

# Newton's Third Law

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# CHAPTER 1

# Newton's Third Law

## Lesson Objectives

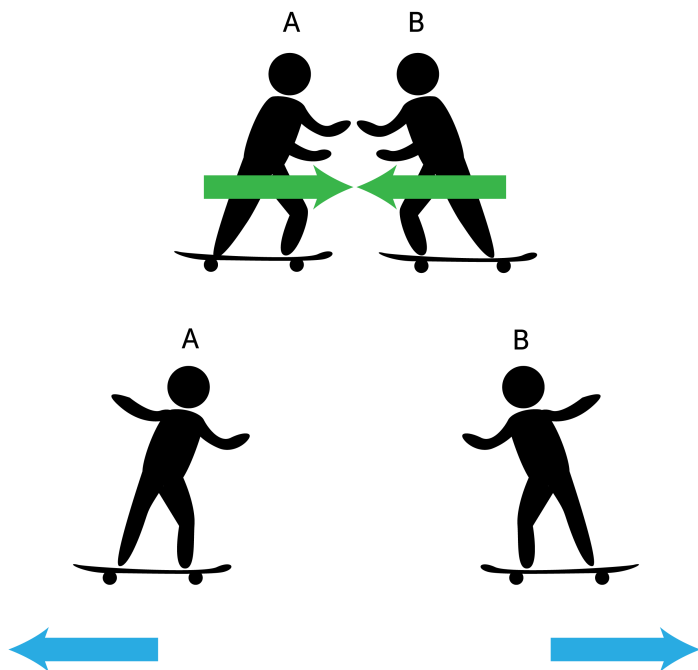
- State Newton's third law of motion.
- Describe momentum and the conservation of momentum.

## Lesson Vocabulary

- law of conservation of momentum
- momentum
- Newton's third law of motion

## Introduction

Look at the skateboarders in **Figure 1.1**. When they push against each other, it causes them to move apart. The harder they push together, the farther apart they move. This is an example of Newton's third law of motion.



**FIGURE 1.1**

A and B move apart by first pushing together.

## Action and Reaction

**Newton's third law of motion** states that every action has an equal and opposite reaction. This means that forces always act in pairs. First an action occurs, such as the skateboarders pushing together. Then a reaction occurs that is equal in strength to the action but in the opposite direction. In the case of the skateboarders, they move apart, and the distance they move depends on how hard they first pushed together. You can see other examples of actions and reactions in **Figure 1.2**. You can watch a video about actions and reactions at this URL: [http://www.nasa.gov/mov/192449main\\_019\\_law\\_of\\_action.mov](http://www.nasa.gov/mov/192449main_019_law_of_action.mov) .



**FIGURE 1.2**

Each example shown here includes an action and reaction.

You might think that actions and reactions would cancel each other out like balanced forces do. Balanced forces, which are also equal and opposite, cancel each other out because they act on the same object. Action and reaction forces, in contrast, act on different objects, so they don't cancel each other out and, in fact, often result in motion. For example, in **Figure 1.2**, the kangaroo's action acts on the ground, but the ground's reaction acts on the kangaroo. As a result, the kangaroo jumps away from the ground. One of the action-reaction examples in the **Figure 1.2** does not result in motion. Do you know which one it is?

## Momentum

What if a friend asked you to play catch with a bowling ball, like the one pictured in **Figure 1.3**? Hopefully, you would refuse to play! A bowling ball would be too heavy to catch without risk of injury —assuming you could even throw it. That's because a bowling ball has a lot of mass. This gives it a great deal of momentum. **Momentum** is a property of a moving object that makes the object hard to stop. It equals the object's mass times its velocity. It can be represented by the equation:

$$\text{Momentum} = \text{Mass} \times \text{Velocity}$$

This equation shows that momentum is directly related to both mass and velocity. An object has greater momentum if it has greater mass, greater velocity, or both. For example, a bowling ball has greater momentum than a softball when both are moving at the same velocity because the bowling ball has greater mass. However, a softball moving at a very high velocity—say, 100 miles an hour—would have greater momentum than a slow-rolling bowling ball. If an object isn't moving at all, it has no momentum. That's because its velocity is zero, and zero times anything is zero.


**FIGURE 1.3**

A bowling ball and a softball differ in mass. How does this affect their momentum?

### Calculating Momentum

Momentum can be calculated by multiplying an object's mass in kilograms (kg) by its velocity in meters per second (m/s). For example, assume that a golf ball has a mass of 0.05 kg. If the ball is traveling at a velocity of 50 m/s, its momentum is:

$$\text{Momentum} = 0.05 \text{ kg} \times 50 \text{ m/s} = 2.5 \text{ kg} \cdot \text{m/s}$$

Note that the SI unit for momentum is kg·m/s.

#### Problem Solving

*Problem:* What is the momentum of a 40-kg child who is running straight ahead with a velocity of 2 m/s?

*Solution:* The child has momentum of:  $40 \text{ kg} \times 2 \text{ m/s} = 80 \text{ kg} \cdot \text{m/s}$ .

