Conservation of Momentum in One-Dimension

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Introduction

This laboratory experiment aims to test the validity of the laws of conservation of momentum and conservation of energy by analyzing the collision of carts with the same or different masses as they travel in a straight line. The experiment aims to differentiate between elastic and inelastic collisions, understand the conditions under which momentum and energy are conserved, and verify these principles through practical data collection and analysis.

Procedure

Experimental Set-up:

- The track was set on a level surface with one motion sensor attached to each end.
- Both motion sensors were connected to the data collection system and adjusted to report consistent velocities for the same object.
- The carts were aligned and set to travel towards each other, ensuring they collided in the middle of the track.

Data Collection:

- Motion sensors recorded the instantaneous positions of the carts at a frequency of 50 Hz.
- Analysis software obtained data on position, velocity, and acceleration as a function of time for each cart.

Elastic Collisions:

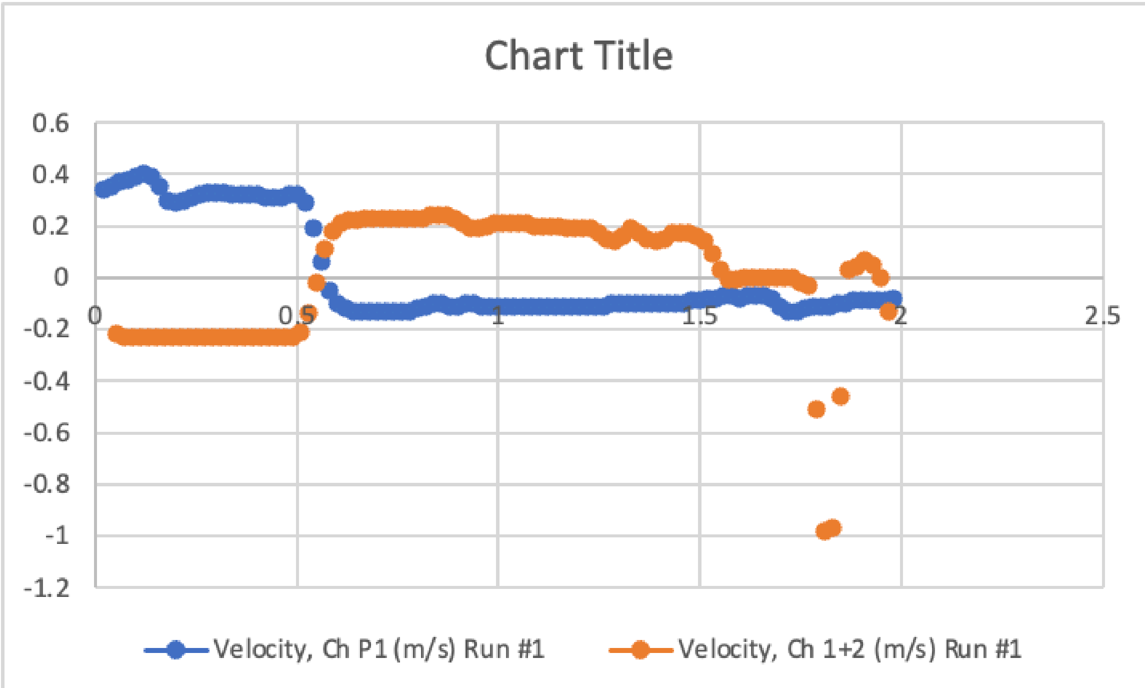
- Carts were aligned with their magnetic sides facing each other.
- Various initial conditions were set, including scenarios where one cart was at rest and both had the same or different masses.
- The graphs of both carts' velocity-time (v(t)) were recorded and analyzed.

Inelastic Collisions:

