

Testing Newton's second law with cart and mass

Sharone Krasnopolsky*, Timur Neyir, and Brady Gorelczenko

Science & Engineering Magnet Program, *Manalapan High School*, Englishtown, NJ 07726 USA

(Dated: December 6, 2024)

Newton's second law states that force equals mass times acceleration ($F = ma$). In our experiment, we used varying masses attached to a cart and pulley system in order to examine the relationship between mass, acceleration, and force. We found that the relationship between force and acceleration is proportional, supporting Newton's second law.

I. INTRODUCTION

Newton's second law of motion states that acceleration of an object is directly proportional to the net force acting on that object and is inversely proportional to its mass [1]:

$$F = ma, \quad (1)$$

where F is the net force, m is the mass, and a is the acceleration. In this experiment, we investigate the relationship between force, mass, and acceleration by analyzing the motion of a cart while it is being pulled over a pulley by a hanging mass. By varying the mass of the hanging mass, we examine how the change in force impacts the cart's acceleration. We hypothesize that if the mass of the hanging weight is increased, then the acceleration of the cart will increase proportionally, in accordance with Newton's second law of motion, which states that acceleration is directly proportional to the net force applied and inversely proportional to the mass of the object.

II. METHODS AND MATERIALS

The experiment used a 0.500 kg PASCO collision cart and a 1.2 m long PASCO aluminum dynamics track as shown in Fig. 1. We used a 0.200 kg weight, a 0.500 kg weight, a 1.000 kg weight, a 1.200 kg weight, and a 1.500 kg weight as our hanging weights. In addition, we also used a PASCO "super pulley with mounting rod" (Fig. 2) as a pulley and a string to connect the weight to the cart. Our procedure started with setting up the track with the cart on top and the pulley hanging off the side as shown in Fig. 1 and Fig. 2.

We attached the 0.200 kg weight to the cart and pulled the cart back 0.45 m from the pulley. The cart was then released and was allowed to freely accelerate until it reached the end of the track. In total, we took three trials for each of the five weights (0.200 kg, 0.500 kg, 1.000 kg, 1.200 kg and 1.500 kg) for a total of 15 trials. During the trials, we measured the amount of time it took for the cart to travel 0.45 m and recorded the data. Using the data, we calculated the tension force exerted on the cart

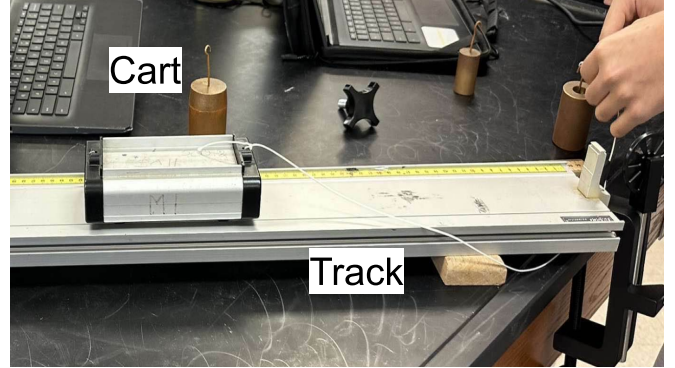


FIG. 1. Track used in experiment

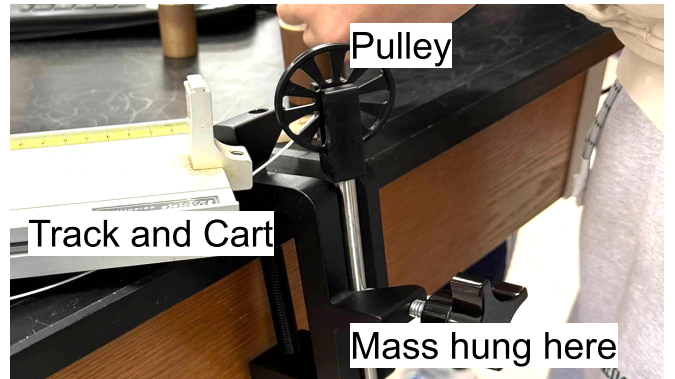


FIG. 2. Pulley where string is pulled, on the left is the cart, on the right, masses are hung

using the formula $F = ma$. To calculate the acceleration, we used the equation $a = 2d/t^2$ to find the acceleration.

III. RESULTS

By taking the average times for each mass, we perform the equation $d = \frac{1}{2}at^2$, which can be rearranged into, $a = 2d/t^2$ to calculate the acceleration of the cart, as shown in Table I.

