**Acceleration Due to Gravity**

**Lab Report**

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**Course: PHYS 141**

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**Abstract**

Using the data obtained from the position vs. time squared graph, we were able to determine acceleration and thus calculate gravity. For an elevated ramp at an angle of 4.87 degrees, one test produced an acceleration of 0.236 m/s^2 and a gravity of 5.56 m/s^2.

**Introduction**

The goal for this lab was to determine and carry out a procedure to develop an understanding of objects falling due to gravity and calculating the acceleration due to gravity. We determine the acceleration by recording the position of the cart over time and finding the slope of a position vs. time squared graph. The lab is split into three trials, with each trial having a different level of elevation for the ramp. Running five tests per trial gives a total of fifteen tests done to determine fifteen different values of acceleration and resulting in fifteen different values of gravity. From the data collected it is then possible to determine potential errors in the data and analyze possible methods of reducing the errors found.

**Procedure**

For the experiment the main goal was to measure the acceleration due to gravity as well as analyze the percentage of error. To obtain reasonable data that would give precise and consistent results, we performed five tests for one trial of a specific angle, with a total of three trials for three different angles. This resulted in a total of fifteen tests, each one giving us a different value for the acceleration and therefore, since gravity was dependent on acceleration, a different value for gravity for each trial. Understandably, for the five tests for one trial, the value for both acceleration and gravity should theoretically not deviate too much as we kept the angle of the ramp consistent throughout the trial and attempted to keep the initial velocity of the cart the same, not changing whether we gave it a push down the ramp or just letting it free fall.

The setup for the experiment is pretty straightforward, the cart will go down the ramp which is raised by a block of wood to achieve an angle that will be measured before any tests are run. For the first series of trials, we set the ramp on the block of wood flat on the ground, using the length of the base as the height of the block to set the ramp on, giving it an incline and an angle that would result in the middle angle in between the second and third trial, which both gave the biggest and smallest angles respectively. For the second series of trials, we kept the block in the same place, however we added on top of the block a level, and then set the ramp on top of the stacked level and block; this gave us the biggest angle of the three trials. The third and final series of trials, we removed the level and used only the block, using the width of its base as the height, giving us the smallest angle of the three trials.

With the setup of the ramp complete, the next step was dropping the cart from the top of the ramp, the raised and higher point, and letting it free fall till it reached the lowest point, the bottom of the ramp. To record the data, position of the cart over time, we start recording the data at the beginning when the cart is released and at the end when the cart hits the stop at the bottom. The data that is collected is then taken from the table produced and the data used are only the values given from when the cart starts out at the top till when it reaches the bottom. Do not count any values that have the cart bouncing off the stop at the bottom. Those values are irrelevant in this case as that is simply a bounce back and not values that will help with the calculations later on.

Taking the data obtained from the position vs. time graphs and/or tables, export the data into Excel and draw two graphs from the data. The first is the position vs. time graph which should produce a quadratic slope. The second graph is position vs. time squared; squaring the time will produce a line of best fit that is linear. The slope will also give the value of acceleration for each test. This value will later help us calculate the value of gravity.

**Theory**

To obtain the angles of elevation given in the three trials, we used the following formula:

Where *Hh = Height of ramp* at its highest point, *Hl = Height of ramp* at its lowest point, and *Lr = Length of ramp*. Length of ramp is a constant and did not change, therefore *Lr = 100 cm*.

The following two formulas (2) and (3) are the *x* and *y* components of the forces acting on the cart. The *x* component (2) is equal to the acceleration of the cart where g sinθ is acceleration (a). The *y* component (3) is irrelevant in our calculations as we do not need to know the value of the normal force being exerted onto the cart by the ramp. This value does not affect our understanding of acceleration due to gravity. Instead, if we were to use the *y* component, it would be to calculate the mass and the normal force being exerted by and onto the cart. The *y* component was included as an additional factor should the need to find the normal force arise.

