QUESTIONS

2. An object is thrown upward at an angle θ above the ground, eventually returning to earth. Is there any place along the trajectory where the velocity and acceleration are perpendicular? If so, where? Is there any place where the velocity and acceleration are parallel? If so, where?

3. Is the acceleration of a projectile equal to zero when it reaches the top of its trajectory? If not, why not?

4. A little league baseball player and a major league baseball player each hit a fly ball to center field. Once in flight, which ball, if either, has the greater acceleration? Provide a reason for your answer.

10. Suppose you are bicycling on a windy day. When you ride against the wind, the wind feels much stronger than when you ride with the wind. Why? Is there any velocity at which you could ride your bike and would *not* notice the effect of the wind? If so, how would this velocity be related to the velocity of the wind? Remember, velocity is a vector, so you must specify both its magnitude and direction.

13. On a riverboat cruise, a plastic bottle is accidentally dropped overboard. A passenger on the boat estimates that the boat pulls ahead of the bottle by 5 meters each second. Is it possible to conclude that the boat is moving at 5 m/s with respect to the shore? Give a reason.

7. A wrench is accidentally dropped from the top of the mast on a sailboat. Will the wrench hit at the same place on the deck whether the sailboat is at rest or moving with a constant velocity? Justify your answer.

PROBLEMS

Section 3.1 Displacement, Velocity, and Acceleration

1. A student rides up a dormitory elevator for a distance of 36 m. She then walks 19 m along a straight hallway to her room. What is the magnitude of her displacement from the base of the elevator to her room?

Section 3.2 Equations of Kinematics in Two Dimensions, Section 3.3 Projectile Motion

12. A spacecraft is traveling with a velocity of $v_{0x} = 5480$ m/s along the $+x$ direction. Two engines are turned on for a time of 842 s. One engine gives the spacecraft an acceleration in the $+x$ direction of $a_x = 1.20$ m/s^2, while the other gives it an acceleration in the $+y$ direction of $a_y = 8.40$ m/s^2. At the end of the firing, find (a) v_x and (b) v_y.

13. The velocity of a spacecraft is 2650 m/s, directed at an angle of 30.0° above the x axis. Two engines fire for a time of 475 s. One gives the spacecraft an acceleration in the $+x$ direction of $a_x = 6.30$ m/s^2. The other produces an acceleration in the $+y$ direction of $a_y = 2.85$ m/s^2. What is the speed of the spacecraft when the engines shut off?

14. A quarterback throws a pass to a receiver, who catches it at the same height as the pass is thrown. The initial velocity of the ball is 15.0 m/s, at an angle of 25.0° above the horizontal. What is the horizontal component of the ball's velocity when the receiver catches it?

15. The punter on a football team tries to kick a football so that it stays in the air for a long "hang time." If the ball is kicked with an initial velocity of 25.0 m/s at an angle of 60.0° above the ground, what is the "hang time"?

16. A rock climber throws a small first aid kit to another climber who is higher up the mountain. The initial velocity of the kit is 11 m/s at an angle of 65° above the horizontal. At the instant when the kit is caught, it is traveling horizontally, so its vertical speed is zero. What is the vertical height between the two climbers?

17. Review Conceptual Example 8 as background for this problem. The acceleration due to gravity on the moon has a magnitude of 1.62 m/s^2. Examples 5–7 deal with a place-kicker kicking a football. Assume that the ball is kicked on the moon instead of on the earth. Find (a) the maximum height H and (b) the range that the ball would attain on the moon. Verify that your answers are consistent with the conclusions reached in Conceptual Example 8.

18. With a particular club, the maximum speed that a golfer can impart to a ball is 30.3 m/s. Assume the tee and green are at the same elevation. (a) What is the longest hole in one that the golfer can make, if the ball does not roll when it hits the green? (b) How much time does the ball spend in the air?

19. During a baseball game a fly ball is hit to center field and is caught 115 m from home plate. Just when the ball is caught, a runner on third base takes off for home, and the center fielder throws the ball to the catcher standing on home plate. The runner takes 3.50 s to reach home, while the baseball is thrown with a velocity whose *horizontal* component is 41 m/s. Which reaches home first, the runner or the ball, and by how much time?

20. A bullet is fired from a rifle that is held 1.6 m above the ground in a horizontal position. The initial speed of the bullet is 1100 m/s. Find (a) the time it takes for the bullet to strike the ground and (b) the horizontal distance traveled by the bullet.

