Total mass or Difference.

For the Difference constant:

For the Total Mass constant:

The constant values that we have calculated should theoretically be close to the value of gravity: 9.8 m/s. However, there are several factors that have contributed to our values not being close to the value of gravity, those which will be discussed in the next section.

**Discussion and Conclusion**

As stated in the previous section, there was a slight error with the calculation for the proportionality constant. This can be attributed to the errors in data collection. For one, one of our hangers was not exactly the same weight as the other hanger. It was missing a small piece of the hanger that may have thrown it off by a gram or two. Nothing too significant that would have severely affected our data; however, the difference was noticeable when there were no masses on the hangers. Another potential factor was how we released the hangers. In our initial test, before we began recording data, we tried a few methods of releasing the hangers. The first method we tried was using a book to hold both hangers, then when the time came to start recording data, move the book away and let the hangers drop/rise. This method was flawed as, if the hanger and mass was heavy enough, it would not slide off the book and would stay there till we either pushed it off or simply dropped the book down. This affected our data as when moving the book, because the hanger was moving as well, it was affecting the pulley system and data was being recorded, data that was useless. The other method that we tried and eventually stuck with for the lab, was to use our hands to hold the hangers, try to get them as level as possible at an equilibrium, and then when the time was right, to let go and let it do its thing. This method may have some errors as we can only use our eyes to determine if the hangers were level and at equilibrium. It was difficult to accurately ensure that there was no initial acceleration as one hanger may have started higher than the other, throwing off the final acceleration as well. One more factor that may have affected the data overall was the length of the string provided. Due to the length of the string, the heavier hanger was hitting the ground a little before the lighter hanger reaches the end of the pulley system. This may have thrown off our data as when it hit the ground, based on visual observations, it caused the lighter hanger to jerk up, hitting the pulley and causing the Smart Gate to record that data. To combat this, we did try to use the visual graph and choose the best data possible within a reasonable range that made sense. Data that was either inconsistent or produced an anomaly was discarded or the trial was done again.

From the data we had collected, the larger the difference between the two masses, the greater the value of acceleration. We see this when the difference, keeping the total mass the same, is rather large (70 grams) the average acceleration is about 6.49 m/s^2. Contrasting, when the difference is minimal (10 grams) the average acceleration is 0.88 m/s^2. When changing the total mass, a larger total mass (110 grams) had a slower average acceleration (1.65 m/s^2) compared to a smaller total mass (40 grams) which has a faster average acceleration (4.56 m/s^2).

**Graphs, Tables, and Other Data**

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| --- | --- | --- | --- | --- | --- |
| **Difference of Two Masses** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Hanger 1 (g) | 35 | 45 | 25 | 10 | 15 |
| Hanger 2 (g) | 55 | 65 | 45 | 30 | 35 |
| Total Hanger Mass (g) | 90 | 110 | 70 | 40 | 50 |
| Run 1 Average Acceleration | 2.083333333 | 1.643888889 | 2.597368421 | 5.021111111 | 3.506842105 |
| Run 2 Average Acceleration | 2.058333333 | 1.639411765 | 2.618333333 | 4.307777778 | 3.954736842 |
| Run 3 Average Acceleration | 1.933684211 | 1.706666667 | 2.406315789 | 4.400526316 | 3.537368421 |
| Run 4 Average Acceleration | 2.041764706 | 1.625555556 | 2.631666667 | 4.551666667 | 3.547368421 |
| Run 5 Average Acceleration | 2.033333333 | 1.633888889 | 2.717894737 | 4.503888889 | 3.408421053 |
| Standard Deviation | 0.057169556 | 0.032471515 | 0.114670185 | 0.276063438 | 0.210655026 |
| Total Average Acceleration | 2.030089783 | 1.649882353 | 2.594315789 | 4.556994152 | 3.590947368 |
| Average Standard Deviation | 0.138205944 |  |  |  |  |
| Total Standard Deviation | 1.18688763 |  |  |  |  |

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| --- | --- |
| **Mass total (g)** | **Total Average Acceleration (m/s^2) (Exponential Graph)** |
| 90 | 2.030089783 |
| 110 | 1.649882353 |
| 70 | 2.594315789 |
| 40 | 4.556994152 |
| 50 | 3.590947368 |

|  |  |
| --- | --- |
| **Mass total (g)** | **Total Average Acceleration (m/s^2) (Linear Graph)** |
| 0.011111111 | 2.030089783 |
| 0.009090909 | 1.649882353 |
| 0.014285714 | 2.594315789 |
| 0.025 | 4.556994152 |
| 0.02 | 3.590947368 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Total of Two Masses** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Hanger 1 (g) | 15 | 10 | 25 | 35 | 45 |
| Hanger 2 (g) | 85 | 90 | 75 | 65 | 55 |
| Total Hanger Mass (g) | 100 | 100 | 100 | 100 | 100 |
| Run 1 Average Acceleration | 6.283157895 | 7 | 4.867647059 | 2.827647059 | 0.903333333 |
| Run 2 Average Acceleration | 6.428421053 | 7.133157895 | 4.434210526 | 2.728888889 | 0.907222222 |
| Run 3 Average Acceleration | 6.778421053 | 7.253888889 | 4.757058824 | 2.877647059 | 0.851578947 |
| Run 4 Average Acceleration | 6.697777778 | 7.378888889 | 6.060555556 | 2.858823529 | 0.868823529 |
| Run 5 Average Acceleration | 6.243684211 | 7.188421053 | 4.441578947 | 2.918823529 | 0.847222222 |
| Standard Deviation | 0.241628159 | 0.140615188 | 0.669838104 | 0.071510592 | 0.028272451 |
| Total Average Acceleration | 6.486292398 | 7.190871345 | 4.912210182 | 2.842366013 | 0.875636051 |
| Average Standard Deviation | 0.230372899 |  |  |  |  |
| Total Standard Deviation | 2.609233939 |  |  |  |  |

|  |  |
| --- | --- |
| **Mass Difference (g)** | **Total Average Acceleration (m/s^2)** |
| 70 | 6.486292398 |
| 80 | 7.190871345 |
| 50 | 4.912210182 |
| 30 | 2.842366013 |
| 10 | 0.875636051 |