PROBLEMS

Section 7.1 The Impulse–Momentum Theorem

1. ssm A 46-kg skater is standing still in front of a wall. By pushing against the wall she propels herself backward with a velocity of –1.2 m/s. Her hands are in contact with the wall for 0.80 s. Ignore friction and wind resistance. Find the magnitude and direction of the average force she exerts on the wall (which has the same magnitude as, but opposite direction to, the force that the wall applies to her).

2. A model rocket is constructed with a motor that can provide a total impulse of 29.0 N · s. The mass of the rocket is 0.175 kg. What is the speed that this rocket achieves when launched from rest? Neglect the effects of gravity and air resistance.

3. Before starting this problem, review Conceptual Example 3. Suppose that the hail described there bounces off the roof of the car with a velocity of +15 m/s. Ignoring the weight of the hailstones, calculate the force exerted by the hail on the roof. Compare your answer to that obtained in Example 2 for the rain, and verify that your answer is consistent with the conclusion reached in Conceptual Example 3.

4. In a performance test, each of two cars takes 9.0 s to accelerate from rest to 27 m/s. Car A has a mass of 1400 kg, and car B has a mass of 1900 kg. Find the net average force that acts on each car during the test.

5. ssm A volleyball is spiked so that its incoming velocity of +4.0 m/s is changed to an outgoing velocity of –21 m/s. The mass of the volleyball is 0.35 kg. What impulse does the player apply to the ball?

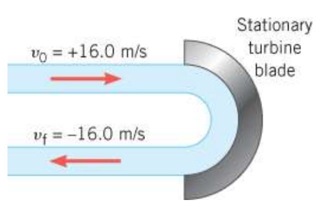
6. Two arrows are fired horizontally with the same speed of 30.0 m/s. Each arrow has a mass of 0.100 kg. One is fired due east and the other due south. Find the magnitude and direction of the total momentum of this two-arrow system. Specify the direction with respect to due east.

7. Refer to Conceptual Example 3 as an aid in understanding this problem. A hockey goalie is standing on ice. Another player fires a puck ($m = 0.17$ kg) at the goalie with a velocity of +65 m/s. **(a)** If the goalie catches the puck with his glove in a time of 5.0×10^{-3} s, what is the average force (magnitude and direction) exerted on the goalie by the puck? **(b)** Instead of catching the puck, the goalie slaps it with his stick and returns the puck straight back to the player with a velocity of –65 m/s. The puck and stick are in contact for a time of 5.0×10^{-3} s. Now what is the average force exerted on the goalie by the puck? Verify that your answers to parts (a) and (b) are consistent with the conclusion of Conceptual Example 3.

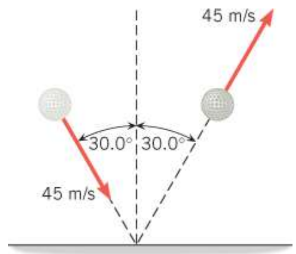
8. When jumping straight down, you can be seriously injured if you land stiff-legged. One way to avoid injury is to bend your knees upon landing to reduce the force of the impact. A 75-kg man just before contact with the ground has a speed of 6.4 m/s. **(a)** In a stiff-legged landing he comes to a halt in 2.0 ms. Find the average net force that acts on him during this time. **(b)** When he bends his knees, he comes to a halt in 0.10 s. Find the average net force now. **(c)** During the landing, the force of the ground on the man points upward, while the force due to gravity points downward. The average net force acting on the man includes both of these forces. Taking into account the directions of the forces, find the force of the ground on the man in parts (a) and (b).

9. A space probe is traveling in outer space with a momentum that has a magnitude of 7.5×10^{7} kg · m/s. A retrorocket is fired to slow down the probe. It applies a force to the probe that has a magnitude of 2.0×10^{6} N and a direction opposite to the probe's motion. It fires for a period of 12 s. Determine the momentum of the probe after the retrorocket ceases to fire.

***10. mmh** A stream of water strikes a stationary turbine blade horizontally, as the drawing illustrates. The incident water stream has a velocity of +16.0 m/s, while the exiting water stream has a velocity of –16.0 m/s. The mass of water per second that strikes the blade is 30.0 kg/s. Find the magnitude of the average force exerted on the water by the blade.

