6.1 Linear Momentum

1. **MC** Linear momentum has units of (a) N/m, (b) $\text{kg}\cdot\text{m/s}$, (c) N/s, (d) all of the preceding. (b)

2. **MC** Linear momentum is (a) always conserved, (b) a scalar quantity, (c) a vector quantity, (d) unrelated to force. (c)

3. **MC** A net force on an object can cause (a) an acceleration, (b) a change in momentum, (c) a change in velocity, (d) all of the preceding. (d)

10. ● In a football game, a lineman usually has more mass than a running back. (a) Will a lineman always have greater linear momentum than a running back? Why? (b) Who has greater linear momentum, a 75-kg running back running at $8.5\,\text{m/s}$ or a 120-kg lineman moving at¤ $5.0\,\text{m/s}$? (a) no (b) the running back, $38\,\text{kg}\cdot\text{m/s}$ more

15. ●● Taking the density of air to be $1.29\,\text{kg/m}^3$, what is the magnitude of the linear momentum of a cubic meter of air moving with a wind speed of (a) $36\,\text{km/h}$ and (b) $74\,\text{mi/h}$ (the wind speed at which a tropical storm becomes a hurricane)? (a) $13\,\text{kg}\cdot\text{m/s}$ (b) $43\,\text{kg}\cdot\text{m/s}$

20. ●● A loaded tractor-trailer with a total mass of 5000 kg traveling at $3.0\,\text{km/h}$ hits a loading dock and comes to a stop in 0.64 s. What is the magnitude of the average force exerted on the truck by the dock? $6.5\times10^3\,\text{N}$

24. ●●● At a basketball game, a 120-lb cheerleader is tossed vertically upward with a speed of $4.50\,\text{m/s}$ by a male cheerleader. (a) What is the cheerleader's change in momentum from the time she is released to just before being caught if she is caught at the height at which she was released? (b) Would there be any difference if she were caught 0.30 m below the point of release? If so, what is the change then? (a) $491\,\text{kg}\cdot\text{m/s}$ downward (b) yes; $524\,\text{kg}\cdot\text{m/s}$ downward

25. ●●● A ball of mass 200 g is released from rest at a height of 2.00 m above the floor and it rebounds straight up to a height of 0.900 m. (a) Determine the ball's change in momentum due to its contact with the floor. (b) If the contact time with the floor was 0.0950 seconds, what was the average force the floor exerted on the ball, and in what direction? (a) $2.09\,\text{kg}\cdot\text{m/s}$ (b) 24.0 N upward

6.2 Impulse

26. **MC** Impulse has units (a) $\text{kg}\cdot\text{m/s}$, (b) $\text{N}\cdot\text{s}$, (c) the same as momentum, (d) all of the preceding. (d)

27. **MC** Impulse is equal to (a) $F\Delta x$, (b) the change in kinetic energy, (c) the change in momentum, (d) $\Delta p/\Delta t$. (c)

38. ●● An astronaut (mass of 100 kg, with equipment) is headed back to her space station at a speed of $0.750\,\text{m/s}$ but at the wrong angle. To correct her direction, she fires rockets from her backpack at right angles to her motion for a brief time. These directional rockets exert a constant force of 100.0 N for only 0.200 s. [Neglect the small loss of mass due to burning fuel and assume the impulse is at right angles to her initial momentum.] (a) What is the magnitude of the impulse delivered to the astronaut? (b) What is her new direction (relative to the initial direction)? (c) What is her new speed? (a) $20.0\,\text{N}\cdot\text{s}$, (b) 14.9°, (c) $0.776\,\text{m/s}$

41. ●● A boy catches—with bare hands and his arms rigidly extended—a 0.16-kg baseball coming directly toward him at a speed of $25\,\text{m/s}$. He emits an audible "Ouch!" because the ball stings his hands. He learns quickly to move his hands with the ball as he catches it. If the contact time of the collision is increased from 3.5 ms to 8.5 ms in this way, how do the magnitudes of the average impulse forces compare? $1.1\times10^3\,\text{N}$ and $4.7\times10^2\,\text{N}$

45. ●● A 15000-N automobile travels at a speed of $45\,\text{km/h}$ northward along a street, and a 7500-N sports car travels at a speed of $60\,\text{km/h}$ eastward along an intersecting street. (a) If neither driver brakes and the cars collide at the intersection and lock bumpers, what will the velocity of the cars be immediately after the collision? (b) What percentage of the initial kinetic energy will be lost in the collision? (a) $36\,\text{km/h}$, 56° north of east (b) 49% lost

46. ●●● In a simulated head-on crash test, a car impacts a wall at $25\,\text{mi/h}$ $(40\,\text{km/h})$ and comes abruptly to rest. A 120-lb passenger dummy (with a mass of 55 kg), without a seatbelt, is stopped by an air bag, which exerts a force on the dummy of 2400 lb. How long was the dummy in contact with the air bag while coming to a stop? 0.057 s

47. ●●● A baseball player pops a pitch straight up. The ball (mass 200 g) was traveling horizontally at $35.0\,\mathrm{m/s}$ just before contact with the bat, and $20.0\,\mathrm{m/s}$ just after contact. Determine the direction and magnitude of the impulse delivered to the ball by the bat. $8.06\ \mathrm{kg\cdot m/s}$, $29.7°$ above $-x$ axis

6.3 Conservation of Linear Momentum

48. **MC** The conservation of linear momentum is described by the (a) momentum-impulse theorem, (b) work-energy theorem, (c) Newton's first law, (d) conservation of energy. (a)

