Questions

1. One car travels due east at 40 km/h, and a second car travels north at 40 km/h. Are their velocities equal? Explain.
2. Can you give several examples of an object's motion in which a great distance is traveled but the displacement is zero?
3. Can the displacement vector for a particle moving in two dimensions ever be longer than the length of path traveled by the particle over the same time interval? Can it ever be less? Discuss.
4. During baseball practice, a batter hits a very high fly ball and then runs in a straight line and catches it. Which had the greater displacement, the batter or the ball?
5. If $\vec{\mathbf{V}} = \vec{\mathbf{V}}_1 + \vec{\mathbf{V}}_2$, is V necessarily greater than V_1 and/or V_2? Discuss.
6. Two vectors have length $V_1 = 3.5\,\text{km}$ and $V_2 = 4.0\,\text{km}$. What are the maximum and minimum magnitudes of their vector sum?
7. Can two vectors of unequal magnitude add up to give the zero vector? Can *three* unequal vectors? Under what conditions?
8. Can the magnitude of a vector ever (*a*) be equal to one of its components, or (*b*) be less than one of its components?
9. Can a particle with constant speed be accelerating? What if it has constant velocity?
10. A child wishes to determine the speed a slingshot imparts to a rock. How can this be done using only a meter stick, a rock, and the slingshot?
11. It was reported in World War I that a pilot flying at an altitude of 2 km caught in his bare hands a bullet fired at the plane! Using the fact that a bullet slows down considerably due to air resistance, explain how this incident occurred.
12. At some amusement parks, to get on a moving "car" the riders first hop onto a moving walkway and then onto the cars themselves. Why is this done?
13. If you are riding on a train that speeds past another train moving in the same direction on an adjacent track, it appears that the other train is moving backward. Why?
14. If you stand motionless under an umbrella in a rainstorm where the drops fall vertically, you remain relatively dry. However, if you start running, the rain begins to hit your legs even if they remain under the umbrella. Why?
15. A person sitting in an enclosed train car, moving at constant velocity, throws a ball straight up into the air in her reference frame. (*a*) Where does the ball land? What is your answer if the car (*b*) accelerates, (*c*) decelerates, (*d*) rounds a curve, (*e*) moves with constant velocity but is open to the air?
16. Two rowers, who can row at the same speed in still water, set off across a river at the same time. One heads straight across and is pulled downstream somewhat by the current. The other one heads upstream at an angle so as to arrive at a point opposite the starting point. Which rower reaches the opposite side first?
17. How do you think a baseball player "judges" the flight of a fly ball? Which equation in this Chapter becomes part of the player's intuition?
18. In archery, should the arrow be aimed directly at the target? How should your angle of aim depend on the distance to the target?
19. A projectile is launched at an angle of 30° to the horizontal with a speed of 30 m/s. How does the horizontal component of its velocity 1.0 s after launch compare with its horizontal component of velocity 2.0 s after launch?
20. Two cannonballs, A and B, are fired from the ground with identical initial speeds, but with θ_A larger than θ_B. (*a*) Which cannonball reaches a higher elevation? (*b*) Which stays longer in the air? (*c*) Which travels farther?