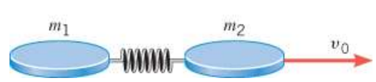


***11.** A student (m = 63 kg) falls freely from rest and strikes the ground. During the collision with the ground, he comes to rest in a time of 0.040 s. The average force exerted on him by the ground is +18 000 N, where the upward direction is taken to be the positive direction. From what height did the student fall? Assume that the only force acting on him during the collision is that due to the ground.
***12.** A golf ball strikes a hard, smooth floor at an angle of 30.0° and, as the drawing shows, rebounds at the same angle. The mass of the ball is 0.047 kg, and its speed is 45 m/s just before and after striking the floor. What is the magnitude of the impulse applied to the golf ball by the floor? *(Hint: Note that only the vertical component of the ball's momentum changes during impact with the floor, and ignore the weight of the ball.)*



***13.** An 85-kg jogger is heading due east at a speed of 2.0 m/s. A 55-kg jogger is heading 32° north of east at a speed of 3.0 m/s. Find the magnitude and direction of the sum of the momenta of the two joggers.
***14.** A basketball (m = 0.60 kg) is dropped from rest. Just before striking the floor, the ball has a momentum whose magnitude is 3.1 kg · m/s. At what height was the basketball dropped?
****15. ssm** A dump truck is being filled with sand. The sand falls straight downward from rest from a height of 2.00 m above the truck bed, and the mass of sand that hits the truck per second is 55.0 kg/s. The truck is parked on the platform of a weight scale. By how much does the scale reading exceed the weight of the truck and sand?

Section 7.2 The Principle of Conservation of Linear Momentum
16. mmh In a science fiction novel two enemies, Bonzo and Ender, are fighting in outer space. From stationary positions they push against each other. Bonzo flies off with a velocity of +1.5 m/s, while Ender recoils with a velocity of –2.5 m/s. **(a)** Without doing any calculations, decide which person has the greater mass. Give your reasoning. **(b)** Determine the ratio $m_{\text{Bonzo}}/m_{\text{Ender}}$ of the masses of these two enemies.
17. A 2.3-kg cart is rolling across a frictionless, horizontal track toward a 1.5-kg cart that is held initially at rest. The carts are loaded with strong magnets that cause them to attract one another. Thus, the speed of each cart increases. At a certain instant before the carts collide, the first cart's velocity is +4.5 m/s, and the second cart's velocity is –1.9 m/s. **(a)** What is the total momentum of the system of the two carts at this instant? **(b)** What was the velocity of the first cart when the second cart was still at rest?
18. As the drawing illustrates, two disks with masses m_1 and m_2 are moving horizontally to the right at a speed of v_0. They are on an air-hockey table, which supports them with an essentially frictionless cushion of air. They move as a unit, with a compressed spring between them, which has a negligible mass. Then the spring is released and allowed to push the disks outward. Consider the situation where disk 1 comes to a momentary halt shortly after the spring is released. Assuming that m_1 = 1.2 kg, m_2 = 2.4 kg, and v_0 = +5.0 m/s, find the velocity of disk 2 at that moment.



19. ssm A lumberjack (mass = 98 kg) is standing at rest on one end of a floating log (mass = 230 kg) that is also at rest. The lumberjack runs to the other end of the log, attaining a velocity of +3.6 m/s relative to the shore, and then hops onto an identical floating log that is initially at rest. Neglect any friction and resistance between the logs and the water. **(a)** What is the velocity of the first log just before the lumberjack jumps off? **(b)** Determine the velocity of the second log if the lumberjack comes to rest on it.
20. mmh An astronaut in his space suit and with a propulsion unit (empty of its gas propellant) strapped to his back has a mass of 146 kg. The astronaut begins a space walk at rest, with a completely filled propulsion unit. During the space walk, the unit ejects some gas with a velocity of +32 m/s. As a result, the astronaut recoils with a velocity of –0.39 m/s. After the gas is ejected, the mass of the astronaut (now

wearing a partially empty propulsion unit) is 165 kg. What percentage of the gas was ejected from the completely filled propulsion unit?

