# A 2 Kg Object Traveling At 5 M/s On A Frictionless Horizontal Surface Collides Head-on With And Sticks

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Understanding the dynamics of collisions is essential in physics, especially when analyzing real-world applications such as vehicle crashes, sports, and industrial processes. In this comprehensive guide, we explore the scenario where a 2 kg object moving at a speed of 5 meters per second on a frictionless horizontal surface collides head-on with another object and sticks to it. This type of collision is classified as a perfectly inelastic collision, and analyzing it provides insights into conservation laws, momentum transfer, and energy dissipation.

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## Introduction to Collision Types and Principles

Before delving into the specifics of the given scenario, it is important to understand the fundamental types of collisions and the physics principles governing them.

### Types of Collisions

Collisions can generally be categorized into three main types:

1. **Elastic Collisions**: Both kinetic energy and momentum are conserved. The objects bounce off each other without any permanent deformation or energy loss.

2. **Inelastic Collisions**: Momentum is conserved, but some kinetic energy is transformed into other forms of energy such as heat, sound, or deformation. The objects may deform or stick together.

3. **Perfectly Inelastic Collisions**: A special case of inelastic collisions where the colliding objects stick together after impact, moving as a single combined mass.

The scenario described involves objects sticking together after the collision, hence it is a perfectly inelastic collision.

## Conservation of Momentum and Energy

- Momentum: The total momentum of a closed system remains constant if no external forces act upon it.
- Kinetic Energy: In elastic collisions, kinetic energy is conserved. In inelastic collisions, it is not necessarily conserved.

Understanding how these principles apply to the given problem allows us to analyze post-collision velocities, kinetic energy loss, and the dynamics involved.

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# Scenario Description and Assumptions

To analyze the problem accurately, let's clearly define the scenario and assumptions:

## Initial Conditions

- Mass of the first object, $m_1 = 2\,kg$
- Initial velocity of the first object, $v_{1i} = 5\,m/s$
- Mass of the second object, $m_2$ (assumed to be known or variable)
- Initial velocity of the second object, $v_{2i}$ (assumed to be known or zero if stationary)

## Assumptions

- The surface is perfectly frictionless, so no external horizontal forces act during the collision.
- The collision occurs head-on along a straight line.
- Post-collision, the objects stick together, forming a single combined mass.
- External forces such as friction, air resistance, or deformation are neglected.
- The collision is instantaneous.

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# Analysis of the Collision

The primary goal is to determine the post-collision velocity and understand the energy considerations.

## Step 1: Conservation of Momentum

Since no external forces act horizontally during the collision, total momentum before and after the collision remains constant:

$$
m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f
$$

Where:
- $v_f$ is the common velocity of the combined mass after collision.

## Step 2: Calculating Final Velocity

Rearranging the conservation of momentum:

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

Depending on whether the second object is stationary or moving, the calculation varies.

Case A: Second Object is Stationary ($v_{2i} = 0$)

$$
v_f = \frac{(2\,kg)(5\,m/s) + (m_2)(0)}{2 + m_2} = \frac{10}{2 + m_2} \, m/s
$$

Case B: Second Object is Moving Towards the First

Suppose $v_{2i}$ is known, then:

$$
v_f = \frac{(2)(5) + m_2 v_{2i}}{2 + m_2}
$$

## Step 3: Kinetic Energy Before and After Collision

Initial Kinetic Energy:

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

Final Kinetic Energy:

$$
KE_{final} = \frac{1}{2} (m_1 + m_2) v_f^2
$$

Since the collision is perfectly inelastic, some kinetic energy is lost, which is transformed into other energy forms.

Energy Loss:

$$
\Delta KE = KE_{initial} - KE_{final}
$$

This energy loss reflects the irreversibility of inelastic collisions.

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# Practical Examples and Calculations

Let's work through specific scenarios with numerical values for clarity.