Problems

3–2 to 3–4 Vector Addition

1. (I) A car is driven 215 km west and then 85 km southwest. What is the displacement of the car from the point of origin (magnitude and direction)? Draw a diagram.
2. (I) A delivery truck travels 18 blocks north, 10 blocks east, and 16 blocks south. What is its final displacement from the origin? Assume the blocks are equal length.
3. (I) Show that the vector labeled "incorrect" in Fig. 3–6c is actually the difference of the two vectors. Is it $\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1$, or $\vec{\mathbf{V}}_1 - \vec{\mathbf{V}}_2$?
4. (I) If $V_x = 6.80$ units and $V_y = -7.40$ units, determine the magnitude and direction of $\vec{\mathbf{V}}$.
5. (II) Graphically determine the resultant of the following three vector displacements: (1) 34 m, 25° north of east; (2) 48 m, 33° east of north; and (3) 22 m, 56° west of south.
6. (II) The components of a vector $\vec{\mathbf{V}}$ can be written (V_x, V_y, V_z). What are the components and length of a vector which is the sum of the two vectors, $\vec{\mathbf{V}}_1$ and $\vec{\mathbf{V}}_2$, whose components are (8.0, −3.7, 0.0) and (3.9, −8.1, −4.4)?
7. (II) $\vec{\mathbf{V}}$ is a vector 14.3 units in magnitude and points at an angle of 34.8° above the negative x axis. (*a*) Sketch this vector. (*b*) Find V_x and V_y. (*c*) Use V_x and V_y to obtain (again) the magnitude and direction of $\vec{\mathbf{V}}$. [*Note*: Part (*c*) is a good way to check if you've resolved your vector correctly.]
8. (II) Vector $\vec{\mathbf{V}}_1$ is 6.6 units long and points along the negative x axis. Vector $\vec{\mathbf{V}}_2$ is 8.5 units long and points at +45° to the positive x axis. (*a*) What are the x and y components of each vector? (*b*) Determine the sum $\vec{\mathbf{V}}_1 + \vec{\mathbf{V}}_2$ (magnitude and angle).

9. (II) An airplane is traveling 735 km/h in a direction 41.5° west of north (Fig. 3–31). (*a*) Find the components of the velocity vector in the northerly and westerly directions. (*b*) How far north and how far west has the plane traveled after 3.00 h?

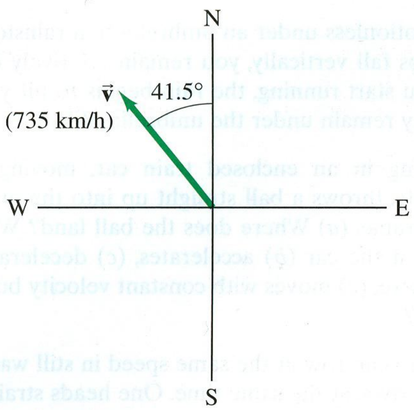


FIGURE 3–31 Problem 9.

10. (II) Three vectors are shown in Fig. 3–32. Their magnitudes are given in arbitrary units. Determine the sum of the three vectors. Give the resultant in terms of (*a*) components, (*b*) magnitude and angle with the *x* axis.

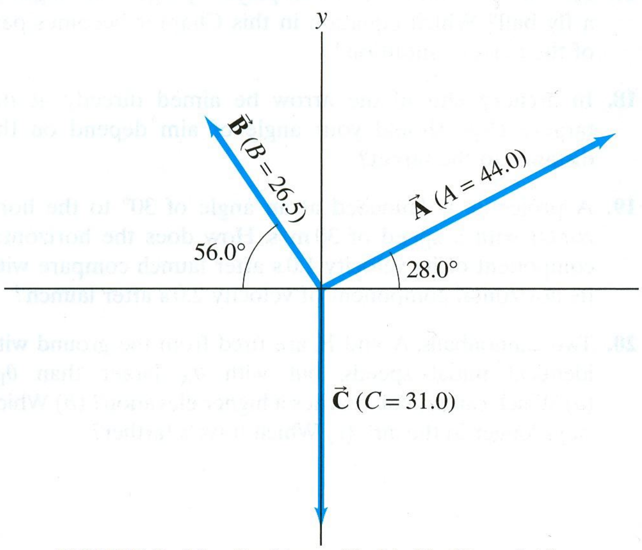


FIGURE 3–32 Problems 10, 11, 12, 13, and 14. Vector magnitudes are given in arbitrary units.

11. (II) Determine the vector $\vec{\mathbf{A}} - \vec{\mathbf{C}}$, given the vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{C}}$ in Fig. 3–32.

12. (II) (*a*) Given the vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ shown in Fig. 3–32, determine $\vec{\mathbf{B}} - \vec{\mathbf{A}}$. (*b*) Determine $\vec{\mathbf{A}} - \vec{\mathbf{B}}$ without using your answer in (*a*). Then compare your results and see if they are opposite.