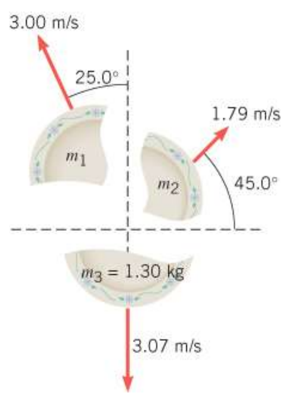
21. ssm A two-stage rocket moves in space at a constant velocity of 4900 m/s. The two stages are then separated by a small explosive charge placed between them. Immediately after the explosion the velocity of the 1200-kg upper stage is 5700 m/s in the same direction as before the explosion. What is the velocity (magnitude and direction) of the 2400-kg lower stage after the explosion?

***22.** A 40.0-kg boy, riding a 2.50-kg skateboard at a velocity of +5.30 m/s across a level sidewalk, jumps forward to leap over a wall. Just after leaving contact with the board, the boy's velocity relative to the sidewalk is 6.00 m/s, 9.50° above the horizontal. Ignore any friction between the skateboard and the sidewalk. What is the skateboard's velocity relative to the sidewalk at this instant? Be sure to include the correct algebraic sign with your answer.

***23.** The lead female character in the movie *Diamonds Are Forever* is standing at the edge of an offshore oil rig. As she fires a gun, she is driven back over the edge and into the sea. Suppose the mass of a bullet is 0.010 kg and its velocity is +720 m/s. Her mass (including the gun) is 51 kg. **(a)** What recoil velocity does she acquire in response to a single shot from a stationary position, assuming that no external force keeps her in place? **(b)** Under the same assumption, what would be her recoil velocity if, instead, she shoots a blank cartridge that ejects a mass of 5.0×10^{-4} kg at a velocity of +720 m/s?

***24. mmh** A 0.015-kg bullet is fired straight up at a falling wooden block that has a mass of 1.8 kg. The bullet has a speed of 810 m/s when it strikes the block. The block originally was dropped from rest from the top of a building and has been falling for a time t when the collision with the bullet occurs. As a result of the collision, the block (with the bullet in it) reverses direction, rises, and comes to a momentary halt at the top of the building. Find the time t.

***25. ssm** By accident, a large plate is dropped and breaks into three pieces. The pieces fly apart parallel to the floor. As the plate falls, its momentum has only a vertical component and no component parallel to the floor. After the collision, the component of the total momentum parallel to the floor must remain zero, since the net external force acting on the plate has no component parallel to the floor. Using the data shown in the drawing, find the masses of pieces 1 and 2.



Problem 25

****26.** Adolf and Ed are wearing harnesses and are hanging at rest from the ceiling by means of ropes attached to them. Face to face, they push off against one another. Adolf has a mass of 120 kg, and Ed has a mass of 78 kg. Following the push, Adolf swings upward to a height of 0.65 m above his starting point. To what height above his own starting point does Ed rise?

****27. ssm** A cannon of mass 5.80×10^3 kg is rigidly bolted to the earth so it can recoil only by a negligible amount. The cannon fires an 85.0-kg shell horizontally with an initial velocity of +551 m/s. Suppose the cannon is then unbolted from the earth, and no external force hinders its recoil. What would be the velocity of an identical shell fired by this loose cannon? *(Hint: In both cases assume that the burning gunpowder imparts the same kinetic energy to the system.)*

Section 7.3 Collisions in One Dimension,
Section 7.4 Collisions in Two Dimensions

28. After sliding down a snow-covered hill on an inner tube, Ashley is coasting across a level snowfield at a constant velocity of +2.7 m/s. Miranda runs after her at a velocity of +4.5 m/s and hops on the inner tube.

How fast do the two slide across the snow together on the inner tube? Ashley's mass is 71 kg and Miranda's is 58 kg. Ignore the mass of the inner tube and any friction between the inner tube and the snow.

29. Consult Multiple-Concept Example 8 for background pertinent to this problem. A 2.50-g bullet, traveling at a speed of 425 m/s, strikes the wooden block of a ballistic pendulum, such as that in Figure 7.12. The block has a mass of 215 g. **(a)** Find the speed of the bullet–block combination immediately after the collision. **(b)** How high does the combination rise above its initial position?

