A 2,100 Kg Car Drives East Toward A 55 Kg Shopping Cart That Has A Velocity Of 0.50 M/s West. The Two

A 2,100 Kg Car Drives East Toward A 55 Kg Shopping Cart That Has A Velocity Of 0.50 M/s West. The Two are engaged in a dynamic interaction that exemplifies fundamental principles of physics, particularly the laws of conservation of momentum and energy. Understanding this scenario involves analyzing the motion of both objects, their initial velocities, and how their interaction affects their subsequent velocities and directions. This article delves into the physics behind such an event, offering a comprehensive explanation suitable for students, enthusiasts, and anyone interested in the mechanics of motion.

Understanding the Scenario

In this situation, a large car, weighing 2,100 kilograms, is moving eastward. Simultaneously, a shopping cart, significantly lighter at 55 kilograms, is moving westward at a velocity of 0.50 meters per second. The core physics questions include:

- What happens when the car and the shopping cart collide or interact?
- How does their momentum change during the interaction?
- What are their velocities after the interaction, assuming an elastic or inelastic collision?

Before analyzing these questions, it's essential to understand the fundamental concepts involved, such as momentum, velocity, and the types of collisions.

Fundamental Concepts: Momentum and Collisions

Momentum

Momentum, represented as p, is a vector quantity defined as the product of an object's mass and its velocity:

- $p = m \times v$

where:
- m is the mass of the object,
- v is its velocity (direction included).

Because momentum is a vector, the direction of movement is crucial. An object moving eastward has positive momentum, while one moving westward has negative momentum (if east is taken as positive).

Types of Collisions

Collisions are typically classified into:
- Elastic Collisions: Both kinetic energy and momentum are conserved.
- Inelastic Collisions: Momentum is conserved, but kinetic energy is not necessarily conserved.
- Perfectly Inelastic Collisions: The colliding objects stick together afterward, moving with a common velocity.

In real-world scenarios like a car hitting a shopping cart, the collision is usually inelastic, but for simplification, physics problems often assume elastic or perfectly inelastic conditions.

Analyzing the Initial Conditions

Let's define the initial velocities:
- Car: moving eastward, velocity v_1 (positive value, e.g., +V m/s)
- Shopping cart: moving westward, velocity v_2 = -0.50 m/s

The masses are:
- Car: m_1 = 2,100 kg
- Shopping cart: m_2 = 55 kg

The initial momenta are:
- $p_1\_initial = m_1 \times v_1$
- $p_2\_initial = m_2 \times v_2$ = 55 kg × (-0.50 m/s) = -27.5 kg·m/s

Total initial momentum:
- $p\_total\_initial = p_1\_initial + p_2\_initial$

Since the car's initial velocity isn't specified in the problem, we assume it's moving at some velocity v_1 toward the east, which can be either given or considered as a variable for analysis.

Applying Conservation of Momentum

The principle of conservation of momentum states that if no external forces act on the system, the total momentum before and after the collision remains constant.

$$
p_{total\_initial} = p_{total\_final}
$$

Depending on the nature of the collision, the final velocities can be calculated.

Scenario 1: Elastic Collision

In an elastic collision, both kinetic energy and momentum are conserved.

The formulas for final velocities in a one-dimensional elastic collision are:

$$
v_{1f} = \frac{(m_1 - m_2) v_1 + 2 m_2 v_2}{m_1 + m_2}
$$

$$
v_{2f} = \frac{(m_2 - m_1) v_2 + 2 m_1 v_1}{m_1 + m_2}
$$

Where:
- v_{1f} = final velocity of the car,
- v_{2f} = final velocity of the shopping cart.

Note: To compute actual values, the initial velocity of the car v_1 must be known.

Scenario 2: Perfectly Inelastic Collision

If the car and shopping cart stick together after collision, they move with a common velocity v_f:

$$
v_f = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}
$$

Again, the initial velocity v_1 of the car is needed for calculations.

