SMART CART – CONSERVATION OF MOMENTUM

Driving Question | Objective

How is the momentum and kinetic energy of a two-object system affected by a collision? Experimentally demonstrate that linear momentum and kinetic energy are conserved in an elastic collision, and that linear momentum is conserved but kinetic energy is not conserved in an inelastic collision.

Materials and Equipment

- Data collection software
- PASCO Smart Cart, blue, with magnetic bumper
- PASCO Smart Cart, red, with magnetic bumper
- PASCO Dynamics Track with feet
- PASCO Dynamics Track End Stop (2)
- Balance, 0.1-g resolution, 2,000-g capacity (1 per class)

Background

The momentum $\vec{p}$ of an object is equal to the product of its mass m and velocity $\vec{v}$:

$$\vec{p} = m\vec{v} \tag{1}$$

For a linear system that is not influenced by outside forces, the total momentum of the system is conserved. This extends to objects experiencing two types of collisions: elastic and inelastic.

Elastic collisions occur when two objects bounce off each other perfectly, without sticking or changing shape, like two billiards balls colliding. Linear momentum is transferred from one object to the next, and if the two objects are the same mass, all of the momentum of the first is transferred to the second.

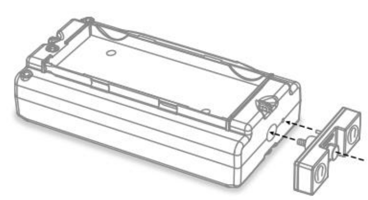
Inelastic collisions occur when two objects don't bounce off each other perfectly, such as two objects sticking fully or partially to each other, like two clay balls colliding and then moving as one object; or two objects colliding and deforming as a result of the collision, like a two-car accident.

In this activity, you will demonstrate that the total momentum of a system consisting of two carts on a flat track is conserved in both elastic and inelastic collisions (implying that the total momentum of the system does not change in either collision type), but the total kinetic energy of the system is only constant in elastic collisions.

Procedure

Part 1 – Elastic Collision

SET UP



1. Power on both smart carts, and then connect them to your data collection software. Attach a magnetic bumper to the front of each smart cart.

2. Set the track on a level surface with one end stop at each end of the track. Adjust the track feet to make sure the track is as level as possible. Set the red cart on the left side of the track, and the blue cart on the right, with both magnetic bumpers facing each other.

3. In your software, use the "Change Sign" function, or create a calculation, to change the motion measurements of the blue cart to measure positive velocity to the right, and negative velocity to the left.

❷ 4. By default, each smart cart measures positive velocity in the direction of the magnetic bumper, regardless of the direction it is facing. Why is it necessary to switch the sign of the velocity measurements made by the blue cart?

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5. Configure your software to show one graph display with time on the *x*-axis, and two *y*-axes: one axis showing the velocity of the red cart, the other axis showing the velocity of the blue cart.

COLLECT DATA

6. Measure the mass of each cart. Record the mass of the red cart into Table 1 next to Trial 1, and the mass of the blue cart into Table 2 next to Trial 2 in the Data Analysis section below.

7. Place the blue cart in the middle of the track with its bumper facing left, and the red cart at the left-side end of the track with its bumper facing right.

8. Start recording data, and then gently push and release the red cart toward the blue cart, allowing them to collide. Stop recording data once the carts have collided.

9. Repeat the same data collection steps two additional times, each time adding one of the 250-g cart masses to the blue cart. Keep the mass of the red cart the same for trials 2 and 3.

10. Use the tools in your graph to find the velocity of the red cart just before the collision (initial velocity) and just after the collision (final velocity) in each trial. Enter the values in Table 1.

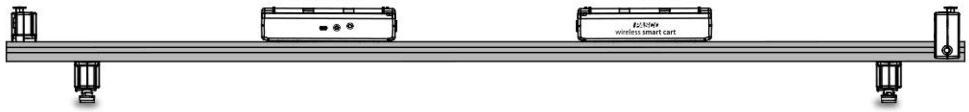
11. Use the tools in your graph to find the velocity of the blue cart just before the collision (initial velocity) and just after the collision (final velocity) in each trial. Enter the values in Table 2.

Part 2 – Inelastic Collision

SET UP

12. Remove the cart masses from the blue cart.

13. Remove the magnetic bumpers from both carts, and then swap the positions of the carts on the track so that the blue cart is now on the left side of the track and the red cart is on the right with the Velcro bumpers facing each other.



COLLECT DATA

13. Repeat the same data collection steps from Part 1. However, in this part you will place the red cart in the middle of the track and push the blue cart into the red cart. When the carts collide they will hit Velcro bumper to Velcro bumper and stick together, resulting in an inelastic collision.

14. Perform three trials, adding one of the 250-g cart masses to the red cart in trial 2, and two cart masses in trial 3.

15. Record the red cart's mass, initial velocity, and final velocity for each trial into Table 4.

16. Record the blue cart's mass, initial velocity, and final velocity for each trial into Table 5.

Data Analysis

Part 1 – Elastic Collision

Table 1: Red cart elastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1							
2							
3							

Table 2: Blue cart elastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1							
2							
3							

1. Calculate the initial and final momentum of each cart in each Part 1 trial. Record the values for the red cart into Table 1 and the values for blue cart into Table 2.

2. Calculate the initial and final kinetic energy of each cart in each Part 1 trial. Record the values for the red cart into Table 1 and the values for blue cart into Table 2.

3. Calculate the total momentum and total kinetic energy of the two-cart system before and after each Part 1 collision. Record the results into Table 3 below.

Table 3: Total system momentum and kinetic energy before and after the elastic collision

Trial	Initial Momentum of System (kg·m/s)	Final Momentum of System (kg·m/s)	Initial Kinetic Energy of System (J)	Final Kinetic Energy of System (J)
1				
2				
3				

Part 2 – Inelastic Collision

Table 4: Red cart inelastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
4							
5							
6							

Table 5: Blue cart inelastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
4							
5							
6							

4. Calculate the initial and final momentum of each cart in each Part 2 trial. Record the values for the red cart into Table 4 and the values for blue cart into Table 5.

5. Calculate the initial and final kinetic energy of each cart in each Part 2 trial. Record the values for the red cart into Table 4 and the values for blue cart into Table 5.

6. Calculate the total momentum and total kinetic energy of the two-cart system before and after each Part 2 collision. Record the results into Table 6 below.

Table 6: Total system momentum and kinetic energy before and after inelastic collision

Trial	Initial Momentum of System (kg·m/s)	Final Momentum of System (kg·m/s)	Initial Kinetic Energy of System (J)	Final Kinetic Energy of System (J)
4				
5				
6				

Analysis Questions

1. What experimental evidence do you have showing that momentum is conserved in inelastic and elastic collisions?

2. How does your data support that kinetic energy is conserved in elastic collisions?

3. How does your data support that kinetic energy is NOT conserved in inelastic collisions?

4. Why is kinetic energy not conserved in inelastic collisions? Where is the energy lost?