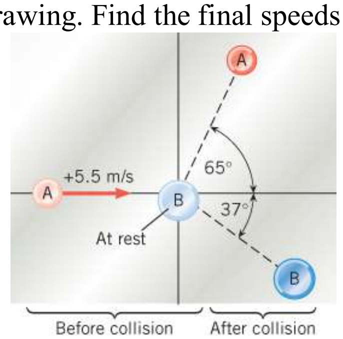
30. One object is at rest, and another is moving. The two collide in a one-dimensional, completely inelastic collision. In other words, they stick together after the collision and move off with a common velocity. Momentum is conserved. The speed of the object that is moving initially is 25 m/s. The masses of the two objects are 3.0 and 8.0 kg. Determine the final speed of the two-object system after the collision for the case when the large-mass object is the one moving initially and the case when the small-mass object is the one moving initially.

31. ssm Batman (mass = 91 kg) jumps straight down from a bridge into a boat (mass = 510 kg) in which a criminal is fleeing. The velocity of the boat is initially +11 m/s. What is the velocity of the boat after Batman lands in it?

32. A car (mass = 1100 kg) is traveling at 32 m/s when it collides head-on with a sport utility vehicle (mass = 2500 kg) traveling in the opposite direction. In the collision, the two vehicles come to a halt. At what speed was the sport utility vehicle traveling?

33. ssm A 5.00-kg ball, moving to the right at a velocity of +2.00 m/s on a frictionless table, collides head-on with a stationary 7.50-kg ball. Find the final velocities of the balls if the collision is **(a)** elastic and **(b)** completely inelastic.

34. The drawing shows a collision between two pucks on an air-hockey table. Puck A has a mass of 0.025 kg and is moving along the *x* axis with a velocity of +5.5 m/s. It makes a collision with puck B, which has a mass of 0.050 kg and is initially at rest. The collision is not head-on. After the collision, the two pucks fly apart with the angles shown in the drawing. Find the final speeds of **(a)** puck A and **(b)** puck B.

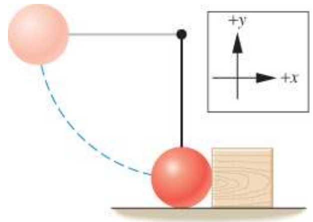


35. ssm A projectile (mass = 0.20 kg) is fired at and embeds itself in a stationary target (mass = 2.50 kg). With what percentage of the projectile's incident kinetic energy does the target (with the projectile in it) fly off after being struck?

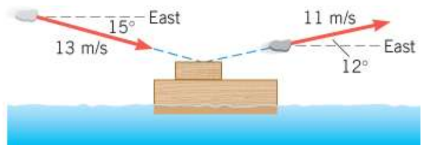
36. Object A is moving due east, while object B is moving due north. They collide and stick together in a completely inelastic collision. Momentum is conserved. Object A has a mass of m_A = 17.0 kg and an initial velocity of $\vec{\mathbf{v}}_{0A} = 8.00\,\mathrm{m/s}$, due east. Object B, however, has a mass of m_B = 29.0 kg and an initial velocity of $\vec{\mathbf{v}}_{0B} = 5.00\,\mathrm{m/s}$, due north. Find the magnitude and direction of the total momentum of the two-object system after the collision.

37. Multiple-Concept Example 7 deals with some of the concepts that are used to solve this problem. A cue ball (mass = 0.165 kg) is at rest on a frictionless pool table. The ball is hit dead center by a pool stick, which applies an impulse of +1.50 N · s to the ball. The ball then slides along the table and makes an elastic head-on collision with a second ball of equal mass that is initially at rest. Find the velocity of the second ball just after it is struck.

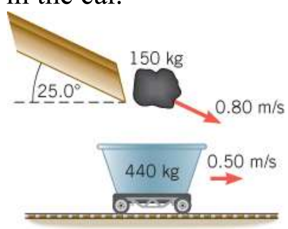
***38.** A ball is attached to one end of a wire, the other end being fastened to the ceiling. The wire is held horizontal, and the ball is released from rest (see the drawing). It swings downward and strikes a block initially at rest on a horizontal frictionless surface. Air resistance is negligible, and the collision is elastic. The masses of the ball and block are, respectively, 1.60 kg and 2.40 kg, and the length of the wire is 1.20 m. Find the velocity (magnitude and direction) of the ball **(a)** just before the collision, and **(b)** just after the collision.