21. A golf ball rolls off a horizontal cliff with an initial speed of 11.4 m/s. The ball falls a vertical distance of 15.5 m into a lake below. (a) How much time does the ball spend in the air? (b) What is the speed v of the ball just before it strikes the water?

22. If a projectile has a launching angle of 52.0° above the horizontal and an initial speed of 18.0 m/s, what is the highest barrier that the projectile can clear?

23. A major league pitcher can throw a baseball in excess of 41 m/s. If a ball is thrown horizontally at this speed, how much can it be expected to drop due to gravity by the time it reaches a catcher who is 17 m away from the point of release? (Pitcher's mounds are raised to compensate for this drop.)

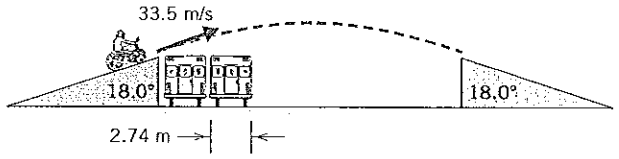
24. A car drives straight off the edge of a cliff that is 54 m high. The police at the scene of the accident note that the point of impact is 130 m from the base of the cliff. How fast was the car traveling when it went over the cliff?

25. A jet fighter is traveling horizontally with a speed of 111 m/s at an altitude of 3.00×10^2 m, when the pilot accidentally releases an outboard fuel tank. (a) How much time elapses before the tank hits the ground? (b) What is the speed of the tank just before it hits the ground?

26. Suppose the water at the top of Niagara Falls has a horizontal speed of 2.7 m/s just before it cascades over the edge of the falls. The height of the falls is 59 m. What is the magnitude of the water's velocity just before the water strikes the bottom? Treat the water particles as if they are in free-fall.

27. A tennis ball is struck such that it leaves the racket horizontally with a speed of 28.0 m/s. The ball hits the court at a horizontal distance of 19.6 m from the racket. What is the height of the tennis ball when it leaves the racket?

28. A motorcycle daredevil is attempting to jump across as many buses as possible (see the drawing). The takeoff ramp makes an angle of 18.0° above the horizontal, and the landing ramp is identical to the takeoff ramp. The buses are parked side by side, and each bus is 2.74 m wide. The cyclist leaves the ramp with a speed of 33.5 m/s. What is the maximum number of buses over which the cyclist can jump?



29. A horizontal rifle is fired at a bull's-eye. The muzzle speed of the bullet is 670 m/s. The barrel is pointed directly at the center of the bull's-eye, but the bullet strikes the target 0.025 m below the center. What is the horizontal distance between the end of the rifle and the bull's-eye?

30. A criminal is escaping across a rooftop and runs off the roof horizontally, landing on the roof of an adjacent building. The horizontal distance between the two buildings is 3.4 m, and the roof of the adjacent building is 2.0 m below the jumping off point. What would be the minimum speed needed by the criminal?

31. As preparation for this problem, review Conceptual Example 9. The two stones described there have identical initial speeds of $v_0 = 13.0$ m/s and are thrown at an angle $\theta = 30.0°$, one below the horizontal and one above the horizontal. What is the distance *between* the points where the stones strike the ground?

32. An archer is standing inside a building whose ceiling is 11 m high. An arrow is shot from ground level at an initial speed of 62 m/s. Calculate the angle of firing (above the horizontal) that gives the greatest possible range inside the building.

captain steer the boat to reach his destination? (b) How much time is required for the yacht to reach the marina?

ADDITIONAL PROBLEMS

61. A baseball player hits a triple and ends up on third base. A baseball "diamond" is a square, each side of length 27.4 m, with home plate and the three bases on the four corners. What is the magnitude of his displacement?

62. Suppose that the plane in Example 2 is traveling with twice the horizontal velocity, that is, with a velocity of +230 m/s. If all other factors remain the same, determine the time required for the package to hit the ground.

63. What is the smallest muzzle speed that a bullet can have if a horizontally fired bullet is to hit a 0.0254-meter-diameter target located 26.2 m away? Assume that the center of the target is on the same horizontal line as is the barrel of the rifle.

64. A diver runs horizontally with a speed of 1.20 m/s off a platform that is 10.0 m above the water. What is his speed just before striking the water?

