PCS 211 Lab 3 : Newton's 2nd Law

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1 Introduction

We shall in the due process of the laboratory experiment, aim to demonstrate the validity of Newton's second law, which asserts that an object's acceleration is directly proportional to the net force exerted on it.

We aim to validate Newton's 2nd law from this experiment by investigating the effects of the system's mass on the acceleration of the system and the effects of the applied force on the acceleration of a system. This was accomplished by analyzing the acceleration of a glider/cart drawn by a string in a pulley system attached to a hanger to where mass can be added.

2 Theory

Before beginning this investigation we must know the methods and the theory behind the investigation and the due course of action.

2.1 Newton's 2nd Law

Newton's 2nd Law of Motion states that When a body is acted upon by a force, the time rate of change of its momentum equals the force. Mathematically,

$$F = \frac{\Delta(mv)}{\Delta t} = m\frac{\Delta v}{\Delta t} = ma$$

2.2 Mass

The mass has an inverse relationship with the acceleration of the cart, which is proportional to the force exerted on the cart. Newton's second law also requires the entire mass of the system to be accounted into for the law to hold true. The mass is the sum of all masses. Mathematically,

$$M = m_1 + m_2$$

Where, m_1 is the mass of the hanger and m_2 is the mass of the glider.

2.3 Tension & Forces

If we assume F_x is the horizontal force and F_y is the vertical force. The total force of our system is equal to the sum of the horizontal force acting on the cart and the net vertical force acting on the hanging mass. Tension (T) is the sole horizontal force acting on the rope. According to Newton's second law, the tension is equal to the glider's mass multiplied by its acceleration, mathematically expressed as:

$$F_x = T = m_2 a$$

The normal force, F_n, which is the same as the tension, is subtracted from the gravitational force, Fg (Tension is opposite in direction), which is calculated as hanging mass multiplied by the gravitational force (T). Mathematically,

$$F_y = F_g - F_n = m_1 g - T = m_1 a$$

2.4 Acceleration

With algebraic manipulation of Newton's law we have,

$$a = \frac{F}{m}$$

Therfore we have,

$$a = \frac{m_1 g}{m_1 + m2}$$

3 Materials Required

- Air-cushioned track and Glider
- Hanger
- 7 Weights (Increments of 50g) & String
- Pulley and Clamps
- Vernier Lab Pro

- Vernier Photogates
- Meter Scale
- Notebook

4 Procedure

4.1 Experiment 1

1. Connect the motion detector software to the computer's hardware, ensure all electronics are switched on and in good working order
2. Utilizing the lab jack and the protractor, angle the track at 15 degrees
3. Adjust the motion detector and cart, so they will not be closer than 15cm from each other
4. Using the Scale, measure the mass of all weights in experiment
5. Ensure you have all necessary materials
6. Measure and record the plate length on top of the glider
7. Using the logger pro software, download and open the file from D2L. Replace the default object length with the recorded measured value of plate
8. Set the two photogate timers to be 0.6 meters from each other
9. Attach the mass to the cart with a string attached to the pulley
10. Attach weights to the glider/cart and the hanger. The starting weight should be 30 grams
11. Set the glider to a starting position
12. Release the cart and press play on the logger pro screen simultaneously Record and store all the data shown on logger pro
13. Repeat steps 8-10 twice for a total of three times
14. Slowly decrease the masses on the cart to add it to the hanger. Repeat till there is no mass on the cart

5 Experimental Data

All the collected laboratory data can be found in the files attached consequently with this laboratory report.

6 Analysis

In order to calculate the experimental acceleration, we need to use the equations of motion. Namely,

$$a = \frac{v_f^2 - v_i^2}{2d}$$

Where v_f is the final velocity, v_i is the initial velocity and d is the distance between the two photogates.

6.1 Sample Calculation

$$a = \frac{v_f^2 - v_i^2}{2d} = 0.394m/s$$

7 Conclusion

1) After completing the lab, answer again the question posed in the pre- lab: If the glider/cart and the hanger had equal masses, will the magnitude of the acceleration of the glider/cart be g, less than g, or bigger than g ? Explain why in words. If, after doing the lab, your answer changed, explain what you had wrong when you first made your prediction.

If the cart and the hanger had equal masses, the acceleration would have been 4.9 m/s^2.

$$a_c = \frac{m_h g}{m_h + m_c}$$

$$a_c = \frac{mg}{2m} = \frac{g}{2} \approx 4.9m/s^2$$

2) In the special case where m_h is much larger than m_g, what do you expect the acceleration of the system to be? Does your formula agree with this special case ?

When m_h is much larger than m_g, the acceleration is significantly less because acceleration is inversely proportional to the mass.

3) In the special case where m_h is much smaller than m_g, what do you expect the acceleration of the system to be ? Does your formula agree with this special case ?

When m_h is much smaller than m_g, the acceleration is significantly higher because acceleration is inversely proportional to the mass.

4) Throughout this lab, we neglected friction. If friction were present (it always is, to some degree), how would your results be affected ? Would the slope of your measured line be larger or smaller than the predicted slope ?

According to Newton's second law, an object's acceleration is inversely correlated with its net external force. Friction always acts in the direction opposing motion. As a result, the measured line's slope should be lower than the expected slope.

5) Conceptually, what differences would you expect to see between the two apparatus (Air Track Glider vs. Rail Cart) ? Comment on the need for different weights between the two systems. While in the lab: discuss your results with the group sitting across from you, are there any noticeable differences ? Try to provide some explanation for these differences.

Conceptually, the differences between the two apparatuses are compensating for the differences in weights because the cart is expected to be far heavier than the air glider.

Bibliography

[1] Serway, R. A., Jewett, J. W. (2018). Physics for Scientists and Engineers. Cengage Learning.