PROBLEMS

Section 7.1 The Impulse–Momentum Theorem

1. What is the impulse of a +35-N force that acts on an object for 0.40 s?

2. (a) The earth travels with an approximate speed of 29.9 km/s (66 900 mi/h) in its journey around the sun. The mass of the earth is 5.98×10^{24} kg. Find the magnitude of its linear momentum. (b) Is the direction of the earth's linear momentum constant? If not, describe how it changes and specify the force that causes it to change.

3. Two joggers are running with the same velocity of 4.00 m/s due south. Their masses are 90.0 and 55.0 kg. (a) Find the magnitude of the total linear momentum and the total kinetic energy of the two-jogger system. (b) Repeat part (a), assuming that one of the joggers is running due north at 4.00 m/s.

4. A freight train moves due north with a speed of 17 m/s. The mass of the train is 6.0×10^6 kg. How fast would a 1500-kg automobile have to be moving due north to have the same momentum as the train?

5. 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.

6. Two men pushing a stalled car generate a net force of +840 N for 5.0 s. What is the final momentum of the car?

7. A woman, driving a golf ball off a tee, gives the ball a velocity of +28 m/s. The mass of the ball is 0.045 kg, and the duration of the impact with the golf club is 6.0×10^{-3} s. (a) What is the change in momentum of the ball? (b) Determine the average force applied to the ball by the club.

Section 7.2 The Principle of Conservation of Linear Momentum

15. 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, determine the recoil velocity.

16. A 55-kg swimmer is standing on a stationary 210-kg floating raft. The swimmer then runs off the raft horizontally with a velocity of +4.6 m/s relative to the shore. Find the recoil velocity that the raft would have if there were no friction and resistance due to the water.

17. With the engines off, a spaceship is coasting at a velocity of +230 m/s through outer space. It fires a rocket straight ahead at an enemy vessel. The mass of the rocket is 1300 kg, and the mass of the spaceship (not including the rocket) is 4.0×10^6 kg. The firing of the rocket brings the spaceship to a halt. What is the velocity of the rocket?

18. An astronaut is motionless in outer space. Upon command, the propulsion unit strapped to his back ejects some gas with a velocity of +14 m/s, and the astronaut recoils with a velocity of −0.50 m/s. After the gas is ejected, the mass of the astronaut is 160 kg. What is the mass of the ejected gas?

19. 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 of the masses ($m_{\text{Bonzo}}/m_{\text{Ender}}$) of these two people.

*23. Two objects have masses m_1 and m_2. They are made from the same material and rest on a horizontal surface. Between them is a compressed spring, which is suddenly released. It shoves the objects apart so quickly that any kinetic friction forces acting on them during the launch can be ignored. However, once the objects are launched, kinetic friction eventually does bring them to a halt. In coming to a halt, object 1 slides three times farther than object 2. Find the ratio m_1/m_2.

**24. A wagon is coasting at a speed v_A along a straight and level road. When ten percent of the wagon's mass is thrown off the wagon, parallel to the ground and in the forward direction, the wagon is brought to a halt. If the direction in which this mass is thrown is exactly reversed, everything else remaining the same, the wagon accelerates to a new speed v_B. Calculate v_B/v_A.

**25. Two people are standing on a 2.0-m-long 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?

Section 7.3 and Section 7.4 Collisions in One and Two Dimensions

26. A 31-kg swimmer runs with a horizontal velocity of +4.0 m/s off a boat dock into a stationary 8.0-kg rubber raft. Find the velocity that the swimmer and raft would have after the impact, if there were no friction and resistance due to the water.

27. In a football game, a receiver is standing still, having just caught a pass. Before he can move, a tackler, running at a velocity of +4.5 m/s, grabs him. The tackler holds onto the receiver, and the two move off together with a velocity of +2.6 m/s. The mass of the tackler is 115 kg. Assuming that momentum is conserved, find the mass of the receiver.

28. 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?

29. Review Example 9. A 2.50×10^{-3}-kg bullet, traveling at a velocity of +425 m/s, strikes the wooden block of a ballistic pendulum. The block has a mass of 0.200 kg. (a) Find the velocity of the bullet/block combination immediately after the collision. (b) How high does the combination rise above its initial position?

30. A golf ball bounces down a flight of steel stairs, striking each stair once on the way down. 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.

31. In Example 8, suppose that ball 1 rebounds to the left after the collision and moves with one-half the speed it had before the collision. Find the ratio of the masses, m_1/m_2.

32. A 0.150-kg projectile is fired with a velocity of +715 m/s at a 2.00-kg wooden block that rests on a frictionless table. The velocity of the block, immediately after the projectile passes through it, is +40.0 m/s. Find the velocity with which the projectile exits from the block.

33. 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. 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?

*35. A 0.010-kg bullet is fired straight up at a falling wooden block that has a mass of 2.0 kg. The bullet has a speed of 750 m/s when it strikes the block. The block originally was dropped from rest from the top of a building and had 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.

