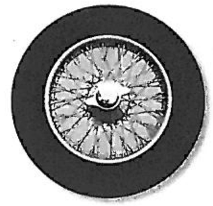
CHAPTER 9 REVIEW

Key Terms

9.1
- impulse
- linear momentum
- impulse-momentum theorem
- angular momentum

9.2
- closed system
- internal force
- external force
- isolated system
- law of conservation of momentum



Summary

9.1 Impulse and Momentum
- When doing a momentum problem, first examine the system before and after the event.
- The momentum of an object is the product of its mass and velocity and is a vector quantity.
- The impulse given an object is the average net force exerted on the object multiplied by the time interval over which the force acts.
- The impulse given an object is equal to the change in momentum of the object.

9.2 The Conservation of Momentum
- Newton's third law of motion explains momentum conservation in a collision because the forces that the colliding objects exert on each other are equal in magnitude and opposite in direction.
- The momentum is conserved in a closed, isolated system.
- Conservation of momentum is used to explain the propulsion of rockets.
- Vector analysis is used to solve momentum-conservation problems in two dimensions.

Reviewing Concepts

Section 9.1

1. Can a bullet have the same momentum as a truck? Explain.
2. A pitcher throws a fastball to the catcher. Assuming that the speed of the ball doesn't change in flight,
   a. which player exerts the larger impulse on the ball?
   b. which player exerts the larger force on the ball?
3. Newton's second law of motion states that if no net force is exerted on a system, no acceleration is possible. Does it follow that no change in momentum can occur?
4. Why are cars made with bumpers that can be pushed in during a crash?

Section 9.2

5. What is meant by an isolated system?
6. A spacecraft in outer space increases its velocity by firing its rockets. How can hot gases escaping from its rocket engine change the velocity of the craft when there is nothing in space for the gases to push against?
7. The cue ball travels across the pool table and collides with the stationary eight-ball. The two balls have equal mass. After the collision, the cue ball is at rest. What must be true regarding the speed of the eight-ball?
8. Consider a ball falling toward Earth.
   a. Why is the momentum of the ball not conserved?
   b. In what system that includes the falling ball is the momentum conserved?
9. A falling ball hits the floor. Just before it hits, the momentum is in the downward direction, and the momentum is in the upward direction after it hits.
   a. The bounce is a collision, so why isn't the momentum of the ball conserved?
   b. In what system is it conserved?
10. Only an external force can change the momentum of a system. Explain how the internal force of a car's brakes brings the car to a stop.

Applying Concepts

11. Explain the concept of impulse using physical ideas rather than mathematics.

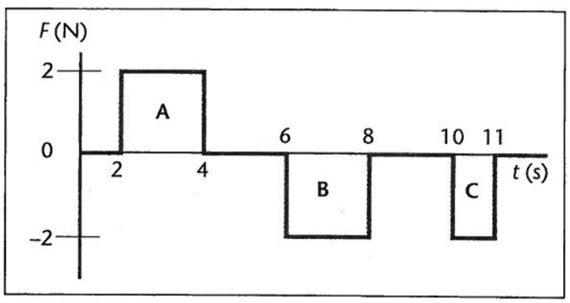
12. Is it possible for an object to obtain a larger impulse from a smaller force than it does from a larger force? How?

13. You are sitting at a baseball game when a foul ball comes in your direction. You prepare to catch it barehanded. In order to catch it safely, should you move your hands toward the ball, hold them still, or move them in the same direction as the moving ball? Explain.

14. A 0.11-g bullet leaves a pistol at 323 m/s, while a similar bullet leaves a rifle at 396 m/s. Explain the difference in exit speeds of the two bullets assuming that the forces exerted on the bullets by the expanding gases have the same magnitude.

15. An object initially at rest experiences the impulses described by the graph in **Figure 9–11.** Describe the object's motion after impulses A, B, and C.

