

# MOMENTUM, ENERGY AND COLLISIONS WITH HANDHELD

## LAB HAND 19

**RELATED TOPICS** Mass  
Velocity  
Forces

## STANDARDS ADDRESSED

*Science and Technology*

3.1.10, 3.1.12

3.2.10, 3.2.12

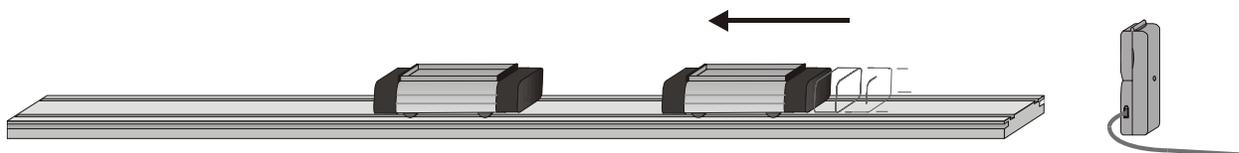
3.4.10, 3.4.12

3.7.10, 3.7.12

## CONSIDERATIONS

The collision of two carts on a track can be described in terms of momentum conservation and, in some cases, energy conservation. If there is no net external force experienced by the system of two carts, then we expect the total momentum of the system to be conserved. This is true regardless of the force acting between the carts. In contrast, energy is only conserved when certain types of forces are exerted between the carts.

Collisions are classified as *elastic* (kinetic energy is conserved), *inelastic* (kinetic energy is lost) or *completely inelastic* (the objects stick together after collision). Sometimes collisions are described as *super-elastic*, if kinetic energy is gained. In this experiment you can observe completely inelastic collisions and test for the conservation of momentum and energy.



## OBJECTIVES

- Observe completely inelastic collisions between two carts, testing for the conservation of momentum.
- Measure energy changes during completely inelastic collisions.

## MATERIALS

LabPro interface  
Palm handheld  
Data Pro program  
Vernier Motion Detector

dynamics cart track  
two low-friction dynamics carts with  
Velcro™ bumpers

## PRELIMINARY QUESTIONS

1. Consider a head-on collision between two cars. One is initially at rest and the other moves toward it. After the collision they stick together. Sketch a position *vs.* time graph for each car, starting with time before the collision and ending a short time afterward.
2. Is momentum conserved in this collision? Is kinetic energy conserved? How can you tell?

## PROCEDURE

1. Measure the masses of your carts and record them in your data table. Label the carts as cart 1 and cart 2.
2. Set up the track so that it is horizontal. Test this by releasing a cart on the track from rest. The cart should not move.
3. Practice creating gentle collisions by placing cart 2 at rest in the middle of the track and release cart 1 so it rolls toward the first cart, Velcro bumper toward Velcro bumper. The carts should stick together after the collision and roll smoothly away from the collision site.
4. Place a Motion Detector at the cart 1 end of the track, allowing for the 0.4 m minimum distance between detector and cart. Always roll cart 1 from this end of the track.
5. Plug the Motion Detector into the DIG/SONIC 1 port of the LabPro interface. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.
6. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap **(New)** to reset the program.
7. Tap **(Start)** to begin taking data. Repeat the collision you practiced above. Make sure you keep your hands out of the way of the Motion Detector after you push the cart.
8. After data collection is complete a graph of distance *vs.* time will be displayed. Use this graph to verify that the Motion Detector can track the cart properly throughout the entire range of motion. You may need to adjust the position of the Motion Detector. If necessary, repeat to the previous step.
9. When you have a good run of data, tap on the y-axis label of the distance graph and choose VEL(m/s) to display a velocity *vs.* time graph. From the velocity graph you can determine an average velocity before and after the collision for each cart. You should see two approximately constant regions in your velocity graph, corresponding to the cart speed before the collision and then the speed of the two carts together after the collision. If you cannot see two such regions, repeat your data collection. To repeat, return to Step 7.

10. Measure the average velocity during the time interval before the collision.
  - a. On the Graph screen, tap .
  - b. On the Analyze screen, tap the Selection button, .
  - c. Tap the data point at the left edge of the first constant-velocity region. An arrow ( $>$ ) is displayed on this line.
  - d. Tap the data point at the end of this region. An arrow ( $<$ ) is displayed on this line.
  - e. Tap . The handheld will display the mean velocity for the time interval. Record this as the initial velocity in your data table, then tap  to return to the Analyze screen.
  - f. Tap the Selection button,  to clear region you just selected in order to select a new region in the next step.
  
