DEPARTMENT OF BIOLOGICAL, CHEMICAL, AND PHYSICAL SCIENCE

ILLINOIS INSTITUTE OF TECHNOLOGY

PHYSICS 123

Newton’s Second Law

**Lab 3**

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Lab Section: 03

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**Statement of Objective**

The object of this lab was to devise an experiment that would show that the acceleration of an object is directly proportional to the force applied on the object, as per Newton’s second law. Then, an explanation must be derived from the results to state that it is impossible to prove that acceleration is inversely proportional to mass simply by using an inclined plane.

**Theory**

Galileo Galilei devised an experiment to measure the velocities and accelerations of different falling objects by using an inclined plane. The setup of this experiment is similar to his original experiment, and allows the use of Newton’s second law to determine the force being applied on the object.

*Equation 1:*

Where a is the acceleration, F is the net force, and m is the mass of the object.

Since the Force is a vector quantity, it is possible to split it into vertical and horizontal components. Therefore, the acceleration in the horizontal and vertical directions can be calculated as follows:

*Equation 2:*

*Equation 3:*

It is also possible to calculate the acceleration simply by knowing the final velocity, the initial velocity, and the distance that the object has travelled.

*Equation 4:*

**Equipment List**

* Air track
* Glider
* Photogate Sensor
* Wooden Blocks
* Rulers
* Weights
* Data Studio Software

**Procedure**

An air track was set up on a flat surface and connected to an air supply. Afterwards, the track was raised on one side by a measured height using wooden blocks. A photogate sensor was placed on the track, and the distance from the start to the glider was measured on the air track. Next, a glider was massed and placed on the track. Using Data Studio, a timer was set up that would measure the velocity at a certain spot of the track. The distance to that spot was recorded and used in the calculation of the acceleration and force. The experiment was conducted several times using different heights for the track and masses for the glider.

**Data**

Trial 1

*figure 1: trial setup*

|  |  |  |
| --- | --- | --- |
| **Height (m)** | **Mass (kg)** | **v (**m/s**)** |
| 0.24 | 0.21 | 0.38 |
| 0.24 | 0.25 | 0.38 |
| 0.24 | 0.37 | 0.37 |

*table 1: height of ramp, mass of glider, recorded velocity at x = .72 m*

Trial 2

*figure 2: trial setup*

|  |  |  |
| --- | --- | --- |
| **Height (m)** | **Mass (kg)** | **v (**m/s**)** |
| 0.50 | 0.21 | 0.54 |
| 0.50 | 0.25 | 0.54 |
| 0.50 | 0.37 | 0.54 |

*table 2: height of ramp, mass of glider, recorded velocity at x = .72 m*

Trial 3

*figure 3: trial setup*

|  |  |  |
| --- | --- | --- |
| **Height (m)** | **Mass (kg)** | **v (**m/s**)** |
| 0.75 | 0.21 | 0.67 |
| 0.75 | 0.25 | 0.67 |
| 0.75 | 0.37 | 0.67 |

*table 3: height of ramp, mass of glider, recorded velocity at x = .72 m*

**Analysis of Data**

The angle was calculated from the track length and the height of the object. The acceleration of the object was calculated using equation 4, and the net force was calculated using equation 1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Height (m)** | **Angle** | **Mass (kg)** | **v (**m/s**)** | **a ()** | (N) |
| 0.24 | 11.34 | 0.21 | 0.38 | 0.10 | .02 |
| 0.24 | 11.34 | 0.25 | 0.38 | 0.10 | .03 |
| 0.24 | 11.34 | 0.37 | 0.37 | 0.10 | .04 |

*table 4: calculated acceleration and force on the object*

*equations used: 1,4*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Height (m)** | **Angle** | **Mass (kg)** | **v (**m/s**)** | **a ()** | (N) |
| 0.50 | 24.19 | 0.21 | 0.54 | 0.20 | 0.04 |
| 0.50 | 24.19 | 0.25 | 0.54 | 0.20 | 0.05 |
| 0.50 | 24.19 | 0.37 | 0.54 | 0.20 | 0.07 |

*table 5: calculated acceleration and force on the object*

*equations used: 1,4*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Height (m)** | **Angle** | **Mass (kg)** | **v (**m/s**)** | **a ()** | (N) |
| 0.75 | 37.93 | 0.21 | 0.67 | 0.31 | 0.07 |
| 0.75 | 37.93 | 0.25 | 0.67 | 0.31 | 0.08 |
| 0.75 | 37.93 | 0.37 | 0.67 | 0.31 | 0.11 |

*table 6: calculated acceleration and force on the object*

*equations used: 1,4*

The average values for the acceleration and force of the glider going down the track at different angles were calculated.

|  |  |  |
| --- | --- | --- |
| **Av. Mass (kg)** | **Av. a ()** | **Av. (N)** |
| 0.27 | 0.10 | 0.03 |
| 0.27 | 0.20 | 0.05 |
| 0.27 | 0.31 | 0.09 |

*table 7: average values for a = F/m equation*

*equations used: 1,4*



*Graph 1: Force vs. Acceleration*

**Discussion of Results**

Part 1:

From Graph 1, the acceleration increases as more force is applied, therefore the acceleration of an object is proportional to the effective force applied. The linear trendline does not perfectly fit the results due to slight systematic errors, such as the presence of friction due to the instability of the glider, or the accuracy of the measurements. However, the results are still accurate to the trendline, and the acceleration increases linearly as more force is applied.

Part 2:

It is not possible to determine that acceleration is inversely proportional to mass using an inclined plane, because the results indicated that the acceleration remained the same regardless of the change in mass. This can be seen in the equation for Newton’s second law:

*Equation 5:*

The masses in the equation cancel each other out, therefore the equation is not on the mass.

**Conclusions**

The accuracy of the results was somewhat dependent on external factors such as the environment and the accuracy of the measurement methods. However, the measured values were accurate enough to prove that Newton’s second law is right, and that the force is proportional to acceleration for an object. The accuracy of the experiment could have been improved with an increased precision in measurements. It was also proved that it is not possible to calculate the inverse relationship between acceleration and mass due to role of mass in the equation for Newton’s second law. The results also verified this, as the mass did not affect acceleration. The lab was a success, and verified the relationship in Newton’s second law.

**Questions**

Question 1

There is a large difference between the two methods in calculating the acceleration.

Question 2

experiment 1:

If the angle is 90, cos(90) = 0, therefore N = 0. If the angle is 0, cos(0) = 1, therefore N = mg.

Question 3

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**References**

1. Physics 123 lab manual, Experiment 3. http://science.iit.edu/sites/science/files/elements/phy/pdfs/2013\_lab\_123\_3.pdf