*39. A girl is skipping stones across a lake. One of the stones accidentally ricochets off a toy boat that is initially at rest in the water (see the drawing). The 0.072-kg stone strikes the boat at a velocity of 13 m/s, 15° below due east, and ricochets off at a velocity of 11 m/s, 12° above due east. After being struck by the stone, the boat's velocity is 2.1 m/s, due east. What is the mass of the boat? Assume the water offers no resistance to the boat's motion.



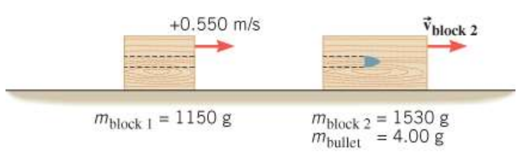
*40. A mine car (mass = 440 kg) rolls at a speed of 0.50 m/s on a horizontal track, as the drawing shows. A 150-kg chunk of coal has a speed of 0.80 m/s when it leaves the chute. Determine the speed of the car–coal system after the coal has come to rest in the car.



*41. ssm A 50.0-kg skater is traveling due east at a speed of 3.00 m/s. A 70.0-kg skater is moving due south at a speed of 7.00 m/s. They collide and hold on to each other after the collision, managing to move off at an angle u south of east, with a speed of v_f. Find **(a)** the angle u and **(b)** the speed v_f, assuming that friction can be ignored.

*42. A 4.00-g bullet is moving horizontally with a velocity of +355 m/s, where the +sign indicates that it is moving to the right (see part *a* of the drawing). The bullet is approaching two blocks resting on a horizontal frictionless surface. Air resistance is negligible. The bullet passes completely through the first block (an inelastic collision) and embeds itself in the second one, as indicated in part *b*. Note that both blocks are moving after the collision with the bullet. The mass of the first block is 1150 g, and its velocity is +0.550 m/s after the bullet passes through it. The mass of the second block is 1530 g. **(a)** What is the velocity of the second block after the bullet embeds itself? **(b)** Find the ratio of the total kinetic energy after the collisions to that before the collisions.

(*a*) Before collisions

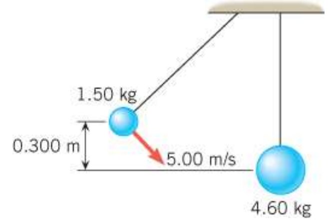


(*b*) After collisions

*43. An electron collides elastically with a stationary hydrogen atom. The mass of the hydrogen atom is 1837 times that of the electron. Assume that all motion, before and after the collision, occurs along the same straight line. What is the ratio of the kinetic energy of the hydrogen atom after the collision to that of the electron before the collision?

*44. A 60.0-kg person, running horizontally with a velocity of +3.80 m/s, jumps onto a 12.0-kg sled that is initially at rest. **(a)** Ignoring the effects of friction during the collision, find the velocity of the sled and person as they move away. **(b)** The sled and person coast 30.0 m on level snow before coming to rest. What is the coefficient of kinetic friction between the sled and the snow?

45. ssm Starting with an initial speed of 5.00 m/s at a height of 0.300 m, a 1.50-kg ball swings downward and strikes a 4.60-kg ball that is at rest, as the drawing shows. **(a)** Using the principle of conservation of mechanical energy, find the speed of the 1.50-kg ball just before impact. **(b)** Assuming that the collision is elastic, find the velocities (magnitude and direction) of both balls just after the collision. **(c)** How high does each ball swing after the collision, ignoring air resistance?



46. mmh Multiple-Concept Example 7 outlines the general approach to problems like this one. Two identical balls are traveling toward each other with velocities of –4.0 and +7.0 m/s, and they experience an elastic head-on collision. Obtain the velocities (magnitude and direction) of each ball after the collision.