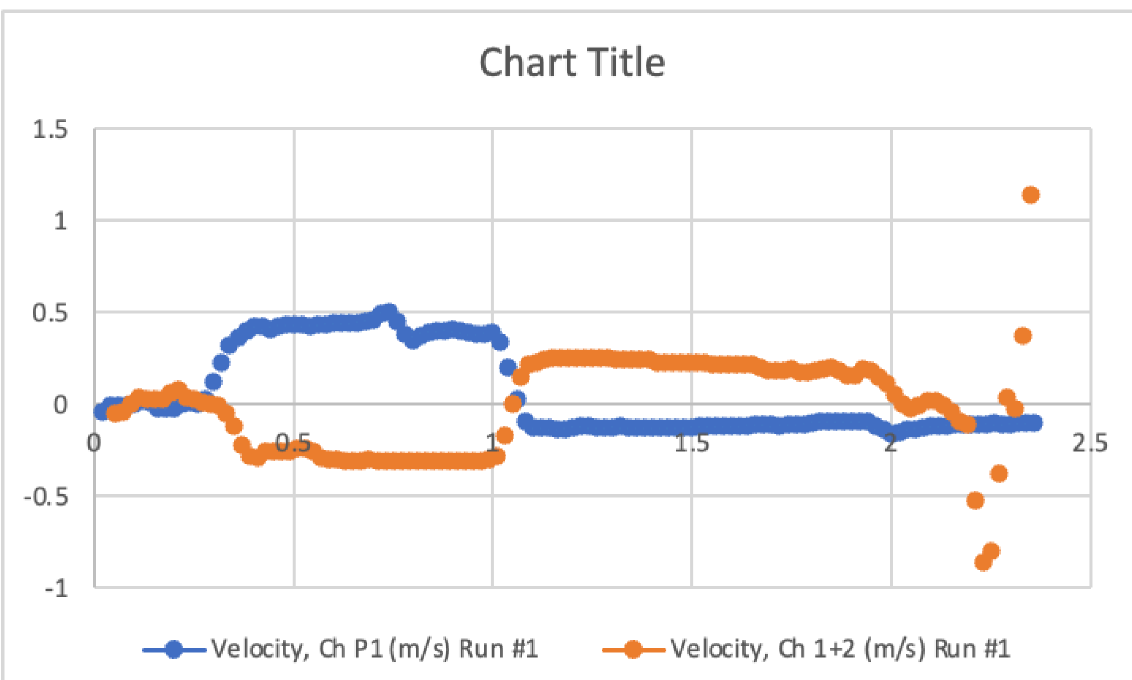
- Carts were turned around to face their non-magnetic sides towards each other.
- Similar initial conditions were set to those in the elastic collision experiments.
- v(t) graphs for both carts were recorded and analyzed.

Data

Elastic:



Trial 1



Trial 2

Table 2: P1 Data from v(t)

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	0.75	0.32	-0.13	0.24	-0.0975	0.0384	0.0063
2	0.75	0.39	-0.13	0.2925	-0.0975	0.057	0.0063

Table 3: P2 Data from v(t)

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	0.75	-0.21	0.22	-0.1575	0.165	0.0165	0.01815
2	0.75	-0.3	0.22	-0.225	0.165	0.03375	0.01815

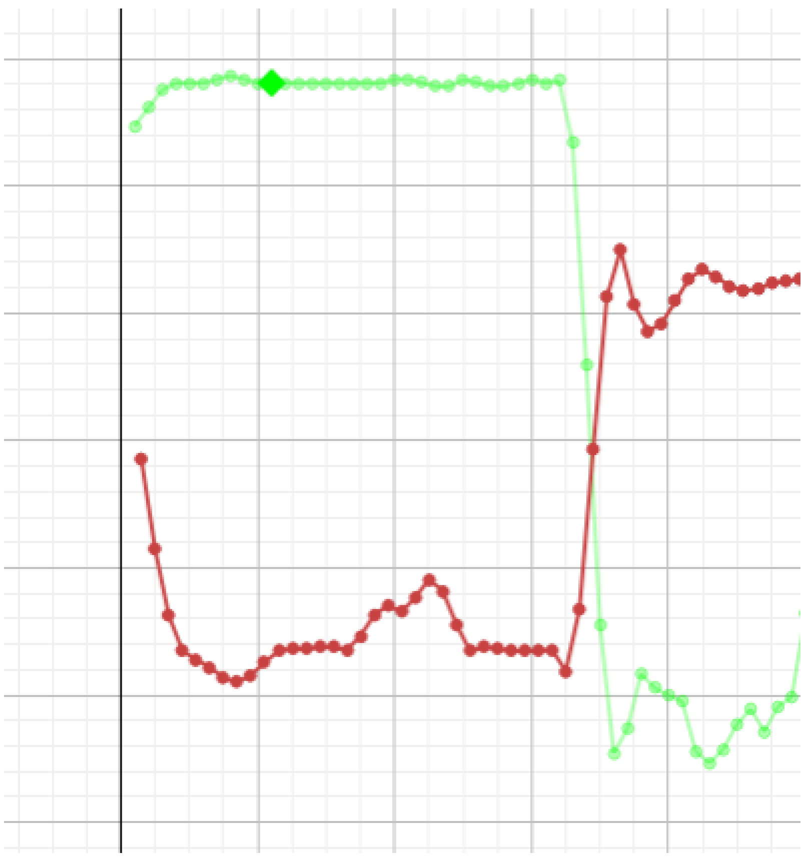
Table 4: P1 Change in Momentum and Energy

