

# 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)

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## 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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## 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