# A 7800-kg Boxcar Traveling At 12 M/s Strikes A Second Boxcar At Rest. The Two Stick Together And Move

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In the realm of physics, understanding the principles of momentum and energy conservation is crucial when analyzing real-world collisions. Consider a scenario where a massive boxcar, weighing 7800 kilograms and moving at a speed of 12 meters per second, collides with a stationary boxcar. After the collision, the two boxcars stick together and continue moving as a single unit. This situation exemplifies a perfectly inelastic collision, a fundamental concept in classical mechanics. By examining this event, we can explore how momentum is conserved, calculate the resulting velocity, and understand the implications of such interactions in railway operations and safety analyses.

## Understanding the Basics: Momentum and Collisions

### What Is Momentum?

Momentum is a vector quantity defined as the product of an object's mass and its velocity:

- **Formula:** $p = m \times v$
- **Units:** kilogram-meter per second (kg·m/s)

It signifies the quantity of motion an object possesses and is conserved in isolated systems during collisions.

### Types of Collisions

Collisions between objects can be categorized as:

1. **Elastic Collisions:** Both momentum and kinetic energy are conserved.
2. **Inelastic Collisions:** Momentum is conserved, but kinetic energy is not necessarily conserved.
3. **Perfectly Inelastic Collisions:** The colliding objects stick together after impact, and maximum kinetic energy is lost.

The scenario in question involves a perfectly inelastic collision.

## Calculating the Post-Collision Velocity

### Applying Conservation of Momentum

In the absence of external forces, the total momentum before collision equals the total momentum after collision:

- **Before collision:** p_initial = p_boxcar1 + p_boxcar2
- **After collision:** p_final = (m1 + m2) × v_final

Where:

- $m1$ = 7800 kg (mass of moving boxcar)
- $v1$ = 12 m/s (initial velocity of moving boxcar)
- $m2$ = mass of the stationary boxcar (assumed to be the same unless specified)
- $v2$ = 0 m/s (initial velocity of stationary boxcar)

## Calculating the Final Velocity

Assuming the second boxcar has the same mass (7800 kg) for simplicity:

Initial total momentum:

$p_{initial} = m1 \times v1 + m2 \times v2 = 7800\ kg \times 12\ m/s + 7800\ kg \times 0 = 93600\ kg \cdot m/s$

After collision, the two stick together and move with velocity $v_{final}$:

$p_{final} = (m1 + m2) \times v_{final} = 15600\ kg \times v_{final}$

Setting $p_{initial} = p_{final}$:

```
93600 kg·m/s = 15600 kg × v_final
```

Solving for $v_{final}$:

```
v_final = 93600 / 15600 = 6 m/s
```

Result: The combined boxcars move at 6 meters per second after the collision.

## Implications of the Collision Dynamics

## Energy Considerations

While momentum is conserved, kinetic energy is not:

- Initial kinetic energy:

```
KE_initial = 0.5 × m1 × v1² + 0.5 × m2 × v2² = 0.5 × 7800 kg × (12 m/s)² + 0
= 561,600 Joules
```

2. Final kinetic energy:

```
KE_final = 0.5 × (m1 + m2) × v_final² = 0.5 × 15600 kg × (6 m/s)² = 280,800
Joules
```

The kinetic energy decreases by 280,800 Joules, primarily converted into heat, sound, and deformation during the collision.

## Real-World Applications

Understanding these dynamics is vital in:

- Designing safer railway cars that absorb impact energy efficiently
- Developing collision avoidance systems
- Calculating stopping distances and safety margins

# Factors Affecting Collision Outcomes

## Mass of the Vehicles

The mass significantly influences the momentum transfer:

- Heavier boxcars carry more momentum at a given speed.
- Matching or varying masses affect the post-collision velocity.

## Initial Velocities

The initial speed of the moving boxcar directly impacts the velocity after collision:

- Higher initial speeds result in higher post-collision speeds if the masses are constant.
- Speed limits and operational controls are designed considering such impact scenarios.

## Collision Type

The degree to which the vehicles stick together influences energy dissipation:

- Perfectly elastic collisions conserve kinetic energy, leading to different post-impact velocities and energy distributions.
- Inelastic collisions, like in our scenario, result in energy loss and deformation.

