A 320-g Air Track Cart Traveling At 1.25 M/s Suddenly Collides Elastically With A Stationary 270-g Cart.

A 320-g Air Track Cart Traveling At 1.25 M/s Suddenly Collides Elastically With A Stationary 270-g Cart.

Introduction

Understanding collision mechanics is fundamental in physics, especially when analyzing real-world interactions like the collision of air track carts. In this scenario, a 320-gram air track cart moving at 1.25 meters per second collides elastically with a stationary 270-gram cart. This incident exemplifies the principles of conservation of momentum and kinetic energy during elastic collisions. In this comprehensive guide, we'll explore the physics behind this collision, calculate the post-collision velocities, and discuss the implications and applications of elastic collisions.

Understanding the Scenario

The Components of the Collision

- Moving Cart (320 g): Initial velocity $v_{1i} = 1.25\, \text{m/s}$
- Stationary Cart (270 g): Initial velocity $v_{2i} = 0\, \text{m/s}$
- Masses: $m_1 = 0.320\, \text{kg}$, $m_2 = 0.270\, \text{kg}$

Assumptions

- The collision is perfectly elastic, meaning no kinetic energy is lost.
- The movement occurs along a single axis (linear collision).
- External forces like friction are negligible during the collision duration.

Fundamental Principles Governing the Collision

Conservation of Momentum

In an isolated system with no external forces, the total momentum before and after the collision remains constant:

$$
m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}
$$

- v_{1f} and v_{2f}: final velocities after collision.

Conservation of Kinetic Energy

For elastic collisions, the total kinetic energy remains unchanged:

$$
\frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2
$$

Calculating the Final Velocities

General Equations for Elastic Collisions

For one-dimensional elastic collisions, the final velocities can be derived using the following formulas:

$$
v_{1f} = \frac{(m_1 - m_2) v_{1i} + 2 m_2 v_{2i}}{m_1 + m_2}
$$

$$
v_{2f} = \frac{(m_2 - m_1) v_{2i} + 2 m_1 v_{1i}}{m_1 + m_2}
$$

Applying the Values

Given:

- $m_1 = 0.320\, \text{kg}$
- $m_2 = 0.270\, \text{kg}$
- $v_{1i} = 1.25\, \text{m/s}$
- $v_{2i} = 0\, \text{m/s}$

Calculations:

$$
v_{1f} = \frac{(0.320 - 0.270) \times 1.25 + 2 \times 0.270 \times 0}{0.320 + 0.270} = \frac{0.050 \times 1.25}{0.59} \approx \frac{0.0625}{0.59} \approx 0.106\, \text{m/s}
$$

$$
v_{2f} = \frac{(0.270 - 0.320) \times 0 + 2 \times 0.320 \times 1.25}{0.59} = \frac{0 + 0.80}{0.59} \approx 1.355\, \text{m/s}
$$

Post-Collision Velocities and Analysis

Final Velocities

- Moving Cart (initially 320 g): approximately 0.106 m/s (still moving forward but much slower).
- Stationary Cart (initially 270 g): approximately 1.355 m/s (now moving forward faster).

Insights

- The heavier cart (320 g) reduces its velocity significantly.
- The stationary lighter cart gains a substantial velocity, overtaking the initial speed of the moving cart.
- The total momentum before and after the collision remains conserved, confirming the calculations.

Energy Considerations

Kinetic Energy Before and After

- Initial KE:

$$
KE_{initial} = \frac{1}{2} \times 0.320 \times (1.25)^2 + 0 = 0.5 \times 0.320 \times 1.5625 \approx 0.25\, \text{J}
$$

- Final KE:

$$
KE_{final} = 0.5 \times 0.320 \times (0.106)^2 + 0.5 \times 0.270 \times (1.355)^2
$$

Calculations:

$$
\approx 0.5 \times 0.320 \times 0.0112 + 0.5 \times 0.270 \times 1.836
$$
$$
\approx 0.0018 + 0.248
$$
$$
\approx 0.25\, \text{J}
$$

The total kinetic energy remains approximately the same, confirming the elastic nature of the collision.

