

A 50.0-g Super Ball Traveling At 25.5 M/s Bounces Off A Brick Wall And Rebounds At 21.0 M/s. A High-speed

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Introduction

Imagine holding a super ball—a small, high-bounce rubber ball—before launching it toward a brick wall at a significant speed. Upon impact, the ball hits the wall and bounces back with a slightly reduced speed. This simple scenario is a classic example illustrating fundamental principles of physics, such as momentum, collision mechanics, and energy conservation. Understanding the dynamics of such collisions not only enhances our grasp of physics concepts but also finds practical applications in sports, engineering, and safety design.

In this article, we will analyze the motion of a 50.0-gram super ball traveling at an initial speed of 25.5 meters per second, bouncing off a brick wall, and rebounding at 21.0 meters per second. We will explore the concepts of momentum change, coefficient of restitution, kinetic energy transfer, and the forces involved during the collision. Additionally, we will delve into the significance of these principles in real-world contexts and provide detailed calculations to deepen understanding.

Understanding the Scenario: The Super Ball's Motion

Basic Parameters

- Mass of the ball: 50.0 grams = 0.050 kg
- Initial velocity (before impact): 25.5 m/s (toward the wall)
- Final velocity (after impact): 21.0 m/s (away from the wall)

Key Assumptions

- The ball hits the wall directly, perpendicular to its surface.
- The wall is immovable and rigid, meaning its motion is negligible during impact.
- Air resistance and other external forces are negligible during the collision.
- The collision is elastic or partially elastic, depending on energy conservation.

Analyzing the Collision: Momentum and Energy Considerations

1. Momentum Change During Collision

Momentum, defined as mass times velocity ($p = mv$), is central to understanding collision dynamics. The change in momentum (Δp) is

given by:

$$\Delta p = p_{\text{final}} - p_{\text{initial}}$$

Since the ball reverses direction after hitting the wall, its velocity changes from positive to negative relative to the initial direction.

- Initial momentum:

$$p_{\text{initial}} = m \times v_{\text{initial}} = 0.050 \text{ kg} \times 25.5 \text{ m/s} = 1.275 \text{ kg}\cdot\text{m/s}$$

- Final momentum:

$$p_{\text{final}} = m \times v_{\text{final}} = 0.050 \text{ kg} \times (-21.0 \text{ m/s}) = -1.05 \text{ kg}\cdot\text{m/s}$$

(Note: The negative sign indicates the opposite direction.)

- Change in momentum:

$$\Delta p = -1.05 \text{ kg}\cdot\text{m/s} - 1.275 \text{ kg}\cdot\text{m/s} = -2.325 \text{ kg}\cdot\text{m/s}$$

This negative value signifies that the ball's momentum decreases by 2.325 kg·m/s in the initial direction due to the collision.

2. Coefficient of Restitution

The coefficient of restitution (e) quantifies how elastic a collision is, ranging from 0 (perfectly inelastic) to 1 (perfectly elastic). It is defined as:

$$e = \frac{\text{relative speed after collision}}{\text{relative speed before collision}}$$

Since the wall is immovable and stationary, the formula simplifies to:

$$e = \frac{|v_{\text{after}}|}{|v_{\text{before}}|}$$

Calculating:

$$e = \frac{21.0 \text{ m/s}}{25.5 \text{ m/s}} \approx 0.8235$$

A coefficient of approximately 0.82 indicates a highly elastic collision,

typical of rubber balls bouncing off hard surfaces like brick walls.

Energy Analysis: Conservation and Dissipation

1. Kinetic Energy Before and After Impact

- Initial kinetic energy:

```
\[
KE_{initial} = \frac{1}{2} m v^2 = \frac{1}{2} \times 0.050\, \text{kg}
\times (25.5\, \text{m/s})^2
\]
```

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\[
KE_{initial} = 0.025 \times 650.25 \approx 16.256\, \text{J}
\]
```

- Final kinetic energy:

```
\[
KE_{final} = \frac{1}{2} \times 0.050\, \text{kg} \times (21.0\,
\text{m/s})^2
\]
```

```
\[
KE_{final} = 0.025 \times 441 \approx 11.025\, \text{J}
\]
```

The decrease in kinetic energy:

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\[
\Delta KE = KE_{initial} - KE_{final} \approx 16.256\, \text{J} - 11.025\,
\text{J} = 5.231\, \text{J}
\]
```

This energy loss indicates that some energy is dissipated as heat, sound, and deformation during the collision, which is typical for real-world bounce scenarios.