11. Measure the average velocity during the time interval *after* the collision.
  - a. On the Analyze screen, tap the Selection button,  so that you may select a new region.
  - b. Tap the data point at the left edge of the second constant-velocity region. An arrow ( $>$ ) is displayed on this line.
  - c. Tap the data point at the end of this second region. An arrow ( $<$ ) is displayed on this line.
  - d. Tap . The handheld will display the mean velocity for this time interval. Record the value in the Data Table. Note that the carts have the same velocity after collision since they are stuck together and then tap  twice to return to the Graph screen.
  
12. Repeat the collision and analysis two more times for a total of three runs.

**DATA TABLE**

|                     |                     |
|---------------------|---------------------|
| Mass of cart 1 (kg) | Mass of cart 2 (kg) |
|---------------------|---------------------|

| Run number | Velocity of cart 1 before collision (m/s) | Velocity of cart 2 before collision (m/s) | Velocity of cart 1 after collision (m/s) | Velocity of cart 2 after collision (m/s) |
|------------|---|---|--|--|
| 1          |   | 0   |  |  |
| 2          |   | 0   |  |  |
| 3          |   | 0   |  |  |

## Momentum, Energy and Collisions

| Run number | Momentum of cart 1 before collision (kg·m/s) | Momentum of cart 2 before collision (kg·m/s) | Momentum of cart 1 after collision (kg·m/s) | Momentum of cart 2 after collision (kg·m/s) | Total momentum before collision (kg·m/s) | Total momentum after collision (kg·m/s) | Ratio of total momentum after/before |
|------------|--|--|---|---|--|---|--------------------------------------|
| 1          |  | 0  |   |   |  |   |                                      |
| 2          |  | 0  |   |   |  |   |                                      |
| 3          |  | 0  |   |   |  |   |                                      |
| Run number | KE of cart 1 before collision (J)            | KE of cart 2 before collision (J)            | KE of cart 1 after collision (J)            | KE of cart 2 after collision (J)            | Total KE before collision (J)            | Total KE after collision (J)            | Ratio of total KE after/before       |
| 1          |  | 0  |   |   |  |   |                                      |
| 2          |  | 0  |   |   |  |   |                                      |
| 3          |  | 0  |   |   |  |   |                                      |

### ANALYSIS

1. Determine the momentum ( $mv$ ) of each cart before the collision, after the collision, and the total momentum before and after the collision. Calculate the ratio of the total momentum after the collision to the total momentum before the collision. Enter the values in your data table.
2. Determine the kinetic energy ( $\frac{1}{2}mv^2$ ) for each cart before and after the collision. Calculate the ratio of the total kinetic energy after the collision to the total kinetic energy before the collision. Enter the values in your data table.
3. If the total momentum for a system is the same before and after the collision, we say that momentum is *conserved*. If momentum were conserved, what would be the ratio of the total momentum after the collision to the total momentum before the collision?
4. If the total kinetic for a system is the same before and after the collision, we say that kinetic energy is *conserved*. If kinetic were conserved, what would be the ratio of the total kinetic energy after the collision to the total kinetic energy before the collision?
5. For your three runs, inspect the momentum ratios. Even if momentum is conserved for a given collision, the measured values may not be exactly the same before and after due to measurement uncertainty. The ratio should be close to one, however. Is momentum conserved in your collisions?
6. Repeat the preceding question for the case of kinetic energy. Is kinetic energy conserved in your completely inelastic collisions?

## **EXTENSIONS**

1. Perform the momentum and energy calculations for the data tables using a spreadsheet.

The following extensions require two Motion Detectors and a LabPro interface. Use a second Motion Detector to measure the speed of cart 2.

2. Explore elastic collisions by measuring the speeds of carts 1 and 2 separately. Use magnetic bumpers to study elastic collisions, and magnetic-to-Velcro collisions to study inelastic (but not completely inelastic) collisions.
3. Using a collision cart with a spring plunger, create a super-elastic collision; that is, a collision where kinetic energy increases. The plunger spring should be compressed and locked before the collision, but then released during the collision. Measure momentum before and after the collision. Is momentum conserved in this case? Is energy conserved?
4. Using the magnetic bumpers, consider other combinations of cart mass by adding weight to one cart. Are momentum or energy conserved in these collisions?
5. Using the magnetic bumpers, consider other combinations of initial velocities. Begin with having both carts moving toward one another initially. Are momentum and energy conserved in these collisions?