Practice

Understanding Concepts

1. What condition(s) must be met for the total momentum of a system to be conserved?
2. State whether you agree or disagree with the following statement: "The law of conservation of momentum for a system on which the net force is zero is equivalent to Newton's first law of motion." Give a reason for your answer.
3. You drop a 59.8-g hairbrush toward Earth (mass 5.98×10^{24} kg).
   (a) What is the direction of the gravitational force exerted by Earth on the hairbrush?
   (b) What is the direction of the gravitational force exerted by the hairbrush on Earth?
   (c) How do the forces in (a) and (b) compare in magnitude?
   (d) What is the net force on the system consisting of Earth and the hairbrush?
   (e) What can you conclude about the momentum of this system?
   (f) If we consider Earth and the hairbrush to be initially stationary, how does Earth move as the hairbrush falls down?
   (g) If the hairbrush reaches a speed of 10 m/s when it hits Earth (initially stationary), what is Earth's speed at this time?
4. A 45-kg student stands on a stationary 33-kg raft. The student then walks with a velocity of 1.9 m/s [E] relative to the water. What is the resulting velocity of the raft, relative to the water, if fluid friction is negligible.
5. Two ice skaters, initially stationary, push each other so that they move in opposite directions. One skater of mass of 56.9 kg has a speed of 3.28 m/s. What is the mass of the other skater if her speed is 3.69 m/s? Neglect friction.
6. A stationary 35-kg artillery shell accidentally explodes, sending two fragments of mass 11 kg and 24 kg in opposite directions. The speed of the 11-kg fragment is 95 m/s. What is the speed of the other fragment?
7. A railway car of mass 1.37×10^4 kg, rolling at 20.0 km/h [N], collides with another railway car of mass 1.12×10^4 kg, also initially rolling north, but moving more slowly. After the collision, the coupled cars have a velocity of 18.3 km/h [N]. What is the initial velocity of the second car?
8. A 0.045-kg golf ball is hit with a driver. The head of the driver has a mass of 0.15 kg, and travels at a speed of 56 m/s before the collision. The ball has a speed of 67 m/s as it leaves the clubface. What is the speed of the head of the driver immediately after the collision?

Applying Inquiry Skills

9. The graph in **Figure 6** shows velocity as a function of time for a system of two carts that undergo an experimental collision on a horizontal, frictionless surface. The mass of cart A is 0.40 kg. The mass of cart B is 0.80 kg.

Answers

3. (g) 1×10^{-25} m/s
4. 2.6 m/s [W]
5. 50.6 kg
6. 44 m/s
7. 16.2 km/h [N]
8. 36 m/s
9. (b) 0.24 kg·m/s [E]
   (c) 0.10 m/s [W]

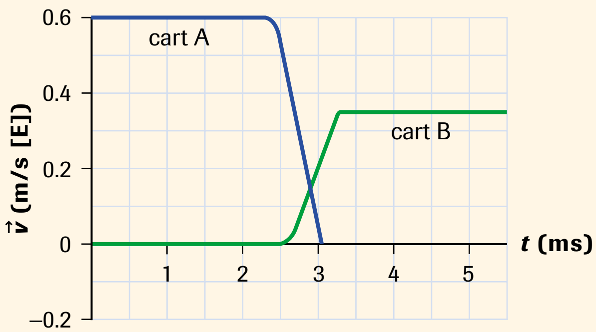

Figure 6
For question 9

(a) If you were conducting this experiment, describe what you would observe based on the graph.
(b) Determine the momentum of the system of carts before the collision.
(c) Assuming momentum is conserved, determine the velocity of cart A after the collision is complete.
(d) Copy the graph into your notebook, and complete the line for cart A. Superimpose lines that you think you would obtain in an experiment in which friction is not quite zero.

Making Connections

10. During a space walk, an astronaut becomes stranded a short distance from the spacecraft. Explain how the astronaut could solve the problem by applying conservation of momentum to return safely to the spacecraft. State any assumptions needed for your solution to work.

SUMMARY Conservation of Momentum in One Dimension

- The law of conservation of linear momentum states that if the net force acting on a system is zero, then the momentum of the system is conserved.
- During an interaction between two objects in a system on which the total net force is zero, the change in momentum of one object is equal in magnitude, but opposite in direction, to the change in momentum of the other object.
- For any collision involving a system on which the total net force is zero, the total momentum before the collision equals the total momentum after the collision.

Section 5.2 Questions

Understanding Concepts

1. A bowling ball (B) moving at high speed is about to collide with a single stationary pin (P) (**Figure 7**). The mass of the ball is more than four times greater than the mass of the pin. For the short time interval in which the collision occurs, state whether each of the following statements is true or false. If the statement is false, write a corrected version.
(a) The magnitude of the force exerted by B on P is greater than the magnitude of the force exerted by P on B.
(b) The magnitude of the change in velocity of B equals the magnitude of the change in velocity of P.