## Example 1: Second Object is Stationary ($m_2 = 3\,kg$), ($v_{2i} = 0$)

- Initial momentum:

$$
p_{initial} = (2)(5) + (3)(0) = 10\,kg\,m/s
$$

- Final velocity:

$$
v_f = \frac{10}{2 + 3} = \frac{10}{5} = 2\,m/s
$$

- Initial kinetic energy:

$$
KE_{initial} = \frac{1}{2} (2)(5)^2 + \frac{1}{2} (3)(0)^2 = 1 \times 25 + 0 = 25\,J
$$

- Final kinetic energy:

$$
KE_{final} = \frac{1}{2} (2 + 3) (2)^2 = \frac{1}{2} (5) \times 4 = 10\,J
$$

- Energy loss:

$$
\Delta KE = 25 - 10 = 15\,J
$$

This indicates that 15 Joules of energy are dissipated during the collision, possibly as heat, sound, or deformation.

## Example 2: Both objects are moving towards each other

Suppose:

- $m_2 = 4\,kg$
- $v_{2i} = -3\,m/s$ (moving in opposite direction)

- Initial momentum:

$$
p_{initial} = (2)(5) + (4)(-3) = 10 - 12 = -2\,kg\,m/s
$$

- Final velocity:

$$
v_f = \frac{-2}{2 + 4} = \frac{-2}{6} = -\frac{1}{3} \approx -0.333\,m/s
$$

- Initial kinetic energy:

$$
KE_{initial} = \frac{1}{2} \times 2 \times 25 + \frac{1}{2} \times 4 \times 9 = 25 + 18 = 43\,J
$$

- Final kinetic energy:

$$
KE_{final} = \frac{1}{2} \times 6 \times (0.333)^2 \approx 3 \times 0.111 = 0.333\,J
$$

- Energy loss:

$$
\Delta KE = 43 - 0.333 \approx 42.667\,J
$$

This significant energy loss emphasizes how in inelastic collisions, kinetic energy is not conserved, even though momentum is.

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# Implications of the Collision Analysis

Understanding the physics behind such collisions has practical implications:

## Energy Dissipation

- The amount of kinetic energy lost during a perfectly inelastic collision can be substantial.
- This energy is often converted into heat, sound, or deformation, which is crucial in designing crash safety features.

## Post-collision Velocity

- The final velocity depends on the masses and initial velocities of the objects.
- Engineers might manipulate these variables to control the outcome of collisions.

## Momentum Conservation in Real-world Situations

- External forces like friction and air resistance can affect conservation laws.
- In controlled environments, ignoring these forces simplifies analysis, but real-world applications must consider them.

## Applications in Engineering and Safety

- Designing vehicles with crumple zones to absorb collision energy.
- Analyzing sports collisions to improve safety gear.
- Industrial processes where material impacts are common.

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# Conclusion

The collision of a 2 kg object traveling at 5 m/s on a frictionless surface with another object and sticking to it exemplifies fundamental principles of physics, notably conservation of momentum and the nature of inelastic collisions. By applying the laws of physics, we can predict the

# Frequently Asked Questions

## What is the final velocity of the combined object after the collision?

Since the objects stick together, use conservation of momentum: initial momentum equals final momentum. If the second object is at rest, the final velocity is (mass of moving object its velocity) / total mass = (2 kg 5 m/s) / (2 kg + 2 kg) = 10 / 4 = 2.5 m/s.

## Is kinetic energy conserved in this inelastic collision?

No, kinetic energy is not conserved in inelastic collisions where objects stick together. Some kinetic energy is transformed into internal energy, heat, or deformation.

## What is the change in momentum of the 2 kg object during the collision?

The change in momentum is final momentum minus initial momentum. If it was moving at 5 m/s and sticks with another object initially at rest, the initial momentum was 2 kg 5 m/s = 10 kg·m/s, and the final momentum is (2 kg + 2 kg) 2.5 m/s = 4 kg 2.5 m/s = 10 kg·m/s. So, the change in momentum is zero, indicating momentum is conserved.

## How does the conservation of momentum apply in this collision?

In an isolated system with no external forces, total momentum before collision equals total momentum after collision. Here, the total momentum before is 10 kg·m/s, and after, it remains 10 kg·m/s, confirming conservation.