47. A ball is dropped from rest from the top of a 6.10-m-tall building, falls straight downward, collides inelastically with the ground, and bounces back. The ball loses 10.0% of its kinetic energy every time it collides with the ground. How many bounces can the ball make and still reach a windowsill that is 2.44 m above the ground?

Section 7.5 Center of Mass

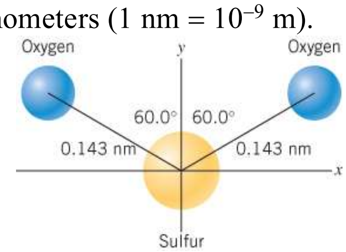
48. Two particles are moving along the x axis. Particle 1 has a mass m_1 and a velocity $v_1 = +4.6$ m/s. Particle 2 has a mass m_2 and a velocity $v_2 = -6.1$ m/s. The velocity of the center of mass of these two particles is zero. In other words, the center of mass of the particles remains stationary, even though each particle is moving. Find the ratio m_1/m_2 of the masses of the particles.

49. ssm Consider the two moving boxcars in Example 5. Determine the velocity of their center of mass **(a)** before and **(b)** after the collision. **(c)** Should your answer in part (b) be less than, greater than, or equal to the common velocity v_f of the two coupled cars after the collision? Justify your answer.

50. John's mass is 86 kg, and Barbara's is 55 kg. He is standing on the x axis at $x_J = +9.0$ m, while she is standing on the x axis at $x_B = +2.0$ m. They switch positions. How far and in which direction does their center of mass move as a result of the switch?

51. Two stars in a binary system orbit around their center of mass. The centers of the two stars are 7.17×10^{11} m apart. The larger of the two stars has a mass of 3.70×10^{30} kg, and its center is 2.08×10^{11} m from the system's center of mass. What is the mass of the smaller star?

***52.** The drawing shows a sulfur dioxide molecule. It consists of two -oxygen atoms and a sulfur atom. A sulfur atom is twice as massive as an oxygen atom. Using this information and the data provided in the drawing, find **(a)** the x coordinate and **(b)** the y coordinate of the center of mass of the sulfur dioxide molecule. Express your answers in nanometers (1 nm = 10^{-9} m).



ADDITIONAL PROBLEMS

53. ssm mmh Two friends, Al and Jo, have a combined mass of 168 kg. At an ice skating rink they stand close together on skates, at rest and facing each other, with a compressed spring between them. The spring is kept from pushing them apart because they are holding each other. When they release their arms, Al moves off in one direction at a speed of 0.90 m/s, while Jo moves off in the opposite direction at a speed of 1.2 m/s. Assuming that friction is negligible, find Al's mass.

54. A golf ball bounces down a flight of steel stairs, striking several steps on the way down, but never hitting the edge of a step. The ball starts at the top step with a vertical velocity component of zero. If all the collisions with the stairs are elastic, and if the vertical height of the staircase is 3.00 m, determine the bounce height when the ball reaches the bottom of the stairs. Neglect air resistance.

55. Multiple-Concept Example 7 presents a model for solving problems such as this one. A 1055-kg van, stopped at a traffic light, is hit directly in the rear by a 715-kg car traveling with a velocity of +2.25 m/s. Assume that the transmission of the van is in neutral, the brakes are not being applied, and the collision is elastic. What are the final velocities of **(a)** the car and **(b)** the van?

56. mmh A baseball (m = 149 g) approaches a bat horizontally at a speed of 40.2 m/s (90 mi/h) and is hit straight back at a speed of 45.6 m/s (102 mi/h). If the ball is in contact with the bat for a time of 1.10 ms, what is the average force exerted on the ball by the bat? Neglect the weight of the ball, since it is so much less than the force of the bat. Choose the direction of the incoming ball as the positive direction.

57. ssm One average force $\bar{\vec{F}}_1$ has a magnitude that is three times as large as that of another average force $\bar{\vec{F}}_2$. Both forces produce the same impulse. The average force $\bar{\vec{F}}_1$ acts for a time interval of 3.2 ms. For what time interval does the average force $\bar{\vec{F}}_2$ act?