The results in Table I are plotted in Fig. 4, which shows the mass of the weight and time it took for the cart to reach the end of the track. The resulting accelerations

* Contact author: 426skrasnopolsky@frhsd.com

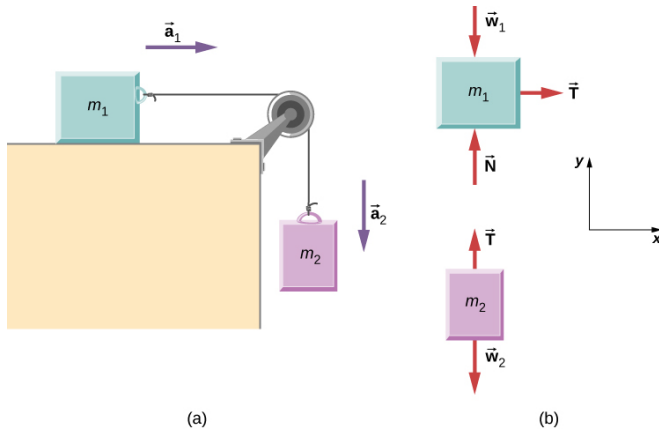


FIG. 3. Free-Body Diagram of the system in motion utilizing an ideal pulley, from <https://pressbooks.online.ucf.edu/phy2048tjb/chapter/6-1-solving-problems-with-newtons-laws/>

TABLE I. Time t for each mass, and measured acceleration a . All values listed as mean $\pm$ one standard deviation for $n = 3$ replicates for each value of m_2 .

m_2 (kg)	t (s)	a (m s^{-2})
0.200	0.56 ± 0.02	2.84 ± 0.15
0.500	0.46 ± 0.02	4.27 ± 0.37
1.000	0.36 ± 0.01	6.82 ± 0.21
1.200	0.31 ± 0.01	9.17 ± 0.33
1.500	0.30 ± 0.01	10.0 ± 0.7

are plotted in Fig. 5. The blue lines show the predictions for the free body diagram given in Fig. 4, $a = \frac{m_2}{m_1 + m_2}g$.

IV. DISCUSSION

In this experiment, we investigated Newton's second law, $F = ma$, by examining how varying weights influenced the acceleration of a cart. Our data demonstrates a strong proportional relationship between force and acceleration, with calculated values aligning closely with theoretical predictions as seen in Figs. 4 and 5.

The slight discrepancies between theoretical and experimental force values can be attributed to friction on the track, which likely reduced the net force acting on the cart. Additionally, timing inaccuracies over short distances may have introduced minor errors in measuring the acceleration. Pulley inefficiencies, such as resistance or string tension losses, could also have contributed to the observed deviations. These could be especially pronounced at the highest levels of m_2 , where forces are high and times are short.

These findings validate Newton's second law while highlighting areas for improvement in the experimental

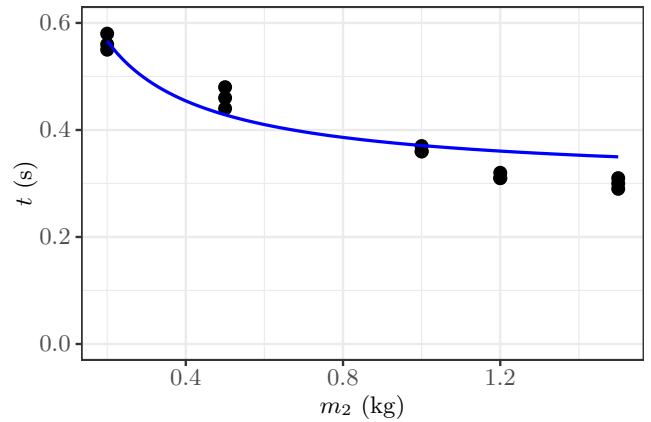


FIG. 4. Graph that shows the mass of the weight (x) and time it took for the cart to reach the end of the track (y)

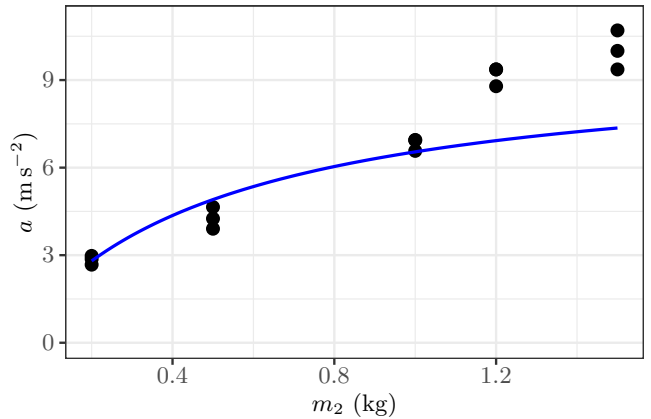


FIG. 5. Graph that shows the mass of the weight (x) and acceleration (y)

setup. Implementing a frictionless track, using a more precise timing mechanism, and optimizing the pulley system could help achieve results that more closely match theoretical values.

V. ACKNOWLEDGEMENTS

We thank several anonymous reviewers for their helpful comments on our manuscript.

SK set up the track, measured the time it took for the cart to travel 0.45 m, and wrote the abstract, introduction, methods and materials, and acknowledgements. TN also helped set up the track, recorded the results, did all calculations, and wrote results and discussions. BG helped prepare experiment materials and helped with pre-trial measurements.

-
- [1] P. A. Tipler and G. Mosca, *Physics for Scientists and Engineers*, 5th ed. (W H Freeman and Company, New York, 2004) .