Newton's Third Law

Introduction

If object 1 exerts a force on object 2, then object 2 simultaneously exerts an equal and opposite force on object 1. This interaction is described by Newton's Third Law: "For every action force, there is an equal and opposite reaction force." These two forces are often called an "action-reaction pair."

In this lab, two Smart Carts exert forces on each other in a variety of situations. Each Smart Cart's force sensor measures the force acting on that cart. In comparing the force measurements for the two carts, the student will gain a better understanding of Newton's Third Law.

Equipment

| Qty	Items	Part Number
1	Smart Cart (Red; including Hook and Magnetic Bumper)	ME-1240
1	Smart Cart (Blue; including Hook and Magnetic Bumper)	ME-1241
1	Dynamics Track Feet (Pair)	ME-8972
1	Dynamics Track End Stops (Only 1 needed)	ME-8971
1	1.2m Starter Dynamics Track	ME-9493
1	Elastic Bumper (Elastic & 1 pair brackets needed)	ME-8998
1	Super Pulley with Clamp (from ME-3420)	ME-9448B
1	250g Cart Mass (Pair)	ME-6757A
1	Mass and Hanger Set	ME-8979
1	String	SE-8050
Required, but not included:		
1	Rubber Band	
1	PASCO Capstone Software	
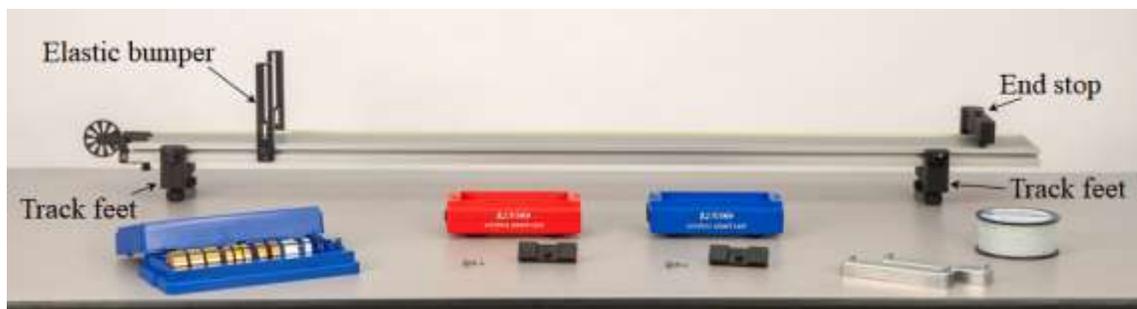
Figure 1: Experimental Setup

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 one end, and an elastic bumper (see Figure 2) at the other 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. Turn on each Smart Cart, and connect each via Bluetooth in Capstone.

Figure 2: Elastic Bumper

Calibrate Force Sensors

1. To set up for the calibration of each force sensor, first attach a Hook to each Smart Cart, as shown in Figure 3, and place the cart on the track against the Elastic Bumper. Each hook is now attached to a cart's internal force sensor.
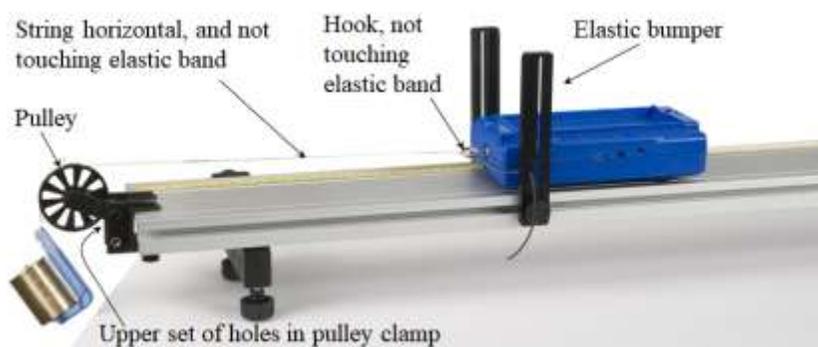

Figure 3: Calibrating a Force Sensor

2. Then clamp the pulley onto the end of the track where the elastic bumper is, as shown in Figure 3. Position the track so the pulley is just beyond the edge of the table. Make sure the pulley is attached to the clamp using the upper set of holes in the clamp.

3. Tie a loop in each end of a string about 0.25 m long. Attach one loop to the hook on one cart, and pass the string over the pulley. See Figure 3. Make sure the elastic bumper does not touch the hook or the string. If it does, move the elastic band up or down a notch in the brackets.

4. Attach a mass hanger to the other end of the string so it hangs below the pulley. Add 270 grams to the 5-gram hanger to make a total of 275 grams. See Figure 3.

5. Adjust the level of the pulley so the string from the cart to the pulley is horizontal. Make sure the string does not touch the elastic band.

6. In Capstone, open Calibration in the left toolbar. Then select: Force as the type of measurement; only for the sensor for the cart now set up as in Figure 3 (Red or Blue); Two Standards (2 point) calibration.

   To calibrate the first point, first remove the string from the cart's hook, so there is no force acting on the force sensor. Enter 0 as the standard value, and then Set Current Value to Standard Value.