49. **MC** The linear momentum of an object is conserved if (a) the force acting on the object is conservative, (b) a single, unbalanced internal force is acting on the object, (c) the mechanical energy is conserved, (d) none of the preceding. (d)

50. **MC** Internal forces do not affect the conservation of momentum because (a) they cancel each other, (b) their effects are canceled by external forces, (c) they can never produce a change in velocity, (d) Newton's second law is not applicable to them. (a)

57. ●● To get off a frozen, frictionless lake, a 65.0-kg person takes off a 0.150-kg shoe and throws it horizontally, directly away from the shore with a speed of $2.00\,\mathrm{m/s}$. If the person is 5.00 m from the shore, how long does he take to reach it? $1.08\times10^{3}\ \mathrm{s} = 18.1\ \mathrm{min}$

67. ●● For a movie scene, a 75-kg stuntman drops from a tree onto a 50-kg sled that is moving on a frozen lake with a velocity of $10\,\mathrm{m/s}$ toward the shore. (a) What is the speed of the sled after the stuntman is on board? (b) If the sled hits the bank and stops, but the stuntman keeps on going, with what speed does he leave the sled? (Neglect friction.) (a) $4.0\ \mathrm{m/s}$ (b) $4.0\ \mathrm{m/s}$

71. ●●● A small asteroid (mass of 10 g) strikes a glancing blow at a satellite in empty space. The satellite was initially at rest and the asteroid traveling at $2000\,\mathrm{m/s}$. The satellite's mass is 100 kg. The asteroid is deflected $10°$ from its original direction and its speed decreases to $1000\,\mathrm{m/s}$, but neither object loses mass. Determine the (a) direction and (b) speed of the satellite after the collision. (a) $9.7°$ (b) $0.10\ \mathrm{m/s}$

6.4 Elastic and Inelastic Collisions

73. **MC** Which of the following is *not* conserved in an inelastic collision: (a) momentum, (b) mass, (c) kinetic energy, or (d) total energy? (c)

74. **MC** A rubber ball of mass *m* traveling horizontally with a speed v hits a wall and bounces back with the same speed. The change in momentum is (a) mv, (b) $-mv$, (c) $-mv/2$, (d) $+2mv$. (d)

75. **MC** In a head-on elastic collision, mass m_1 strikes a stationary mass m_2. There is a complete transfer of energy if (a) $m_1 = m_2$, (b) $m_1 \gg m_2$, (c) $m_1 \ll m_2$, (d) the masses stick together. (a)

76. **MC** The condition for a two-object inelastic collision is (a) $K_f < K_i$, (b) $p_i \neq p_f$, (c) $m_1 > m_2$, (d) $v_1 < v_2$. (a)

84. ●● At a county fair, two children ram each other head-on while riding on the bumper car attraction. Jill and her car, traveling left at $3.50\,\mathrm{m/s}$, have a total mass of 325 kg. Jack and his car, traveling to the right at $2.00\,\mathrm{m/s}$, have a total mass of 290 kg. Assuming the collision to be elastic, determine their velocities after the collision. $1.69\,\mathrm{m/s}$, right; $-3.81\,\mathrm{m/s}$, left

91. **IE** ●● A car traveling east and a minivan traveling south collide in a completely inelastic collision at a perpendicular intersection. (a) Right after the collision, will the car and minivan move toward a general direction (1) south of east, (2) north of west, or (3) either due south or due east? Why? (b) If the initial speed of the 1500-kg car was $90.0\,\mathrm{km/h}$ and the initial speed of the 3000-kg minivan was $60.0\,\mathrm{km/h}$, what is the velocity of the vehicles immediately after collision? (a) (1) south of east (b) $13.9\ \mathrm{m/s}$, $53.1°$ south of east

95. ●●● In nuclear reactors, subatomic particles called *neutrons* are slowed down by allowing them to collide with the atoms of a moderator material, such as carbon atoms, which are 12 times as massive as neutrons. (a) In a head-on elastic collision with a carbon atom, what percentage of a neutron's energy is lost? (b) If the neutron has an initial speed of $1.5\times10^{7}\ \mathrm{m/s}$, what will be its speed after collision? (a) 28% (b) $1.3\times10^{7}\ \mathrm{m/s}$

96. ●●● In a noninjury chain-reaction accident on a foggy freeway, car 1 (mass of 2000 kg) moving at $15.0\,\mathrm{m/s}$ to the right elastically collides with car 2, initially at rest. The mass of car 2 is 1500 kg. In turn, car 2 then goes on to lock bumpers (that is, it is a completely inelastic collision) with car 3, which has a mass of 2500 kg and was also at rest. Determine the speed of all cars immediately after this unfortunate accident. $v_1 = 2.14\ \mathrm{m/s}$, $v_2 = 1.71\ \mathrm{m/s}$, $v_{23} = 6.41\ \mathrm{m/s}$

6.5 Center of Mass

99. **MC** The center of mass of an object (a) always lies at the center of the object, (b) is at the location of the most massive particle in the object, (c) always lies within the object, (d) none of the preceding. (d)

100. **MC** The center of mass and center of gravity coincide (a) if the acceleration due to gravity is constant, (b) if momentum is conserved, (c) if momentum is not conserved, (d) only for irregularly shaped objects. (a)

111. ●● Two cups are placed on a uniform board that is balanced on a cylinder (▼Fig. 6.39). The board has a mass of 2.00 kg and is 2.00 m long. The mass of cup 1 is 200 g and it is placed 1.05 m to the left of the balance point. The mass of cup 2 is 400 g. Where should Cup 2 be placed for balance (relative to the right end of the board)? 0.175 m