

An Undergraduate Physics Experiment—A Study of Motion

Christopher A. Tucker, Department of Physics, University of Utah, Salt Lake City, Utah 84102

Abstract:

This paper is a discussion of findings of a study of motion in three dimensions. I propose an experiment which tests the tenets of Newton's theory with results specific to my scenario. The goals of this experiment are to further illustrate how these laws are important for undergraduate study.

THEORY:

This experiment is the first, full-fledged experiment where we as students get to design and submit an experimental model and procedure based on principles outlined in first semester undergraduate physics. The experiment is to test Newton's theory of motion complete with derivations and solutions to the equations. Our experimental goal is to determine values of a for each experimental setup.

EXPERIMENTAL METHOD:

This experiment studies the motion of a glider forced to accelerate down a laboratory air track. This track is frictionless so the equations are simplified to a degree. We will cause the glider to accelerate along an upwardly inclined track. At some position approximately halfway along the travel path of the glider, the initial force will be removed and the glider will begin to slow down. The total motion of the glider consists of three stages: (1) a positive forward acceleration produced by a hand push (the force), (2) a deceleration after the force is removed, and (3) after the motion ceases, the glider will change directions and begin accelerating by the force of gravity back down the track.

The experimental apparatus is illustrated by figure 1:

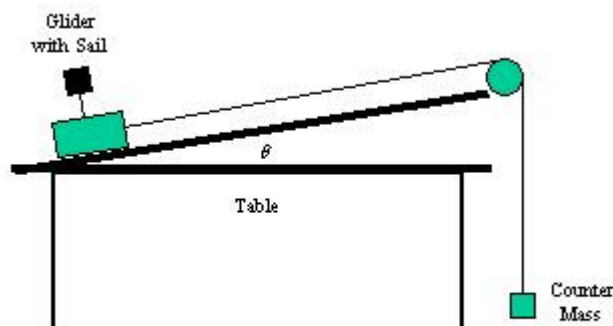


Figure 1: Experimental Apparatus

The total experiment will consist of three scenarios: Finding the forward positive and negative accelerations, and a finding reverse-direction acceleration. Our procedure will begin by determining the equations of motion for the three scenarios. Each of the three acceleration determinations by scenarios are represented as a_1 , a_2 , and a_3 respectively. The equations of motion are:

$$ma_1 = T - mg \sin \theta \quad (1.1)$$

$$ma_1 = m_1g - T \quad (1.2)$$

$$ma_2 = -mg \sin \theta \quad (1.3)$$

$$ma_3 = mg \sin \theta \quad (1.4)$$

Physics has suggested three different stages of motion with a uniform acceleration, our scenarios agree. However, our derived equations are manipulations of the one-dimensional Newtonians which, during data mapping, become critical. With the assumption of uniform acceleration, the following Newtonians are:

$$\begin{aligned} x &= x_0 + v_0t + \frac{1}{2}at^2 \\ v &= v_0 + at \\ v^2 &= v_0^2 + 2a(x - x_0) \end{aligned} \quad (1.5)$$

To further illustrate our point of uniform acceleration, our force diagram for each of the three scenarios is:

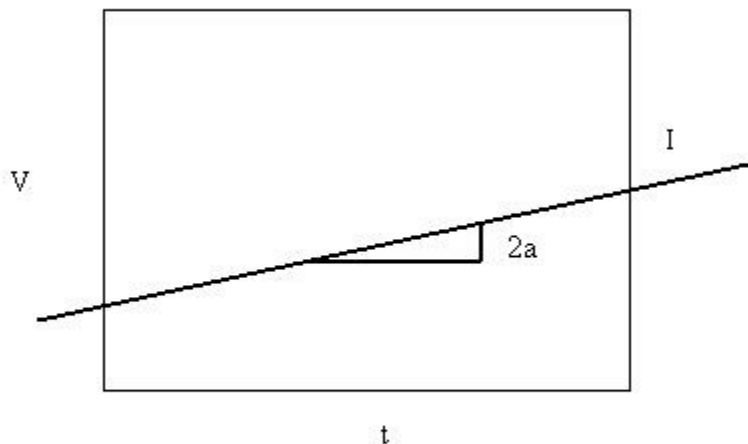


Figure 2: The Force Diagram

Where V is the velocity, t is time, and I is the impulse.

DATA GATHERING:

We will be timing the motion of a glider as it passes through two photo-gates. These photo-gates are a part of a physics laboratory program called *DataStudio*. The number from each experiment will be exported to Microsoft *Excel* where we can generate tables of data. We will then export the data back to *DataStudio* where we can graph the data.

Using this type of apparatus requires careful analysis of how we will obtain our data. *DataStudio* allows us to measure the motion of the glider with a high degree of accuracy, but we need to tell the program how long each of the two photo-gates will be blocked to get an accurate representation of the motion. To achieve this we measure the sail of the glider. We then input that number into the software. The program adjust the final calculation of the glider's velocity and acceleration through each of three scenarios. This achieves determining Δd . This value is necessary to compute the average velocity which is also the instantaneous speed at the mid-point of the time interval. We ignored friction in this experiment. The track is representative of a frictionless surface if the external force (the hand push) is not to great to cause the glider to pitch or yawl. With this condition, friction is small enough that for the purposes of this experiment it can be ignored.

EXPERIMENTAL ERROR:

We performed the experiment as described and generated data which demonstrated uniform acceleration. Each of the three scenarios are represented in the attached figures. We made assumptions about the apparatus accuracies, however, we give our error to be as follows:

X: +/- 0.1cm

V: +/- 0.2m/s

A: +/- 0.2m/s²

Our error equations were:

$$\begin{aligned}
V &= \frac{\Delta d}{\Delta t} \\
\delta v &= \sqrt{\frac{\partial(\Delta d)}{\Delta t} + \frac{\partial(\Delta t)\Delta d}{(\Delta t)^2}} \\
\delta v &= v \left(\frac{\delta d}{d} \right) \\
\delta v &= v \left(\frac{0.0001}{0.0241} \right)
\end{aligned}
\tag{1.6}$$

Our sources of error lie in hand calculation of the glider sail, in measurement of the distance between the two photo-gates, and measurement of the counter mass. Our final acceleration calculations for the graphs give our error to be +/- 0.02m/s².

CONCLUSION:

We began this experiment thinking about the nature of Newton's equations of motion and how valid they are in the classical sense. Far from being any representation of accuracy, it yields a reasonable approximation of the forces in nature. We assumed the purposes of this experiment was to familiarize ourselves not only with Newton's equations, but to have first hand experience at creating and performing a laboratory experiment. It is crucial that undergraduate physics students receive this kind of training whether or not they decide to continue on the noble path. I personally see physics as the only valid line of inquiry for the human race, without it we have not the growing monolith of technology which threatens to bury us every breathing day. A slave to the machine, we purport this series of goals to illustrate the more obvious tenets of classical mechanics. I believe these goals have been accomplished to the fullest degree.