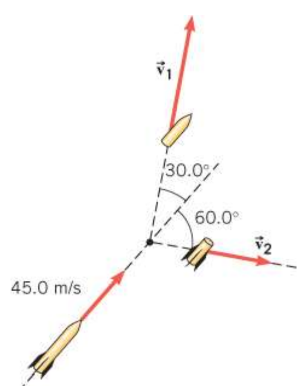
58. mmh For tests using a *ballistocardiograph*, a patient lies on a horizontal platform that is supported on jets of air. Because of the air jets, the friction impeding the horizontal motion of the platform is negligible. Each time the heart beats, blood is pushed out of the heart in a direction that is nearly parallel to the platform. Since momentum must be conserved, the body and the platform recoil, and this recoil can be detected to provide information about the heart. For each beat, suppose that 0.050 kg of blood is pushed out of the heart with a velocity of +0.25 m/s and that the mass of the patient and platform is 85 kg. Assuming that the patient does not slip with respect to the platform, and that the patient and platform start from rest, determine the recoil velocity.

59. mmh The carbon monoxide molecule (CO) consists of a carbon atom and an oxygen atom separated by a distance of 1.13×10^{-10} m. The mass m_C of the carbon atom is 0.750 times the mass m_O of the oxygen atom, or $m_C = 0.750\, m_O$. Determine the location of the center of mass of this molecule relative to the carbon atom.

60. A wagon is rolling forward on level ground. Friction is negligible. The person sitting in the wagon is holding a rock. The total mass of the wagon, rider, and rock is 95.0 kg. The mass of the rock is 0.300 kg. Initially the wagon is rolling forward at a speed of 0.500 m/s. Then the person throws the rock with a speed of 16.0 m/s. Both speeds are relative to the ground. Find the speed of the wagon after the rock is thrown directly forward in one case and directly backward in another.

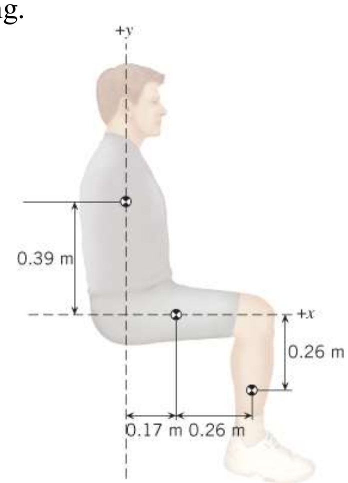
***61.** Three guns are aimed at the center of a circle, and each fires a bullet simultaneously. The directions in which they fire are 120° apart. Two of the bullets have the same mass of 4.50×10^{-3} kg and the same speed of 324 m/s. The other bullet has an unknown mass and a speed of 575 m/s. The bullets collide at the center and mash into a stationary lump. What is the unknown mass?

***62. mmh** A fireworks rocket is moving at a speed of 45.0 m/s. The rocket suddenly breaks into two pieces of equal mass, which fly off with velocities $\vec{v}_1$ and $\vec{v}_2$, as shown in the drawing. What are the magnitudes of **(a)** $\vec{v}_1$ and **(b)** $\vec{v}_2$?



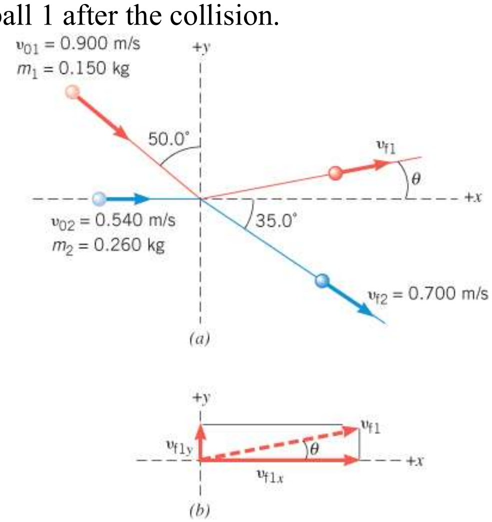
***63.** Two ice skaters have masses m_1 and m_2 and are initially stationary. Their skates are identical. They push against one another, as in Figure 7.9, and move in opposite directions with different speeds. While they are pushing against each other, any kinetic frictional forces acting on their skates can be ignored. However, once the skaters separate, kinetic frictional forces eventually bring them to a halt. As they glide to a halt, the magnitudes of their accelerations are equal, and skater 1 glides twice as far as skater 2. What is the ratio m_1/m_2 of their masses?

