PHYS11 CH8: Understanding Momentum

From Everyday Motion to Conservation Laws

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Think About This...

Opening Scenario

Why is it harder to stop...

- A heavy truck moving slowly, or
- A light car moving quickly?

- This question introduces us to the concept of **momentum**
- By the end of this lesson, you'll understand exactly why both situations are challenging!

Learning Objectives

By the end of this lesson, you will be able to:

- **Explain** momentum using everyday examples
- **Calculate** the momentum of moving objects
- **Describe** how force and time relate to changing momentum
- **Apply** conservation of momentum to real situations
- **Analyze** different types of collisions

Understanding Momentum: The Basics

Momentum: A Measure of Motion

Think of momentum as an object's "motion strength"

- Like a moving bowling ball vs. a moving ping pong ball
- Two factors determine momentum:
  - How much stuff is moving (mass)
  - How fast it's moving (velocity)
- More mass OR more velocity = more momentum

Key Point

Momentum combines MASS and VELOCITY into a single measure of motion

The Mathematics of Momentum

Definition

Momentum ($\vec{p}$) = mass $\times$ velocity

$$\vec{p} = m\vec{v}$$

Units:

- Mass (kg)
- Velocity (m/s)
- Momentum (kgm/s)

Remember:

- Momentum is a vector
- Direction matters!
- Same direction as velocity

Momentum in Real Life

Sports Examples

- Football player running (large mass, moderate velocity)
- Baseball pitch (small mass, high velocity)
- Ice skater gliding (medium mass, low velocity)

Transportation Examples

- Heavy truck at highway speed
- Bicycle commuter
- High-speed train

Example: Understanding Momentum (I Do)

Problem

A 75 kg football player runs at 8 m/s. Calculate their momentum.

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Step-by-Step Solution

1. Identify what we know:
   - Mass (m) = 75 kg
   - Velocity (v) = 8 m/s

Example: Understanding Momentum (I Do)

Problem

A 75 kg football player runs at 8 m/s. Calculate their momentum.

Step-by-Step Solution

1. Identify what we know:
   - Mass (m) = 75 kg
   - Velocity (v) = 8 m/s
2. Apply the momentum formula:

$$\vec{p} = m\vec{v} = (75 \text{ kg})(8 \text{ m/s}) = 600 \text{ kgm/s}$$

Let's Try Together (We Do)

Problem

A 0.145 kg baseball is thrown at 40 m/s. Calculate:

- The ball's momentum
- Compare it to the football player's momentum

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Solution Steps

1. Calculate baseball momentum:

$$\vec{p} = (0.145 \text{ kg})(40 \text{ m/s}) = 5.8 \text{ kgm/s}$$

2. Compare:
   - Baseball: 5.8 kgm/s
   - Football player: 600 kgm/s

Changing Momentum: Understanding Impulse

Key Concept: Impulse

Impulse = Force $\times$ Time = Change in Momentum

$$F\Delta t = \Delta p$$

- Same effect can be achieved by:
  - Large force for short time
  - Small force for long time
- Examples:
  - Catching a baseball (extend arms to increase time)
  - Car airbags (increase collision time)
  - Karate board break (large force, very short time)

Conservation of Momentum

The Big Idea

In an isolated system (no external forces), total momentum stays constant

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- Object 1 momentum
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- Total $= p_1 + p_2$

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Key Equation

$$p_1 + p_2 = p_1' + p_2'$$

Understanding Collisions

Elastic Collisions

- Objects bounce apart
- Kinetic energy preserved
- Example: Pool balls
- Perfect elasticity rare

Inelastic Collisions

- Objects stick together
- Energy converted to heat/sound
- Example: Car crashes
- More common in real life

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Remember

Momentum is conserved in BOTH types of collisions!

Your Turn! (You Do)

Challenge Problem

A 1200 kg car moving at 15 m/s collides with a stationary 800 kg car. They stick together. What is their final velocity?

Hints

- This is an inelastic collision (they stick together)
- Use conservation of momentum
- Remember: $\text{mass}_1 v_1 + \text{mass}_2 v_2 = (\text{mass}_1 + \text{mass}_2) v_{\text{final}}$

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Solution Framework

$(1200)(15) + (800)(0) = (1200 + 800) v_{\text{final}}$

Momentum in the Real World

Safety Applications

- Vehicle crumple zones
- Sports padding and helmets
- Playground surface materials

Engineering Applications

- Rocket propulsion
- Impact testing
- Vehicle design

Key Takeaways

Main Concepts

- Momentum $=$ mass $\times$ velocity
- Impulse changes momentum
- Momentum is conserved in isolated systems
- Collisions can be elastic or inelastic

Why This Matters

Understanding momentum helps us:

- Design safer vehicles
- Improve sports equipment
- Predict motion in collisions
- Solve real-world problems

Questions to Consider

Think About

- Why do heavy vehicles need longer to stop?
- How do martial artists break boards?
- Why do catchers "give" with the ball?
- How do airbags protect us?

Next Steps

- Practice with example problems
- Connect concepts to daily life
- Observe momentum in action