Summary

THE BIG IDEA **Momentum is conserved for all collisions as long as external forces don't interfere.**

8.1 Momentum

A moving object can have a large momentum if it has a large mass, a high speed, or both.

- **Momentum** is the mass of the object multiplied by its velocity.
- A moving truck has more momentum than a car moving at the same speed because the truck has more mass.
- A fast car can have more momentum than a slow truck.
- A truck at rest has no momentum at all.

8.2 Impulse Changes Momentum

The change in momentum depends on the force that acts and the length of time it acts.

- The quantity *force* × *time interval* is called **impulse.** In short-hand notation, impulse = $F\Delta t$.
- The greater the impulse exerted on something, the greater will be the change in momentum. The exact relationship is impulse = change in momentum or $Ft = \Delta(mv)$.
- To increase the momentum of an object, apply the greatest force possible for as long as possible. A golfer teeing off and a baseball player trying for a home run do both of these things when they swing as hard as possible and follow through with their swings.
- In the case of decreasing momentum, a longer contact time reduces the force and decreases the resulting deceleration. A padded dashboard in a car is safer than a rigid, metal one because the padded dashboard increases the time of contact.

8.3 Bouncing

The impulse required to bring an object to a stop and then to "throw it back again" is greater than the impulse required merely to bring the object to a stop.

- It takes a greater impulse to catch a flower pot and throw it back up than merely to catch it.
- A karate expert strikes the bricks in such a way that her hand is made to bounce back, yielding as much as twice the impulse to the bricks.

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8.4 Conservation of Momentum

The law of conservation of momentum states that, in the absence of an external force, the momentum of a system remains unchanged.

- The law of conservation of momentum describes the momentum of a system.
- If a system undergoes changes wherein all forces are internal—for example, in atomic nuclei undergoing radioactive decay, cars colliding, or stars exploding—the net momentum of the system before and after the event is the same.
- The momentum before firing a cannon is zero. After firing, the momentum is still zero because the momentum of the cannon is equal and opposite to the momentum of the cannonball.

8.5 Collisions

Whenever objects collide in the absence of external forces, the net momentum of both objects before the collision equals the net momentum of both objects after the collision.

- When objects collide without being permanently deformed and without generating heat, the collision is said to be an **elastic collision.**
- Colliding *objects* bounce perfectly in perfect elastic collisions.
- A collision in which the colliding objects become distorted and generate heat during the collision is an **inelastic collision.**
- Whenever colliding objects become tangled or couple together, a totally inelastic collision occurs.
- Perfectly elastic collisions are not common in the everyday world. At the microscopic level, however, perfectly elastic collisions are commonplace. For example, electrically charged particles bounce off one another without generating heat.

8.6 Momentum Vectors

The vector sum of momenta is the same before and after a collision.

- Momentum is conserved even when the interacting objects don't move along the same straight line.
- The momentum of a car wreck is equal to the vector sum of the momenta of each of the cars before the collision.
- When a firecracker bursts, the vector sum of the momenta of its fragments adds up to the firecracker's momentum just before bursting.

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Exercises

8.1 Momentum (page 125)

1. Define momentum. ______________________
2. What is the equation for momentum? ______________________
3. A moving object can have a large momentum if it has a(n) ______________, a(n) ______________, or both.

8.2 Impulse Changes Momentum (pages 125–129)

4. Is the following sentence true or false? If the momentum of an object changes, either the mass or the velocity or both change. ______________
5. If a force is increased on an object, what happens to the velocity and the momentum? ______________________
6. The change in momentum depends on the ______________ that acts and the length of ______________ it acts.
7. What is the short-hand notation for impulse? ______________
8. What is the formula that relates impulse and change in momentum? ______________________
9. Explain why a baseball player follows through with his or her swing. ______________________
10. Is the following sentence true or false? By hitting a soft object, such as a haystack, instead of a hard object, such as a concrete wall, you extend the contact time in which the momentum is brought to zero. ______________
11. Circle the letter of each sentence that is true about impulse and momentum.
    a. When jumping from an elevated position down to the ground, you should keep your legs stiff to decrease the momentum.
    b. A wrestler thrown to the floor should extend his time hitting the mat by relaxing his muscles and spreading the impulse to his foot, knee, hip, ribs, and shoulder.
    c. When a boxer gets punched, she should move her head away from the punch to increase the contact time and reduce the force.
    d. A dropped dish is more likely to survive a fall on carpet rather than concrete, because the softness of the carpet leads to increased contact time.

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8.3 Bouncing (pages 129–130)

12. Is the following sentence true or false? The impulse required to bring an object to a stop and then to "throw it back again" is less than the impulse merely to bring the object to a stop. ______________

13. Explain how a person practicing karate can break bricks with his or her bare hand.

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14. Use the diagram of the Pelton Wheel above to explain how the blades work.

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8.4 Conservation of Momentum (pages 130–131)

Match each phrase with another phrase that makes the statement true.

_____ 15. If you wish to change the momentum of an object,

_____ 16. The force or impulse must be exerted on the object

_____ 17. If no outside force is present,

_____ 18. The force on the cannonball inside the cannon barrel is equal

a. no change in momentum is possible.

b. exert an impulse on it.

c. and opposite to the force causing the cannon to recoil.

d. by something outside the object.