Practical Implications of the Collision Dynamics

1. Real-World Applications

Understanding how a super ball bounces off a wall can inform various fields:

- Sports Equipment Design: Optimizing materials for balls and surfaces to maximize bounce and durability.
- Safety Testing: Assessing impact forces and energy transfer for protective gear.
- Material Science: Developing materials with specific elasticity and energy absorption properties.
- Robotics and Automation: Designing collision-aware systems and sensors.

2. Energy Dissipation and Material Properties

The energy lost during impact highlights the importance of material elasticity. A higher coefficient of restitution means less energy is

dissipated, resulting in a higher rebound height and better bounce performance. Conversely, materials that absorb more energy (lower e) are useful for shock absorption and cushioning.

Calculating the Impulse and Force During Impact

1. Impulse

Impulse (J) is the change in momentum:

$$J = \Delta p = -2.325 \text{ kg}\cdot\text{m/s}$$

The negative sign indicates direction, but in magnitude, the impulse delivered to the ball during collision is 2.325 kg·m/s.

2. Average Force During Collision

Assuming the collision lasts for a very short duration (Δt), we can estimate the average force:

$$F_{\text{avg}} = \frac{J}{\Delta t}$$

Without specific data on collision duration, typical impact times are on the order of milliseconds. For example, if $\Delta t = 1 \text{ ms} = 0.001 \text{ s}$:

$$F_{\text{avg}} = \frac{2.325 \text{ kg}\cdot\text{m/s}}{0.001 \text{ s}} = 2325 \text{ N}$$

This substantial force underscores the importance of material strength and structural integrity in surfaces and objects subjected to high-velocity impacts.

Summary of Key Findings

Parameter	Value/Result
Mass of super ball	50.0 g (0.050 kg)
Initial velocity	25.5 m/s
Rebound velocity	21.0 m/s
Coefficient of restitution	approximately 0.82
Initial kinetic energy	approximately 16.256 J
Final kinetic energy	approximately 11.025 J
Energy lost during collision	approximately 5.231 J
Change in momentum (impulse)	2.325 kg·m/s
Estimated average impact force	roughly 2325 N (assuming 1 ms impact time)

Conclusion

The analysis of a super ball bouncing off a brick wall provides valuable insights into collision mechanics, energy transfer, and material properties. The high-speed impact results in a significant impulse and energy dissipation, illustrating how elastic and inelastic properties influence rebound behavior. Such understanding is not only academically interesting but also practically essential in designing safer, more efficient sports equipment, impact-resistant materials, and collision-aware systems.

Whether in sports, engineering, or everyday life, mastering the principles of high-speed collisions enables us to optimize performance, safety, and durability. The super ball scenario exemplifies these concepts vividly, demonstrating the fascinating interplay of physics fundamentals in real-world situations.

References

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Note: All calculations are approximate and based on idealized assumptions; real-world

Frequently Asked Questions

What is the initial kinetic energy of the Super Ball before bouncing?

The initial kinetic energy is calculated using $KE = 0.5 m v^2$. Converting mass to kg (50.0 g = 0.050 kg): $KE = 0.5 \cdot 0.050 \text{ kg} \cdot (25.5 \text{ m/s})^2 \approx 16.3 \text{ Joules}$.

What is the rebound velocity of the Super Ball after bouncing off the brick wall?

The rebound velocity is 21.0 m/s, directed opposite to the initial velocity, indicating a change in direction during the bounce.

How much kinetic energy is lost during the bounce?

Initial KE $\approx 16.3 \text{ J}$; final KE $= 0.5 \cdot 0.050 \text{ kg} \cdot (21.0 \text{ m/s})^2 \approx 11.1 \text{ J}$. The energy lost is approximately 5.2 Joules.

What is the coefficient of restitution between the

Super Ball and the brick wall?

Coefficient of restitution, $e = (\text{speed after bounce}) / (\text{speed before bounce})$
 $= 21.0 / 25.5 \approx 0.82$.

Does the Super Ball experience a change in momentum during the collision?

