

Newton's Second Law

EQUIPMENT

1	250 g Stackable Masses (set of 2)	ME-6757A
1	Smart Cart Blue	ME-1241
1	Mass and Hanger Set	ME-8979
1	Dynamics Track Feet (set of 2)	ME-8972
1	Elastic Bumper	ME-8998
1	Super Pulley with Clamp	ME-9448B
1	1.2 m Dynamics Track	ME-9493
1	Braided Physics String	SE-8050
Required, but not included:		
1	PASCO Capstone Software	

INTRODUCTION

The purpose of this experiment is to verify Newton's Second Law for a one dimensional system. A measured force is applied to a low friction cart and the resulting acceleration is measured.

THEORY

The following equation is Newton's Second Law:

$$\sum \vec{F} = m\vec{a}$$

The sum of the forces, \vec{F} , acting upon a mass, m causes the mass to accelerate with acceleration \vec{a} , where \vec{F} and \vec{a} are vectors. Since our system is one dimensional and there is only one force (the vertical forces cancel out), this reduces to

$$F = ma$$

In this lab, the acceleration must be measured from a velocity-time graph. Since acceleration is defined as the change in the velocity per unit time, then the slope of the velocity-time graph equals the acceleration.

SET-UP

1. Open PASCO Capstone software. Turn on the Smart Cart, open the Hardware Setup in Capstone, and connect through Bluetooth to the Smart Cart.
2. Use adjustable feet on both ends to level the track. Give the cart a little push in one direction to see if it coasts to a stop or accelerates and then push it in the direction to see if the cart coasts to a stop equally in both directions.
3. Clamp the pulley to the other end of the track. Place this end over the edge of the table. Attach the elastic end-stop to prevent damage to the pulley.
4. Tie a loop in one end of a one meter length of string. Attach the notch of the mass hanger to the loop. Add 5 g to the hanger for a total of 10 g (including the 5 g hanger.) Tie a loop in the other end of the string and attach the loop to the hook of the Smart Cart. Hang the mass hanger over the pulley. Adjust the string so the mass is just above the floor when the cart plunger strikes the end-stop.
5. Level the string by adjusting the pulley.
6. In PASCO Capstone, Set the sample rate of the Smart Cart Position Sensor and the Smart Cart Force Sensor to 40 Hz.
7. Create a graph of velocity vs. time.
8. Create a table with two columns. Create a User-Entered Data Set called " a_1 " with units of m/s^2 . Create another User-Entered Data Set called " a_2 " with units of m/s^2 .
9. Create a new page in Capstone and make a graph of Force vs. Time. Create a table with two columns. Create a User-Entered Data Set called " F_1 " with units of N. Create another User-Entered Data Set called " F_2 " with units of N.

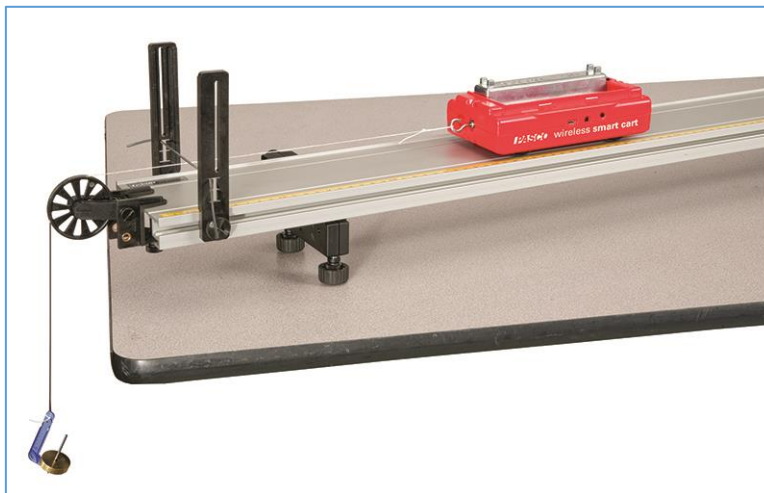
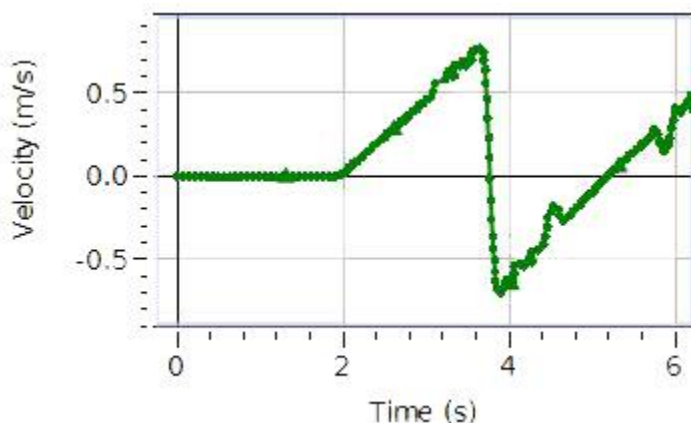