   To calibrate the second point, reattach the string to the cart's hook, and set the cart at rest against the elastic bumper. Enter 2.70 N as the standard value (because the 275-gram mass weighs 2.70 N), and then Set Current Value to Standard Value.

   Review your calibration, checking that the new calibration live value is 2.70 N. Remove the string from the hook and check that the new calibration live value is 0 N. Then Finish.

7. Replace the first Smart Cart with the second Smart Cart, and repeat the calibration procedure for the second cart's force sensor.

8. Remove the hanging mass.

Tug-O-War – Setup

1. Before each recording you take, it is a good idea to zero the carts' force sensors, as follows:

   Place a cart at rest on the track, and make sure nothing is touching the cart's hook. In the lower toolbar in Capstone: Select that Smart Cart Force Sensor, and then Zero the force sensor.

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Repeat for the other cart.

2. Time-synchronize the wireless sensors with each other (lower toolbar).

3. Put the two carts on the track with their force sensor hooks facing each other. Attach a rubber band to the force sensor hooks as shown in Figure 4.

Figure 4: Tug-O-War Setup

4. On the lower toolbar in Capstone, open Recording Conditions and create a Stop Condition to be Time Based for a record time of 5 s

5. In the lower toolbar in Capstone, select one Smart Cart Force Sensor and change the sample rate to 25 Hz. Repeat for the other Smart Cart Force Sensor.

Tug-O-War – Procedure

1. In Capstone, create a graph of Red Smart Cart Force vs. Time. Then add a similar measurement Blue Smart Cart Force to the vertical axis.

2. Start recording. Then play a little tug-o-war game by pulling on both carts, as shown in Figure 5. Do not exceed 100 N. Vary the force with time, and make this tug-o-war a "tie" with neither car "winning." After 5 seconds, data recording will automatically stop.

Figure 5: Tug-O-War Game

If necessary, use the lower toolbar to delete unwanted data runs, and redo.

3. Open Data Summary in the Capstone left toolbar, and find the current run under one of the Smart Cart Force Sensors. Change this run's name to "Nobody wins".

4. Repeat the previous steps to record a tug-o-war game which the red cart "wins." (The red cart moves backward and the blue cart is made to follow.) Change this run's name to "Red wins".

5. Repeat again but now the blue cart wins. Name it "Blue wins".

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Tug-O-War – Analysis

1. Select the "Nobody wins" run on the graph, and use the toolbar to scale-to-fit. Click the graph legend icons to toggle back and forth between the two data sets. How do the two forces compare at any time?

   Repeat for the "Red wins" run, and then the "Blue wins" run.

2. Are the action/reaction forces equal in magnitude (size)? Does it matter if one cart is winning the tug-o-war?

3. Was the action force (acting on the red cart) opposite in direction to the reaction force (acting on the blue cart)? Explain how you know.

Collision – Setup

1. In the lower toolbar in Capstone, select one Smart Cart Force Sensor and change the sample rate to 500 Hz. Repeat for the other Smart Cart Force Sensor. This is needed to record collisions that happen over a very short time interval.

2. On the lower toolbar in Capstone, open Recording Conditions.

   Create a Start Condition based on a measurement of Force, is below -0.20. Pre-record for a time of 0.25 s. (A negative force reading corresponds to a "push" on the force sensor. This will start recording as soon as the collision begins, and capture the beginning of the collision before -0.20 N was reached.)

   Create a Stop Condition to be Time Based for a record time of 0.5 s.

   You can adjust the Recording Conditions as needed to suit your experiment.

3. Remove the hooks from the carts, and replace them with magnetic bumpers. Set the carts on the track with the magnetic bumpers facing each other, as shown in Figure 6.

Figure 6: Collision Setup

4. Pull the carts far apart so the magnetic bumpers have no forces acting on them, and zero each force sensor in the Capstone lower toolbar.

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5. Time synchronize the sensors (lower toolbar).

Collision – Procedure

1. Practice pushing the carts toward each other with their magnetic bumpers facing each other. If you go too fast, the carts will jump the track and stick together.

2. Start with one cart at each end of the track, and start recording. Push the carts together with similar speeds. Recording should start and then stop automatically.

3. In Capstone, open Data Summary and name this run "Symmetric Collision".

4. Repeat with the red cart at rest before the collision. Name this run "Red Cart at rest".

5. Place the two cart masses on the red cart so that its mass is now much larger than that of the blue cart.

6. Before proceeding, make a prediction: Which cart do you think will experience the larger force in this case? Explain.

7. Begin recording. With the red cart at rest, send the blue cart to collide with the red cart. Name this run "Heavy Red Cart".

Collision – Analysis

1. Select the "Symmetric Collision" run on the graph, and use the toolbar to scale-to-fit. Click the graph legend icons to toggle back and forth between the two data sets. How do the two forces compare at any time?

    Repeat for the other collision runs you took.

2. Are the action/reaction forces equal in magnitude (size)? Does it matter if one cart is more massive?

3. Was the action force (acting on the red cart) opposite in direction to the reaction force (acting on the blue cart)? Explain how you know.