## What role does the frictionless surface play in this collision scenario?

The frictionless surface ensures no external horizontal forces act on the objects, allowing the conservation of momentum to hold true during the collision.

## If the second object had an initial velocity of 3 m/s towards the 2 kg object, what would be the final velocity after they stick?

Using conservation of momentum: (2 kg 5 m/s) + (2 kg (-3 m/s)) = total initial momentum = 10 - 6 = 4 kg·m/s. Total mass after collision is 4 kg, so final velocity = 4 / 4 = 1 m/s in the original direction of the first object.

## What is the kinetic energy lost during the collision?

Initial kinetic energy is (1/2)2 kg(5 m/s)^2 = 25 J. Final kinetic energy is (1/2)4 kg(2.5 m/s)^2 = (2)6.25 = 12.5 J. The kinetic energy lost is 25 J - 12.5 J = 12.5 J.

## Can the collision be considered elastic? Why or why not?

No, because the objects stick together after collision, indicating an inelastic collision. Elastic collisions conserve both momentum and kinetic energy, which is not the case here.

## What assumptions are made in analyzing this collision?

Assumptions include a frictionless horizontal surface, no external forces acting horizontally, and perfectly inelastic collision where objects stick together without bouncing apart.

# Additional Resources

A 2 Kg Object Traveling At 5 M/s On A Frictionless Horizontal Surface Collides Head-on With And Sticks

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# Introduction: Analyzing the Dynamics of a Perfectly Inelastic Collision

**In physics, the study of collisions provides fundamental insights into the conservation laws governing motion, energy, and momentum. When a 2 kg object moving at 5 meters per second on a frictionless horizontal surface collides head-on with another object and they stick together, the event exemplifies a perfectly inelastic collision—a scenario where kinetic energy is not conserved, but momentum is. This analysis explores the key principles, calculations, and implications of such a collision, providing a comprehensive understanding of the mechanics involved.**

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# Understanding the Initial Conditions

## The Object's Properties and State

The scenario involves a single object characterized by the following parameters:

- Mass (m): 2 kg
- Initial velocity (v): 5 m/s
- Surface: Frictionless horizontal plane

This initial information sets the stage for analyzing the collision dynamics. The object’s momentum before impact, given the absence of external forces on a frictionless surface, is straightforward:

$$p_{initial} = m \times v = 2\, \text{kg} \times 5\, \text{m/s} = 10\, \text{kg·m/s}$$

However, because the problem involves a collision where the object "collides head-on with and sticks," it implies there is a second object involved, which is essential for a complete analysis.

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# Assumptions and Additional Considerations

## Presence of a Second Object

To analyze a collision where two objects stick together, the scenario generally presumes:

- Object A: 2 kg, moving at 5 m/s toward Object B
- Object B: Unknown mass and initial velocity

Alternatively, the scenario could involve a single object colliding with a stationary object. Since the prompt states "collides head-on with and sticks," it suggests an inelastic collision between two objects.

Common assumptions for simplicity:

- The second object is stationary before collision
- Both objects are on a frictionless surface
- The collision is perfectly inelastic (objects stick together)

Clarification: Single Object Colliding with a Stationary Object

Most analyses of such problems typically involve a moving object hitting a stationary one of unknown mass $m_2$. For completeness, the article will analyze both possibilities:

1. Object A colliding with a stationary object B
2. Two objects moving towards each other

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# Conservation of Momentum: The Cornerstone Principle

## Fundamentals of Momentum Conservation

In an isolated system with no external forces, the total momentum before and after collision remains constant:

$$p_{initial} = p_{final}$$

This principle is especially relevant on a frictionless surface, where external forces are negligible.

