Inertia and Newton's Second Law

Introduction

When you shake an object back and forth, you feel a "resistance" to the acceleration you are causing. We commonly refer to this as the "inertia" of the object.

In this lab, Smart Cart, alone and then with extra masses on board, is pushed and pulled back and forth along a track. The Smart Cart's force sensor measures the force on the cart, and its position sensor is used to find the resulting acceleration. Analysis of a Force vs. Acceleration graph allows the student to quantify the concept of inertia.

Equipment

Qty	Items	Part Number
1	Smart Cart (Blue; including Hook)	ME-1241
1	Dynamics Track Feet (Pair)	ME-8972
1	Dynamics Track End Stops (Pair)	ME-8971
1	1.2m Starter Dynamics Track	ME-9493
1	250g Cart Mass (Pair)	ME-6757A
Required, but not included:		
1	Balance	SE-8723
1	PASCO Capstone Software	

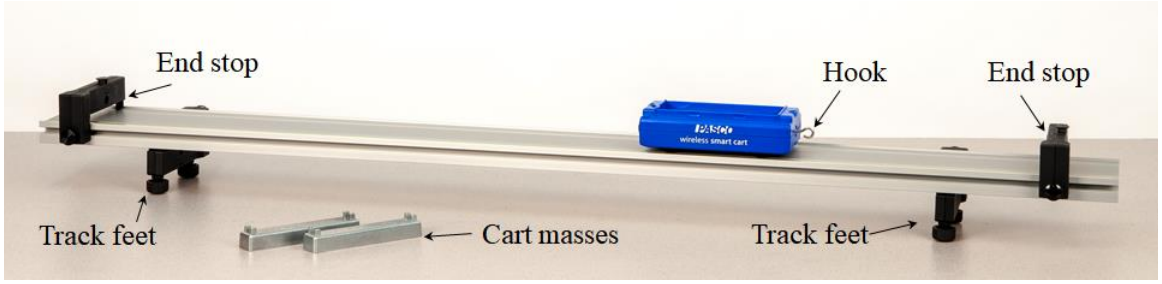

Figure 1: Experimental Setup

Setup

1. As shown in Figure 1, set up the track with feet underneath at both ends. On the upper side of the track, attach an end stop at each end.

2. Adjust the feet to make the track level. To test the level: Give the cart a little push in one direction to see if it coasts to a stop or accelerates. Then push it in the opposite direction to see if the cart coasts to a stop equally in both directions.

3. Attach the Hook to the front of the Smart Cart as shown in Figure 1.

4. Turn on the Smart Cart, and then wirelessly connect it via Bluetooth in Capstone software.

   In the lower toolbar, select Smart Cart Position Sensor and change the sample rate to 50 Hz. Then do the same for the Smart Cart Force Sensor.

5. Create a graph of Force vs. Time.

6. To zero the Smart Cart's force sensor:

   Make sure the cart is at rest with nothing touching the hook (which is attached to the force sensor). In the lower toolbar in Capstone: Select the Smart Cart Force Sensor, and then Zero the force sensor.

   Start recording. The force graph should read nearly zero since the string is removed. If not nearly zero, then stop recording, re-zero, and restart recording.

7. In Capstone, on the Force vs. Time graph, add a second plot area and create a graph of Acceleration (under Smart Cart Position Sensor) vs. Time. This acceleration is calculated from the Smart Cart Position Sensor data.

Force and Acceleration

1. With the cart near the center of the track, push and pull on the hook (which is attached to the Smart Cart's internal force sensor) to make the cart oscillate back and forth by about 10 cm. Make sure you push and pull only in the direction parallel to the track, not up-and-down or side-to-side. The cart wheels should always remain in the track grooves.

   While oscillating the cart in this way, start recording, take about 5 seconds of data, and then stop recording.

2. Examine the Force and Acceleration graphs. If needed, use the toolbar button to scale the axes to show all data. How does the shape of the Force graph compare to that of the Acceleration graph? Why is this so?

Force vs. Acceleration

1. In Capstone, create a graph of Force vs. Acceleration. The graph won't look like a single line, but a series of approximately parallel overlapping lines.

   Turn on curve fit on the toolbar. Select a Linear fit.

2. What physical property does the slope of the Force vs. Acceleration graph represent? Hint: What are the units of the slope?

3. If "F" is net force, and "a" is acceleration, what is the missing term in this equation? What is the name of this equation?

$$F = (?)\ a$$

4. In Capstone, create a table. Create three user-entered data sets for three columns in the table: "Slope, cart alone", "Slope, cart + 1 mass", and "Slope, cart + 2 masses". These should each have the same units as the slope of the Force vs. Acceleration graph.

   Turn on statistics in the toolbar, and select the mean and standard deviation.

5. In the "Slope, cart alone" column, record the slope of the Force vs. Acceleration graph. (Ignore the sign.)

6. Take several more runs for the cart alone, and record the slope each time in the "Slope, cart alone" column. Try shaking the cart more slowly, or more rapidly, or let different people do the shaking, so the motion is different for each run. However, remember to push and pull only in a direction parallel to the track, not up-and-down or side-to-side, always keeping the cart wheels in the grooves of the track.

7. Add a cart mass to the cart, and take several runs, recording the slope of the Force vs. Acceleration graph for each run in the "Slope, cart + 1 mass" column of the table.

8. Add a second cart mass to the cart, and repeat for the "Slope, cart + 2 masses" column.

9. For each column in the table: Record the slope's mean value and standard deviation. Then use a balance to find the actual mass of the object (cart alone, cart + 1 mass, or cart + 2 masses), and compare to the slope for that column.

10. Describe the idea of "inertia" in your own words. It may help you to think about the "feel" of shaking the cart back and forth, and how it varied when you added the cart masses.