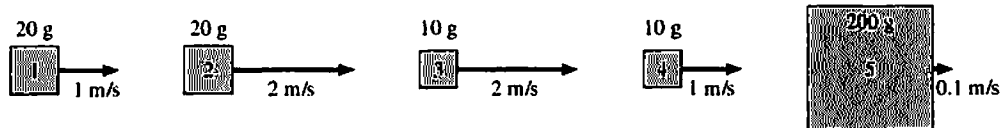


9 Impulse and Momentum

9.1 Momentum and Impulse

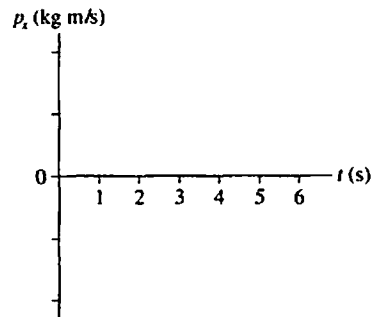
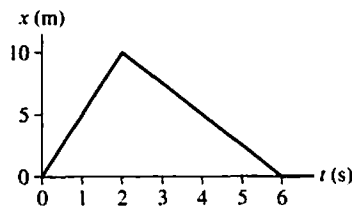
9.2 Solving Impulse and Momentum Problems

1. Rank in order, from largest to smallest, the momenta $(p_x)_1$ to $(p_x)_5$.

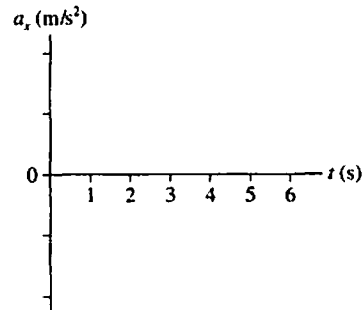
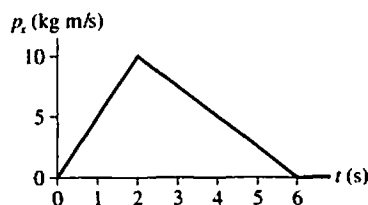


Order:

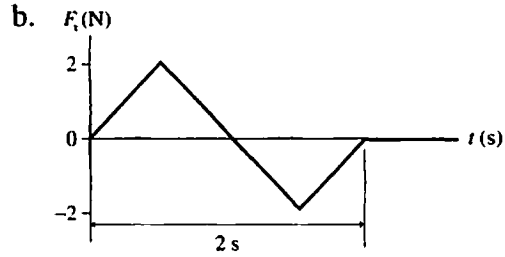
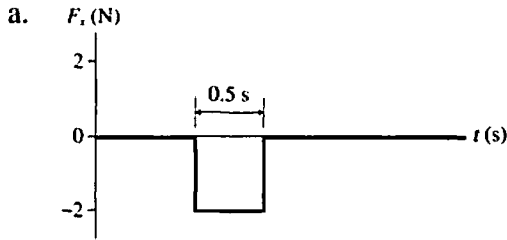
2. The position-versus-time graph is shown for a 500 g object. Draw the corresponding momentum-versus-time graph. Supply an appropriate scale on the vertical axis.



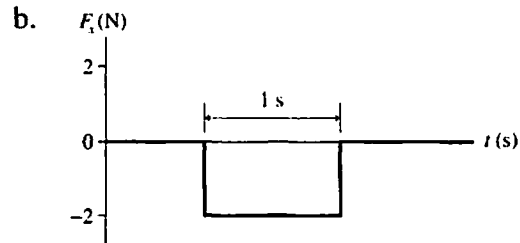
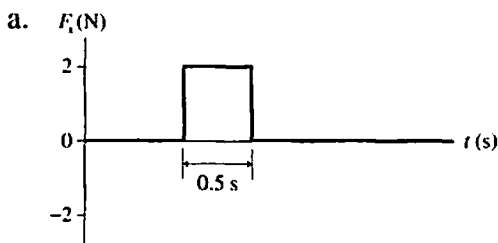
3. The momentum-versus-time graph is shown for a 500 g object. Draw the corresponding acceleration-versus-time graph. Supply an appropriate scale on the vertical axis.



4. A 2 kg object is moving to the right with a speed of 1 m/s when it experiences an impulse due to the force shown in the graph. What is the object's speed and direction after the impulse?