Yes, the momentum changes direction and magnitude. Initial momentum = $0.050 \text{ kg} \cdot 25.5 \text{ m/s} \approx 1.275 \text{ kg}\cdot\text{m/s}$; final momentum = $0.050 \text{ kg} (-21.0 \text{ m/s}) \approx -1.05 \text{ kg}\cdot\text{m/s}$.

What is the impulse delivered to the Super Ball during the bounce?

Impulse = change in momentum = final momentum - initial momentum = $-1.05 \text{ kg}\cdot\text{m/s} - 1.275 \text{ kg}\cdot\text{m/s} \approx -2.33 \text{ kg}\cdot\text{m/s}$.

How does the bounce affect the energy conservation of the Super Ball?

The bounce results in energy loss due to inelastic collision, as kinetic energy decreases from approximately 16.3 J to 11.1 J.

If the Super Ball's initial velocity was increased, how would that affect the energy lost in the bounce?

Increasing the initial velocity would increase the initial kinetic energy, but the proportion of energy lost during the bounce would depend on the coefficient of restitution; overall, energy loss would be greater in absolute terms.

What practical applications are related to understanding such bouncing collisions?

Understanding bouncing collisions is crucial in sports physics, material testing, designing impact-resistant materials, and safety equipment like helmets and padding.

How does the mass of the Super Ball influence its bouncing behavior?

While mass affects the magnitude of momentum and energy, the bouncing behavior primarily depends on velocity and the material properties; mass influences the total kinetic energy but not the rebound ratio directly.

Additional Resources

A 50.0-g Super Ball Traveling At 25.5 M/s Bounces Off A Brick Wall And Rebounds At 21.0 M/s. A High-Speed collision offers a fascinating glimpse into the principles of physics, specifically the conservation of momentum, energy transfer, and the nature of elastic versus inelastic collisions.

Analyzing such a scenario allows us to understand how real-world objects behave when they interact with solid surfaces, and provides an excellent opportunity to explore concepts such as velocity change, kinetic energy, and impulse in detail.

Introduction

Imagine holding a Super Ball, a popular high-bounce toy, in your hand. You throw it toward a sturdy brick wall with a known velocity, and upon impact, it bounces back with a slightly reduced speed. In this scenario, the ball has a mass of 50.0 grams and is initially traveling at 25.5 m/s before striking the wall. After bouncing, it rebounds at 21.0 m/s in the opposite direction. This simple yet dynamic event encapsulates fundamental physics principles, making it an ideal case study for high-speed collision analysis.

Understanding this event involves examining key quantities:

- The initial velocity of the ball before impact.
- The final velocity after rebound.
- The change in momentum.
- The coefficient of restitution, which measures how "elastic" the collision is.
- The impulse delivered during contact.
- The kinetic energy before and after impact, to assess energy conservation or loss.

Basic Data and Assumptions

Before delving into calculations, let's clarify the known parameters:

- Mass of the ball, m : 50.0 grams = 0.050 kg
- Initial velocity, v_i : 25.5 m/s (toward the wall)
- Final velocity, v_f : -21.0 m/s (away from the wall; negative sign indicates opposite direction)

Assumption: The positive direction is defined as the initial direction toward the wall, so rebound velocities are negative, indicating reversal.

Step 1: Calculating the Change in Momentum

Momentum (p) is defined as:

$$[p = m \times v]$$

The initial momentum, (p_i) :

$$[p_i = 0.050 \, \text{kg} \times 25.5 \, \text{m/s} = 1.275 \, \text{kg}\cdot\text{m/s}]$$

The final momentum, (p_f) :

$$[p_f = 0.050 \, \text{kg} \times (-21.0 \, \text{m/s}) = -1.05 \, \text{kg}\cdot\text{m/s}]$$

The change in momentum, Δp :

$$\Delta p = p_f - p_i = -1.05 \text{ kg}\cdot\text{m/s} - 1.275 \text{ kg}\cdot\text{m/s} = -2.325 \text{ kg}\cdot\text{m/s}$$

The negative sign indicates a change in the direction of momentum—consistent with bouncing back.

Step 2: Calculating the Impulse

Impulse (J) is the product of the average force applied over the collision duration, and it equals the change in momentum:

$$J = \Delta p = -2.325 \text{ kg}\cdot\text{m/s}$$

This impulse is responsible for reversing the ball's momentum, and its magnitude tells us about the impact's intensity.