Equation (4) gives us the formula for the line of the position vs. time squared graph where ½ *a* = slope. From the above equations, it is known that the acceleration of the cart is *g sinθ,* as depicted by Equation (5). Plugging (5) into Newton’s Second Law of *F=ma*, and substituting *a*, Equation (6) is produced.

To solve for the slope, we recall that the slope of the position vs. time squared graph is Equation (7). Then, substituting *a* again, we get the second half of Equation (7).

To solve for *g*, Equation (8) is produced by rearranging Equation (7).

**Sample Calculations and Results**

For Equation (1), an example of an angle found when doing the first set of trials is as follows:

With Hh = 18 cm and Hl = 9.5 cm.

An example of Equation (8) can be seen below using *a = 0.236* and *θ =4.87 degrees*:

**Discussion and Conclusions**

From the data recorded, two graphs are produced, a position vs. time graph (quadratic) and a position vs. time squared graph (linear). The reason why the linear graph is chosen to find the value of the acceleration is because acceleration is constant throughout on the linear graph. The slope of the line does not change at all, making the value easy to define and use in calculations later on. In order to obtain the time squared, it was as simple as taking the time recorded in the position vs. time graph and squaring it. Then taking that data and plotting it against the positions from the original graph gave the linear graph of position vs. time squared. The slope of the linear graph was generally consistent throughout when a line of best fit was run through the plots. There was some deviation, and this could be caused by gentle pushes when letting go of the cart leading to an initial acceleration and thus throwing off the data collected. There were some more deviations towards the end when the cart reached the bottom of the ramp. It is unknown why this was the case, although it was consistent throughout the data collected. To improve the accuracy of the measurements and data recorded, it is plausible to perform several tests, as done so, taking the average of the slopes, and calculating the average *g* value. This may help to reduce the percentage of error and provide more precise and consistent results should time allow for more than five tests per trial. Another method for reducing errors would be to keep the method of releasing the cart the same throughout the whole experiment. For this particular experiment, hands were the method and that proved somewhat inaccurate as reflected by the data, at the start there was initial acceleration instead of zero acceleration to show that the cart had started from rest and dropped down solely due to gravity, instead the data reflected the cart being given a slight gentle push which caused it to move down initially before accelerating due to gravity. A clamp would be a viable method of releasing the car, when the time is right it would be released, and the cart would drop down unaffected by the hands and rather by gravity which is the intention.

There were some discrepancies with the data as shown by Table 3. Under the Gravity column, three values stand out when compared with the other values for their respective angles. It is uncertain what caused this large deviation, however, based on the potential errors discussed above, it may be attributed to the method of releasing the cart. These errors are also reflected in Graph 3 where the respective Gravity values are shown as well as the error bars. The data is fairly consistent, with the deviations of each angle being kept under 2. Angle 1.72 degrees had the biggest standard deviation of 1.916, whilst Angle 4.87 had the smallest standard deviation of 0.986. This data is reflected in Table 3 alongside the standard deviation for all fifteen tests, the average value of *g*, and the percentage error of the data collected.

**Graphs and Tables**

A set of graphs and the respective data from one of the fifteen trials have been included as a sample of the data collected.

Figure :Graph 1 plots data from Table 1 for Angle 4.87 degrees. This falls under Trial 1. Graph is quadratic.

