When this bumper car collides with another car, two forces are exerted. Each car in the collision exerts a force on the other.

Newton's Third Law

- What is Newton's third law of motion?
- According to Newton's third law of motion, whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

Newton's Third Law

Action and Reaction Forces

- The force your bumper car exerts on the other car is the action force.
- The force the other car exerts on your car is the reaction force.
- These two forces are equal in size and opposite in direction.

Newton's Third Law

Suppose you press your hand against a wall.

- Your hand exerts an action force on the wall.
- The wall exerts an equal and opposite reaction force against your hand.

Newton's Third Law

Action-Reaction Forces and Motion

A swimmer pushing against the water is an action force.

The reaction force acting on the swimmer causes motion through the water.

Newton's Third Law

Action-reaction forces propel the swimmer through the water. The swimmer pushes against the water, and the water pushes the swimmer.

Newton's Third Law

Action-Reaction Forces Do Not Cancel

For the swimmer, why do the action and reaction forces not cancel each other and produce a net force of zero?

Newton's Third Law

Action-Reaction Forces Do Not Cancel

For the swimmer, why do the action and reaction forces not cancel each other and produce a net force of zero?

The action and reaction forces do not act on the same object.

Momentum

What is needed for an object to have a large momentum?

Momentum is the product of an object's mass and its velocity.

An object has a large momentum if the product of its mass and velocity is large.

Momentum

An object with large momentum is harder to stop than an object with small momentum.

The momentum for any object at rest is zero.

Momentum

Mass is measured in kilograms.

Velocity is measured in meters per second.

Momentum is measured kilogram-meters per second.

Momentum Formula

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

Momentum

Which has more momentum, a 0.046-kilogram golf ball with a speed of 60.0 meters per second, or a 7.0-kilogram bowling ball with a speed of 6.0 meters per second?

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The bowling ball has considerably more momentum than the golfball.

Conservation of Momentum

How is momentum conserved?

A closed system means other objects and forces cannot enter or leave a system.

In a closed system, the loss of momentum of one object equals the gain in momentum of another object— momentum is conserved.

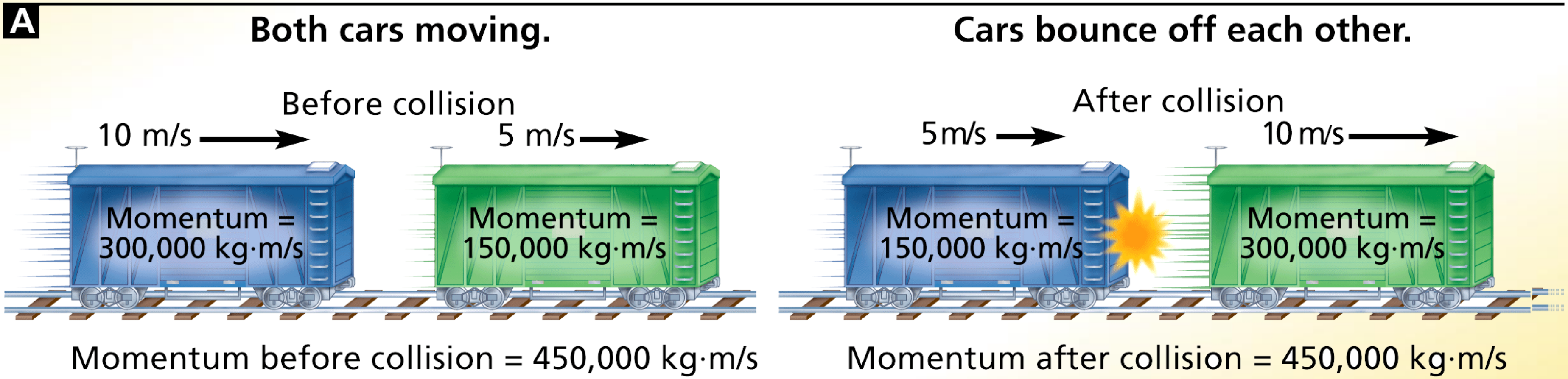
Conservation of Momentum

Objects within a closed system can exert forces on one another.

