Momentum, Energy and Collisions

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 most of these types of collisions and test for the conservation of momentum and energy in each case.

OBJECTIVES

- Observe collisions between two carts, testing for the conservation of momentum.
- Measure energy changes during different types of collisions.
- Classify collisions as elastic, inelastic, or completely inelastic.

MATERIALS

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computers	dynamics cart track
Vernier computer interface	two low-friction dynamics carts with
Logger *Pro*	magnetic and Velcro™ bumpers
two Vernier Motion Detectors	

PRELIMINARY QUESTIONS

1. Consider a head-on collision between two billiard balls. One is initially at rest and the other moves toward it. Sketch a position *vs.* time graph for each ball, starting with time before the collision and ending a short time afterward.

2. As you have drawn the graph, is momentum conserved in this collision? Is kinetic energy conserved?

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, magnetic bumper toward magnetic bumper. The carts should smoothly repel one another without physically touching.

4. Place a Motion Detector at each end of the track, allowing for the 0.15 m minimum distance between detector and cart. Connect the Motion Detectors to the DIG/SONIC 1 and DIG/SONIC 2 channels of the interface. If the Motion Detectors have switches, set them to Track.

5. Open the file "18 Momentum Energy Coll" from the *Physics with Vernier* folder.

6. Click ▸ Collect to begin taking data. Repeat the collision you practiced above and use the position graphs to verify that the Motion Detectors can track each cart properly throughout the entire range of motion. You may need to adjust the position of one or both of the Motion Detectors.

7. Place the two carts at rest in the middle of the track, with their Velcro bumpers toward one another and in contact. Keep your hands clear of the carts and click 0 Zero . Select both sensors and click OK . This procedure will establish the same coordinate system for both Motion Detectors. Verify that the zeroing was successful by clicking ▸ Collect and allowing the still-linked carts to roll slowly across the track. The graphs for each Motion Detector should be nearly the same. If not, repeat the zeroing process.
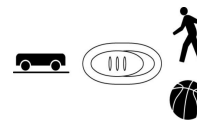
Part I: Magnetic Bumpers

8. Reposition the carts so the magnetic bumpers are facing one another. Click ▸ Collect to begin taking data and repeat the collision you practiced in Step 3. Make sure you keep your hands out of the way of the Motion Detectors after you push the cart.

9. From the velocity graphs you can determine an average velocity before and after the collision for each cart. To measure the average velocity during a time interval, drag the cursor across the interval. Click the Statistics button ⎀STAT to read the average value. Measure the average velocity for each cart, before and after collision, and enter the four values in the data table. Delete the statistics box.

10. Repeat Step 9 as a second run with the magnetic bumpers, recording the velocities in the data table.

Part II: Velcro Bumpers

11. Change the collision by turning the carts so the Velcro bumpers face one another. The carts should stick together after collision. Practice making the new collision, again starting with cart 2 at rest.

12. Click ▸ Collect to begin taking data and repeat the new collision. Using the procedure in Step 9, measure and record the cart velocities in your data table.

13. Repeat the previous step as a second run with the Velcro bumpers.

Part III: Velcro to Magnetic Bumpers

14. Face the Velcro bumper on one cart to the magnetic bumper on the other. The carts will not stick, but they will not smoothly bounce apart either. Practice this collision, again starting with cart 2 at rest.

15. Click ▸ Collect to begin data collection and repeat the new collision. Using the procedure in Step 9, measure and record the cart velocities in your data table.

16. Repeat the previous step as a second run with the Velcro to magnetic bumpers.

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		
4		0		
5		0		
6		0		

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					
4		0					
5		0					
6		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					
4		0					
5		0					
6		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 energy 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. 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 the magnetic bumper collisions? How about the Velcro collisions? Is kinetic energy consumed in the third type of collision studies? Classify the three collision types as elastic, inelastic, or completely inelastic.

EXTENSIONS

1. 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?

2. Using the magnetic bumpers, consider other combinations of cart mass by adding weight to one cart. Are momentum or energy conserved in these collisions?

3. 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?

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

Vernier Lab Safety Instructions Disclaimer

THIS IS AN EVALUATION COPY OF THE VERNIER STUDENT LAB.

This copy does not include:

- **Safety information**
- **Essential instructor background information**
- **Directions for preparing solutions**
- **Important tips for successfully doing these labs**

The complete *Physics with Vernier* lab manual includes 35 labs and essential teacher information. The full lab book is available for purchase at:
http://www.vernier.com/cmat/pwv.html

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