FIGURE 9–11



16. During a space walk, the tether connecting an astronaut to the spaceship breaks. Using a gas pistol, the astronaut manages to get back to the ship. Explain why this method was effective, using the language of the impulse-momentum theorem and a diagram.

17. As a tennis ball bounces off a wall, its momentum is reversed. Explain this action in terms of the law of conservation of momentum, defining the system and using a diagram.

18. You command *Spaceship Zero,* which is moving through interplanetary space at high speed. How could you slow your ship by applying the law of conservation of momentum?

19. Two trucks that appear to be identical collide on an icy road. One was originally at rest. The trucks stick together and move off at more than half the original speed of the moving truck. What can you conclude about the contents of the two trucks?

20. Explain, in terms of impulse and momentum, why it is advisable to place the butt of a rifle against your shoulder when first learning to shoot.

21. Two bullets of equal mass are shot at equal speeds at blocks of wood on a smooth ice rink. One bullet, which is made of rubber, bounces off the wood. The other bullet, made of aluminum, burrows into the wood. In which case does the wood move faster? Explain.

Problems

Section 9.1

LEVEL 1

22. Your brother's mass is 35.6 kg, and he has a 1.3-kg skateboard. What is the combined momentum of your brother and his skateboard if they are going 9.50 m/s?

23. A hockey player makes a slap shot, exerting a constant force of 30.0 N on the hockey puck for 0.16 s. What is the magnitude of the impulse given to the puck?

24. A hockey puck has a mass of 0.115 kg and is at rest. A hockey player makes a shot, exerting a constant force of 30.0 N on the puck for 0.16 s. With what speed does it head toward the goal?

25. Before a collision, a 25-kg object is moving at +12 m/s. Find the impulse that acted on the object if, after the collision, it moves at:
a. +8.0 m/s. **b.** −8.0 m/s.

26. A constant force of 6.00 N acts on a 3.00-kg object for 10.0 s. What are the changes in the object's momentum and velocity?

27. The velocity of a 625-kg auto is changed from 10.0 m/s to 44.0 m/s in 68.0 s by an external, constant force.
a. What is the resulting change in momentum of the car?
b. What is the magnitude of the force?

28. An 845-kg dragster accelerates from rest to 100 km/h in 0.90 seconds.
a. What is the change in momentum of the car?
b. What is the average force exerted on the car?
c. What exerts that force?

LEVEL 2

29. A 0.150-kg ball, moving in the positive direction at 12 m/s, is acted on by the impulse shown in the graph in **Figure 9–12.** What is the ball's speed at 4.0 s?

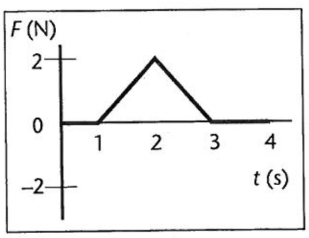


FIGURE 9–12

30. Small rockets are used to make tiny adjustments in the speed of satellites. One such rocket has a thrust of 35 N. If it is fired to change the velocity of a 72 000-kg spacecraft by 63 cm/s, how long should it be fired?

31. A car moving at 10 m/s crashes into a barrier and stops in 0.050 s. There is a 20-kg child in the car. Assume that the child's velocity is changed by the same amount as the car's in the same time period.
a. What is the impulse needed to stop the child?
b. What is the average force on the child?
c. What is the approximate mass of an object whose weight equals the force in part **b**?
d. Could you lift such a weight with your arm?
e. Why is it advisable to use a proper infant restraint rather than hold a child on your lap?

32. An animal-rescue plane flying due east at 36.0 m/s drops a bale of hay from an altitude of 60.0 m. If the bale of hay weighs 175 N, what is the momentum of the bale the moment before it strikes the ground? Give both magnitude and direction.

33. A 60-kg dancer leaps 0.32 m high.
a. With what momentum does the dancer reach the ground?
b. What impulse is needed to stop the dancer?
c. As the dancer lands, his knees bend, lengthening the stopping time to 0.050 s. Find the average force exerted on the dancer's body.
d. Compare the stopping force to the dancer's weight.