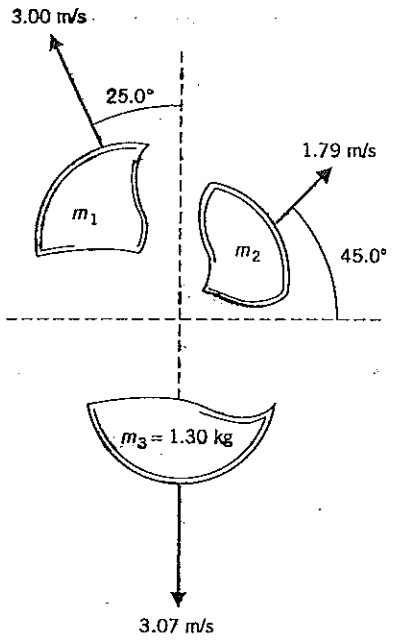
*36. By accident, a large plate is dropped and breaks into three pieces. The pieces fly apart parallel to the floor. As the plate falls, its momentum has only a vertical component, and no component parallel to the floor. After the collision, the component of the total momentum parallel to the floor must remain zero, since the 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.

*37. 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 θ south of east, with a speed of v_f. Find (a) the angle θ and (b) the speed v_f, assuming that friction can be ignored.

*38. A mine car, whose mass is 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 velocity of the car/coal system after the coal has come to rest in the car.

**39. Two identical balls are traveling toward each other with speeds 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.

**40. A ball is dropped from rest at the top of a 6.10-m-tall building, falls straight downward, collides inelastically with



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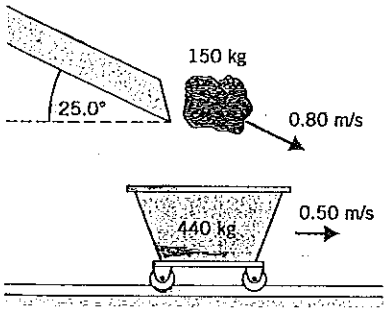

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the ground, and bounces back. The ball loses 10.0% of its kinetic energy every time it collides with the ground. How many bounces can the ball make and still reach a window sill that is 2.44 m above the ground?

Section 7.5 Rocket Propulsion

42. A rocket burns propellant at a rate of $\Delta m/\Delta t = 1.5$ kg/s, ejecting gases with a speed of 7800 m/s relative to the rocket. Find the magnitude of the thrust.

42. At what rate $\Delta m/\Delta t$ must a rocket burn propellant to achieve a thrust whose magnitude is 14 000 N, if the speed of the ejected gases is 6400 m/s relative to the rocket?

43. A fireman is directing water at the rate of 16 kg/s onto a burning building. The speed of the water within the horizontal hose is 3.0 m/s. However, because of the tapered shape of the nozzle, the speed at which the water leaves the hose is 11.0 m/s. To keep the hose from moving because of the thrust of the water, the fireman must apply a force to the hose. How much force must the fireman apply?

***44.** During a launch, a rocket (mass $= 2.72 \times 10^4$ kg) lifts off vertically from rest. The engine burns propellant at a rate of $\Delta m/\Delta t = 584$ kg/s and ejects gases with a speed of 1680 m/s relative to the rocket. (a) Determine the magnitude of the thrust developed by the engine. (b) Find the initial upward acceleration of the rocket. (c) Noting that the mass of the rocket is smaller because fuel has been consumed, determine the acceleration of the rocket at the end of 10.0 s.

ADDITIONAL PROBLEMS

45. A boy is at rest on a skateboard. The total mass of the boy and the skateboard is 30.0 kg. He is at the foot of a hill when he catches a 5.00-kg ball and, as a result, moves up the hill. When he catches the ball, it is moving nearly parallel to the ground and has a speed of 10.0 m/s. Ignore the effects of friction and gravity during the short time the ball is being caught. Through what maximum vertical height will the boy coast up the hill?

46. In the James Bond movie *Diamonds Are Forever*, the lead female character fires a machine gun while standing at the edge of an off-shore oil rig. As she fires the 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. If her mass (including the gun) is 51 kg, what recoil velocity does she acquire in response to a single shot from a stationary position?

47. 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?

48. (a) What is the momentum and the kinetic energy of a car (mass $= 2.00 \times 10^3$ kg) that is moving due north at a speed of 15.0 m/s? If the speed is tripled, by what factor does (b) the momentum increase and (c) the kinetic energy increase?

49. A 1550-kg car, traveling with a velocity of +12.0 m/s, plows into a 1220-kg stationary car. During the collision, the two cars lock bumpers and then move together as a unit. (a) What is their common velocity just after the impact? (b) What fraction of the initial kinetic energy remains after the collision?

50. In problem 49, suppose that both cars have special bumpers, so the collision is elastic. What is the velocity of each car after the collision?

51. 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 mag-