

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

- PASCO Smart Cart, blue, with magnetic bumper
- PASCO Smart Cart, red, with magnetic bumper
- PASCO Dynamics Track with feet
- PASCO Cart Masses, 250-g (2)
- 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} :

$$\vec{p} = m\vec{v} \quad (1)$$

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.

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 two-cart system is conserved in both elastic and inelastic collisions (the total combined momentum of the carts does not change), but the total kinetic energy of the system is only constant in elastic collisions.

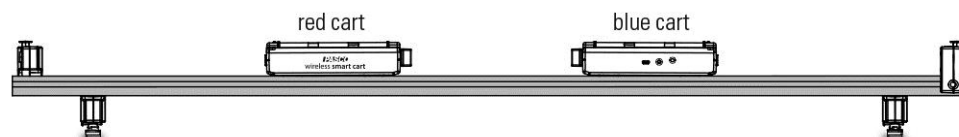
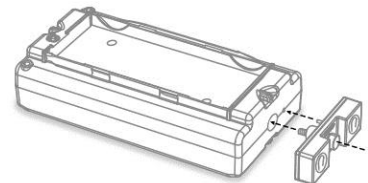
DOWNLOAD THE CONSERVATION OF MOMENTUM CAPSTONE FILE:

<http://tinyurl.com/y83863xj>

SEE APPENDIX A: For Bluetooth Cart Connection Instructions

Procedure Part 1 – Elastic Collision

1. 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.
2. Attach a magnetic bumper to the front of each smart cart, and then 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.



- Open the experiment file (previously downloaded) **SC Conservation of Momentum**, and then power-on both Smart Carts and connect them wirelessly to your software.
- In the experiment file is a graph of velocity versus time for both carts. Positive velocity is measured toward the right, and negative velocity is measured toward the left

COLLECT DATA

- 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 1 in the Data Analysis section below.
- 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.
- 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.
- 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.

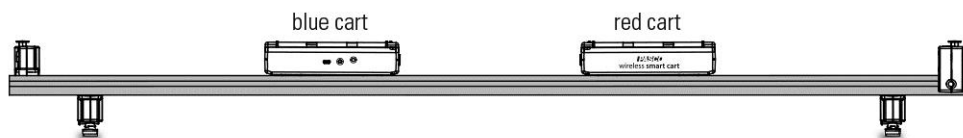
NOTE: When measuring cart mass, be sure to measure the mass of the blue cart plus any masses that you've added. Record the red cart's mass in Table 1 and the blue cart's mass in Table 2.

- Use the tools in your graph to find the velocity of both carts just before the collision (initial velocity) and just after the collision (final velocity) in each trial. Enter the red cart velocity values in Table 1, and the blue cart velocity values in Table 2.

Part 2 – Inelastic Collision

SET UP

- Remove the cart masses from the blue cart.
- 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

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

- 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.
- 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.
- 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 | | | | | | | |

18. 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.
19. 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.
20. 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?

Appendix A

Instructions for bluetooth connection for SMART Cart in PASCO Capstone

- 1) Gather SMART Cart(s) and USB Bluetooth Dongle
- 2) Plug the Bluetooth dongle into USB port
- 3) Launch the Capstone file from the link listed in this lab.
- 4) Turn on the SMART cart(s)
- 5) The SMART carts will populate in a list on the Capstone Hardware Tab
note: The SMART carts have unique serial numbers listed on the device (i.e., cart)
- 6) After clicking each cart, you are now ready to collect data.