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Understanding the dynamics of collisions is fundamental in physics, especially in the study of motion and momentum transfer. In this article, we explore a specific scenario involving a ball with a mass of 0.25 kg that experiences a head-on collision with an identical ball. Notably, this collision results in the ball losing one-third of its velocity. We will analyze the physics principles involved, perform relevant calculations, and discuss the implications of such an event.

Introduction to Collision Mechanics

Basics of Collisions

Collisions occur when two or more bodies come into contact with each other, resulting in a transfer of energy and momentum. They are classified into:

1. Elastic Collisions: where kinetic energy is conserved.
2. Inelastic Collisions: where some kinetic energy is transformed into other forms of energy, such as heat or deformation.

In our scenario, we consider an elastic or nearly elastic collision, given the typical behavior of rigid balls.

Understanding Head-on Collisions

A head-on collision involves two objects moving directly toward each other along a straight line. The key parameters include:

1. Initial velocities of the objects before collision.
2. Final velocities after collision.
3. Masses of the objects involved.

Scenario Description and Assumptions

Given Data

- Mass of each ball (m) = 0.25 kg
- The ball in question (Ball A) loses one-third of its velocity during collision.
- The collision is head-on and with an identical ball (Ball B).

Assumptions

- The collision is perfectly elastic or nearly elastic.
- Both balls are rigid and spherical.
- External forces (like friction or air resistance) are negligible during the collision.
- Before collision, the balls are moving along a straight line toward each other.

Analyzing the Velocity Change

Initial and Final Velocities of Ball A

Let's denote:

- $v_{A,i}$ = initial velocity of Ball A
- $v_{A,f}$ = final velocity of Ball A

Since Ball A loses one-third of its velocity during collision:

$$
v_{A,f} = v_{A,i} - \frac{1}{3}v_{A,i} = \frac{2}{3}v_{A,i}
$$

The directionality matters; if we assume Ball A initially moves in the positive direction:

- Before collision: $v_{A,i}$ (positive)
- After collision: $v_{A,f} = \frac{2}{3}v_{A,i}$ (direction depends on collision specifics)

Alternatively, if Ball A is moving toward Ball B, which is stationary or moving in the opposite direction, the velocities will be more precisely defined.

Determining Initial Velocity of Ball A

Suppose Ball B is initially at rest ($v_{B,i} = 0$). The initial momentum of the system:

$$
p_{initial} = m v_{A,i} + m v_{B,i} = 0.25 \times v_{A,i} + 0
$$

After collision, the velocities are:

- $v_{A,f} = \frac{2}{3}v_{A,i}$

- $v_{B,f}$ = velocity of Ball B after the collision.

Applying conservation of momentum:

$$
m v_{A,i} = m v_{A,f} + m v_{B,f}
$$

$$
0.25 v_{A,i} = 0.25 \times \frac{2}{3}v_{A,i} + 0.25 v_{B,f}
$$

Simplifying:

$$
0.25 v_{A,i} = 0.1667 v_{A,i} + 0.25 v_{B,f}
$$

$$
0.25 v_{A,i} - 0.1667 v_{A,i} = 0.25 v_{B,f}
$$

$$
0.0833 v_{A,i} = 0.25 v_{B,f}
$$

$$
v_{B,f} = \frac{0.0833}{0.25} v_{A,i} = 0.333 v_{A,i}
$$

Thus, after the collision:

- Ball A's velocity is $\frac{2}{3}v_{A,i}$ (which is approximately 0.6667 times its initial velocity).
- Ball B's velocity is approximately 0.333 times $v_{A,i}$.

Key insight: The velocities after collision are proportional to the initial velocity of Ball A, consistent with elastic collision dynamics between equal masses.

Calculating the Initial Velocity of the Ball

Suppose we know the final velocity of Ball A after collision, or we want to find the initial velocity based on observable data.

Example Calculation

- If, after collision, Ball A's velocity is known to be 4 m/s, then:

$$
v_{A,i} = \frac{v_{A,f}}{\frac{2}{3}} = 4 \div \frac{2}{3} = 4 \times \frac{3}{2} = 6\, \text{m/s}
$$

- Correspondingly, Ball B's velocity after collision:

$$
v_{B,f} = 0.333 \times 6 = 2\, \text{m/s}
$$

Interpretation: Initially, Ball A was moving at 6 m/s, and after collision, it moves at 4 m/s, losing one-third of its velocity, while Ball B gains 2 m/s.

Energy Considerations

Kinetic Energy Before and After Collision

Assuming an elastic collision:

$$
KE_{initial} = \frac{1}{2} m v_{A,i}^2 + \frac{1}{2} m v_{B,i}^2
$$

Since $v_{B,i} = 0$:

$$
KE_{initial} = 0.125 \times v_{A,i}^2
$$

After collision:

$$
KE_{final} = 0.125 \times v_{A,f}^2 + 0.125 \times v_{B,f}^2
$$

Substituting the velocities:

$$
v_{A,f} = \frac{2}{3} v_{A,i}
$$
$$
v_{B,f} = 0.333 v_{A,i}
$$

Calculate:

$$
KE_{final} = 0.125 \times \left(\frac{2}{3} v_{A,i}\right)^2 + 0.125 \times (0.333 v_{A,i})^2
$$

$$
= 0.125 \times \frac{4}{9} v_{A,i}^2 + 0.125 \times 0.111 v_{A,i}^2
$$

$$
= 0.125 \times 0.444 v_{A,i}^2 + 0.125 \times 0.111 v_{A,i}^2
$$

$$
= 0.0555 v_{A,i}^2 + 0.0139 v_{A,i}^2 = 0.0694 v_{A,i}^2
$$

\]

Compared to initial KE:

$$
KE_{initial} = 0.125 v_{A,i}^2
$$

The energy loss:

$$
\Delta KE = KE_{initial} - KE_{final} = (0.125 - 0.0694) v_{A,i}^2 = 0.0556 v_{A,i}^2
$$

This indicates some energy is lost during the collision, likely due to inelastic effects or internal energy transformation, which is common in real-world collisions.

Implications and Applications

Real-World Relevance

Understanding how objects lose velocity during collisions has practical applications:

1. Designing safer vehicles with collision absorption features.
2. Analyzing sports dynamics, such as ball collisions in tennis or billiards.
3. Engineering mechanical systems where impact forces are critical.

Educational Significance

This scenario offers a valuable teaching example for physics students to:

1. Apply conservation of momentum and energy principles.
2. Understand elastic and inelastic collision differences.
3. Perform real-world calculations of velocities and energy transfer.

Summary and Key Takeaways

- A ball with a mass of 0.25 kg loses one-third of its velocity during a head-on collision with an identical ball.

- The velocity reduction can be directly related to the initial velocity, assuming the collision is elastic or nearly elastic.