A 30.0-g Object Moving To The Right At 20.5 Cm/s Overtakes And Collides Elastically With A 13.0-g Object

A 30.0-g Object Moving To The Right At 20.5 Cm/s Overtakes And Collides Elastically With A 13.0-g Object

Understanding the dynamics of collisions is fundamental in physics, especially when analyzing elastic collisions where kinetic energy and momentum are conserved. In this article, we explore a specific scenario involving a 30.0-gram object moving to the right at 20.5 cm/s as it overtakes and collides elastically with a 13.0-gram object. We will delve into the physics principles behind such interactions, analyze the problem step-by-step, and examine the outcomes using conservation laws. This comprehensive discussion aims to clarify key concepts in elastic collisions, provide relevant calculations, and highlight the importance of mass and velocity in collision outcomes.

Understanding Elastic Collisions

What Is an Elastic Collision?

An elastic collision occurs when two objects collide without any loss of kinetic energy. In such collisions:

- The total kinetic energy before and after the collision remains the same.
- The total momentum of the system is conserved.
- No deformation or heat is generated during the collision.

Elastic collisions are idealized scenarios often used in physics to simplify real-world interactions, such as collisions between billiard balls or gas particles.

Key Principles of Elastic Collisions

- Conservation of Momentum:

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

- Conservation of Kinetic Energy:

\[

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

Where:
- m_1, m_2 are the masses of the objects.
- v_{1i}, v_{2i} are initial velocities.
- v_{1f}, v_{2f} are final velocities.

Scenario Breakdown: The Moving Object and Its Collision

Initial Conditions

In this scenario:

- Object 1 (the 30.0 g object):
- Mass $m_1 = 30.0\,g = 0.030\,kg$
- Initial velocity $v_{1i} = 20.5\,cm/s = 0.205\,m/s$ (moving to the right)

- Object 2 (the 13.0 g object):
- Mass $m_2 = 13.0\,g = 0.013\,kg$
- Initial velocity v_{2i} (assumed to be stationary unless specified otherwise)

Note: The problem states that the 30.0 g object "overtakes" the 13.0 g object, which suggests the second object might initially be at rest or moving slower than 20.5 cm/s. For simplicity, we'll assume that the second object is initially stationary unless specified, which is a common scenario in such problems.

- Initial velocities:
- $v_{2i} = 0\,cm/s = 0\,m/s$

Understanding the Overtaking and Collision

The 30.0 g object moving at 20.5 cm/s will eventually catch up to the 13.0 g object, leading to a collision. Since the collision is elastic, both kinetic energy and momentum are conserved, and the velocities after the collision can be calculated using the conservation laws.

Calculating Post-Collision Velocities

Using Conservation Laws

For elastic collisions in one dimension, the final velocities are given by the formulas:

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

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

Given that $v_{2i} = 0\,m/s$, these equations simplify to:

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

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

Numerical Calculations

Plugging in the values:

- $m_1 = 0.030\,kg$
- $m_2 = 0.013\,kg$
- $v_{1i} = 0.205\,m/s$

Calculate v_{1f}:

$$
v_{1f} = \frac{(0.030 - 0.013) \times 0.205}{0.030 + 0.013} = \frac{0.017 \times 0.205}{0.043} \approx \frac{0.003485}{0.043} \approx 0.081\,m/s
$$

Calculate v_{2f}:

$$
v_{2f} = \frac{2 \times 0.030 \times 0.205}{0.043} = \frac{0.0123}{0.043} \approx 0.286\,m/s
$$

Results:

- The 30.0 g object slows down from 0.205 m/s to approximately 0.081 m/s to the right.
- The 13.0 g object starts from rest and gains a velocity of approximately 0.286 m/s to the right after the collision.

Implications of the Collision Outcomes

Velocity Changes and Momentum Transfer

The collision results in the lighter object (13.0 g) gaining a significant portion of the initial kinetic energy of the heavier object, as expected in elastic collisions. The heavier object slows down but continues moving to the right, albeit at a reduced velocity.

Key observations:

- The lighter object accelerates more relative to its mass.
- The heavier object retains most of its initial momentum, but reduces its velocity.
- The total system momentum remains conserved:

$$
p_{initial} = m_1 v_{1i} + m_2 v_{2i} = 0.030 \times 0.205 + 0.013 \times 0 = 0.00615\,kg\cdot m/s
$$

- After collision:

$$
p_{final} = m_1 v_{1f} + m_2 v_{2f} = 0.030 \times 0.081 + 0.013 \times 0.286 \approx 0.00243 + 0.00372 = 0.00615\,kg\cdot m/s
$$

Matching the initial momentum, confirming conservation.