Real-World Applications of Elastic Collisions

Physics Education

Demonstrating elastic collisions with air track carts helps students visualize and understand fundamental physics principles like conservation laws.

Engineering and Design

Designing collision-safe vehicles and safety systems often relies on understanding elastic and inelastic collision dynamics.

Sports Science

Analyzing ball collisions in sports such as billiards, tennis, or baseball involves elastic collision principles.

Space Exploration

Understanding planetary collisions and spacecraft impacts requires knowledge of elastic collision mechanics.

Factors Influencing Collision Outcomes

Mass Ratios

The relative masses of colliding objects significantly affect their final velocities post-collision.

Initial Velocities

The initial speed and direction determine the energy and momentum distribution after the collision.

External Forces

Friction, air resistance, and other external factors can alter the idealized outcomes predicted by physics equations.

Collision Type

While this scenario assumes a perfectly elastic collision, many real-world collisions are inelastic, where kinetic energy is lost as heat, sound, or deformation.

Practical Considerations in Experiments

Ensuring Elasticity

- Use smooth, rigid surfaces to minimize energy loss.
- Conduct experiments in controlled environments to reduce external influences.

Accurate Measurements

- Precise timing and measurement tools ensure reliable data.
- Use high-speed cameras or motion sensors for velocity analysis.

Safety Precautions

- Secure the carts and track to prevent accidents.
- Keep a safe distance during high-velocity collisions.

Conclusion

The collision between a 320-gram air track cart moving at 1.25 m/s and a stationary 270-gram cart exemplifies the core principles of elastic collisions. By applying conservation of momentum and kinetic energy, we determined that post-collision, the lighter cart accelerates to approximately 1.355 m/s, while the heavier cart slows down to about 0.106 m/s. These calculations not only reinforce fundamental physics concepts but also have broad applications across science and engineering disciplines. Understanding such interactions enhances our ability to analyze and design systems that involve collisions, from educational demonstrations to advanced technological innovations.

References

- Serway, R. A., & Jewett, J. W. (2014). Physics for Scientists and Engineers. Cengage Learning.
- Halliday, D., Resnick, R., & Walker, J. (2013). Fundamentals of Physics. Wiley.
- HyperPhysics. (n.d.). Elastic Collisions. Georgia State University. Retrieved from hyperphysics.phy-astr.gsu.edu

---

This article provides a detailed analysis of elastic collision mechanics relevant for students, educators, and professionals interested in physics and engineering applications.

Frequently Asked Questions

What is the total momentum of the system before the collision?

The total momentum before the collision is the sum of the momenta of both carts: (1.25 m/s × 0.32 kg) + (0 m/s × 0.27 kg) = 0.4 kg·m/s.

What are the velocities of both carts immediately after an elastic collision?

In an elastic collision, the velocities can be calculated using conservation of momentum and kinetic energy. The 320-g cart will slow down or speed up depending on the collision, and the 270-g cart will gain velocity. Exact values require applying elastic collision equations.

How does the conservation of kinetic energy apply in this collision?

Since the collision is elastic, kinetic energy is conserved. The total kinetic energy before and after collision remains the same, allowing calculation of velocities post-collision.

What is the significance of the collision being elastic in this scenario?

An elastic collision means no kinetic energy is lost as heat or deformation, so the total kinetic energy of the system remains constant, simplifying calculations of post-collision velocities.

How do you calculate the final velocities of both carts after the elastic collision?

Use the formulas for elastic collisions: for two objects with masses $m1$ and $m2$, initial velocities $u1$ and $u2$, the final velocities $v1$ and $v2$ are given by: $v1 = [(m1 - m2)u1 + 2m2u2] / (m1 + m2)$, $v2 = [(m2 - m1)u2 + 2m1u1] / (m1 + m2)$.

What impact does the mass difference have on the post-collision velocities?

The mass difference affects how momentum and kinetic energy are redistributed; the lighter cart (Air Track Cart) tends to change velocity more significantly than the heavier one during the collision.

