Physics 161

Newton's Laws II

Introduction

In this experiment, you will explore Newton's Second Law using Capstone and the Dynamics Track. You will use hanging weights to accelerate a cart away from a motion sensor and use the data you record to measure the acceleration of gravity and test Newton's Second Law.

Reference

Young and Freedman, University Physics, 12th Edition: Chapter 4, section 4.3-4.4, Chapter 5 sections 5.1-5.3

Theory

Newton's Second Law is written as $\sum \vec{F} = m\vec{a}$. From this equation, we see that the force applied to an object and its mass affect the acceleration of the object. For example, a more massive object will require a greater force in order to achieve the same acceleration as a less massive object.

In this experiment, the force used to accelerate a cart is applied by hanging weights. When the cart is pulled by the hanging weights, the total system, both the cart and the hanging weights system, is accelerated. When we neglect friction, Newton's Second Law can be written as:

$$m_{hanging}\, g = \left(m_{cart} + m_{hanging}\right)a \tag{1}$$

If we define $m_{cart} + m_{hanging} = m_{total}$, this can be rewritten as:

$$m_{hanging}\, g = m_{total}\, a \tag{2}$$

By plotting $m_{total}\, a$ versus $m_{hanging}$, one can find g as the slope of this plot.

Procedure

1. Check that the track is level by making sure that the cart does not roll spontaneously. The experimental set up is shown in Figure 1.

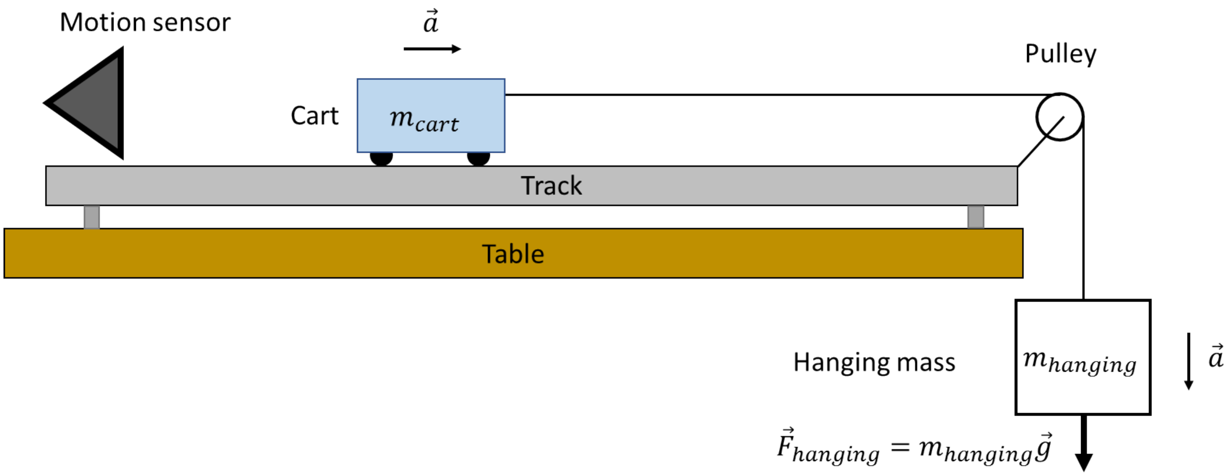

Figure 1: Sketch of the track, table, and cart.

2. To decrease the acceleration of the cart, add 500 g to the cart. Measure the mass of the cart with the force sensor attached and the added weight, convert it to kilograms and record it in Excel in the column m_{cart}. This mass will be constant in the experiment.

3. Connect the motion sensor to the PASCO 850 Universal Interface. In Capstone, under **Hardware Setup,** digitally plug in the **Motion sensor II** from the **Sensors** menu. Change the Motion sensor's trigger rate to 50 Hz. Drag a **Graph** icon into the workspace area and set the y-axis to **velocity.**

4. Place the cart on the track 15 cm away from the motion sensor. Attach a string to the end of the cart and place it over the pulley. The other end of the string should be connected to the hanging mass of 150 g.

5. One student should hold the cart in place while the other student presses ***RECORD*** to collect data in Capstone. You may want to delay releasing the cart for a moment in order to make sure you capture all the data.

6. Be sure to catch the cart before it hits the end of the track, then hit ***Stop*** in Capstone.

7. Highlight the points on your graph that follow a straight line. The slope of the line should be positive because the cart is accelerating away from the motion sensor. Do not include the end points of this line segment in the data, as these values may be affected by forces your hands apply in releasing and stopping the cart.

8. Measure the slope of the velocity versus time plot using the **Linear Fit** tool. Record this value, the acceleration a, in a table in Excel. Your table should have the following information:

Table 1: Acceleration and gravity.

$m_{hanging}\ (kg)$	$m_{cart}\ (kg)$	$m_{total}\ (kg)$	$a\ (m/s^2)$	$F\ (N)$	$g\ (m/s^2)$
0.15					
0.14					
0.13					
0.12					
0.11					
0.10					

where $m_{hanging}$ is the hanging mass, m_{cart} is the mass of the cart with the force sensor plus the added 0.5 kg, the total mass of the system is $m_{total} = m_{cart} + m_{hanging}$, and the force is $F = m_{total}\, a$.

9. Now remove 10 grams of mass from the hanging mass. Perform steps 6 through 8. Continue removing 10 g of mass until the hanging mass is 100 g. Remember to record the m_{total} in kilograms.

10. Once you have recorded all of your mass and acceleration values, calculate the total mass times acceleration of the cart during each run and complete the above table in Excel.

11. Using your data in the table, plot $m_{total}\, a$ versus $m_{hanging}$. Make a trendline for this plot and determine the acceleration of gravity. Perform a linear regression and find the slope and the uncertainty of the slope.

12. Calculate g using Equation (3). Then find the average g and the standard deviation σ_g.

$$g = \frac{m_{total}}{m_{hanging}}\, a \tag{3}$$

13. Uncertainty analysis. In order to determine whether your measurement of gravity is in agreement with the expected value of 9.8 m/s^2 take the difference between your value and the expected value and divide by the standard deviation you found for the slope. How many standard deviations do they differ by? If it is greater than 2 it is highly unlikely that your measurement agrees with the expected value.