Force and Motion

Examining Newton's Second Law

Abstract

In this lab we will experimentally demonstrate Newton's second law, F = ma. Newton's second law relates the acceleration on an object to the net force applied to the object and the objects mass.

Background

Newton's second law states that a net force applied to an object will accelerate the object in the same direction as the applied net force when the net force is multiplied by the inverse of the objects mass. Utilizing Newton's first two laws we know that an object will not accelerate unless acted on by some external net.

Materials

Air Track
Air Cart
Computer with logger pro software
Vernier LabPro Capture Device
Photogate Pulley

Procedures

Before beginning the experiments level the air track. Weigh the cart and convert to kilograms.

For both experiments listed below develop an equation to calculate acceleration using a free body diagram of the *system* (the cart and hanging mass). Perform the experiments below and compare the measured acceleration to your calculated acceleration. The measured acceleration can be found both by reading from the graphs directly or analyzing the slope of the velocity vs time graph (which as you already know is acceleration).

- Turn on the vacuum and attach it to the air track
- Level the air track
- Open Logger Pro
- Open a new experiment (File → New)
- Plug the Vernier Lab Pro to the computer with the provided usb cable
- Plug the Vernier Lab Pro to AC power using the supplied power cable
- Now attach the photogate to the Vernier Lab Pro using one of the digital inputs
- Add the sensor for data capture (Experiment → Set Up Sensors → Lab Pro 1)
- Move the photogate to the corresponding digital input.
- Right-click on the photogate and choose **Distance and Length** using the pull down options choose 10 spoke in groove, if your pulley has 10 spokes. If your pulley has three circles, choose 3 spokes inside groove.
- Next setup the data capture (Experiment → Data Collection) change ***Length*** to a value more than 30secs and the ***sample frequency*** to 100 samples/sec.

- Now you are ready to begin taking data by simply pressing the capture button. Remember to start data capture before letting the cart go.

Case 1 (Varying the Force – Constant Mass) :

For this experiment begin by hanging a mass of 5 (g) over the pulley while placing 20 (g) on the air cart. Measure the acceleration by plotting the velocity as a function time and then finding the slope of the line. Remember to begin collecting data before releasing the cart. Record the mass on the cart and the acceleration. Then, remove 5 kg from the cart and add it to the hanging mass (now the cart has 15 g and the hanging mass has 10g). Remove another 5 kg from the cart and add it to the hanging mass. Continue until all the mass has been removed from the cart and added to the hanging mass. Plot the calculated force with the corresponding acceleration using the graphing function of LoggerPro (yes, open a new graph and plot). Analyze the slope of the line – what is it and what does it represent?

Case 2 (Vary the Mass – Constant Force) :

For case 2 the hanging mass needs to remain constant, so choose a total hanging mass greater or equal to 20 (g) and less then or equal to 25 (g). Start with the cart and no extra weight on the cart and measure and record the acceleration, force, and the mass of the system. Next add one set of weights and repeat the experiment. Lastly place both of the weight sets on the cart and again measure and record the acceleration, force, and mass of the system. When all three runs are complete plot the acceleration vs the ***inverse of the mass***. Analyze the slope of the line – what is it and what does it represent?

Calculate the percent errors* between the measured and expected (calculated) values. Did friction play a role in this simulation and can you see its effects? What errors systematic or random could have affected the results? Was Newton right – does F = ma?

* Calculating percent error: $\left(\frac{calculated - measured}{calculated}\right) * 100$