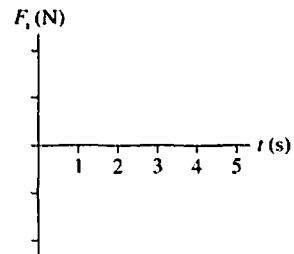
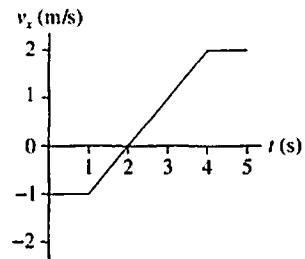


5. A 2 kg object is moving to the left with a speed of 1 m/s when it experiences an impulse due to the force shown in the graph. What is the object's speed and direction after the impulse?

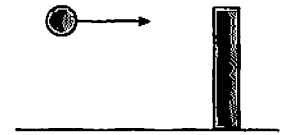


6. A 2 kg object has the velocity graph shown.

- What is the object's initial momentum? _____
- What is the object's final momentum? _____
- What impulse does the object experience? _____
- Draw the graph showing the force on the object.



7. A carnival game requires you to knock over a wood post by throwing a ball at it. You're offered a very bouncy rubber ball and a very sticky clay ball of equal mass. Assume that you can throw them with equal speed and equal accuracy. You only get one throw.



a. Which ball will you choose? Why?

.....

b. Let's think about the situation more carefully. Both balls have the same initial momentum p_{ix} just before hitting the post. The clay ball sticks, the rubber ball bounces off with essentially no loss of speed. In terms of p_{ix} , what is the final momentum of each ball?

Clay ball: $p_{fx} =$ Rubber ball $p_{fx} =$

Hint: Momentum has a sign. Did you take the sign into account?

c. What is the *change* in the momentum of each ball?

Clay ball: $\Delta p_x =$ Rubber ball $\Delta p_x =$

d. Which ball experiences a larger impulse during the collision? Explain.

.....

e. From Newton's third law, the impulse that the ball exerts on the post is equal in magnitude, although opposite in direction, to the impulse that the post exerts on the ball. Which ball exerts the larger impulse on the post?

.....

f. Don't change your answer to part a, but are you still happy with that answer? If not, how would you change your answer? Why?

.....

8. A falling rubber ball bounces on the floor.

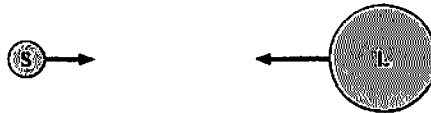
a. Use the language of force, acceleration, and action/reaction to describe what happens.

.....

b. Use the language of impulse and momentum to describe what happens.

.....

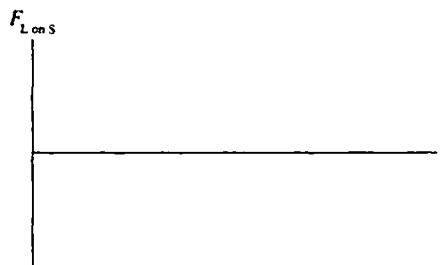
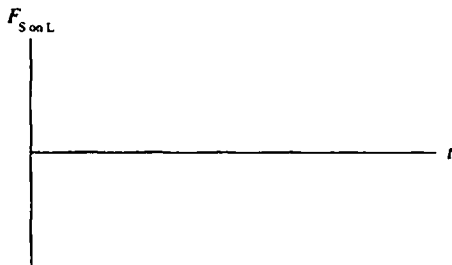
9. A small, light ball S and a large, heavy ball L move toward each other, collide, and bounce apart.



a. Compare the force that S exerts on L to the force that L exerts on S. That is, is $F_{S \text{ on } L}$ larger, smaller, or equal to $F_{L \text{ on } S}$? Explain.

b. Compare the time interval during which S experiences a force to the time interval during which L experiences a force. Are they equal, or is one longer than the other?

c. Sketch a graph showing a *plausible* $F_{S \text{ on } L}$ as a function of time and another graph showing a *plausible* $F_{L \text{ on } S}$ as a function of time. Be sure think about the *sign* of each force.



d. Compare the impulse delivered to S to the impulse delivered to L. Explain.