Section 9.2

LEVEL 1

34. A 95-kg fullback, running at 8.2 m/s, collides in midair with a 128-kg defensive tackle moving in the opposite direction. Both players end up with zero speed.
a. Identify "before" and "after" and make a diagram of the situations.
b. What was the fullback's momentum before the collision?
c. What was the change in the fullback's momentum?
d. What was the change in the tackle's momentum?
e. What was the tackle's original momentum?
f. How fast was the tackle moving originally?

35. Marble A, mass 5.0 g, moves at a speed of 20.0 cm/s. It collides with a second marble, B, mass 10.0 g, moving at 10.0 cm/s in the same direction. After the collision, marble A continues with a speed of 8.0 cm/s in the same direction.
a. Sketch the situation, identify the system, define "before" and "after," and assign a coordinate axis.
b. Calculate the marbles' momenta before the collision.
c. Calculate the momentum of marble A after the collision.
d. Calculate the momentum of marble B after the collision.
e. What is the speed of marble B after the collision?

36. A 2575-kg van runs into the back of a 825-kg compact car at rest. They move off together at 8.5 m/s. Assuming the friction with the road can be negligible, find the initial speed of the van.

37. A 0.115-kg hockey puck, moving at 35.0 m/s, strikes a 0.265-kg octopus thrown onto the ice by a hockey fan. The puck and octopus slide off together. Find their velocity.

38. A 50-kg woman, riding on a 10-kg cart, is moving east at 5.0 m/s. The woman jumps off the front of the cart and hits the ground at 7.0 m/s eastward, relative to the ground.
  a. Sketch the situation, identifying "before" and "after," and assigning a coordinate axis.
  b. Find the velocity of the cart after the woman jumps off.

39. Two students on roller skates stand face-to-face, then push each other away. One student has a mass of 90 kg; the other has a mass of 60 kg.
  a. Sketch the situation, identifying "before" and "after," and assigning a coordinate axis.
  b. Find the ratio of the students' velocities just after their hands lose contact.
  c. Which student has the greater speed?
  d. Which student pushed harder?

40. A 0.200-kg plastic ball moves with a velocity of 0.30 m/s. It collides with a second plastic ball of mass 0.100 kg, which is moving along the same line at a speed of 0.10 m/s. After the collision, both balls continue moving in the same, original direction, and the speed of the 0.100-kg ball is 0.26 m/s. What is the new velocity of the first ball?

LEVEL 2

41. A 92-kg fullback, running at 5.0 m/s, attempts to dive directly across the goal line for a touchdown. Just as he reaches the line, he is met head-on in midair by two 75-kg linebackers both moving in the direction opposite the fullback. One is moving at 2.0 m/s, the other at 4.0 m/s. They all become entangled as one mass.
  a. Sketch the situation, identifying "before" and "after."
  b. What is their velocity after the collision?
  c. Does the fullback score?

42. A 5.00-g bullet is fired with a velocity of 100.0 m/s toward a 10.00-kg stationary solid block resting on a frictionless surface.
  a. What is the change in momentum of the bullet if it is embedded in the block?
  b. What is the change in momentum of the bullet if it ricochets in the opposite direction with a speed of 99 m/s?
  c. In which case does the block end up with a greater speed?

43. The diagrams in **Figure 9–13** show a brick weighing 24.5 N being released from rest on a 1.00-m frictionless plane, inclined at an angle of 30.0°. The brick slides down the incline and strikes a second brick weighing 36.8 N.