#### You Try It!

*Problem:* Which football player has greater momentum?

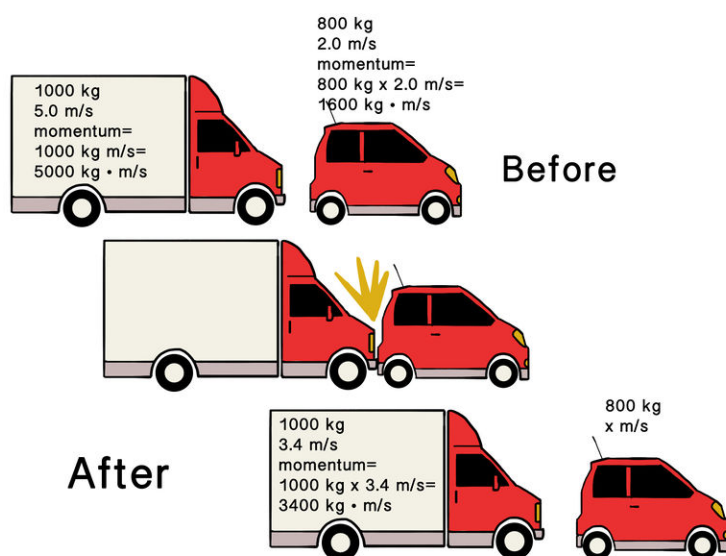
Player A: mass = 60 kg; velocity = 2.5 m/s

Player B: mass = 65 kg; velocity = 2.0 m/s

## Conservation of Momentum

When an action and reaction occur, momentum is transferred from one object to the other. However, the combined momentum of the objects remains the same. In other words, momentum is conserved. This is the **law of conservation of momentum**.

Consider the example of a truck colliding with a car, which is illustrated in **Figure 1.4**. Both vehicles are moving in the same direction before and after the collision, but the truck is moving faster than the car before the collision occurs. During the collision, the truck transfers some of its momentum to the car. After the collision, the truck is moving slower and the car is moving faster than before the collision occurred. Nonetheless, their combined momentum is the same both before and after the collision. You can see an animation showing how momentum is conserved in a head-on collision at this URL: <http://www.physicsclassroom.com/mmedia/momentum/cthoi.cfm> .



**FIGURE 1.4**

How can you tell momentum has been conserved in this collision?

## KQED: Newton's Laws of Motion

Paul Doherty of the Exploratorium performs a "sit-down" lecture on one of Sir Issac Newton's most famous laws. For more information on Newton's laws of motion, see <http://science.kqed.org/quest/video/quest-lab-newtons-laws-of-motion/> .



### MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/129626>

## KQED: Out of the Park - The Physics of Baseball

At UC Berkeley, a team of undergrads is experimenting with velocity, force, and aerodynamics. But you won't find them in a lab – they work on a baseball diamond, throwing fast balls, sliders and curve balls. QUEST discovers how the principles of physics can make the difference between a strike and a home run. For more information on the physics of baseball, see <http://science.kqed.org/quest/video/out-of-the-park-the-physics-of-baseball/> .



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## Lesson Summary

- Newton's third law of motion states that every action has an equal and opposite reaction.
- Momentum is a property of a moving object that makes it hard to stop. It equals the object's mass times its velocity. When an action and reaction occur, momentum may be transferred from one object to another, but their combined momentum remains the same. This is the law of conservation of momentum.

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## Lesson Review Questions

### Recall

1. State Newton's third law of motion.
2. Define momentum.
3. If you double the velocity of a moving object, how is its momentum affected?

### Apply Concepts

4. A large rock has a mass of 50 kg and is rolling downhill at 3 m/s. What is its momentum?
5. Create a diagram to illustrate the transfer and conservation of momentum when a moving object collides with a stationary object.

### Think Critically

6. The reaction to an action is an equal and opposite force. Why doesn't this yield a net force of zero?
7. Momentum is a property of an object, but it is different than a physical or chemical property, such as boiling point or flammability. How is momentum different?

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## Points to Consider

In this chapter, you learned about forces and motions of solid objects, such as balls and cars. In the next chapter, "Fluid Forces," you will learn about forces in fluids, which include liquids and gases.

- How do fluids differ from solids?
- What might be examples of forces in fluids? For example, what force allows some objects to float in water?

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## References

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2. Kangaroo: Chris Samuel; Kayaker: Mike Baird; Break dancer: angelo (Flickr:yapsnaps); Space shuttle: Courtesy of NASA. Kangaroo: <http://www.flickr.com/photos/chrissamuel/5366854530/>; Kayaker: <http://www.flickr.com/photos/mikebaird/6201271669/>; Break dancer: <http://www.flickr.com/photos/maladjusted/130569375/>; Space shuttle: [http://commons.wikimedia.org/wiki/File:Space\\_Shuttle\\_Columbia\\_launching.jpg](http://commons.wikimedia.org/wiki/File:Space_Shuttle_Columbia_launching.jpg) . Kangaroo, Kayaker, Break dancer: CC BY 2.0; Space shuttle: Public Domain
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