If the stationary cart starts to move after the collision, what does this tell us about the momentum transfer?

It indicates that momentum has been transferred from the moving cart to the stationary cart, resulting in the stationary cart gaining velocity while the original moving cart slows down.

How can this collision be used to demonstrate principles of conservation laws in physics?

This collision exemplifies conservation of momentum and kinetic energy, illustrating fundamental principles in physics through an elastic collision scenario involving different masses and velocities.

Additional Resources

A 320-g Air Track Cart Traveling At 1.25 m/s Suddenly Collides Elastically With A Stationary 270-g Cart

---

Introduction

In the realm of physics, collisions serve as fundamental phenomena that provide insight into the principles governing motion, energy conservation, and momentum transfer. The scenario involving a 320-g air track cart traveling at 1.25 m/s suddenly colliding elastically with a stationary 270-g cart presents an excellent case study for exploring these concepts practically and theoretically. This investigation aims to dissect the mechanics of this collision, analyze the resulting motion, and understand the underlying principles governing such interactions.

Context and Significance

Why Investigate Collisions?

Collisions are ubiquitous in both natural and engineered systems—from molecular interactions to vehicle crashes. Studying idealized elastic collisions allows physicists and engineers to validate models, design safer vehicles, and develop precise measurement techniques. The specific parameters—mass, initial velocity, and elastic nature—make this scenario particularly suitable for applying conservation laws and kinematic equations.

The Experimental Setup

The scenario assumes an air track setup, which minimizes frictional forces, effectively creating a near-ideal environment for studying elastic collisions. The key components include:

- Cart A: Mass = 320 grams (0.320 kg), initial velocity = 1.25 m/s
- Cart B: Mass = 270 grams (0.270 kg), initially stationary

The collision occurs along a frictionless track, ensuring that kinetic energy and momentum are conserved precisely during interaction.

Fundamental Principles in Play

Conservation of Momentum

In a closed system without external forces, the total momentum before and after the collision remains constant. Mathematically:

$$ m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f} $$

Where:

- m_1, m_2 are the masses of carts A and B respectively
- v_{1i}, v_{2i} are initial velocities
- v_{1f}, v_{2f} are velocities after collision

Conservation of Kinetic Energy

An elastic collision implies no kinetic energy is lost:

$$ \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2 $$

Elastic Collisions Characteristics

- Reversal of velocities in some cases
- Conservation of both kinetic energy and momentum
- Usually modeled for ideal systems without friction or deformation

---

Theoretical Analysis

Initial Conditions

Given:

- $m_1 = 0.320\,kg$
- $v_{1i} = 1.25\,m/s$
- $m_2 = 0.270\,kg$

- $v_{2i} = 0\,m/s$

Post-Collision Velocities

Applying the standard equations for elastic collisions between two objects moving along a straight line:

$$
v_{1f} = \frac{(m_1 - m_2)}{m_1 + m_2} v_{1i} + \frac{2 m_2}{m_1 + m_2} v_{2i}
$$

$$
v_{2f} = \frac{2 m_1}{m_1 + m_2} v_{1i} + \frac{(m_2 - m_1)}{m_1 + m_2} v_{2i}
$$

Substituting the known values:

$$
v_{1f} = \frac{(0.320 - 0.270)}{0.320 + 0.270} \times 1.25 + \frac{2 \times 0.270}{0.590} \times 0
$$

$$
v_{1f} = \frac{0.050}{0.590} \times 1.25 + 0
$$

$$
v_{1f} \approx 0.08475 \times 1.25 \approx 0.106\,m/s
$$

Similarly,

$$
v_{2f} = \frac{2 \times 0.320}{0.590} \times 1.25 + \frac{(0.270 - 0.320)}{0.590} \times 0
$$

$$
v_{2f} \approx 1.08475 \times 1.25 + (-0.08475) \times 0
$$

$$
v_{2f} \approx 1.356\,m/s
$$

Summary:

- Post-collision velocity of Cart A: approximately +0.107 m/s (still moving forward but at reduced speed)
- Post-collision velocity of Cart B: approximately +1.356 m/s (now moving forward, faster than initial)

This indicates that the stationary cart gains significant velocity, overtaking the initial cart's speed after the elastic collision.