|  |  |
| --- | --- |
| **Time (s)** | **Position (m)** |
| 0.55 | 0.0013 |
| 0.6 | 0.0046 |
| 0.65 | 0.0098 |
| 0.7 | 0.0169 |
| 0.75 | 0.0256 |
| 0.8 | 0.0363 |
| 0.85 | 0.0485 |
| 0.9 | 0.0626 |
| 0.95 | 0.0786 |
| 1 | 0.0964 |
| 1.05 | 0.1163 |
| 1.1 | 0.1379 |
| 1.15 | 0.161 |
| 1.2 | 0.1861 |
| 1.25 | 0.2132 |
| 1.3 | 0.242 |
| 1.35 | 0.2725 |
| 1.4 | 0.305 |
| 1.45 | 0.3393 |
| 1.5 | 0.3752 |
| 1.55 | 0.413 |
| 1.6 | 0.4527 |
| 1.65 | 0.494 |
| 1.7 | 0.5374 |
| 1.75 | 0.5822 |
| 1.8 | 0.6291 |
| 1.85 | 0.6776 |
| 1.9 | 0.7281 |
| 1.95 | 0.78 |
| 2 | 0.834 |
| 2.05 | 0.8896 |
| 2.1 | 0.9469 |
| 2.15 | 0.9977 |

Figure : Table 1 data collected for Graph 1, position vs. time graph.

Figure : Graph 2 plots data from Table 2. Is a linear graph.

|  |  |
| --- | --- |
| **Time Squared (s)** | **Position (m)** |
| 0.3025 | 0.0013 |
| 0.36 | 0.0046 |
| 0.4225 | 0.0098 |
| 0.49 | 0.0169 |
| 0.5625 | 0.0256 |
| 0.64 | 0.0363 |
| 0.7225 | 0.0485 |
| 0.81 | 0.0626 |
| 0.9025 | 0.0786 |
| 1 | 0.0964 |
| 1.1025 | 0.1163 |
| 1.21 | 0.1379 |
| 1.3225 | 0.161 |
| 1.44 | 0.1861 |
| 1.5625 | 0.2132 |
| 1.69 | 0.242 |
| 1.8225 | 0.2725 |
| 1.96 | 0.305 |
| 2.1025 | 0.3393 |
| 2.25 | 0.3752 |
| 2.4025 | 0.413 |
| 2.56 | 0.4527 |
| 2.7225 | 0.494 |
| 2.89 | 0.5374 |
| 3.0625 | 0.5822 |
| 3.24 | 0.6291 |
| 3.4225 | 0.6776 |
| 3.61 | 0.7281 |
| 3.8025 | 0.78 |
| 4 | 0.834 |
| 4.2025 | 0.8896 |
| 4.41 | 0.9469 |
| 4.6225 | 0.9977 |

Figure : Table 2 takes the time from Table 1 and squares it to give Graph 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Angle (Degrees)** | **Slope (m/s^2)** | **Gravity (m/s^2)** | **For Each Trial** | **Calculated Values** |
| 4.87 | 0.236 | 5.56 | Standard deviation of 5 test per angle | 0.985535387 |
| 4.87 | 0.244 | 5.75 |  |  |
| 4.87 | 0.255 | 6.01 |  |  |
| 4.87 | 0.328 | 7.73 |  |  |
| 4.87 | 0.311 | 7.33 |  |  |
| 7.18 | 0.485 | 7.76 | Standard deviation of 5 test per angle | 1.740870472 |
| 7.18 | 0.599 | 9.59 |  |  |
| 7.18 | 0.462 | 7.39 |  |  |
| 7.18 | 0.713 | 11.41 |  |  |
| 7.18 | 0.47 | 7.52 |  |  |
| 1.72 | 0.138 | 9.19 | Standard deviation of 5 test per angle | 1.916368962 |
| 1.72 | 0.199 | 13.26 |  |  |
| 1.72 | 0.123 | 8.19 |  |  |
| 1.72 | 0.145 | 9.66 |  |  |
| 1.72 | 0.148 | 9.86 |  |  |
|  |  |  |  |  |
| Standard deviation | 2.122639193 |  |  |  |
| Average Value of g (m/s^2) | 8.414 |  |  |  |
| % error | 14.23037717 |  |  |  |

Figure :Table 3 is a summary of the data found for all fifteen tests as well as the % error, standard deviation, and average value of g.

Figure :Graph 3 plots the values of g calculated as well as their error bars.