According to the **law of conservation of momentum,** if no net force acts on a system, then the total momentum of the system does not change.

Conservation of Momentum

In each collision, the total momentum of the train cars does not change—momentum is conserved.



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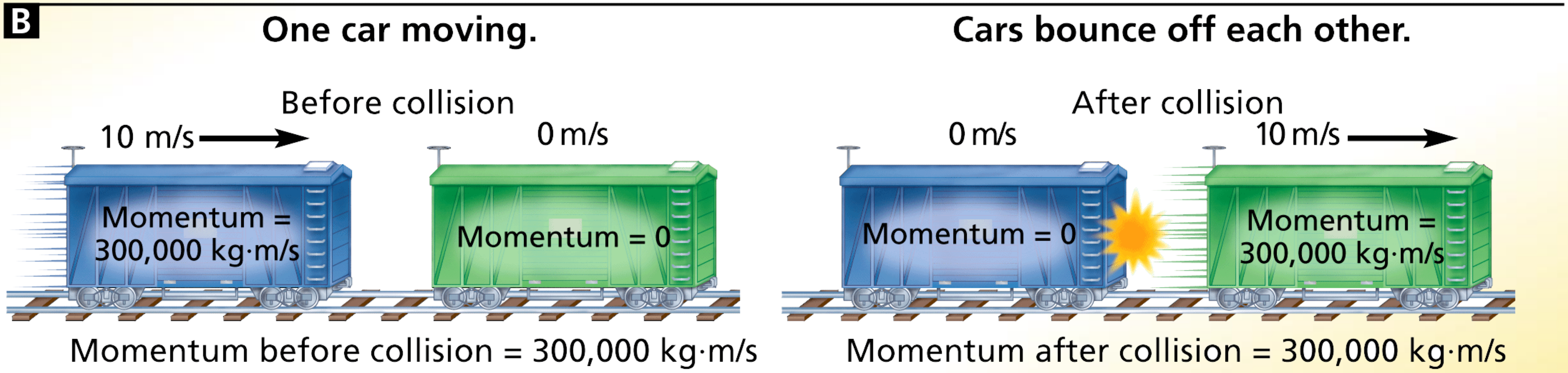

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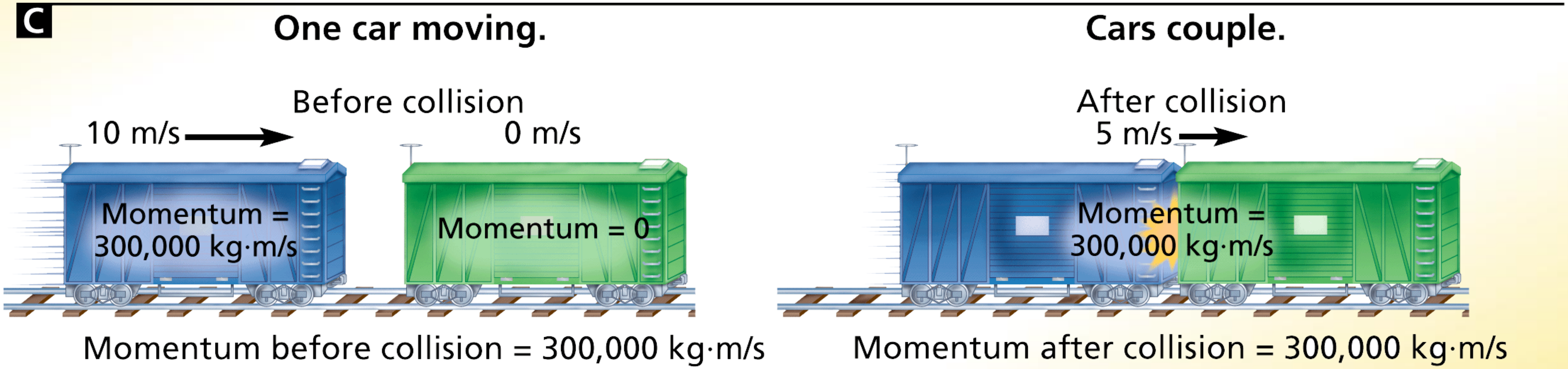