Experimental Considerations and Validation

Practical Factors

While the theoretical calculations assume ideal conditions, real-world experiments involve factors such as:

- Residual friction on the air track
- Air resistance
- Minor imperfections in cart mass and surface contact
- Measurement inaccuracies in velocity and mass

Measurement Techniques

- Use of high-speed cameras or motion sensors to accurately record velocities before and after collision.
- Precise mass measurement using calibrated scales.
- Multiple trials to ensure consistency and account for experimental errors.

Data Collection and Analysis

Data from experiments can be compared with theoretical predictions to validate the conservation laws. Discrepancies can highlight the impact of non-ideal factors or measurement errors.

Deeper Insights: Momentum and Energy Transfer

Momentum Transfer

The collision results in:

- Cart A: velocity decreases from 1.25 m/s to approximately 0.107 m/s
- Cart B: velocity increases from 0 to approximately 1.356 m/s

This transfer is consistent with the conservation of momentum, which can be confirmed by summing initial and final momenta:

$$
\text{Initial total momentum} = (0.320 \times 1.25) + (0.270 \times 0) = 0.4\,kg \cdot m/s
$$
$$
\text{Final total momentum} = (0.320 \times 0.107) + (0.270 \times 1.356) \approx 0.034 + 0.366 = 0.4\,kg \cdot m/s
$$

Matching initial and final totals confirms momentum conservation.

Kinetic Energy Analysis

Calculating initial and final kinetic energies:

- Initial:

$$
KE_{initial} = \frac{1}{2} \times 0.320 \times (1.25)^2 = 0.25\,J
$$

- Final:

$$
KE_{final} = \frac{1}{2} \times 0.320 \times (0.107)^2 + \frac{1}{2} \times 0.270 \times (1.356)^2 \approx 0.00183 + 0.247 \approx 0.249\,J
$$

Close agreement demonstrates near-perfect energy conservation, consistent with an elastic collision.

Broader Implications and Applications

Educational Value

This scenario serves as an excellent teaching tool for physics students to visualize and calculate the effects of elastic collisions, reinforcing concepts like conservation laws.

Engineering and Design

Understanding elastic collisions guides the design of systems where energy transfer efficiency is critical, such as in collision mitigation devices or particle accelerators.

Scientific Research

High-precision collision studies underpin research in molecular physics and materials science, where atomic and subatomic particles undergo elastic interactions.

Limitations and Further Research

While the idealized scenario offers clarity, real-world systems often involve inelastic effects:

- Energy loss due to internal deformation
- Frictional forces not eliminated entirely
- Non-ideal contact surfaces

Future research could involve:

- Quantifying energy losses in real-world experiments
- Extending models to inelastic collisions
- Studying multi-body collision interactions

Conclusion

The analysis of A 320-g air track cart traveling at 1.25 m/s suddenly colliding elastically with a stationary 270-g cart exemplifies fundamental physics principles with clarity and precision. Through theoretical calculations, experimental validation, and critical analysis, it highlights the conservation of momentum and kinetic energy. Such investigations not only deepen our understanding of collision dynamics but also have profound implications across scientific disciplines and engineering applications. As technology advances, refining experimental techniques will continue to shed light on the nuances of collision phenomena, bridging idealized models with real-world complexities.

A 320 G Air Track Cart Traveling At 1 25 M S Suddenly Collides Elastically With A Stationary 270 G Cart

A 320 G Air Track Cart Traveling At 1 25 M S Suddenly Collides Elastically With A Stationary 270 G Cart

Related Articles

- A Declaration Of The Immediate Causes Which Induce And Justify The Secession Of The State Of Mississippi
- A Sample Of 238/92U Is Decaying At A Rate Of 450 Decays/s . The Half-life Is 4.468109yr.What Is The Mass
- A Metal Sphere Of Radius R Carries A Total Charge Q. What Is The Force Of Repulsion Between The Northern

Back to Home