Mathematical Expression for Collisions

- Before collision:

$$ p_{initial} = m_1 v_{1,i} + m_2 v_{2,i} $$

- After collision:

$$ p_{final} = (m_1 + m_2) v_{final} $$

where:

- $m_1, m_2$: masses of the objects
- $v_{1,i}, v_{2,i}$: initial velocities
- $v_{final}$: common velocity after collision (since objects stick together)

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# Calculations: Determining Post-collision Velocity

## Case 1: Object A Collides with a Stationary Object B

Suppose:

- Object A: 2 kg, moving at 5 m/s
- Object B: $m_2$ kg, stationary ($v_{2,i} = 0$)

Applying conservation of momentum:

$$
m_1 v_{1,i} + m_2 v_{2,i} = (m_1 + m_2) v_{final}
$$

$$
(2\, \text{kg} \times 5\, \text{m/s}) + (m_2 \times 0) = (2 + m_2) v_{final}
$$

$$
10 = (2 + m_2) v_{final}
$$

$$
v_{final} = \frac{10}{2 + m_2}
$$

Interpretation:

- The final velocity depends on the mass of the stationary object.
- For example, if $m_2 = 2\, \text{kg}$:

\[

$$
v_{final} = \frac{10}{2 + 2} = \frac{10}{4} = 2.5\, \text{m/s}
$$

- The combined mass moves at 2.5 m/s after collision.

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### Case 2: Two Objects Moving Towards Each Other

Suppose both objects are moving:

- Object A: 2 kg, velocity $v_{1,i} = 5\, \text{m/s}$
- Object B: $m_2$ kg, velocity $v_{2,i} = -v$ (opposite direction)

Total initial momentum:

$$
p_{initial} = 2 \times 5 + m_2 \times (-v)
$$

Assuming $v_{2,i}$ is known or negligible, the calculation proceeds similarly.

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## Energy Considerations: Kinetic Energy Loss

### Why Kinetic Energy Is Not Conserved

In perfectly inelastic collisions, kinetic energy isn't conserved because some of it is transformed into other forms of energy like heat, sound, or deformation.

- Initial kinetic energy:

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

- Final kinetic energy:

$$
KE_{final} = \frac{1}{2} (m_1 + m_2) v_{final}^2
$$

Calculating the energy loss:

$$
\Delta KE = KE_{initial} - KE_{final}
$$

This difference quantifies the energy dissipated during the collision, reflecting real-world energy transformations that occur when objects stick together.

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# Implications and Real-World Applications

## Practical Relevance of Inelastic Collisions

Understanding such collision mechanics is vital in fields like automotive safety, where crash dynamics involve inelastic collisions leading to deformation and energy dissipation. Engineers use these principles to design safer vehicles that absorb impact energy efficiently, minimizing injuries.

Examples of Applications:

- Crash testing: Simulating inelastic collisions to assess vehicle safety.
- Material science: Studying how materials deform and absorb energy.
- Sports physics: Analyzing impacts in sports like billiards or football tackles.
- Spacecraft design: Predicting collision outcomes in microgravity environments.

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# Limitations and Advanced Considerations

## Assumptions and Real-World Deviations

While the idealized scenario provides clarity, real-world collisions involve complexities:

- Friction: Even slight frictional forces can influence momentum transfer.
- Elasticity: Not all collisions are perfectly inelastic; some retain kinetic energy.
- Rotational Dynamics: Collisions may involve torque, causing objects to spin.
- Deformation: Material properties affect how objects deform and dissipate energy.

Advanced models incorporate these factors, often requiring computational simulations for accurate predictions.

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## Conclusion: The Significance of Collision Mechanics

The collision of a 2 kg object traveling at 5 m/s on a frictionless surface with another object—especially one it sticks to—serves as a fundamental example illustrating core physics principles like conservation of momentum and the nature of inelastic collisions. Through mathematical analysis, we see how the final velocity depends on the mass of the objects involved, and how kinetic energy diminishes during the event.

Such studies not only deepen our understanding of classical mechanics but also inform the design of safety features, materials, and systems across engineering and scientific disciplines. Recognizing the intricacies of energy transformation and momentum transfer in these collisions enables scientists and engineers to predict outcomes with greater precision, fostering innovations that improve safety, efficiency, and performance across various fields.

In summary, the collision scenario underscores the elegance of physics principles and their practical applications, illustrating how fundamental laws govern the behavior of objects in motion and impact.

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