13. (II) For the vectors given in Fig. 3–32, determine (*a*) $\vec{\mathbf{A}} - \vec{\mathbf{B}} + \vec{\mathbf{C}}$, (*b*) $\vec{\mathbf{A}} + \vec{\mathbf{B}} - \vec{\mathbf{C}}$, and (*c*) $\vec{\mathbf{C}} - \vec{\mathbf{A}} - \vec{\mathbf{B}}$.

14. (II) For the vectors shown in Fig. 3–32, determine (*a*) $\vec{\mathbf{B}} - 2\vec{\mathbf{A}}$, (*b*) $2\vec{\mathbf{A}} - 3\vec{\mathbf{B}} + 2\vec{\mathbf{C}}$.

15. (II) The summit of a mountain, 2450 m above base camp, is measured on a map to be 4580 m horizontally from the camp in a direction 32.4° west of north. What are the components of the displacement vector from camp to summit? What is its magnitude? Choose the *x* axis east, *y* axis north, and *z* axis up.

16. (II) You are given a vector in the *xy* plane that has a magnitude of 70.0 units and a *y* component of −55.0 units. What are the two possibilities for its *x* component?

3–5 and 3–6 Projectile Motion (neglect air resistance)

17. (I) A tiger leaps horizontally from a 6.5-m-high rock with a speed of 3.5 m/s. How far from the base of the rock will she land?

18. (I) A diver running 1.8 m/s dives out horizontally from the edge of a vertical cliff and 3.0 s later reaches the water below. How high was the cliff, and how far from its base did the diver hit the water?

19. (II) A fire hose held near the ground shoots water at a speed of 6.8 m/s. At what angle(s) should the nozzle point in order that the water land 2.0 m away (Fig. 3–33)? Why are there two different angles? Sketch the two trajectories.

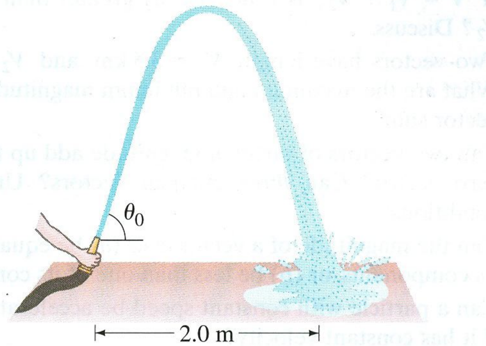


FIGURE 3–33 Problem 19.

20. (II) Romeo is chucking pebbles gently up to Juliet's window, and he wants the pebbles to hit the window with only a horizontal component of velocity. He is standing at the edge of a rose garden 4.5 m below her window and 5.0 m from the base of the wall (Fig. 3–34). How fast are the pebbles going when they hit her window?

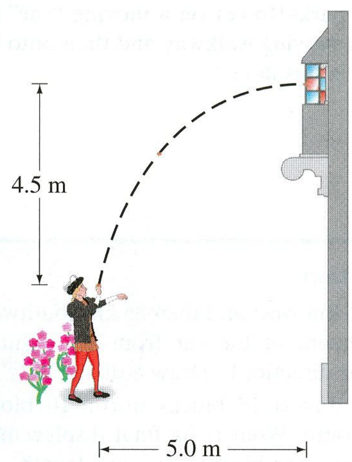


FIGURE 3–34 Problem 20.

21. (II) A ball is thrown horizontally from the roof of a building 45.0 m tall and lands 24.0 m from the base. What was the ball's initial speed?

22. (II) A football is kicked at ground level with a speed of 18.0 m/s at an angle of 35.0° to the horizontal. How much later does it hit the ground?

23. (II) A ball thrown horizontally at 22.2 m/s from the roof of a building lands 36.0 m from the base of the building. How tall is the building?

24. (II) An athlete executing a long jump leaves the ground at a 28.0° angle and travels 7.80 m. (*a*) What was the takeoff speed? (*b*) If this speed were increased by just 5.0%, how much longer would the jump be?

25. (II) Determine how much farther a person can jump on the Moon as compared to the Earth if the takeoff speed and angle are the same. The acceleration due to gravity on the Moon is one-sixth what it is on Earth.