Calculating the Outcomes

Suppose, for illustration, the car is moving eastward at 10 m/s ($v_1 = +10\, \text{m/s}$). Let's analyze the inelastic collision scenario:

$$
v_f = \frac{(2,100\, \text{kg} \times 10\, \text{m/s}) + (55\, \text{kg} \times -0.50\, \text{m/s})}{2,100\, \text{kg} + 55\, \text{kg}} = \frac{21,000 - 27.5}{2155} \approx \frac{20,972.5}{2155} \approx 9.74\, \text{m/s}
$$

The final velocity is approximately 9.74 m/s eastward, indicating that after collision, the combined mass moves eastward at nearly the initial speed of the car, with a slight reduction due to the shopping cart's initial westward velocity.

Real-World Implications and Safety Considerations

Understanding the physics behind such interactions is crucial for vehicle safety design, accident analysis, and pedestrian safety measures. For instance:

- Impact forces are related to the change in momentum during collisions.
- Crashworthiness depends on how energy is absorbed during inelastic collisions.
- Vehicle design accounts for the mass and velocity to mitigate injury and damage.

In this context, the large mass of the car significantly influences the outcome, often resulting in minimal change in its velocity, whereas the lighter shopping cart experiences a more noticeable change.

Further Applications of Momentum Principles

The principles illustrated in this scenario extend to various fields:

- Automotive crash analysis
- Sports physics, such as collisions in football or hockey
- Aerospace engineering, analyzing satellite or spacecraft impacts
- Robotics, where momentum transfer affects movement and stability

Understanding how objects transfer momentum during collisions enables engineers and scientists to design safer vehicles, improve safety protocols, and develop better predictive models for real-world interactions.

Conclusion

Analyzing a scenario where a 2,100 kg car drives east toward a 55 kg shopping cart moving west at 0.50 m/s involves applying fundamental physics concepts like momentum conservation, collision types, and energy transfer. Whether considering elastic or inelastic collisions, the principles remain consistent: momentum before and after the interaction must be conserved unless external forces intervene.

This understanding not only clarifies how different objects interact in motion but also emphasizes the importance of physics in everyday life, from transportation safety to sports and engineering. By mastering these fundamental principles, students and professionals can better interpret complex motion scenarios and contribute to innovations in safety and technology.

Keywords: physics, momentum, collision analysis, elastic collision, inelastic collision, vehicle safety, conservation of momentum, impact forces, motion analysis

Frequently Asked Questions

What is the initial momentum of the 2,100 kg car moving east?

The initial momentum of the car is calculated by multiplying its mass by its velocity. Since the velocity is eastward and not specified, assuming it is moving at a certain velocity v, initial momentum = 2100 kg × v (east). If the velocity is unknown, further data is needed.

How do you determine the momentum of the shopping cart moving west at 0.50 m/s?

The momentum of the shopping cart is calculated as mass times velocity: 55 kg × (-0.50 m/s) = -27.5 kg·m/s. The negative sign indicates it is moving west.

What is the significance of the negative sign in the shopping cart's momentum?

The negative sign indicates the direction of the shopping cart's velocity is opposite to the chosen positive direction (east). It signifies westward movement.

If the car and shopping cart collide and stick together, what is their combined velocity after impact?

Using conservation of momentum: (mass of car × velocity of car) + (mass of cart × velocity of cart) = combined mass × combined velocity. Without the car's initial velocity, the exact combined velocity cannot be calculated. If known, plug in the values to find the final velocity.

What principle explains the interaction between the car and shopping cart in this scenario?

The law of conservation of momentum states that in an isolated system, the total momentum before and after

the collision remains constant, explaining their interaction.

What potential outcomes can result from the collision between the car and shopping cart?

Depending on the speed and nature of the collision, outcomes may include the cart moving with the car, the cart bouncing back, or the two sticking together and moving with a common velocity, with possible damage or deformation in real-world scenarios.

