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Force Table Project: Cycle 1 South

Physics 201 Lab: Meets on Wednesdays 4:40-6:40

Due: September 21, 2012 @ PSC 704H

**Abstract**

In the lab “Newton’s Second Law” the relationship between the acceleration of objects of different masses was investigated. Two photogates were placed over a track. A Pasco cart on the track had a plastic fence on it and was attached to a string with a paper clip for weights to be attached. The string was suspended over a pulley and mass was added to the cart and the paper clip. Mass from the cart was removed in increments of 10 grams and added it to the paper clip. The amount of time it took for the Pasco cart to travel through the two photogates with the different masses on it and on the paperclip was measured. Experimental acceleration was than calculated for each of these conditions. It was discovered that it took less time for the cart to travel through the photogates as the mass on the paper clip increased and the total mass of the cart decreased. This is due to the fact that the acceleration of the cart increases as the force pulling it (mass on the paper clip) increases and the mass of the cart decreases as shown by Newton’s Second Law, F=ma.

**Introduction**

Sir Isaac Newton found that there are two factors that determine an object’s acceleration. Newton’s Second Law of Motion states that when a net force acts on an object with a mass, m, the resulting acceleration, a, is directly proportional to the net force and has a magnitude that is inversely proportional to the mass. The direction of the acceleration is the same as the direction of the net force. The equation he found that explains this is F=ma, therefore a=F/m.1 In this lab we found the relationship between the acceleration of objects with different masses. Our apparatus used in this lab was a cart with a picket fence attached to a string suspended over a pulley. At the end of the string was a paper clip that we added mass to. The cart was placed on a tract with two photogates 50cm apart. We started the experiment with 40 grams on the cart and 15 on the paper clip. We recorded the time it took for the cart to pass through the two photogates. We took mass off of the cart in increments of 10 grams and added it to the paper clip until there was 0 grams on the cart and 55 grams on the paper clip. At each increment we recorded the times, five trials for each. We used this time to find our experimental acceleration. We found that acceleration increased as the mass on the cart decreased and the force pulling on it increased which directly demonstrates Newton’s Second Law.

**Procedures**

The experiment was begun with making sure that the track was even with a bubble level. We then weighed the cart, recorded its mass, and then added 40 grams of mass to the top. Next we attached a paperclip with 15 grams added to it to the string and hung this string over the pulley on the end of the table. The photogates were placed at 30 cm and 80 cm. We then set the timer to Time and mode to Two Gates and put the fence on the cart. The photogates were then adjusted so that the string did not run through them but only the fence did. The cart catcher was positioned near the second gate so that the cart did not run into the pulley. The cart holder (who lets the cart go) put a finger in front of the cart and held the cart in place so that the red light on the photogate just turns off. We hit the start/stop button and the cart holder removed their finger. The cart catcher stopped the cart before it hit the pulley. Time was then recorded.

This was repeated five times. Then we removed one 10 gram mass from the cart and attached it to the pulley and repeated the procedure five times. This was repeated until there was no mass on the cart and all the weights had been moved to the paper clip. All times were recorded on a table, than average time and average time squared was calculated. Next we calculated the accelerations for each of the times and found the averages of the accelerations. Theoretical accelerations were then calculated. Experimental accelerations vs the hanging mass was then graphed. Theoretical accelerations were also plotted on this same graph. We compared the line of best fit with our system mass. Finally we drew free body diagrams of all forces active in the experiment.



Pasco Cart, Track, and Photogate

**Results**

**Time Between Two Photogates**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Mass on Hangar (g)** | **Trial 1**  **(s)** | **Trial 2**  **(s)** | **Trial 3**  **(s)** | **Trial 4**  **(s)** | **Trial 5**  **(s)** | **Avg of Trials**  **(s)** |
| **15** | 1.62 | 1.68 | 1.63 | 1.62 | 1.60 | 1.63 |
| **25** | 1.24 | 1.24 | 1.23 | 1.20 | 1.25 | 1.51 |
| **35** | 1.07 | 1.06 | 1.07 | 1.06 | 1.05 | 1.06 |
| **45** | 0.92 | 0.91 | 0.91 | 0.92 | 0.92 | 0.92 |
| **55** | 0.84 | 0.85 | 0.85 | 0.85 | 0.83 | 0.84 |