26. (II) A hunter aims directly at a target (on the same level) 75.0 m away. (*a*) If the bullet leaves the gun at a speed of 180 m/s, by how much will it miss the target? (*b*) At what angle should the gun be aimed so as to hit the target?

27. (II) The pilot of an airplane traveling 180 km/h wants to drop supplies to flood victims isolated on a patch of land 160 m below. The supplies should be dropped how many seconds before the plane is directly overhead?

28. (II) Show that the speed with which a projectile leaves the ground is equal to its speed just before it strikes the ground at the end of its journey, assuming the firing level equals the landing level.

29. (II) Suppose the kick in Example 3–5 is attempted 36.0 m from the goalposts, whose crossbar is 3.00 m above the ground. If the football is directed correctly between the goalposts, will it pass over the bar and be a field goal? Show why or why not.

30. (II) A projectile is fired with an initial speed of 65.2 m/s at an angle of 34.5° above the horizontal on a long flat firing range. Determine (*a*) the maximum height reached by the projectile, (*b*) the total time in the air, (*c*) the total horizontal distance covered (that is, the range), and (*d*) the velocity of the projectile 1.50 s after firing.

31. (II) A projectile is shot from the edge of a cliff 125 m above ground level with an initial speed of 65.0 m/s at an angle of 37.0° with the horizontal, as shown in Fig. 3–35. (*a*) Determine the time taken by the projectile to hit point P at ground level. (*b*) Determine the range X of the projectile as measured from the base of the cliff. At the instant just before the projectile hits point P, find (*c*) the horizontal and the vertical components of its velocity, (*d*) the magnitude of the velocity, and (*e*) the angle made by the velocity vector with the horizontal. (*f*) Find the maximum height above the cliff top reached by the projectile.

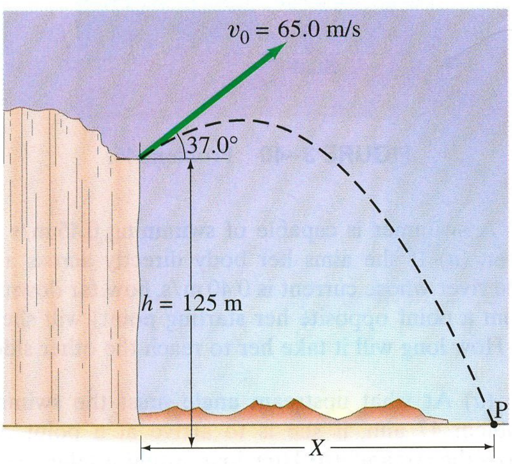


FIGURE 3–35 Problem 31.

32. (II) A shotputter throws the shot with an initial speed of 15.5 m/s at a 34.0° angle to the horizontal. Calculate the horizontal distance traveled by the shot if it leaves the athlete's hand at a height of 2.20 m above the ground.

33. (II) At what projection angle will the range of a projectile equal its maximum height?

34. (III) Revisit Conceptual Example 3–7, and assume that the boy with the slingshot is *below* the boy in the tree (Fig. 3–36), and so aims *upward*, directly at the boy in the tree. Show that again the boy in the tree makes the wrong move by letting go at the moment the water balloon is shot.

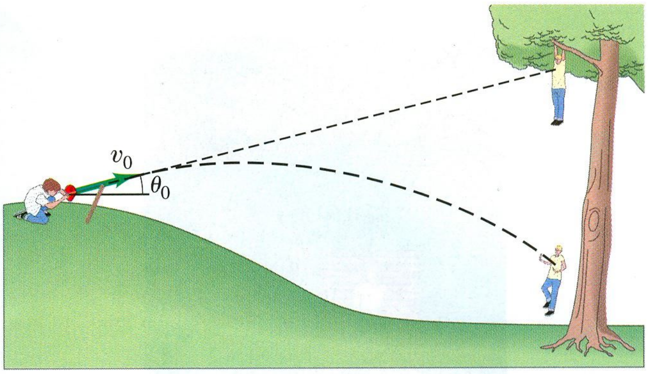


FIGURE 3–36 Problem 34.

