Relative Motion in One Dimension

Equipment

2	Motion Sensor	PS-2103A
1	1.2 m PAScar Dynamics System	ME-6955
1	Cart Adapter Accessory	ME-6743
1	Motorized Cart	ME-9781
1	Car Sail	ME-9595
1	Elastic Bumper	ME- 8998
	Required, but not included:	
1	850 Universal Interface	UI-5000

Introduction

The purpose of this lab is to study motion relative to a moving reference frame. The speed of the red PAScar (see Fig. 1) as measured by the Motion Sensor at the far right, is not the same as the speed measured by the Motion Sensor located on the moving Motorized Cart. This "relative velocity" of the red car is measured directly by the Motion Sensor and compared to the expected value.
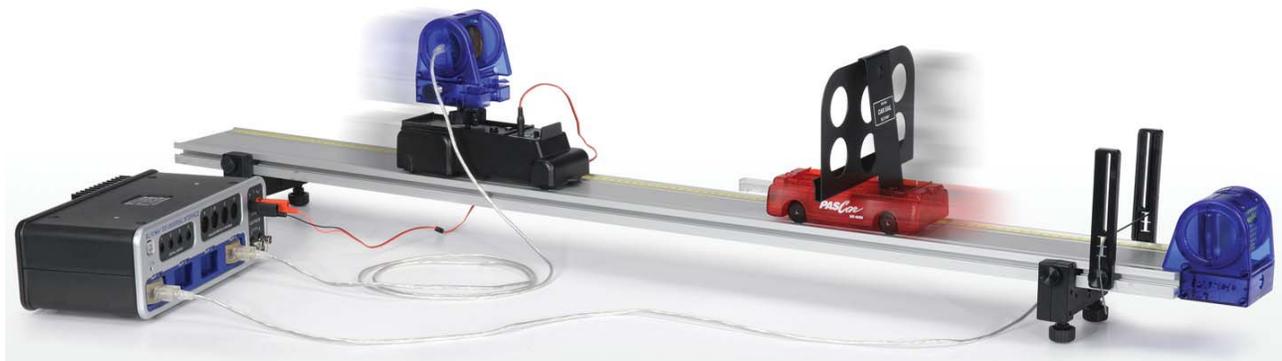

Figure 1: Measuring Relative Motion from Moving Cart

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Setup

1. The Motion Sensor connects to the Cart Adapter with the 1/4 -20 screw into the bottom of the Motion Sensor. Fasten Cart Adapter in the Motorized Cart top tray. Position the Motion Sensor so it points forward and use the large knob to lock it into position.

2. The Motion Sensor on the Motorized Cart MUST be plugged into PASPORT port #4 as shown in Figure 2. Plug the Motorized Cart power cord into Output #1, and make sure it is on the OFF/EXTERNAL SETTING.

3. It is easier to install the Elastic Bumper (Fig. 3) first. The Motion Sensor then slides onto the end of the track. This second Motion Sensor MUST be plugged into PASPORT port #1. Make sure the range switch is on the "cart" icon for BOTH sensors.

4. Mount the Car Sail Bracket on the red car. Use the adjustable feet to level the track so that the red car doesn't move when released.

5. The Motion Sensor on the track will measure the motion of the cart. The Motion Sensor on the Motorized Cart will measure from the Car Sail Bracket (mounted on the car) and is thus the relative motion between the two.

6. In the PASCO Capstone Summary, change the default units on the Position of each Motion Sensor to cm. Create a graph of Position, Port P1, vs. time. Then add a similar measurement Position, Port P4, by clicking on the vertical axis Position label and choosing "Add Similar Measurement". The sample rate for both Motion Sensors should be 20 Hz.
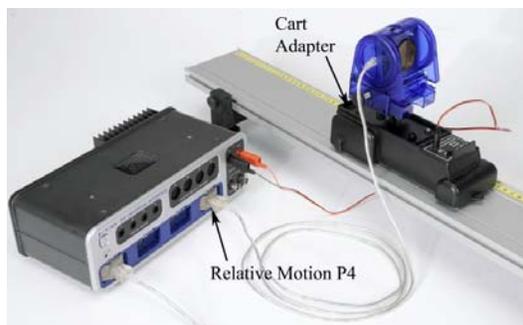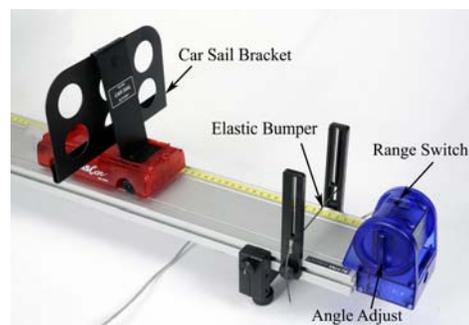