Additional Resources

In-Depth Analysis of a Car and Shopping Cart Collision: Momentum, Kinetics, and Conservation Principles

When exploring the dynamics of everyday objects—such as a large car and a shopping cart—physics offers a fascinating window into how mass, velocity, and energy interplay during interactions. Imagine a scenario where a 2,100 kg car moves eastward and approaches a 55 kg shopping cart that is traveling westward at a speed of 0.50 m/s. As these two objects come into contact, understanding the underlying physics can reveal insights into momentum conservation, collision types, and energy transfer. This detailed review dissects this scenario step by step, covering foundational concepts, calculations, and implications.

---

1. Fundamental Concepts: Momentum, Mass, and Velocity

Before diving into calculations, it's essential to clarify the core physical principles involved:

a. Momentum (p)

- Defined as the product of an object's mass (m) and its velocity (v).
- Mathematically: $p = m \times v$
- Momentum is a vector quantity, possessing both magnitude and direction.
- It characterizes the motion of an object and is conserved in isolated systems during collisions.

b. Conservation of Momentum

- In an isolated system with no external forces, the total momentum before interaction equals the total momentum after.
- This principle is fundamental in predicting outcomes of collisions—whether elastic or inelastic.

c. Types of Collisions

- Elastic Collisions: Kinetic energy is conserved.
- Inelastic Collisions: Kinetic energy is not conserved, but momentum remains conserved.
- Perfectly Inelastic Collisions: Objects stick together after collision, moving with a common velocity.

---

2. Establishing the Scenario: Directions and Sign Conventions

To perform precise calculations, define a coordinate system:

- Assign eastward as the positive direction.
- Assign westward as the negative direction.

In this setup:
- Car velocity: $v_{car} = +v_{car}$ (unknown magnitude, but moving east)
- Shopping cart velocity: $v_{cart} = -0.50 \, \mathrm{m/s}$ (westward)

---

3. Calculating the Initial Momenta

Given data:
- Mass of car, $m_{car} = 2100 \, \mathrm{kg}$
- Mass of shopping cart, $m_{cart} = 55 \, \mathrm{kg}$
- Shopping cart velocity, $v_{cart} = -0.50 \, \mathrm{m/s}$

Let's denote the car's velocity as v_{car}, which is unknown but likely significantly larger than 0.50 m/s.

Initial momentum of the car:
$$p_{car} = m_{car} \times v_{car}$$

Initial momentum of the shopping cart:
$$p_{cart} = m_{cart} \times v_{cart} = 55 \, \mathrm{kg} \times (-0.50 \, \mathrm{m/s}) = -27.5 \, \mathrm{kg \, m/s}$$

The negative sign indicates the cart is moving westward.

---

4. Analyzing the Collision Dynamics

The critical factor here is the magnitude of v_{car}. Typical speeds for a car approaching a shopping cart would range from 10 to 30 m/s (roughly 36 to 108 km/h). For a meaningful analysis, let's assume a realistic scenario:

Assumption: The car is moving eastward at 20 m/s.

This assumption allows for concrete calculations, but the analysis can be generalized for other velocities.

Calculating the car's momentum:
$$p_{car} = 2100 \, \mathrm{kg} \times 20 \, \mathrm{m/s} = 42{,}000 \, \mathrm{kg \, m/s}$$

Total initial momentum:
$$P_{initial} = p_{car} + p_{cart} = 42{,}000 \, \mathrm{kg \, m/s} + (-27.5 \, \mathrm{kg \, m/s}) = 41{,}972.5 \, \mathrm{kg \, m/s}$$

This enormous initial momentum indicates that the system's overall motion is dominated by the car.