Trial	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	0.24	-0.0975	-0.3375	0.0384	0.0063	-0.0321
2	0.2925	-0.0975	-0.39	0.057	0.0063	-0.0507

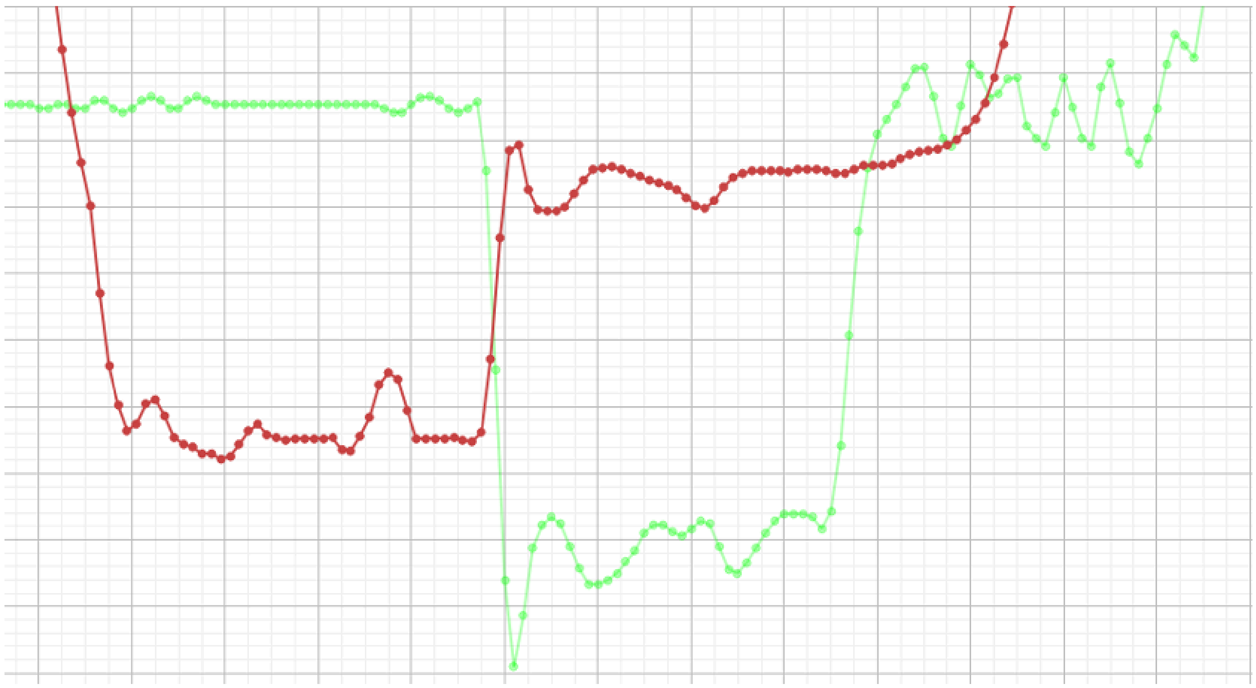
Table 5: P2 Change in Momentum and Energy

Trial	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	-0.1575	0.165	0.3225	0.0165	0.01815	0.00165
2	-0.225	0.165	0.39	0.03375	0.01815	-0.0156

Inelastic:



Trial 1



Trial 2

Table 6: P1 Data from v(t) (Inelastic Collisions)

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	0.75	0	-0.27	0	-0.2025	0	0.0273
2	0.75	0	-0.19	0	-0.1425	0	0.0137

Table 7: P2 Data from v(t) (Inelastic Collisions)

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	0.75	-0.56	-0.25	-0.42	-0.1875	0.1176	0.0234

2	0.75	-0.38	-0.16	-0.285	-0.12	0.05415	0.0096

Table 8: P1 Change in Momentum and Energy (Inelastic Collisions)

Trial	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	0	-0.2025	-0.2025	0	0.0273	0.0273
2	0	-0.1425	-0.1425	0	0.0137	0.0137

Table 9: P2 Change in Momentum and Energy (Inelastic Collisions)

Trial	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Change in Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)	Change in Kinetic Energy (J)
1	-0.42	-0.1875	0.2325	0.1176	0.0234	-0.0942
2	-0.285	-0.12	0.165	0.05415	0.0096	-0.04455

Calculations and Error Analysis

Elastic Collision Analysis:

For Trial 1:
P1:

- Initial Momentum: 0.75kg×0.32m/s= **0.24 kg*m/s**
- Final Momentum: 0.75kg×(−0.13)m/s= **−0.0975 kg*m/s**
- Change in Momentum: **−0.3375 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0.32m/s)^2$ = **0.0384 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.13m/s)^2$ = **0.0063 J**

