

A 3.6 Kg Block Moving With A Velocity Of 4.3 M/s Makes An Elastic Collision With A Stationary Block Of

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Understanding the dynamics of collisions is fundamental in physics, especially when analyzing the behavior of objects during interactions. In this article, we delve into the scenario where a 3.6 kg block moving at a velocity of 4.3 m/s collides elastically with a stationary block. We will explore the principles of elastic collisions, apply conservation laws, and examine the resulting velocities and energies post-collision. This comprehensive analysis aims to clarify the mechanics involved and provide a solid understanding of such collision phenomena.

Fundamentals of Elastic Collisions

What Is an Elastic Collision?

An elastic collision is a type of collision where the total kinetic energy and momentum of the system are conserved. Unlike in inelastic collisions, where some kinetic energy is transformed into other forms of energy such as heat or deformation, elastic collisions preserve the total kinetic energy.

Key features of elastic collisions include:

- Conservation of momentum.
- Conservation of kinetic energy.
- No permanent deformation or generation of heat.

Examples in Real Life

Elastic collisions are common in the microscopic world and certain macroscopic situations:

- Gas particle collisions.
- Billiard balls striking each other.
- Atomic and subatomic particle interactions.

Analyzing the Collision Scenario

Initial Conditions and Known Data

Let's define the known parameters:

- Mass of the moving block, $m_1 = 3.6 \text{ kg}$

- Initial velocity of moving block, $(v_1 = 4.3, \text{m/s})$
- Mass of stationary block, $(m_2 = ?)$ (to be specified or assumed)
- Initial velocity of stationary block, $(v_2 = 0, \text{m/s})$

Note: For a complete analysis, the mass of the stationary block (m_2) must be known or assumed. For illustration, we will consider scenarios with different (m_2) values.

Assumption for the Second Block

Suppose the stationary block has a mass $(m_2 = 2.0, \text{kg})$. This value can be adjusted based on the specific problem context.

Applying Conservation Laws

Conservation of Momentum

In an elastic collision, momentum before and after impact remains constant:

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$

Where:

- (v_1') and (v_2') are the velocities of blocks 1 and 2 after collision.

Given $(v_2 = 0)$, the equation simplifies to:

$$m_1 v_1 = m_1 v_1' + m_2 v_2'$$

Conservation of Kinetic Energy

Similarly, kinetic energy before and after collision is conserved:

$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2$$

With $(v_2 = 0)$, this reduces to:

$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2$$

Calculating Final Velocities

Using Standard Elastic Collision Formulas

For one-dimensional elastic collisions, the velocities after collision are given by:

$$v_1' = \frac{(m_1 - m_2)}{m_1 + m_2} v_1$$

$$v_2' = \frac{2 m_1}{m_1 + m_2} v_1$$

Note: These formulas assume the second object is initially at rest and motion occurs along a straight line.

Calculating with the Assumed Masses

Using $(m_1 = 3.6, \text{kg})$, $(v_1 = 4.3, \text{m/s})$, and $(m_2 = 2.0, \text{kg})$:

$$v_1' = \frac{(3.6 - 2.0)}{3.6 + 2.0} \times 4.3 = \frac{1.6}{5.6} \times 4.3 \approx 1.23, \text{m/s}$$

$$v_2' = \frac{2 \times 3.6}{3.6 + 2.0} \times 4.3 = \frac{7.2}{5.6} \times 4.3 \approx 5.54, \text{m/s}$$

Results:

- The moving block slows down from 4.3 m/s to approximately 1.23 m/s after collision.
- The stationary block gains speed, moving at approximately 5.54 m/s.

Note: The directions of motion are assumed to be along the same line, and velocities are scalar quantities with positive indicating motion in the initial direction.

Energy and Momentum Verification

Check of Momentum Conservation

Initial momentum:

$$p_{\text{initial}} = m_1 v_1 + m_2 v_2 = 3.6 \times 4.3 + 2.0 \times 0 = 15.48, \text{kg}\cdot\text{m/s}$$

\]

Final momentum:

\[

$$p_{\text{final}} = m_1 v_1' + m_2 v_2' = 3.6 \times 1.23 + 2.0 \times 5.54 \approx 4.43 + 11.08 = 15.51 \text{ kg}\cdot\text{m/s}$$

\]

The slight discrepancy is due to rounding; in precise calculations, momentum is conserved.

Check of Kinetic Energy Conservation

Initial kinetic energy:

\[

$$KE_{\text{initial}} = \frac{1}{2} \times 3.6 \times 4.3^2 \approx 0.5 \times 3.6 \times 18.49 \approx 33.28 \text{ J}$$

\]

Final kinetic energy:

\[

$$KE_{\text{final}} = 0.5 \times 3.6 \times 1.23^2 + 0.5 \times 2.0 \times 5.54^2 \approx 0.5 \times 3.6 \times 1.51 + 1.0 \times 30.69 \approx 2.71 + 30.69 = 33.4 \text{ J}$$

\]

Again, minor differences are due to rounding, but overall energy is conserved.