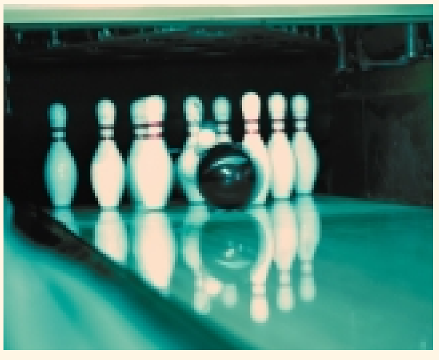

Figure 7
The bowling ball has a greater mass than the pin.

(c) The time interval of the collision for B equals the time interval of the collision for P.
(d) The magnitude of the change in momentum of B is less than the magnitude of the change in momentum of P.

2. Can individual objects in a system have nonzero momentum while the momentum of the entire system is zero? If "yes," give an example. If "no," explain why not.

3. In which of the following situations is the momentum conserved for the system of objects A and B?
(a) A vacationer A stands in a stationary raft B; the vacationer then walks in the raft. (Neglect fluid friction.)
(b) A freely rolling railway car A strikes a stationary railway car B.
(c) A veggie burger A is dropped vertically into a frying pan B and comes to rest.

4. In 1920, a prominent newspaper wrote the following about Robert Goddard, a pioneer of rocket ship development: "Professor Goddard does not know the relationship of action to reaction, and of the need to have something better than a vacuum against which to react. Of course, he only seems to lack the knowledge ladled out daily in high schools." Explain why the newspaper was wrong (as it itself admitted years later).

5. A 57-kg factory worker takes a ride on a large, freely rolling 27-kg cart. The worker initially stands still on the cart, and they both move at a speed of 3.2 m/s relative to the floor. The worker then walks on the cart in the same direction as the cart is moving. The worker's speed is now 3.8 m/s relative to the floor. What are the magnitude and direction of the final velocity of the cart?

6. A hiker of mass 65 kg is standing on a stationary raft of mass 35 kg. He is carrying a 19-kg backpack, which he throws horizontally. The resulting velocity of the hiker and the raft is 1.1 m/s [S] relative to the water. What is the velocity with which the hiker threw the backpack, relative to the water?

7. Two automobiles collide. One automobile of mass 1.13×10^3 kg is initially travelling at 25.7 m/s [E]. The other automobile of mass 1.25×10^3 kg has an initial velocity of 13.8 m/s [W]. The vehicles become attached during the collision. What is their common velocity immediately after the collision?

8. (a) Determine the magnitude and direction of the change in momentum for each automobile in question 7.
(b) How are these two quantities related?
(c) What is the total change in momentum of the two-automobile system?

9. A stationary quarterback is tackled by an 89-kg linebacker travelling with an initial speed of 5.2 m/s. As the two players move together after the collision, they have a speed of 2.7 m/s. What is the mass of the quarterback?

10. Two balls roll directly toward each other. The 0.25-kg ball has a speed of 1.7 m/s; the 0.18-kg ball has a speed of 2.5 m/s. After the collision, the 0.25-kg ball has reversed its direction and has a speed of 0.10 m/s. What is the magnitude and direction of the velocity of the 0.18-kg ball after the collision?

Applying Inquiry Skills

11. You are given two dynamics carts of masses m_1 and m_2, with nearly frictionless wheels. The carts are touching each other and are initially at rest. Cart 1 has an internal spring mechanism that is initially compressed (**Figure 8**). The spring is suddenly released, driving the carts apart. Describe an experimental procedure that you could use to test conservation of momentum for this "exploding" system. Include a list of apparatus you would need, safety precautions you would follow, and measurements you would take.

Making Connections

12. On a two-lane highway where the posted speed limit is 80 km/h, a car of mass m_C and an SUV of mass m_S have a head-on collision. The collision analyst observes that both vehicles came to a stop at the location of the initial impact. Researching the mass of the vehicles, the analyst found that $m_S = 2m_C$. Both drivers survived the collision and each claimed to be travelling at the legal speed limit when the collision occurred.
(a) It is obvious that the analyst cannot believe both drivers. Use numerical data to explain why.
(b) If both vehicles had been travelling at the legal speed limit before the collision, how would the accident scene have been different? (Assume that the collision was still head-on.)

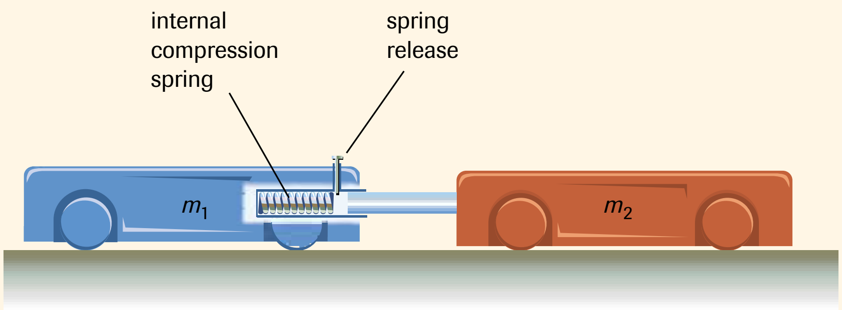

Figure 8
For question 11