65. A fire hose ejects a stream of water at an angle of 35.0° above the horizontal. The water leaves the nozzle with a speed of 25.0 m/s. Assuming that the water behaves like a projectile, how far from the building should the fire hose be located to hit the highest possible fire?

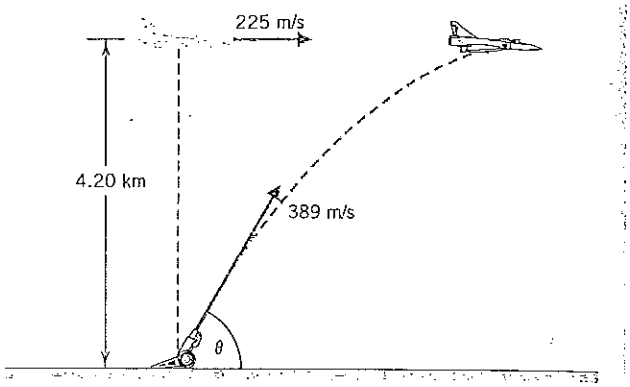
66. Two cars with different velocities are approaching an intersection. Car A, traveling due east, has a speed of 15 m/s. Car B, traveling due north, has a speed of 21 m/s. What is the velocity (magnitude and direction) of B as seen by the passengers in A?

67. At a certain point along its trajectory, a golf ball has the following velocity components: $v_x = +14.0$ m/s and $v_y = +18.9$ m/s, with upward and to the right being positive. (a) What is the speed at this point? (b) At what angle does the velocity vector point relative to the horizontal direction?

68. A hot-air balloon is rising straight up with a speed of 3.0 m/s. A ballast bag is released from rest relative to the balloon when it is 9.5 m above the ground. How much time elapses before the ballast bag hits the ground?

69. A box of .22-caliber bullets has the following message written on it: "Warning! Maximum range, 2.0 km." Assume that the muzzle speed of a bullet is 340 m/s and calculate the maximum range ($\theta = 45°$). Give a reason why the actual range of 2 km is less than the range that you calculated.

*70. A remote-controlled "target" plane is flying horizontally at an altitude of 4.20 km with a speed of 225 m/s. When the plane is directly overhead, a projectile is fired at an angle θ with the ground and has an initial speed of 389 m/s, as the diagram shows. The projectile hits the plane. Find the angle θ.



*71. During a hot-air balloon rally, two balloons are rising upward. Balloon A is rising straight up with a speed of 0.50 m/s relative to the ground. Due to a breeze, balloon B is moving away from A. Balloon B rises at an angle of 75° above the horizontal at a speed of 0.40 m/s relative to the ground. What is the speed of B relative to A?

*72. A small aircraft is headed due south with a speed of 57.8 m/s with respect to still air. Then, for 9.00×10^2 s a wind blows the plane so that it moves in a direction 45.0° west of south, even though the plane continues to point due south. The plane travels 81.0 km with respect to the ground in this time. Determine the velocity (magnitude and direction) of the wind with respect to the ground.

*73. A projectile is fired at an angle θ above the horizontal. Prove that the time for the projectile to travel from the ground to its maximum height is equal to the time to travel from its maximum height back to the ground.

*74. A soccer player kicks the ball toward a goal that is 29.0 m in front of him. The ball leaves his foot at a speed of 19.0 m/s and an angle of 32.0° above the ground. Find the speed of the ball when the goalie catches it in front of the net. (*Note: The answer is not 19.0 m/s.*)

**75. A jetliner can fly 6.00 hours on a full load of fuel. Without any wind it flies at a speed of 2.40×10^2 m/s. The plane is to make a round-trip by heading due west for a certain distance, turning around, and then heading due east for the return trip. During the entire flight, however, the plane encounters a 57.8 m/s wind from the jet stream, which blows from west to east. What is the maximum distance that the plane can travel due west and just be able to return home?

**76. A projectile is launched at an angle that yields the maximum possible range. Show, for this particular angle, that the range is four times greater than the maximum height reached by the projectile.

**77. A baseball is hit into the air at an initial speed of 36.6 m/s and an angle of 50.0° above the horizontal. At the same time, the center fielder starts running away from the batter and catches the ball 0.914 m above the level at which it was hit. If the center fielder is initially 1.10×10^2 m from home plate, what must be his average speed?