Implications and Applications

Understanding Collisions in Physics

The analysis demonstrates how elastic collisions adhere to conservation principles and how velocities change based on masses. This understanding is crucial in:

- Designing collision-based experiments.
- Analyzing particle interactions.
- Engineering systems involving collision dynamics.

Real-World Applications

Knowledge of elastic collisions applies in various fields:

- Automotive safety testing.
- Sports physics, such as billiards or tennis.
- Satellite and space debris collision analysis.
- Particle accelerators.

Advanced Topics and Considerations

Variable Masses and Multiple Collisions

In more complex scenarios, such as variable mass systems or multiple sequential collisions, the principles extend but require more advanced tools like differential equations or simulation software.

Elastic Collisions in Two or Three Dimensions

While this analysis assumes linear motion, elastic collisions can also occur in two or three dimensions, involving vector components and angles of collision.

Energy Loss in Inelastic Collisions

Real-world collisions often involve some energy loss, making inelastic collision analysis necessary for comprehensive understanding.

Conclusion

In the scenario where a 3.6 kg block moving at 4.3 m/s collides elastically with a stationary block, the fundamental laws of physics—conservation of momentum and kinetic energy—allow us to precisely calculate the velocities of the blocks post-collision. Assuming the stationary block has a mass of 2.0 kg, the moving block slows down to approximately 1.23 m/s, while the stationary block accelerates to about 5.54 m/s. This analytical approach illustrates the core principles governing elastic collisions and underscores their significance in both theoretical and practical contexts.

Understanding such collision dynamics is vital across scientific disciplines and engineering applications, providing insights that inform safety standards, experimental designs, and technological innovations. By mastering these principles, students and professionals can better interpret and predict the behavior of objects during elastic interactions, fostering advancements in physics and related fields.

Frequently Asked Questions

What is the principle behind elastic collisions between two blocks?

Elastic collisions conserve both kinetic energy and momentum, meaning the total kinetic energy and momentum before and after the collision remain unchanged.

How can we calculate the velocity of the stationary block after

an elastic collision?

Using conservation of momentum and kinetic energy, the velocity of the stationary block after collision can be determined with the formulas derived from these principles, often resulting in the moving block transferring some velocity to the stationary one.

In an elastic collision between a moving 3.6 kg block at 4.3 m/s and a stationary block, what factors influence the final velocities of both blocks?

The initial velocity and mass of the moving block, as well as the mass of the stationary block, determine how the velocities are redistributed after the collision, considering conservation laws.

What is the typical outcome in terms of velocity for the stationary block after being hit by a 3.6 kg block moving at 4.3 m/s in an elastic collision?

In an elastic collision, the stationary block will typically acquire a velocity proportional to the initial velocity of the moving block, depending on the mass ratio, often resulting in the blocks exchanging velocities if their masses are equal.

How does the mass of the blocks affect the outcome of an elastic collision in this scenario?

The mass ratio determines how momentum and kinetic energy are distributed; if the blocks have equal mass, they tend to swap velocities, while differing masses result in more complex velocity distributions post-collision.

Additional Resources

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In the realm of classical mechanics, understanding collisions provides crucial insights into how kinetic energy and momentum are conserved and transferred between objects. Recently, a scenario involving a moving block colliding elastically with a stationary counterpart has garnered interest among physics enthusiasts and students alike. This case study explores the dynamics of such a collision, focusing on the principles that govern elastic interactions, the calculations involved, and the broader implications of these fundamental physical phenomena.

Understanding the Scenario: The Moving and Stationary Blocks

Imagine a solid, uniform block with a mass of 3.6 kilograms moving along a frictionless surface at a velocity of 4.3 meters per second. At the moment of collision, this moving block encounters a stationary block—meaning its initial velocity is zero. The key parameters are:

- Mass of moving block (m_1): 3.6 kg
- Initial velocity of moving block (v_1): 4.3 m/s
- Mass of stationary block (m_2): Unknown (assumed to be of similar or different mass)
- Initial velocity of stationary block (v_2): 0 m/s

The primary goal is to analyze the outcome of this elastic collision, including how the velocities of both blocks change post-collision, and to understand the conservation laws at play.

Fundamentals of Elastic Collisions

Before delving into calculations, it's essential to grasp what distinguishes elastic collisions from inelastic ones.

What Is an Elastic Collision?

An elastic collision is one in which both kinetic energy and momentum are conserved. Unlike inelastic collisions, where part of the energy is transformed into deformation, heat, or sound, elastic collisions are idealized scenarios often used to model interactions at the atomic or molecular levels, or in perfectly elastic macroscopic systems.

Key Principles:

- Conservation of Momentum: The total momentum before and after collision remains unchanged.
- Conservation of Kinetic Energy: The total kinetic energy before and after collision remains unchanged.