Energy Analysis

Initial and Final Kinetic Energies

Calculate initial kinetic energy:

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

$$
KE_{initial} = 0.5 \times 0.030 \times (0.205)^2 + 0.5 \times 0.013 \times 0^2 \approx 0.015 \times 0.042 + 0 \approx 0.00063\,J
$$

Calculate final kinetic energy:

$$
KE_{final} = 0.5 \times 0.030 \times (0.081)^2 + 0.5 \times 0.013 \times (0.286)^2
$$

$$
= 0.015 \times 0.00656 + 0.0065 \times 0.0818 \approx 0.000098 + 0.000533 \approx 0.000631\,J
$$

The initial and final kinetic energies are nearly equal, confirming the elastic nature of the collision.

Real-World Applications and Significance

Practical Examples of Elastic Collisions

- Billiard balls colliding on a pool table
- Gas particles colliding in an ideal gas
- Sports physics, such as baseball or cricket ball impacts

Significance in Physics Education

Analyzing such collisions helps students:

- Understand conservation laws
- Develop problem-solving skills
- Connect theoretical physics with real-world phenomena

Summary and Conclusions

In this scenario, a 30.0-gram object moving at 20.5 cm/s to the right collides elastically with a stationary 13.0-gram object. Applying conservation of momentum and kinetic energy, we find:

- The

Frequently Asked Questions

What is the primary principle governing the collision between the 30.0-g and 13.0-g objects?

The collision is elastic, meaning both momentum and kinetic energy are conserved during the interaction.

How do the masses of the objects influence their velocities after an elastic collision?

The masses determine the final velocities; the heavier object tends to retain more of its initial velocity, while the lighter object experiences a more significant change, according to elastic collision equations.

What is the velocity of the 13.0-g object after the collision if the 30.0-g object moves to the right at 20.5 cm/s before impact?

Using elastic collision formulas, the 13.0-g object's velocity after collision can be calculated as approximately 29.4 cm/s to the right, indicating it speeds up post-collision.

Can the 30.0-g object reverse direction after the collision, and under what conditions?

Yes, if the collision parameters are such that the 30.0-g object transfers enough momentum to the 13.0-g object, it can slow down and potentially reverse direction, though in this case, it's more likely to continue moving right at a reduced speed.

Why is understanding elastic collisions important in real-world applications?

Elastic collisions model idealized interactions in physics that are relevant for understanding molecular dynamics, particle physics, and designing systems like colliding particles or elastic materials.

Additional Resources

A 30.0-g Object Moving To The Right At 20.5 cm/s Overtakes And Collides Elastically With A 13.0-g Object

Understanding the dynamics of elastic collisions is fundamental in physics, especially in classical mechanics. The scenario involving a 30.0-gram object moving at 20.5 cm/s to the right and overtaking a 13.0-gram object provides an excellent case study to explore conservation laws, kinematic equations, and the resulting velocities post-collision. Such analyses are not only theoretically intriguing but also have practical implications in fields ranging from materials science to vehicle safety testing. This article delves into the detailed examination of this collision, dissecting the principles involved, solving for the post-collision velocities, and discussing the broader implications of elastic collisions.

Understanding the Scenario

At the core, this scenario involves two objects moving along a straight line (say, a frictionless surface or an idealized medium), with the larger mass (30.0 g) moving to the right at 20.5 cm/s, and the smaller mass (13.0 g) initially stationary or moving differently such that it is overtaken by the larger object. The phrase "overtakes" suggests that the smaller object might be behind or initially stationary, but the key is that the larger object catches up and collides with it. The collision is specified as elastic, meaning kinetic energy and momentum are conserved.

Fundamental Principles at Play

Conservation of Momentum

In any isolated system absent external forces, the total momentum before and after the collision remains constant:

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

where:
- $m_1 = 30.0\, \text{g}$
- $m_2 = 13.0\, \text{g}$
- $v_{1i} = 20.5\, \text{cm/s}$ (initial velocity of the larger object)
- v_{2i} (initial velocity of the smaller object, which we need to clarify)
- v_{1f} and v_{2f} (final velocities after collision)

The initial velocities are crucial; if the smaller object is initially at rest ($v_{2i} = 0$), the analysis simplifies, but the problem statement should clarify that. For this discussion, we assume the smaller object is initially stationary, as that aligns with the typical overtaking scenario.

Elastic Collision Conditions

An elastic collision preserves both momentum and kinetic energy:

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

Given that the collision is elastic, these two conservation laws can be combined to solve for the unknown velocities after the impact.

Assumptions and Initial Conditions

For simplicity, and based on typical problem setups, the initial conditions are assumed as:
- Larger object: $m_1 = 30.0\, \text{g}$, $v_{1i} = 20.5\, \text{cm/s}$ (to the right)
- Smaller object: $m_2 = 13.0\, \text{g}$, $v_{2i} = 0\, \text{cm/s}$

This means the larger mass is moving toward a stationary smaller mass, overtakes it, and collides elastically.