35. (III) A rescue plane wants to drop supplies to isolated mountain climbers on a rocky ridge 235 m below. If the plane is traveling horizontally with a speed of 250 km/h (69.4 m/s), (*a*) how far in advance of the recipients (horizontal distance) must the goods be dropped (Fig. 3–37a)? (*b*) Suppose, instead, that the plane releases the supplies a horizontal distance of 425 m in advance of the mountain climbers. What vertical velocity (up or down) should the supplies be given so that they arrive precisely at the climbers' position (Fig. 3–37b)? (*c*) With what speed do the supplies land in the latter case?

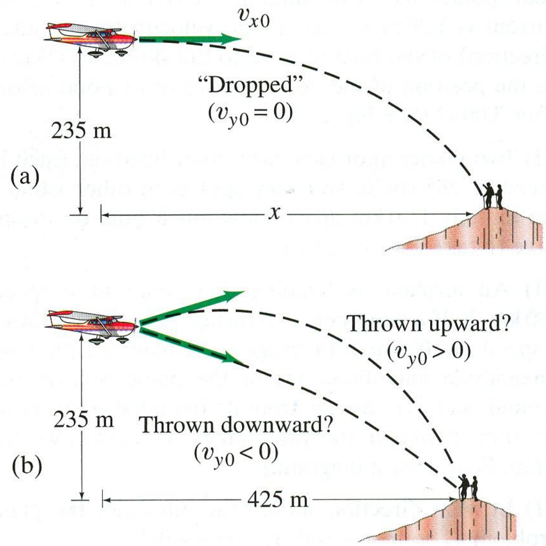


FIGURE 3–37 Problem 35.

* 3–8 Relative Velocity

* **36.** (I) A person going for a morning jog on the deck of a cruise ship is running toward the bow (front) of the ship at 2.2 m/s while the ship is moving ahead at 7.5 m/s. What is the velocity of the jogger relative to the water? Later, the jogger is moving toward the stern (rear) of the ship. What is the jogger's velocity relative to the water now?

* **37.** (II) Huck Finn walks at a speed of 0.60 m/s across his raft (that is, he walks perpendicular to the raft's motion relative to the shore). The raft is traveling down the Mississippi River at a speed of 1.70 m/s relative to the river bank (Fig. 3–38). What is Huck's velocity (speed and direction) relative to the river bank?

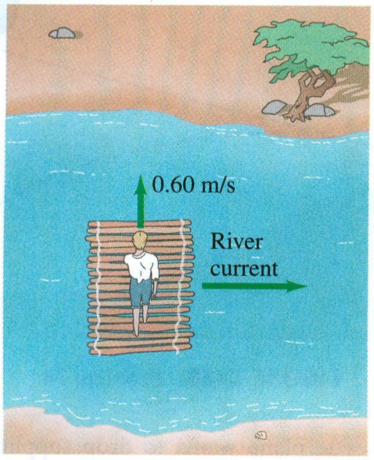


FIGURE 3–38 Problem 37.

* **38.** (II) You are driving south on a highway at 25 m/s (approximately 55 mi/h) in a snowstorm. When you last stopped, you noticed that the snow was coming down vertically, but it is passing the windows of the moving car at an angle of 30° to the horizontal. Estimate the speed of the snowflakes relative to the car and relative to the ground.

* **39.** (II) A boat can travel 2.30 m/s in still water. (*a*) If the boat points its prow directly across a stream whose current is 1.20 m/s, what is the velocity (magnitude and direction) of the boat relative to the shore? (*b*) What will be the position of the boat, relative to its point of origin, after 3.00 s? (See Fig. 3–30.)

* **40.** (II) Two planes approach each other head-on. Each has a speed of 785 km/h, and they spot each other when they are initially 11.0 km apart. How much time do the pilots have to take evasive action?

* **41.** (II) An airplane is heading due south at a speed of 600 km/h. If a wind begins blowing from the southwest at a speed of 100 km/h (average), calculate: (*a*) the velocity (magnitude and direction) of the plane relative to the ground, and (*b*) how far from its intended position will it be after 10 min if the pilot takes no corrective action. [*Hint*: First draw a diagram.]

* **42.** (II) In what direction should the pilot aim the plane in Problem 41 so that it will fly due south?