Mathematically, for two objects:

Momentum:

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Kinetic Energy:

$$(1/2)m_1v_1^2 + (1/2)m_2v_2^2 = (1/2)m_1v_1'^2 + (1/2)m_2v_2'^2$$

Where:

- v_1 and v_2 are velocities before collision
- v_1' and v_2' are velocities after collision

Analyzing the Collision: Assumptions and Known Data

To proceed with concrete calculations, certain assumptions are made:

- The surface is frictionless, eliminating energy loss due to friction.
- The collision is perfectly elastic.
- The mass of the stationary block (m_2) is known or can be estimated.
- The initial velocity of the stationary block is zero.

Suppose the stationary block has a mass similar to or different from the moving block; the calculations will differ accordingly. For illustration, let's analyze two scenarios:

1. Equal masses: $m_2 = 3.6 \text{ kg}$
2. Different masses: $m_2 = 2.0 \text{ kg}$ (for diversity)

Scenario 1: Equal Masses ($m_1 = m_2 = 3.6 \text{ kg}$)

Post-Collision Velocities

In elastic collisions involving equal masses, the objects effectively exchange velocities.

Result:

- The moving block (initially at 4.3 m/s) comes to rest after collision.
- The stationary block gains the original velocity of the moving block, moving at 4.3 m/s.

Derivation:

Using conservation of momentum:

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$
$$3.6 \times 4.3 + 3.6 \times 0 = 3.6 \times v_1' + 3.6 \times v_2'$$

Simplifies to:

$$15.48 = 3.6(v_1' + v_2')$$

Conservation of kinetic energy:

$$(1/2) \times 3.6 \times (4.3)^2 = (1/2) \times 3.6 \times (v_1')^2 + (1/2) \times 3.6 \times (v_2')^2$$

Calculating initial KE:

$$(0.5) \times 3.6 \times (18.49) \approx 33.28 \text{ Joules}$$

Since masses are equal and collision is elastic:

$$v_1' = v_2 \text{ (initial velocity of the stationary block),}$$
$$v_2' = v_1 \text{ (initial velocity of the moving block).}$$

Final velocities:

- Block 1: 0 m/s (comes to rest)
- Block 2: 4.3 m/s (moves away with initial velocity of block 1)

This exchange is a classical result for equal masses in elastic collisions.

Scenario 2: Different Masses ($m_2 = 2.0$ kg)

When the masses differ, the final velocities are derived from the conservation equations without the simplifying assumption of equal exchange.

Calculations:

Using the standard formulas for elastic collisions:

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

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

Plugging in the values:

- $m_1 = 3.6$ kg
- $m_2 = 2.0$ kg
- $v_1 = 4.3$ m/s
- $v_2 = 0$ m/s

Calculating v_1' :

$$v_1' = \frac{(3.6 - 2.0)}{3.6 + 2.0} \times 4.3 + \frac{2 \times 2.0}{3.6 + 2.0} \times 0$$

$$v_1' = \frac{1.6}{5.6} \times 4.3 + 0 \approx 0.2857 \times 4.3 \approx 1.228 \text{ m/s}$$

Calculating v_2' :

$$v_2' = \frac{2 \times 3.6}{5.6} \times 4.3 + \frac{(2.0 - 3.6)}{5.6} \times 0$$

$$v_2' = \frac{7.2}{5.6} \times 4.3 + 0 \approx 1.2857 \times 4.3 \approx 5.529 \text{ m/s}$$

Interpretation:

- The moving block (mass 3.6 kg) slows down from 4.3 m/s to approximately 1.23 m/s in the original direction.
- The stationary block (mass 2.0 kg) is propelled forward at approximately 5.53 m/s, faster than the initial velocity of the moving block.

Kinetic Energy Check:

Initial KE:

$$\frac{1}{2} \times 3.6 \times (4.3)^2 \approx 33.28 \text{ Joules}$$

Final KE:

$$\begin{aligned} &\frac{1}{2} \times 3.6 \times (1.228)^2 + \frac{1}{2} \times 2.0 \times (5.529)^2 \\ &= 1.8 \times 1.509 + 1.0 \times 30.56 \approx 2.716 + 30.56 \approx 33.28 \text{ Joules} \end{aligned}$$

Total kinetic energy remains conserved, confirming the elastic nature.

Implications and Broader Context

The detailed calculations showcase fundamental physics principles that are widely applicable beyond simple laboratory setups. Elastic collisions are foundational in understanding phenomena ranging from atomic interactions to macroscopic systems like billiards or planetary motion.

Real-World Applications:

- Particle Physics: Elastic collisions at the atomic level help probe the structure of matter.
- Engineering: Impact analysis in vehicle safety design often assumes elastic or inelastic collision models.
- Astrophysics: Collisional dynamics influence planetary formation and celestial body interactions.

Limitations and Assumptions:

While idealized, these models assume perfect elasticity and no external forces like friction or air resistance. Real-world collisions often involve some energy loss, making inelastic models more accurate in many cases.

Conclusion: The Power of Conservation Laws

The collision between a moving 3.6 kg block and a stationary block exemplifies how fundamental conservation laws govern physical interactions. Whether the blocks have equal or different masses, the principles of momentum and kinetic energy conservation allow precise prediction of post-collision velocities. These insights not only deepen our understanding of classical mechanics but also underpin numerous technological and scientific applications, highlighting the

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