# Safety and Engineering Considerations

## Designing for Impact Absorption

Railway industries employ various techniques:

- Crush zones and energy-absorbing materials
- Automatic braking systems to reduce collision velocity
- Structural reinforcements to minimize deformation and injury risk

## Operational Protocols

Operators are trained to:

- Maintain safe distances between trains
- Monitor speed regulations diligently
- Implement emergency response plans for collision scenarios

## Conclusion: The Significance of Physics in Railway Safety

The collision of a 7800-kg boxcar traveling at 12 m/s with a stationary counterpart, leading to both moving together at 6 m/s, exemplifies fundamental physics principles that underpin railway safety and engineering. Understanding momentum conservation, energy dissipation, and collision dynamics allows engineers and operators to design safer vehicles, establish effective safety protocols, and develop technologies to mitigate the impacts of unavoidable collisions. As rail transport remains a vital component of logistics worldwide, continuous research and application of physics principles will ensure safer and more efficient rail networks for the future.

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Summary of Key Points:
- Momentum conservation allows calculation of post-collision velocity.
- The combined boxcars move at half the initial speed of the moving car.
- Kinetic energy decreases, highlighting energy dissipation during inelastic collisions.
- Real-world safety measures are based on these fundamental physics principles.
- Proper understanding aids in designing safer railway systems and accident prevention strategies.

By applying these principles, the railway industry can improve safety standards and reduce the risks associated with train collisions, ultimately safeguarding lives and cargo.

## Frequently Asked Questions

### What is the combined velocity of the two boxcars after they stick together?

Using conservation of momentum, the combined velocity is calculated as (mass1 velocity1 + mass2 velocity2) divided by the total mass. Since the second boxcar is at rest, the velocity after collision is

(7800 kg 12 m/s) / (7800 kg + 7800 kg) = 93,600 / 15,600 = 6 m/s.

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

Initial kinetic energy is (1/2) 7800 kg (12 m/s)^2 = 561,600 Joules. Final kinetic energy is (1/2) 15600 kg (6 m/s)^2 = 280,800 Joules. Therefore, kinetic energy lost is 561,600 - 280,800 = 280,800 Joules.

## Is momentum conserved in this collision?

Yes, momentum is conserved. The total momentum before collision is 7800 kg 12 m/s = 93,600 kg·m/s. After collision, the combined mass moves at 6 m/s, resulting in 15,600 kg 6 m/s = 93,600 kg·m/s, which is the same value.

## What type of collision is this: elastic or inelastic?

This is an inelastic collision because the two boxcars stick together after impact, resulting in kinetic energy loss and deformation or heat, characteristic of inelastic collisions.

## How can the concept of conservation of momentum be applied to solve this problem?

By setting the total momentum before the collision equal to the total momentum after the collision, you can solve for the unknown velocity after impact. In this case, total initial momentum equals total final momentum, allowing calculation of the combined velocity.

## What assumptions are made in solving this problem?

The assumptions include no external forces acting during the collision, perfectly inelastic collision where the boxcars stick together, and that the system is isolated with no energy lost to external factors like friction or deformation outside the collision process.

## Additional Resources

A 7800-kg Boxcar Traveling At 12 M/s Strikes A Second Boxcar At Rest. The Two Stick Together And Move is a classic physics problem that illustrates fundamental principles of momentum and conservation laws. This scenario offers a rich context for understanding collision dynamics, energy transfer, and the practical implications of inelastic collisions, particularly in transportation and engineering contexts. By analyzing this problem comprehensively, we can appreciate both the theoretical underpinnings and real-world applications.

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## Introduction to the Scenario

This problem involves a moving boxcar with a substantial mass colliding with a stationary boxcar of equal or different mass. The key parameters are:

- Mass of the moving boxcar: 7800 kg
- Initial velocity of the moving boxcar: 12 m/s
- Mass of the stationary boxcar: assumed to be identical unless otherwise specified
- Final state: both boxcars stick together and move with a common velocity after collision

Understanding this scenario requires an exploration of the principles of momentum conservation, inelastic collisions, and energy considerations.