* **43.** (II) Determine the speed of the boat with respect to the shore in Example 3–11.

* **44.** (II) A passenger on a boat moving at 1.50 m/s on a still lake walks up a flight of stairs at a speed of 0.50 m/s (Fig. 3–39). The stairs are angled at 45° pointing in the direction of motion as shown. What is the velocity of the passenger relative to the water?

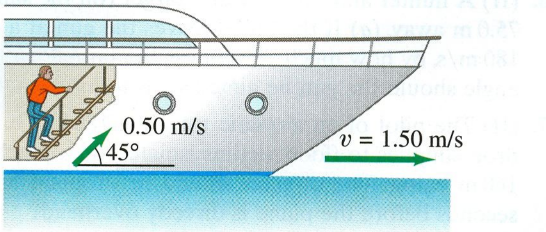


FIGURE 3–39 Problem 44.

* **45.** (II) A motorboat whose speed in still water is 2.60 m/s must aim upstream at an angle of 28.5° (with respect to a line perpendicular to the shore) in order to travel directly across the stream. (*a*) What is the speed of the current? (*b*) What is the resultant speed of the boat with respect to the shore? (See Fig. 3–28.)

* **46.** (II) A boat, whose speed in still water is 1.70 m/s, must cross a 260-m-wide river and arrive at a point 110 m upstream from where it starts (Fig. 3–40). To do so, the pilot must head the boat at a 45° upstream angle. What is the speed of the river's current?

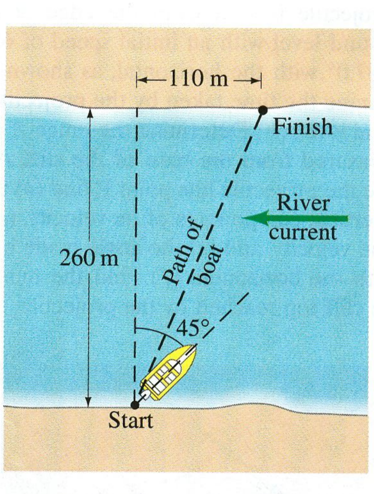


FIGURE 3–40 Problem 46.

* **47.** (II) A swimmer is capable of swimming 0.45 m/s in still water. (*a*) If she aims her body directly across a 75-m-wide river whose current is 0.40 m/s, how far downstream (from a point opposite her starting point) will she land? (*b*) How long will it take her to reach the other side?

* **48.** (II) (*a*) At what upstream angle must the swimmer in Problem 47 aim, if she is to arrive at a point directly across the stream? (*b*) How long would it take her?

* **49.** (III) An airplane whose air speed is 620 km/h is supposed to fly in a straight path 35.0° north of east. But a steady 95 km/h wind is blowing from the north. In what direction should the plane head?

* **50.** (III) An unmarked police car, traveling a constant 95 km/h, is passed by a speeder traveling 145 km/h. Precisely 1.00 s after the speeder passes, the policeman steps on the accelerator. If the police car's acceleration is 2.00 m/s^2, how much time elapses after the police car is passed until it overtakes the speeder (assumed moving at constant speed)?

* **51.** (III) Assume in Problem 50 that the speeder's speed is not known. If the police car accelerates uniformly as given above, and overtakes the speeder after 7.00 s, what was the speeder's speed?

* **52.** (III) Two cars approach a street corner at right angles to each other (Fig. 3–41). Car 1 travels at a speed relative to Earth $v_{1E} = 35 \text{ km/h}$, and car 2 at $v_{2E} = 55 \text{ km/h}$. What is the relative velocity of car 1 as seen by car 2? What is the velocity of car 2 relative to car 1?

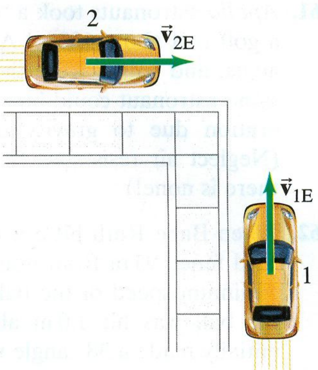


FIGURE 3–41 Problem 52.