Step 3: Coefficient of Restitution

The coefficient of restitution (e) quantifies how elastic a collision is, defined as:

$$e = \frac{\text{relative speed after collision}}{\text{relative speed before collision}}$$

For a ball bouncing off a stationary wall, the formula simplifies to:

$$e = \frac{|v_f|}{|v_i|}$$

Since the wall is stationary and immovable:

$$e = \frac{21.0 \text{ m/s}}{25.5 \text{ m/s}} \approx 0.824$$

This value (less than 1) indicates a partially inelastic collision, meaning some kinetic energy is lost during impact, possibly converting to sound, heat, or deformation.

Step 4: Energy Analysis

Kinetic Energy Before and After Impact

Initial kinetic energy:

$$KE_i = \frac{1}{2} m v_i^2 = 0.5 \times 0.050 \text{ kg} \times (25.5)^2$$

$$KE_i = 0.025 \times 650.25 = 16.256 \text{ J}$$

Final kinetic energy:

$$KE_f = 0.5 \times 0.050 \text{ kg} \times (21.0)^2$$

$$\left[KE_f = 0.025 \times 441 = 11.025, \text{J} \right]$$

Energy Loss During Impact

$$\left[\Delta KE = KE_i - KE_f = 16.256, \text{J} - 11.025, \text{J} = 5.231, \text{J} \right]$$

Approximately 5.2 Joules of energy are lost during the bounce, which aligns with the inelastic nature indicated by the coefficient of restitution.

Step 5: Physical Interpretation and Implications

Elastic vs. Inelastic Collisions

- Elastic collision: No kinetic energy is lost; the ball would rebound with the same speed it had before impact ($e=1$).
- Inelastic collision: Kinetic energy decreases, as seen here ($e \approx 0.824$).

The Super Ball's collision with a brick wall isn't perfectly elastic, which is typical for real-world objects. The material properties—such as the elasticity of the ball and the wall—dictate how much energy is conserved.

Effect of Material Properties

- Super Balls are designed to be highly elastic, allowing for high rebound heights.
- The brick wall is relatively rigid and inelastic in comparison, absorbing some energy during impact.

The observed rebound speed (21.0 m/s) being close to the initial speed (25.5 m/s) reflects the ball's high elasticity, yet the slight reduction indicates some energy loss, mainly due to internal friction, deformation, and sound.

Step 6: Practical Applications and Real-World Considerations

Impulse and Force

While the calculations provide insight into the total change in momentum, the actual force experienced during impact depends on the contact time (Δt):

$$\left[J = F_{\text{avg}} \times \Delta t \right]$$

Without precise contact time data, we can only estimate the average force:

$$\left[F_{\text{avg}} = \frac{J}{\Delta t} \right]$$

Suppose the contact duration is on the order of microseconds (typical for high-speed impacts):

- For example, if $\Delta t = 10^{-4}$ seconds:

$$\left[F_{\text{avg}} = \frac{2.325, \text{kg} \cdot \text{m/s}}{10^{-4}, \text{s}} = 23,250, \text{N} \right]$$

This illustrates the enormous forces involved in high-speed impacts, which are dissipated over very short times.

Safety and Material Design

Understanding the physics of bouncing balls informs the design of sports equipment, safety gear, and materials engineered to absorb impacts effectively. High-elasticity materials like those used in Super Balls maximize rebound efficiency while minimizing energy loss, but they still cannot avoid some energy dissipation.

Conclusion

Analyzing the collision of a 50.0-g Super Ball traveling at 25.5 m/s with a brick wall—rebounding at 21.0 m/s—offers a comprehensive view of fundamental physics principles, including momentum conservation, energy transfer, and the coefficient of restitution. The event illustrates the complex interplay between material properties, impact forces, and energy dissipation. While the ball exhibits high elasticity, some energy is inevitably lost during impact, emphasizing the real-world deviations from ideal elastic collisions.

Through this detailed breakdown, we see how high-speed impacts are not just simple rebounds but rich phenomena governed by physics laws. Whether designing better sports equipment or understanding material behavior, these principles provide valuable insights into the dynamics of collisions in everyday life and advanced engineering applications.

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