Calculating Post-Collision Velocities

Using Conservation of Momentum

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

Plugging in the values:

$$ (30.0)(20.5) + (13.0)(0) = 30.0 v_{1f} + 13.0 v_{2f} $$

$$ 615.0\, \text{cm·g/s} = 30.0 v_{1f} + 13.0 v_{2f} $$

Using Relative Velocity in Elastic Collisions

A key property of elastic collisions in one dimension is that the relative velocity of approach before collision equals the relative velocity of separation after collision:

$$ v_{1i} - v_{2i} = - (v_{1f} - v_{2f}) $$

Given $v_{2i} = 0$:

$$ 20.5 - 0 = - (v_{1f} - v_{2f}) $$

$$ 20.5 = - v_{1f} + v_{2f} $$

Rearranged:

$$ v_{2f} = v_{1f} + 20.5 $$

Solving the System of Equations

From momentum conservation:

$$ 615.0 = 30.0 v_{1f} + 13.0 v_{2f} $$

Substitute $v_{2f} = v_{1f} + 20.5$:

$$ 615.0 = 30.0 v_{1f} + 13.0 (v_{1f} + 20.5) $$

$$ 615.0 = 30.0 v_{1f} + 13.0 v_{1f} + 13.0 \times 20.5 $$

$$ 615.0 = (30.0 + 13.0) v_{1f} + 266.5 $$

$$ 615.0 - 266.5 = 43.0 v_{1f} $$

$$ 348.5 = 43.0 v_{1f} $$

$$ v_{1f} = \frac{348.5}{43.0} \approx 8.10\, \text{cm/s} $$

Now, find v_{2f}:

$$ v_{2f} = v_{1f} + 20.5 = 8.10 + 20.5 = 28.60\, \text{cm/s} $$

Interpreting the Results

The calculations reveal that after the elastic collision:

- The larger object (initially moving at 20.5 cm/s) slows down to approximately 8.10 cm/s to the right.
- The smaller object, initially stationary, accelerates to approximately 28.60 cm/s to the right.

This outcome aligns with the expectations of elastic collisions: the lighter object gains a significant velocity boost, while the heavier object slows down, but both continue moving in the same general direction.

Physical Implications and Broader Context

Energy Transfer in Elastic Collisions

This scenario embodies a classic example of kinetic energy transfer. The larger object, initially carrying most of the kinetic energy, imparts a portion of it to the smaller object during the elastic collision. The lighter mass gains a higher velocity post-collision, which is consistent with the principles of momentum and energy conservation.

Features:

- The lighter object achieves a higher velocity than the initial velocity of the heavier object.
- Total kinetic energy before and after remains unchanged, confirming the elastic nature.

Pros:

- Demonstrates fundamental physics principles clearly.
- Useful in designing systems where energy transfer efficiency is critical (e.g., elastic impact systems, particle physics).

Cons:

- Assumes ideal conditions (no friction, perfect elasticity), which are rarely met in real-world systems.
- Simplifies to one-dimensional motion; real collisions are often three-dimensional.

Practical Applications and Relevance

Understanding such collisions is pivotal in various domains:

- Material Science: Designing materials that can withstand impacts without energy loss.
- Automotive Safety: Modeling crumple zones and collision dynamics.

- Particle Physics: Analyzing elastic scattering events in accelerators.
- Robotics and Mechanical Design: Creating impact-absorbing mechanisms that utilize elastic collision principles.

Features:

- Provides foundational understanding applicable across disciplines.
- Can be extended to more complex multi-body systems.

Pros:

- Enhances problem-solving skills in physics.
- Offers insights into energy transfer mechanisms.

Cons:

- Simplified models may not account for real-world complexities like friction, deformation, or inelastic effects.

Limitations and Further Considerations

While the analysis offers valuable insights, real-world scenarios involve complexities such as:

- Inelastic Collisions: Energy is dissipated as heat, sound, or deformation, deviating from ideal elastic behavior.
- Friction and Air Resistance: External forces can alter velocities.
- Three-Dimensional Motion: Real impacts are rarely perfectly linear.

Future studies could incorporate these factors to make models more realistic and applicable to practical engineering problems.

Conclusion

The scenario of a 30.0-gram object moving to the right

[A 30 0 G Object Moving To The Right At 20 5 Cm S Overtakes And Collides Elastically With A 13 0 G Object]

A 30 0 G Object Moving To The Right At 20 5 Cm S Overtakes And Collides Elastically With A 13 0 G

Object

Related Articles

- When Responding To Sound, The Human Eardrum Vibrates About Its Equilibrium Position. Suppose An Eardrum
- 1. According To The Semistrong-form Of The Efficient Market Hypothesis, . A. Stock Prices Rapidly Adjust
- What Type Of Vessel Is Built To Handle The Highest Pressure Of Any Vessel In The Cardiovascular System?

Back to Home