General Problems

53. William Tell must split the apple atop his son's head from a distance of 27 m. When William aims directly at the apple, the arrow is horizontal. At what angle must he aim it to hit the apple if the arrow travels at a speed of 35 m/s?

54. A plumber steps out of his truck, walks 50 m east and 25 m south, and then takes an elevator 10 m down into the subbasement of a building where a bad leak is occurring. What is the displacement of the plumber relative to his truck? Give your answer in components, and also give the magnitude and angles with the x axis in the vertical and horizontal planes. Assume x is east, y is north, and z is up.

55. On mountainous downhill roads, escape routes are sometimes placed to the side of the road for trucks whose brakes might fail. Assuming a constant upward slope of 32°, calculate the horizontal and vertical components of the acceleration of a truck that slowed from 120 km/h to rest in 6.0 s. See Fig. 3–42.

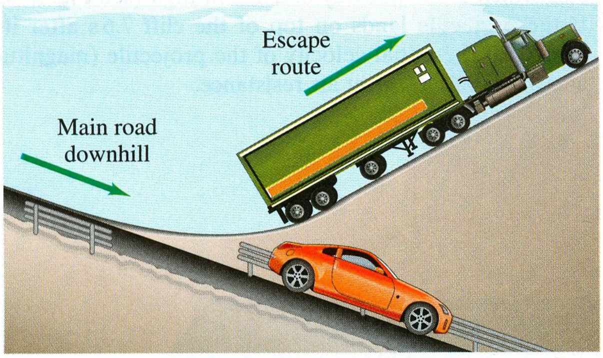


FIGURE 3–42 Problem 55.

56. What is the y component of a vector (in the xy plane) whose magnitude is 88.5 and whose x component is 75.4? What is the direction of this vector (angle it makes with the x axis)?

57. Raindrops make an angle θ with the vertical when viewed through a moving train window (Fig. 3–43). If the speed of the train is v_T, what is the speed of the raindrops in the reference frame of the Earth in which they are assumed to fall vertically?

FIGURE 3–43 Problem 57.

58. A light plane is headed due south with a speed of 155 km/h relative to still air. After 1.00 hour, the pilot notices that they have covered only 125 km and their direction is not south but southeast (45.0°). What is the wind velocity?

59. A car moving at 95 km/h passes a 1.00-km-long train traveling in the same direction on a track that is parallel to the road. If the speed of the train is 75 km/h, how long does it take the car to pass the train, and how far will the car have traveled in this time? What are the results if the car and train are instead traveling in opposite directions?

60. An Olympic long jumper is capable of jumping 8.0 m. Assuming his horizontal speed is 9.1 m/s as he leaves the ground, how long is he in the air and how high does he go? Assume that he lands standing upright—that is, the same way he left the ground.

61. *Apollo* astronauts took a "nine iron" to the Moon and hit a golf ball about 180 m! Assuming that the swing, launch angle, and so on, were the same as on Earth where the same astronaut could hit it only 35 m, estimate the acceleration due to gravity on the surface of the Moon. (Neglect air resistance in both cases, but on the Moon there is none!)

62. When Babe Ruth hit a homer over the 7.5-m-high right-field fence 95 m from home plate, roughly what was the minimum speed of the ball when it left the bat? Assume the ball was hit 1.0 m above the ground and its path initially made a 38° angle with the ground.

63. The cliff divers of Acapulco push off horizontally from rock platforms about 35 m above the water, but they must clear rocky outcrops at water level that extend out into the water 5.0 m from the base of the cliff directly under their launch point. See Fig. 3–44. What minimum pushoff speed is necessary to clear the rocks? How long are they in the air?