Figure 2: Motorized Cart with Motion Sensor

Figure 3. Motion Sensor on Track

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Procedure – Measuring Position

1. Position the Motorized Cart on the track at the far end from the Motion Sensor. Place the red car about 20 cm from the Motorized Cart.

2. Start recording, and then move the red Car to the opposite end of the track. Note placement of hand on cart in Figure 4, below. Stop Recording.

3. Identify which data set is for which cart. The data needs to be continuous with no glitches. Turn the handle (Fig. 3) on the Motion Sensor to adjust the angle to improve data. Note that the Motion Sensor cannot measure a distance of less than 15 cm.

4. You can delete unwanted runs using the Delete Run feature in the Control Palette at the bottom.

Figure 4. Moving the Cart

Procedure – Measuring Speed

The speeds measured by the Motion Sensors in this lab are calculations that include an absolute value. Thus all values measured by the computer will be positive.

The Motion Sensor on the track will measure the actual speed of the red car. The Motion Sensor on the Motorized Cart measures the relative speed between the two carts. The actual speed of the Motorized Cart is determined by the voltage applied in the next section.

5. In the Capstone calculator, create two calculations:
    V cart=abs(derivative(5,[Position, Ch P1 (cm)],[Time (s)]))
    V rel=abs(derivative(5,[Position, Ch P4 (cm)],[Time (s)]))

6. Make a graph of both the velocity calculations vs. time. Right-click on the vertical axis and, in the Properties, make the Axis Label have a custom name called "Speed".

7. With the red car in the middle of the track, start recording. Smoothly move the red car to the left (10 to 20 cm) and then to the right and then back to center in a total time of about 5 seconds.

8. How does it look? Identify which data set was measured where. The data needs to be continuous with a minimum of glitches.

9. Once you have the system working so that you are getting good data from both sensors, delete all runs (using the Delete Run feature in the Control Palette at the bottom) and proceed to the next page.

Motorized Cart

10. Position the Motorized Cart on the track at the far end from the Motion Sensor. Place the red car at rest against the Elastic Bumper.

11. Set DC Voltage Output #1 to 2.00 volts. Start recording, then click the Output "On". Click the output "Off" before the Motorized Cart reaches other end.

12. Note the speed (Vrel) of the Motorized Cart, using graph and digits displays. Set the voltage to 2.10 volts and repeat. How does that change the speed?

13. Adjust the voltage to get the speed of Motorized Cart as close as possible to 10 cm/s.

14. Set the Output to "Auto" mode. This will automatically turn on the Motorized Cart when you start recording, and turn it off when you stop recording. Try a few trial runs to make sure the Motorized Cart turns on and off properly, and that the speed of the Motorized Cart is 10 cm/s.

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Relative Motion

15. For this part, use the Speed (of both) vs. Time graph you made previously. Also make a table with a User-Entered Data Set called "Calculated Speed" with units of (cm/s) in the first column and another User-Entered Data Set called "Measured Speed" with units of (cm/s) in the second column.

16. Position the Motorized Cart on the track at the far end from the Motion Sensor. Starting with the red car near the middle, push the red car (away from the Motorized Cart) towards the Motion Sensor on the track, and allow it to bounce off the Elastic Bumper. Start recording as soon as the cart has changed directions. Stop recording before the two collide.

17. Pick a time on the graph where you have smooth speed data for both. Use the coordinate tool to measure the speed of the red car.

18. Calculate the relative speed. Remember that the speed of the Motorized Cart is 10 cm/s. For a head-on collision, how do you calculate the relative speed? Do you add the speeds or subtract?

19. Measure the relative speed off the graph and compare to your calculation. Repeat for two other trials.

20. Repeat for the two carts moving in same direction.

Analysis

21. For each of your data pairs, compare the measured speed to the calculated (accepted) value using the % error calculation:

$$\%error = \left| \frac{Measured - Accepted}{Accepted} \right| \times 100$$

22. Record your values.

23. In general, how well do the values compare?