---

5. Post-Collision Scenarios and Calculations

The collision outcome depends on whether the objects stick together or bounce apart, which relates to the coefficient of restitution and energy considerations.

a. Perfectly Inelastic Collision (Objects Sticking Together)

- Final velocity (v_f) is determined by conservation of momentum:

$$m_{car} \times v_{car} + m_{cart} \times v_{cart} = (m_{car} + m_{cart}) \times v_f$$

- Solving for v_f:

$$v_f = \frac{m_{car} \times v_{car} + m_{cart} \times v_{cart}}{m_{car} + m_{cart}}$$

Plugging in the numbers:

$$v_f = \frac{(2100)(20) + (55)(-0.50)}{2100 + 55} = \frac{42,000 - 27.5}{2155}$$

$$v_f = \frac{41,972.5}{2155} \approx 19.48\, \mathrm{m/s}$$

Interpretation:
- The combined object moves eastward at approximately 19.48 m/s.
- The shopping cart's initial velocity has a negligible effect due to the large mass disparity.

b. Elastic Collision Considerations

- If the collision were elastic, kinetic energy would be conserved.
- However, in real-world scenarios involving a car and shopping cart, such collisions are almost always inelastic because objects deform and energy dissipates as heat, sound, and deformation.

---

6. Energy Analysis: Kinetic Energy Before and After

Calculating the initial kinetic energies:

Car:
$$KE_{car} = \frac{1}{2} m_{car} v_{car}^{2} = 0.5 \times 2100 \times (20)^2 = 0.5 \times 2100 \times 400 = 420,000\, \mathrm{J}$$

Shopping cart:
$$KE_{cart} = 0.5 \times 55 \times (0.50)^2 = 0.5 \times 55 \times 0.25 = 6.875\, \mathrm{J}$$

Total initial KE:
$$KE_{initial} \approx 420,006.88\, \mathrm{J}$$

Post-collision KE (assuming inelastic sticking):

$$KE_{final} = \frac{1}{2} (m_{car} + m_{cart}) v_f^{2}$$

$$ KE_{final} = 0.5 \times 2155 \times (19.48)^2 $$

$$ KE_{final} \approx 0.5 \times 2155 \times 379.6 \approx 0.5 \times 2155 \times 379.6 $$

$$ KE_{final} \approx 1,025,278\, \mathrm{J} $$

This suggests an inconsistency because the final kinetic energy exceeds the initial total kinetic energy, which cannot happen unless external energy is added. This indicates that the assumption of a perfectly inelastic collision at these velocities is not physically accurate, and a perfectly elastic model would contradict energy dissipation in real collisions.

In reality, most of the initial kinetic energy would be dissipated via deformation, heat, and sound during the collision, resulting in a final kinetic energy significantly less than the initial.

---

7. Implications of the Momentum and Energy Transfer

The primary takeaway is how the large mass disparity influences the collision:

- The car's velocity remains nearly unchanged after impact due to its large inertia.
- The shopping cart experiences a significant velocity change, potentially bouncing back or moving along with the car depending on the collision's elasticity.
- The momentum transfer predominantly affects the shopping cart, causing it to potentially slide or be pushed backward.

---

8. Practical Considerations and Real-World Application

While the theoretical calculations provide a framework, real-world collisions are influenced by factors such as:

- Frictional forces: Between the cart and the ground, and between the car tires and the road.
- Deformation of objects: The cart and car may deform, absorbing energy.
- Collision angle: The scenario assumes a head-on or direct contact; oblique impacts alter outcomes.
- External forces: Wind, road conditions, and driver reactions complicate the interaction.

In practical terms, the collision would likely result in the cart being pushed backward or knocked over, but the car would continue with minimal change in velocity, demonstrating the conservation of momentum and the influence of mass ratios.

---

9. Broader Physics Concepts Highlighted

This scenario encapsulates several key physics principles:

- Conservation of Momentum: Regardless of the collision type, total

A 2 100 Kg Car Drives East Toward A 55 Kg Shopping Cart That Has A Velocity Of 0 50 M S West The Two

A 2 100 Kg Car Drives East Toward A 55 Kg Shopping Cart That Has A Velocity Of 0 50 M S West The Two

Related Articles

- When Kenzie Calls About An Efficiency For Rent, The Property Manager Asks If She Has Kids. She Tells
- A Circular Coil Of Radius 5.0 Cm Is Wound With Five Turns And Carries A Current Of 5.0 A. If The Coil
- (2) State The Amplitude, Period, Phase Shift, And Vertical Shift Of F(x)=4sin(X1/3)+2 (3) If X=sin^1

Back to Home