Momentum

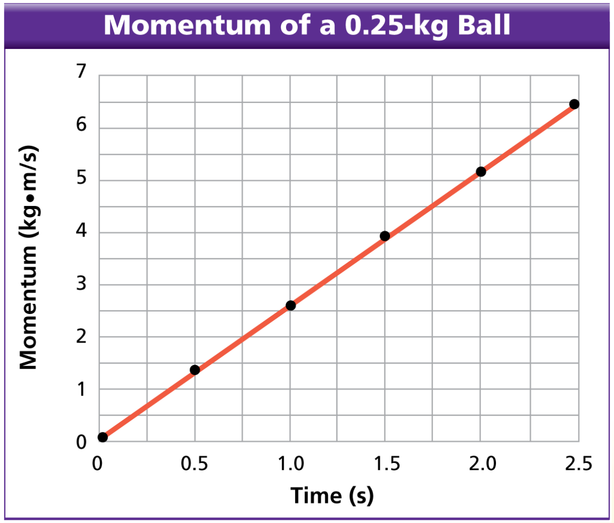
Data Analysis

A class studied the speed and momentum of a 0.25-kilogram ball dropped from a bridge. The graph shows the momentum of the ball from the time it was dropped until the time it hit the river flowing below the bridge.

Momentum

Data Analysis

1. **Applying Concepts** At what time did the ball have zero momentum? Describe this point in the ball's motion.



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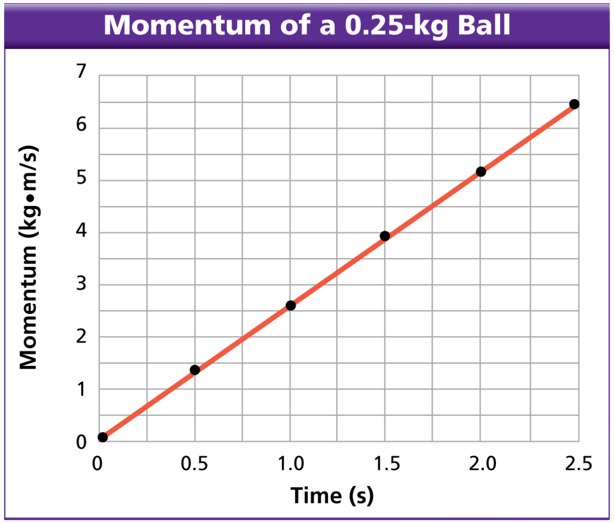
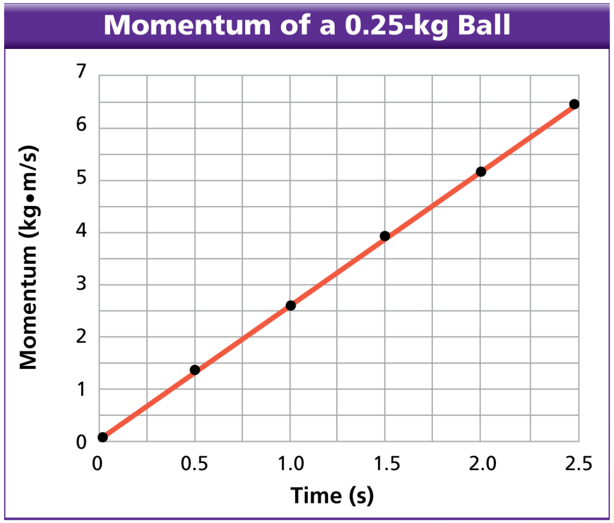


Answer: At t = 0 s; the ball has zero momentum before it is released.

Momentum

Data Analysis

2. **Using Graphs** At what time did the ball have the greatest momentum? What was the peak momentum value?