***64.** The drawing shows a human figure in a sitting position. For purposes of this problem, there are three parts to the figure, and the center of mass of each one is shown in the drawing. These parts are: (1) the torso, neck, and head (total mass = 41 kg) with a center of mass located on the *y* axis at a point 0.39 m above the origin, (2) the upper legs (mass = 17 kg) with a center of mass located on the *x* axis at a point 0.17 m to the right of the origin, and (3) the lower legs and feet (total mass = 9.9 kg) with a center of mass located 0.43 m to the right of and 0.26 m below the origin. Find the *x* and *y* coordinates of the center of mass of the human figure. Note that the mass of the arms and hands (approximately 12% of the whole-body mass) has been ignored to simplify the drawing.



****65. ssm** Two people are standing on a 2.0-m-long stationary platform, one at each end. The platform floats parallel to the ground on a cushion of air, like a hovercraft. One person throws a 6.0-kg ball to the other, who catches it. The ball travels nearly horizontally. Excluding the ball, the total mass of the platform and people is 118 kg. Because of the throw, this 118-kg mass recoils. How far does it move before coming to rest again?

***66.** For the situation depicted in the figure, use momentum conservation to determine the magnitude and direction of the final velocity of ball 1 after the collision.



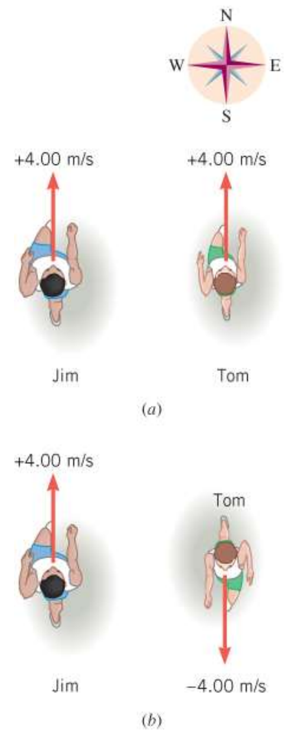
Problem 66

(*a*) Top view of two balls colliding on a horizontal surface.
(*b*) This part of the drawing shows the *x* and *y* components of the velocity of ball 1 after the collision.

CONCEPTS AND CALCULATIONS PROBLEMS

Momentum and energy are two of the most fundamental concepts in physics. As we have seen in this chapter, momentum is a vector and, like all vectors, has a magnitude and a direction. In contrast, energy is a scalar quantity, as Chapter 6 discusses, and does not have a direction associated with it. Problem 67 provides the opportunity to review how the vector nature of momentum and the scalar nature of kinetic energy influence calculations using these quantities. Problem 68 explores some further differences between momentum and kinetic energy.

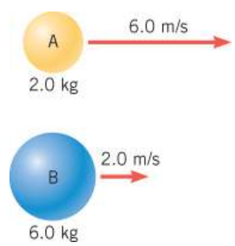
***67.** **ssm** Two joggers, Jim and Tom, are both running at a speed of 4.00 m/s (see the figure). Jim has a mass of 90.0 kg, and Tom has a mass of 55.0 kg. *Concepts:* (i) Does the total kinetic energy of the two-jogger system have a smaller value in part *a* or *b* of the figure, or is it the same in both cases? (ii) Does their total momentum have a smaller magnitude in part *a* or *b* of the figure, or is it the same for each? *Calculations:* Find the kinetic energy and momentum of the two-jogger system when **(a)** Jim and Tom are both running due north as in part *a* of the figure, and **(b)** Jim is running due north and Tom is running due south, as in part *b* of the figure.



Problem 67

***68.** The table gives mass and speed data for the two objects in the figure. *Concepts:* (i) Is it possible for two objects to have different speeds when their momenta have the same amplitude? Explain your answer. (ii) If two objects have the same momenta do they necessarily have the same kinetic energy? Explain. *Calculations:* Find the magnitude of the momentum and the kinetic energy for each object.

	Mass	Speed
Object A	2.0 kg	6.0 m/s
Object B	6.0 kg	2.0 m/s



Problem 68