Figure 1: Complete Setup

PROCEDURE A

1. In Capstone, select the Smart Cart Force Sensor in the Sampling Control Bar at the bottom of the page. Remove the string from the Smart Cart Force Sensor hook and press the "ZERO" button in the Sampling Control Bar (next to the sample rate) in Capstone. Then replace the string.
2. Pull the cart back as far as possible without allowing the mass hanger to contact the pulley.
3. Start recording and release the cart.
4. Click STOP after the cart strikes the end-stop.
5. The graph should look like the picture below. The region of interest in this example is the accelerated region between 2.0 s and 3.5 s. Delete bad data runs by clicking on the Delete Last Run at the lower right of the screen.



6. Click on the Data Summary button on the left toolbar. Double-click on the run you just made in any box and re-label it 10 g Run 1. Then close the Summary.
7. Repeat the above steps 2-6 four more times using masses of 20 g, 30 g, 40 g, and 50 g on the end of the string. Label them 20 g Run 1, etc. *Do not repeat step 1!!!!*

ANALYSIS

1. Create a table and create a user-entered data set called a_1 with units of m/s^2 in the first column and another user-entered data set called a_2 with units of m/s^2 in the second column.
2. On the toolbar at the top of the velocity graph, click the black triangle of the Run Select tool, and select the "10 g Run 1".

3. Click the Selection Tool (graph toolbar) and drag the handles on the selection box to select the initial accelerated portion of the run where the data is clean (no spikes) and linear. Write down the time range you have selected. You will use this in step 10 below.
4. Select a Linear Fit.
5. Record the slope (m) from the Linear Curve Fit box in line 1 of the “ a_1 ” column in the table. You want a precision of 2 decimal places. You may adjust that using the Gear Icon in the Curve Fit box. First right click anywhere in the Linear box. Then click on the Curve Fit Properties and select 2 Fixed Decimals.
6. Repeat the above steps for the “20 g Run 1”, entering the acceleration in line 2, and so on for all five runs.
7. Create a new page in Capstone and make a graph of force vs. time.
8. Create a second table and create a user-entered data set called f_1 with units of N in the first column and another user-entered data set called f_2 with units of N in the second column.
9. On the toolbar at the top of the graph, click the Run Select tool, and select the “10 g Run 1”.
10. Click the Selection Tool and drag the handles on the selection box to select the same time range you selected in step 3 above.
11. Click on the Statistics tool (graph toolbar) to turn it on and then on the black triangle and select Mean. The mean value for the selected region should show on the screen. We want a precision of three decimal places here. To change the precision, click open Data Summary (left of screen), click on Force, click on the Gear icon that appears, and choose 3 Fixed Decimals from the pop-up that appears. Although the data looks rather noisy, the average is well defined. Record the Mean value in the table on line 1 of the “ f_1 ” column.
12. Repeat the above steps 7 and 8 for the “20 g Run 1”, entering the force in line 2, and so on for all five runs.

PROCEDURE B

1. Add a 250-gram mass bar to the cart.
2. Repeat Procedure (Part A) except label the runs “10 g Run 2”, etc.
3. Repeat the Analysis except enter the acceleration values in column “ a_2 ” and the force values in column “ f_2 ”.
4. Find the mass in kilograms of the Smart Cart and the mass of the Smart Cart plus the mass bar.

5. Uncertainty:

- a. It is valuable to estimate the uncertainties in this experiment. An easy way to do this is to repeat the “50 g Run 2” two more times and see how much the acceleration varies. Enter your extra two values under in lines 6 and 7 of the “ a_2 ” column of the first table.
 - b. What is your estimate of the uncertainty in the acceleration?
6. On a new page in Capstone, create a graph of f_1 vs. a_1 and another graph of f_2 vs. a_2 .

CONCLUSIONS

1. Examine the force vs. acceleration graphs. Graph 1 is the force (f_1) versus acceleration (a_1) plot for the cart and sensor. Graph 2 is the force (f_2) versus acceleration (a_2) for the cart with the compact mass added.
2. Do these graphs support Newton’s second law? Explain your answer fully! Don’t forget that there is some uncertainty here (Δa from Procedure B). Does it explain any deviations from what Newton would predict?
3. Would you expect the vertical intercept to equal zero? Is it? Explain.
4. What physical property does the slope of a Force vs. Acceleration graph represent? Hint: what are the units of the slope? Why are the slopes different? Explain.
5. How well do your slopes match what you should expect?