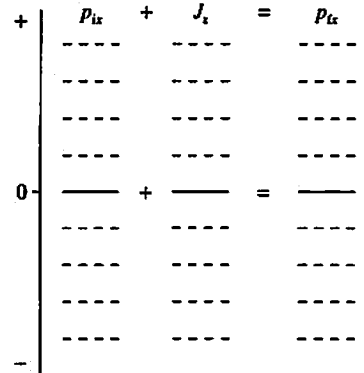
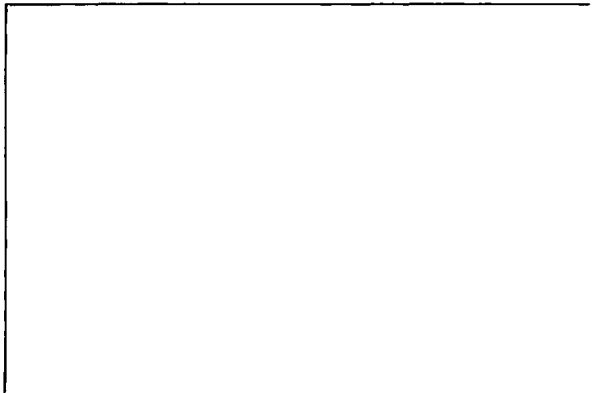
e. Compare the momentum change of S to the momentum change of L.

f. Compare the velocity change of S to the velocity change of L.

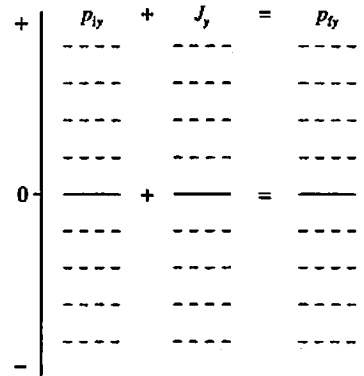
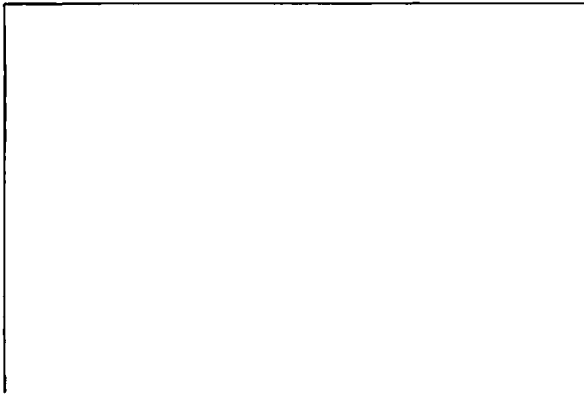
g. What is the change in the *sum* of the momenta of the two balls? Is it positive, negative, or zero?

Exercises 10–12: Draw a momentum bar chart to show the momenta and impulse for the situation described.

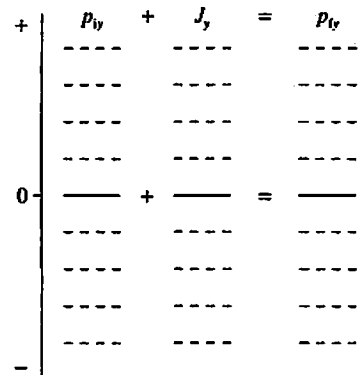
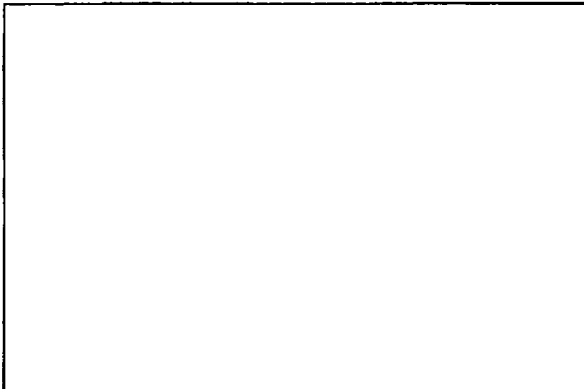
10. A compressed spring shoots a ball to the right. The ball was initially at rest.



11. A rubber ball is tossed straight up and bounces off the ceiling. Consider only the collision with the ceiling.



12. A clay ball is tossed straight up and sticks to the ceiling. Consider only the collision with the ceiling.



9.3 Conservation of Momentum

13. A golf club continues forward after hitting the golf ball. Is momentum conserved in the collision? Explain, making sure you are careful to identify the “system.”

14. As you release a ball, it falls—gaining speed and momentum. Is momentum conserved?
a. Answer this question from the perspective of choosing the ball alone as the system.

- b. Answer this question from the perspective of choosing ball + earth as the system.

