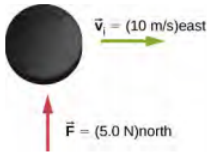
5.E: Conservation of Momentum (Exercises)

Conceptual Questions

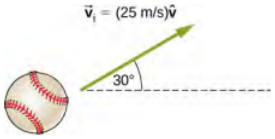
1. Under what circumstances is momentum conserved?
2. Can momentum be conserved for a system if there are external forces acting on the system? If so, under what conditions? If not, why not?
3. Explain in terms of momentum and Newton's laws how a car's air resistance is due in part to the fact that it pushes air in its direction of motion.
4. Can objects in a system have momentum while the momentum of the system is zero? Explain your answer.
5. A sprinter accelerates out of the starting blocks. Can you consider him as a closed system? Explain.

Problems

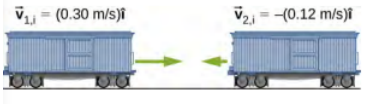
6. A hockey puck of mass 150 g is sliding due east on a frictionless table with a speed of 10 m/s. Suddenly, a constant force of magnitude 5 N and direction due north is applied to the puck for 1.5 s. Find the north and east components of the momentum at the end of the 1.5-s interval.



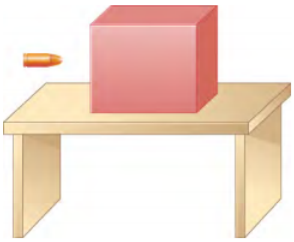
7. A ball of mass 250 g is thrown with an initial velocity of 25 m/s at an angle of 30° with the horizontal direction. Ignore air resistance. What is the momentum of the ball after 0.2 s? (Do this problem by finding the components of the momentum first, and then constructing the magnitude and direction of the momentum vector from the components.)



8. Train cars are coupled together by being bumped into one another. Suppose two loaded train cars are moving toward one another, the first having a mass of 1.50 x 10^5 kg and a velocity of (0.30 m/s) in the x-direction, and the second having a mass of 1.10 x 10^5 kg and a velocity of −(0.12 m/s) in the x-direction. What is their final velocity?



9. The figure below shows a bullet of mass 200 g traveling horizontally towards the east with speed 400 m/s, which strikes a block of mass 1.5 kg that is initially at rest on a frictionless table. After striking the block, the bullet is embedded in the block and the block and the bullet move together as one unit. (a) What is the magnitude and direction of the velocity of the block/bullet combination immediately after the impact? (b) What is the magnitude and direction of the impulse by the block on the bullet? (c) What is the magnitude and direction of the impulse from the bullet on the block? (d) If it took 3 ms for the bullet to change the speed from 400 m/s to the final speed after impact, what is the average force between the block and the bullet during this time?



10. Explain why a cannon recoils when it fires a shell.
11. Two figure skaters are coasting in the same direction, with the leading skater moving at 5.5 m/s and the trailing skating moving at 6.2 m/s. When the trailing skater catches up with the leading skater, he picks her up without applying any horizontal forces on his skates. If the trailing skater is 50% heavier than the 50-kg leading skater, what is their speed after he picks her up?
12. A 2000-kg railway freight car coasts at 4.4 m/s underneath a grain terminal, which dumps grain directly down into the freight car. If the speed of the loaded freight car must not go below 3.0 m/s, what is the maximum mass of grain that it can accept?
13. A 90.0-kg ice hockey player hits a 0.150-kg puck, giving the puck a velocity of 45.0 m/s. If both are initially at rest and if the ice is frictionless, how far does the player recoil in the time it takes the puck to reach the goal 15.0 m away?
14. A 100-g firecracker is launched vertically into the air and explodes into two pieces at the peak of its trajectory. If a 72-g piece is projected horizontally to the left at 20 m/s, what is the speed and direction of the other piece?
15. You are standing on a very slippery icy surface and throw a 1-kg football horizontally at a speed of 6.7 m/ s. What is your velocity when you release the football? Assume your mass is 65 kg.
16. A 35-kg child sleds down a hill and then coasts along the flat section at the bottom, where a second 35-kg child jumps on the sled as it passes by her. If the speed of the sled is 3.5 m/s before the second child jumps on, what is its speed after she jumps on?
17. Two hockey players approach each other head on, each traveling at the same speed v_i. They collide and get tangled together, falling down and moving off at a speed $\frac{v_i}{5}$. What is the ratio of their masses?
18. A load of gravel is dumped straight down into a 30 000-kg freight car coasting at 2.2 m/s on a straight section of a railroad. If the freight car's speed after receiving the gravel is 1.5 m/s, what mass of gravel did it receive?
19. Two carts on a straight track collide head on. The first cart was moving at 3.6 m/s in the positive x direction and the second was moving at 2.4 m/s in the opposite direction. After the collision, the second car continues moving in its initial direction of motion at 0.24 m/s. If the mass of the second car is 5.0 times that of the first, what is the final velocity of the first car?
20. A 90-kg football player jumps vertically into the air to catch a 0.50-kg football that is thrown essentially horizontally at him at 17 m/s. What is his horizontal speed after catching the ball?
21. Three skydivers are plummeting earthward. They are initially holding onto each other, but then push apart. Two skydivers of mass 70 and 80 kg gain horizontal velocities of 1.2 m/s north and 1.4 m/s southeast, respectively. What is the horizontal velocity of the third skydiver, whose mass is 55 kg?
22. A kitten (3.5 kg) is running 5.0 m/s to the east and tackles a puppy (6.0 kg) who is running 2.0 m/s to the south. The kitten holds onto the puppy after the collision. Write down both the initial momentum of the kitten and the initial momentum of the puppy in column vector form. What is the velocity (magnitude and direction) of the kitten and puppy both travel after the collision?
23. A soccer ball (0.4 kg) is kicked with a speed of 20 m/s to the north. It hits a stationary basketball (0.6 kg) and bounces back with a speed of 15 m/s to the south. The basketball moves to the north after the collision. Write down both the initial momentum of the soccer ball and the initial momentum of the basketball in column vector form. What is the velocity (magnitude and direction) of the basketball after the collision?
24. A snowball (0.2 kg) is thrown with a speed of 10 m/s to the west. It collides with another snowball (0.3 kg) that is moving with a speed of 5 m/s to the north. The snowballs stick together after the collision and move as one mass. Write down both the initial momentum of the first snowball and the initial momentum of the second snowball in column vector form. What is the velocity (magnitude and direction) of the combined snowballs after the collision?
25. A baseball player (80 kg) is running with a speed of 6 m/s to the east to catch a fly ball. He collides with another player (70 kg) who is running with a speed of 5 m/s to the north. They both catch the ball (0.15 kg) and hold onto it after the collision. Write down both the initial momentum of the first player and the initial momentum of the second player in column vector form. What is the velocity (magnitude and direction) of the players and the ball after the collision?

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