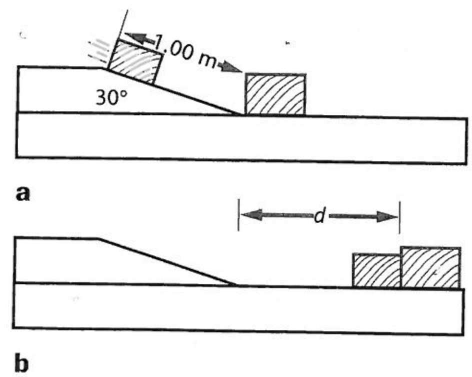


FIGURE 9-13

  a. Calculate the speed of the first brick at the bottom of the incline.
  b. If the two bricks stick together, with what initial speed will they move along?
  c. If the force of friction acting on the two bricks is 5.0 N, how much time will elapse before the bricks come to rest?
  d. How far will the two bricks slide before coming to rest?

44. Ball A, rolling west at 3.0 m/s, has a mass of 1.0 kg. Ball B has a mass of 2.0 kg and is stationary. After colliding with ball B, ball A moves south at 2.0 m/s.
  a. Sketch the system, showing the velocities and momenta before and after the collision.
  b. Calculate the momentum and velocity of ball B after the collision.

45. A space probe with a mass of 7.600×10^3 kg is traveling through space at 125 m/s. Mission control decides that a course correction of 30.0° is needed and instructs the probe to fire rockets perpendicular to its present direction of motion. If the gas expelled by the rockets has a speed of 3.200 km/s, what mass of gas should be released?

46. The diagram in **Figure 9–14,** which is drawn to scale, shows two balls during a collision. The balls enter from the left, collide, and then bounce away. The heavier ball at the bottom of the diagram has a mass of 0.600 kg, and the other has a mass of 0.400 kg. Using a vector diagram, determine whether momentum is conserved in this collision. What could explain any difference in the momentum of the system before and after the collision?

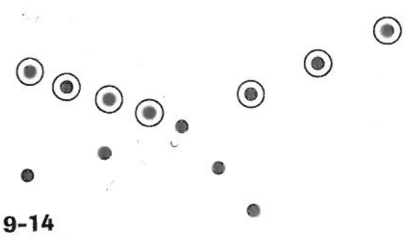


FIGURE 9-14

Critical Thinking Problems

47. A compact car, mass 875 kg, moving south at 15 m/s, is struck by a full-sized car, mass 1584 kg, moving east at 12 m/s. The two cars stick together, and momentum is conserved in the collision.
   a. Sketch the situation, assigning coordinate axes and identifying "before" and "after."
   b. Find the direction and speed of the wreck immediately after the collision, remembering that momentum is a vector quantity.
   c. The wreck skids along the ground and comes to a stop. The coefficient of kinetic friction while the wreck is skidding is 0.55. Assume that the acceleration is constant. How far does the wreck skid?

48. Your friend has been in a car accident and wants your help. She was driving her 1265-kg car north on Oak Street when she was hit by a 925-kg compact car going west on Maple Street. The cars stuck together and slid 23.1 m at 42° north of west. The speed limit on both streets is 50 mph (22 m/s). Your friend claims that she wasn't speeding, but that the other car was. Can you support her case in court? Assume that momentum was conserved during the collision and that acceleration was constant during the skid. The coefficient of kinetic friction between the tires and the pavement is 0.65.

Going Further

Team Project How can you survive a car crash? Work with a team to design a model for testing automobile safety devices. Your car can be a dynamics cart or other device with low-friction wheels. Make a seat out of wood that you securely mount on the car. Use clay to model a person. For a dashboard, use a piece of metal fastened to the front of the cart. Allow the car to roll down a ramp and collide with a block at the bottom of the ramp. Devise a testing procedure so that the car starts from the same distance up the ramp and comes to rest at the same place in every test. First, crash the car with no protection for the person. Examine the clay and describe the damage done. Then, design a padded dash by using a piece of rubber tubing. Use a piece of string or ribbon to make a lap and shoulder belt. Fasten the belt to the seat. Finally, model an airbag by placing a small, partially inflated balloon between the passenger and the dashboard.

Summarize your experiments, including an explanation of the forces placed on the passenger in terms of the change in momentum, the impulse, the average force, and the time interval over which the impulse occurred.

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