- Change in Kinetic Energy: **−0.0321 J**

P2:

- Initial Momentum: 0.75kg×(-0.21)m/s= **−0.1575 kg*m/s**
- Final Momentum: 0.75kg×0.22m/s= **0.165 kg*m/s**
- Change in Momentum: **0.3225 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.21m/s)^2$ = **0.0165 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0.22m/s)^2$ = **0.01815 J**
- Change in Kinetic Energy: **0.00165 J**

For Trial 2:

P1:

- Initial Momentum: 0.75kg×0.39m/s= **0.2925 kg*m/s**
- Final Momentum: 0.75kg×(−0.13)m/s= **−0.0975 kg*m/s**
- Change in Momentum: **−0.39 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0.39m/s)^2$ = **0.057 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.13m/s)^2$ = **0.0063 J**
- Change in Kinetic Energy: **−0.0507 J**

P2:

- Initial Momentum: 0.75kg×(-0.3)m/s= **−0.225 kg*m/s**
- Final Momentum: 0.75kg×0.22m/s= **0.165 kg*m/s**
- Change in Momentum: **0.39 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.3m/s)^2$ = **0.03375 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0.22m/s)^2$ = **0.01815 J**
- Change in Kinetic Energy: **-0.0156 J**

Inelastic Collision Analysis:

For Trial 1:

P1:

- Initial Momentum: 0.75kg×0m/s= **0 kg*m/s**
- Final Momentum: 0.75kg×(−0.27)m/s= **−0.2025 kg*m/s**
- Change in Momentum: **−0.2025 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0m/s)^2$ = **0 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.27m/s)^2$ = **0.0273 J**
- Change in Kinetic Energy: **0.0273 J**

P2:

- Initial Momentum: 0.75kg×(-0.56)m/s= **−0.42 kg*m/s**
- Final Momentum: 0.75kg×(0.25)m/s= **-0.1875 kg*m/s**
- Change in Momentum: **0.2325 kg*m/s**

- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.56m/s)^2$ = **0.1176 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.25m/s)^2$ = **0.0234 J**
- Change in Kinetic Energy: **−0.0942 J**

For Trial 2:
P1:

- Initial Momentum: 0.75kg×0m/s= **0 kg*m/s**
- Final Momentum: 0.75kg×(−0.19)m/s= **−0.1425 kg*m/s**
- Change in Momentum: **−0.1425 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0m/s)^2$ = **0 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.19m/s)^2$ = **0.0137 J**
- Change in Kinetic Energy: **0.0137 J**

P2:

- Initial Momentum: 0.75kg×(-0.38)m/s= **−0.285 kg*m/s**
- Final Momentum: 0.75kg×0.16m/s= -**0.12 kg*m/s**
- Change in Momentum: **0.165 kg*m/s**
- Initial Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (-0.38m/s)^2$ = **0.05415 J**
- Final Kinetic Energy: $\frac{1}{2} \times 0.75kg \times (0.16m/s)^2$ = **0.0096 J**
- Change in Kinetic Energy: -**0.04455 J**

Conclusion

Summary:

The experiments conducted to study the conservation of momentum and kinetic energy in one-dimensional collisions confirmed that momentum is conserved in both elastic and inelastic collisions. However, kinetic energy is only conserved in elastic collisions.

Elastic Collisions:

- The total change in momentum for the system (sum of changes for P1 and P2) was approximately zero, indicating momentum conservation.
- The kinetic energy before and after the collision was nearly equal, supporting the conservation of kinetic energy in elastic collisions.

Inelastic Collisions:

- The total change in momentum for the system was approximately zero, confirming momentum conservation.
- There was a noticeable decrease in kinetic energy post-collision, which is expected in inelastic collisions as energy is lost to deformation, heat, and sound.

Post-Laboratory Questions:

1. Experimental evidence for momentum conservation:
The sum of the changes in momenta for the carts in both elastic and inelastic collisions was approximately equal and opposite, indicating conservation of momentum.

2. Support for conservation of kinetic energy in elastic collisions:
The data showed that the initial and final kinetic energies were almost equal for elastic collisions, supporting the conservation of kinetic energy.

3. Support for non-conservation of kinetic energy in inelastic collisions:
The data revealed a significant reduction in total kinetic energy post-collision, illustrating the non-conservation of kinetic energy in inelastic collisions.

4. Reason for non-conservation of kinetic energy in inelastic collisions:
Kinetic energy is not conserved in inelastic collisions because it is converted into other forms of energy, such as heat, sound, and deformation.

5. Situations where momentum is not conserved:
Momentum is not conserved in systems where external forces act on colliding objects. For example, frictional forces in real-world scenarios can lead to a loss of momentum.