19. Explain why the total momentum of a cannon–cannonball system is zero after firing.

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20. Is momentum a vector or a scalar quantity? ____________

21. Is the following sentence true or false? The law of conservation of momentum states that, in the absence of an external force, the momentum of a system remains unchanged. ____________

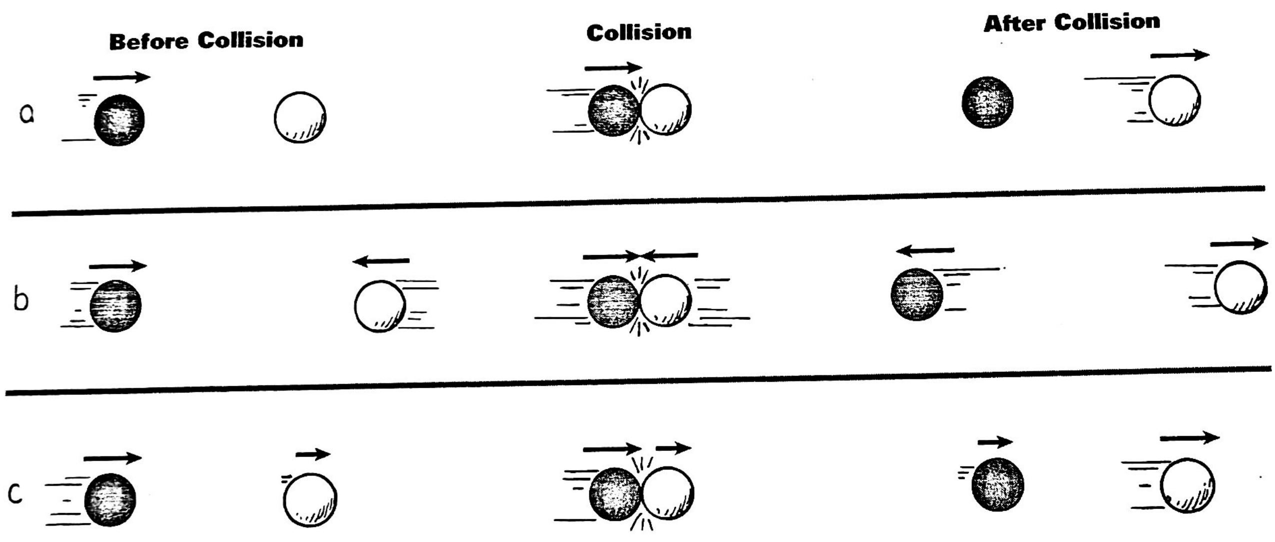
22. Is the following sentence true or false? If a system undergoes changes wherein all the forces are internal, such as an atomic nuclei undergoing nuclear decay, the net momentum of the system before and after the event is the same. ____________

8.5 Collisions (pages 132–134)

23. Is the following sentence true or false? Whenever objects collide in the absence of external forces, the net momentum of both objects before the collision does not equal the net momentum of both objects after the collision. ____________

24. When objects collide without being permanently deformed and without generating heat, the collision is said to be a(n) ____________.

25. Describe how the velocities of each of the billiard balls changes in the elastic collisions below.



a. ____________

____

b. ____________

____

c. ____________

____

26. A collision in which the colliding objects become distorted and generate heat during the collision is a(n) ______________.
27. What is the equation for the conservation of momentum?

    ____

28. Since there is no air resistance in space, what is the only opposing force that affects two docking space stations? ______________
29. What is an example of a perfectly elastic collision at the microscopic level?

    ____

8.6 Momentum Vectors (pages 135–136)

30. Is this sentence true or false? Momentum is conserved only when interacting objects move along the same straight path.

    ____

31. Circle the letter of each sentence that is true.
    a. The vector sum of the momenta is the same before and after a collision.
    b. The momentum of the car wreck is not equal to the vector sum of the momenta of car A and car B before the collision.
    c. When a firecracker bursts, the vector sum of the momenta of its fragments add up to the firecracker's momentum just before bursting.
    d. Momentum is not conserved for high-speed elementary particles in bubble chambers.
32. What two conservation laws are the most powerful tools in the study of mechanics?

    ____

Momentum

A 0.5-kg toy truck moving at a velocity of 0.5 m/s collides head-on with a 0.75-kg toy truck that is at rest. The trucks become entangled and lock together. What is the velocity of the two toy trucks after the collision?

1. Read and Understand

What information are you given?

$m_{toy\ 1} = 0.5$ kg

$v_{toy\ 1} = 0.5$ m/s

$m_{toy\ 2} = 0.75$ kg

$v_{toy\ 2} = 0$ m/s

2. Plan and Solve

What unknown are you trying to calculate?

$v_{after} = ?$

What formula contains the given quantities and the unknown?

$(\text{net } mv)_{before} = (\text{net } mv)_{after}$

Replace each variable with its known value.

$(0.5 \text{ kg})(0.5 \text{ m/s}) + (0.75 \text{ kg})(0 \text{ m/s}) = (0.5 \text{ kg} + 0.75 \text{ kg})(v_{after})$

$0.25 \text{ kg} \cdot \text{m/s} = (1.25 \text{ kg})(v_{after})$

$v_{after} = 0.2$ m/s

3. Look back and check

Is your answer reasonable?

Yes, the number calculated is the quotient of distance and speed, and the units indicate a velocity.

Math Practice

On a separate sheet of paper, solve the following problems.

1. A 0.25-kg ball rolling at 1.0 m/s rolls and overtakes a 0.3-kg ball rolling in the same direction at 0.5 m/s. The balls stick together on impact. What is the velocity of the two balls after the collision?

2. A 5.0-kg puppy running at 2.0 m/s picks up a 1.0-kg stick that is sitting on the ground. What is the momentum of the puppy and the stick after the puppy picks up the stick?