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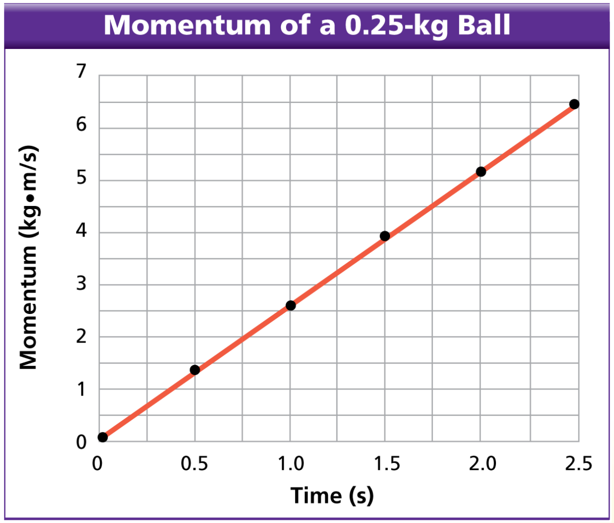
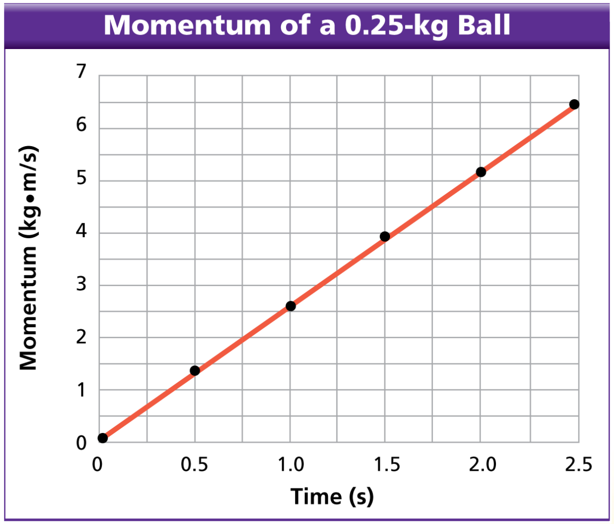


Answer: At t = 2.5 s; about 6.5 kg•m/s

Momentum

Data Analysis

3. **Calculating** What is the ball's speed after 1.25 seconds?
(*Hint:* Use the graph and the momentum formula.)



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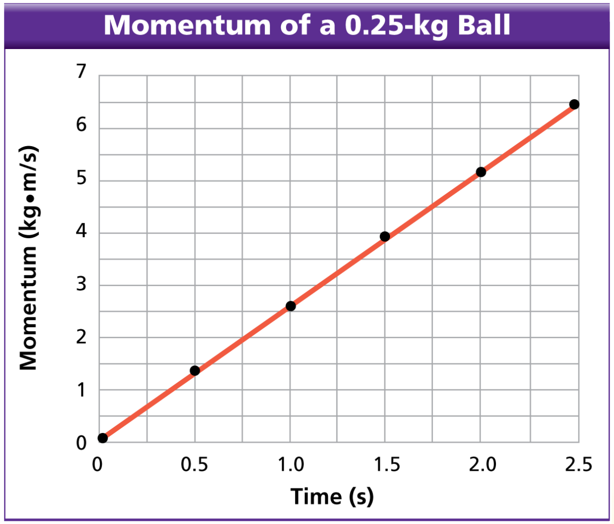

Answer: *(m)(v)* = 3.25 kg•m/s

v = (3.25 kg•m/s)/(0.25 kg) = 13 m/s upward

The speed is 13 m/s.

Assessment Questions

1. A stationary figure skater pushes off the boards around an ice skating rink and begins gliding backward, away from the boards. Which law explains why the figure skater moves backward?
   a. the law of conservation of energy
   b. the law of inertia
   c. Newton's second law
   d. Newton's third law

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   ANS: D

Assessment Questions

2. A red puck with Velcro on its side is sliding toward a stationary blue Velcro puck of the same mass. The pucks will stick together upon contact. After contact, how will the red puck's velocity compare to its initial velocity? (In this collision the law of conservation of momentum is obeyed, and friction is ignored.)
   a. The red puck's velocity is the same as before.
   b. The red puck's velocity is the same magnitude but in the opposite direction.
   c. The red puck's velocity is half its initial velocity and in the same direction.
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