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## Fundamental Concepts Involved

## Momentum Conservation

Momentum, defined as the product of mass and velocity, is a conserved quantity in isolated systems. In this case, since external forces such as friction or external pushes are not considered, the total momentum before and after the collision remains constant.

Mathematically:

Total initial momentum = Total final momentum

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

where:

$$
p_{initial} = m_1 v_1 + m_2 v_2
$$

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

## Inelastic Collisions

Since the two boxcars stick together after collision, this is an inelastic collision. Unlike elastic collisions, kinetic energy is not conserved in inelastic collisions; some energy is dissipated as heat, sound, deformation, etc.

The key features:

- Momentum is conserved
- Kinetic energy is not conserved
- The combined mass moves with a velocity determined by momentum conservation

## Calculating the Final Velocity

Assuming the second boxcar is initially at rest, and both boxcars have equal mass:

$$
m_1 = m_2 = 7800\, \text{kg}
$$

Initial velocities:

$$
v_1 = 12\, \text{m/s}
$$

$$
v_2 = 0\, \text{m/s}
$$

Applying conservation of momentum:

$$
m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_{final}
$$

Plugging in the values:

$$
(7800)(12) + (7800)(0) = (7800 + 7800) v_{final}
$$

$$
93600 = 15600 \times v_{final}
$$

$$
v_{final} = \frac{93600}{15600} = 6\, \text{m/s}
$$

Result: The combined boxcars move together at 6 m/s after the collision.

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# Implications and Features of the Scenario

## Energy Considerations

While momentum is conserved, kinetic energy is reduced due to the inelastic nature of the collision. The initial kinetic energy:

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

$$
KE_{initial} = \frac{1}{2} \times 7800 \times 12^2 + 0 = 0.5 \times 7800 \times 144 = 561,600\, \text{J}
$$

\]

The final kinetic energy:

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

$$
KE_{final} = 0.5 \times 15600 \times 6^2 = 0.5 \times 15600 \times 36 = 280,800\, \text{J}
$$

The energy lost:

$$
\Delta KE = KE_{initial} - KE_{final} = 561,600 - 280,800 = 280,800\, \text{J}
$$

This energy appears as heat, sound, or deformation.

Features:

- Energy loss illustrates the inelastic nature
- Potential for damage or deformation in real-world rail systems

## Practical Applications

Understanding such collision dynamics is vital for:

- Designing safer railcar couplings

- Developing energy-absorbing features in transportation
- Accident analysis and prevention

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# Pros and Cons of Inelastic Collisions in Engineering Contexts

Pros:

- Simplifies energy dissipation analysis
- Useful for designing crash barriers and safety systems
- Reflects realistic collision scenarios where deformation occurs

Cons:

- Energy loss complicates efficiency calculations
- Damage potential increases due to inelastic deformation
- Less ideal for energy conservation in transportation systems

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# Additional Considerations and Variations

## Different Masses and Velocities

If the second boxcar has a different mass or initial velocity, the calculations change accordingly. For example, if the second boxcar has a mass of 6500 kg and is moving at 8 m/s, the final velocity after collision can be calculated similarly with the adjusted parameters.

### Elastic Collisions

If the collision were elastic, both kinetic energy and momentum would be conserved. In such a case, the velocities after collision would be different, often requiring solving a system of equations to find the velocities of both boxcars.

### Real-World Limitations

In real scenarios, factors such as friction, rolling resistance, and deformation influence outcomes. The simplified physics model provides a foundation but must be adjusted for practical engineering applications.

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## Conclusion

The scenario of a 7800-kg boxcar traveling at 12 m/s colliding with a stationary boxcar and moving together afterward offers profound insights into the principles of momentum conservation, inelastic collisions, and energy dissipation. Its relevance extends beyond theoretical physics into practical engineering, safety design, and transportation efficiency. The calculations reveal how mass and velocity influence the final state and energy distribution, emphasizing that in real-world systems, understanding these dynamics is crucial for optimizing safety and performance. Whether in designing safer railcars, understanding accident mechanics, or developing energy-absorbing structures, mastering the principles demonstrated by this scenario is invaluable for engineers and physicists alike.

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