**Supplemental Data**

|  |  |  |
| --- | --- | --- |
| **Mass on Hangar (g)** | **Avg. Time2**  **(s2)** | **Total System Mass (Total Cart Mass + Hanging Mass) in g** |
| **15** | 2.66 | 571 |
| **25** | 1.51 | 571 |
| **35** | 1.12 | 571 |
| **45** | 0.85 | 571 |
| **55** | 0.70 | 571 |

**Acceleration (m/s2)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Weight** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | **Avg acc.** |
| **40 grams** | .283 | .286 | .271 | .286 | .289 | .283 |
| **30 grams** | .857 | .706 | .890 | .842 | .783 | .812 |
| **20 grams** | 1.235 | 1.132 | 1.321 | 1.108 | 1.352 | 1.22 |
| **10 grams** | 1.731 | 1.687 | 1.644 | 1.731 | 1.877 | 1.73 |
| **0 grams** | 2.163 | 2.163 | 2.163 | 2.227 | 2.227 | 2.163 |

**Experimental and Theoretical Acceleration**

|  |  |  |
| --- | --- | --- |
| **Mass on Hangar (g)** | **Experimental Acceleration (m/s2)** | **Theoretical Acceleration (m/s2)** |
| **15** | 0.376 | 0.258 |
| **25** | 0.662 | 0.430 |
| **35** | 0.89 | 0.601 |
| **45** | 1.18 | 0.773 |
| **55** | 1.43 | 0.945 |

**Calculations**

**Experimental Acceleration** was determined using the equation **aExp=2D/ t2**

**D = Distance Between Photogates, 0.50 m**

**t = average time in seconds**

Example for 15g of hanging mass: Experimental Acceleration = 2 (0.5) / 1.632

= 1 / 2.66

= 0.376 m/s2

**Theoretical Acceleration** was determined by dividing the applied force (hanging mass on multiplied by gravity) by the total system mass (total mass on the cart + the hanging mass).

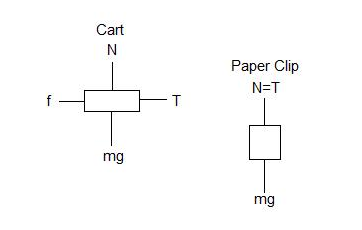
Example for 15 g of hanging mass:

Theoretical Acceleration = (15 g x 9.81 m/s2) / (15+556)

=147.15 / 571

= 0.258 m/s2

**Free Body Diagram**

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According to our theoretical calculations, as the weight on the pulley (i.e. the force) increased, the acceleration increased, as exemplified by the equation F=ma1. The time it took lessened as the weight increased, showing a positive correlation with our theoretical calculations. Our experimental accelerations echoed this trend. However, our experimental results were much larger than our theoretical calculations, possibly exemplifying an error. Our graph shows these trends.

**Questions**

* Our predictions of Newton’s second law of motion do not agree with our results. Our theoretical accelerations were much smaller than our experimental yields. Our cart did not start at rest, which made its initial velocity greater than 0 which in turn influenced our results in this way.
* The slope of our theoretical data was 565, which was very close to our system mass of 559.3 g. So the theoretical accelerations for our system were correct since these two values were so similar.
* This was a frictionless system.

**Conclusion**

Our data was off as explained above. Our values for average experimental acceleration were off by an entire decimal point when compared to the theoretical value. A reason for this was explained in the questions section above.

In everyday life, we can view this phenomenon when pulling a child in a wagon and when dogs pull a sleigh. The harder one pulls on the handle of the wagon (i.e. the more force one pulls it with), the faster the wagon will accelerate. Similarly, the more dogs pulling the sleigh, the faster it will move. The dog example is very similar to our experiment because the dogs will be pulling the sleigh on ice, a relatively frictionless surface.

**References**

1.      Cutnell, John and Kenneth Johnson. Physics. Ed. Stuart Johnson. John Wiley & Sons, Inc., 2007. 90.