15. Two particles collide, one of which was initially moving and the other initially at rest.
a. Is it possible for *both* particles to be at rest after the collision? Give an example in which this happens, or explain why it can't happen.

- b. Is it possible for *one* particle to be at rest after the collision? Give an example in which this happens, or explain why it can't happen.

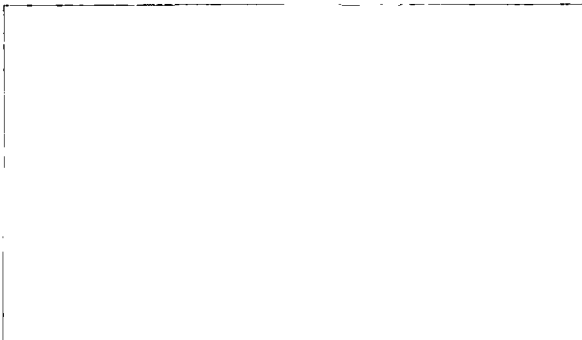
9.4 Inelastic Collisions

9.5 Explosions

Exercises 16–18: Prepare a pictorial representation for these problems, but *do not* solve them.

- Draw pictures of “before” and “after.”
- Define symbols relevant to the problem.
- List known information, and identify the desired unknown.

16. A 50 kg archer, standing on frictionless ice, shoots a 100 g arrow at a speed of 100 m/s. What is the recoil speed of the archer?



17. The parking brake on a 2000 kg Cadillac has failed, and it is rolling slowly, at 1 mph, toward a group of small innocent children. As you see the situation, you realize there is just time for you to drive your 1000 kg Volkswagen head-on into the Cadillac and thus to save the children. With what speed should you impact the Cadillac to bring it to a halt?

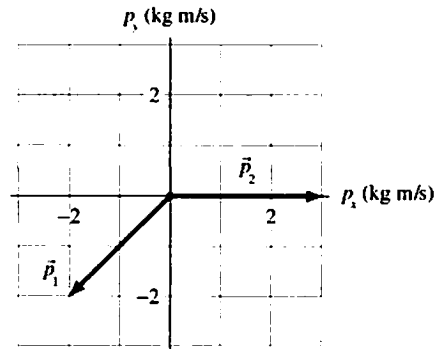


18. Dan is gliding on his skateboard at 4 m/s. He suddenly jumps backward off the skateboard, kicking the skateboard forward at 8 m/s. How fast is Dan going as his feet hit the ground? Dan’s mass is 50 kg and the skateboard’s mass is 5 kg.

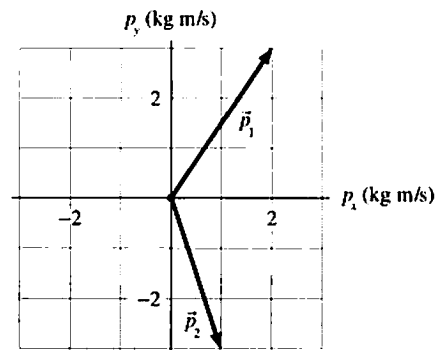


9.6 Momentum in Two Dimensions

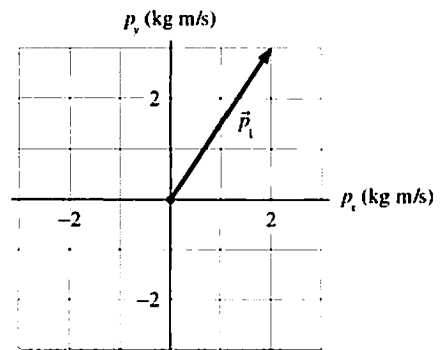
19. An object initially at rest explodes into three fragments. The momentum vectors of two of the fragments are shown. Draw the momentum vector \vec{p}_3 of the third fragment.



20. An object initially at rest explodes into three fragments. The momentum vectors of two of the fragments are shown. Draw the momentum vector \vec{p}_3 of the third fragment.



21. A 500 g ball traveling to the right at 8.0 m/s collides with and bounces off another ball. The figure shows the momentum vector \vec{p}_1 of the first ball after the collision. Draw the momentum vector \vec{p}_2 of the second ball.



22. A 500 g ball traveling to the right at 4.0 m/s collides with and bounces off another ball. The figure shows the momentum vector \vec{p}_1 of the first ball after the collision. Draw the momentum vector \vec{p}_2 of the second ball.