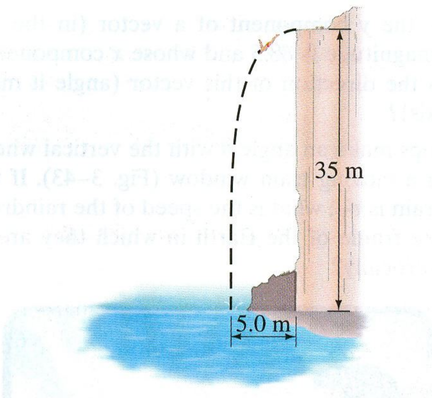
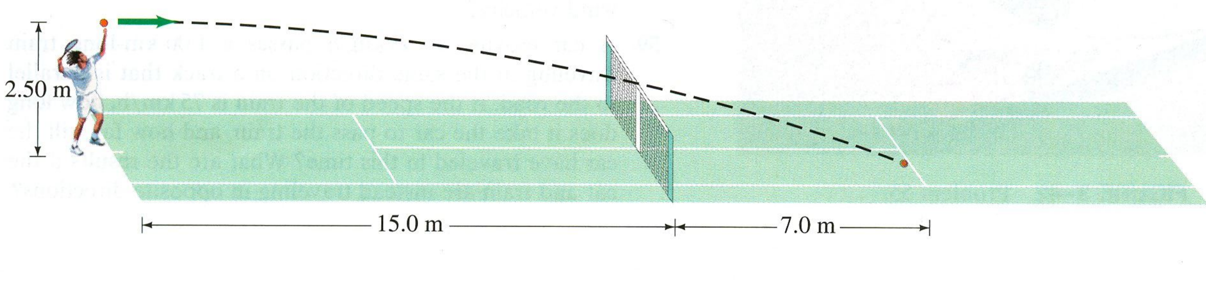


FIGURE 3–44 Problem 63.

64. At serve, a tennis player aims to hit the ball horizontally. What minimum speed is required for the ball to clear the 0.90-m-high net about 15.0 m from the server if the ball is "launched" from a height of 2.50 m? Where will the ball land if it just clears the net (and will it be "good" in the sense that it lands within 7.0 m of the net)? How long will it be in the air? See Fig. 3–45.

FIGURE 3–45 Problem 64.



65. Spymaster Paul, flying a constant 215 km/h horizontally in a low-flying helicopter, wants to drop secret documents into his contact's open car which is traveling 155 km/h on a level highway 78.0 m below. At what angle (to the horizontal) should the car be in his sights when the packet is released (Fig. 3–46)?

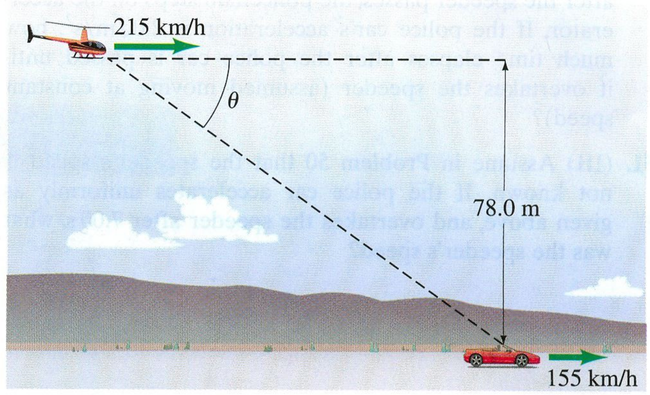


FIGURE 3–46 Problem 65.

66. The speed of a boat in still water is v. The boat is to make a round trip in a river whose current travels at speed u. Derive a formula for the time needed to make a round trip of total distance D if the boat makes the round trip by moving (*a*) upstream and back downstream, (*b*) directly across the river and back. We must assume $u < v$; why?

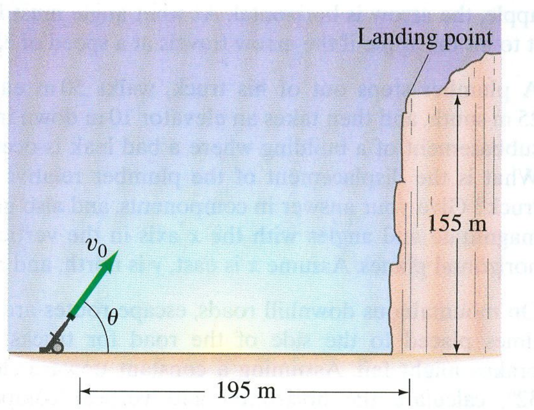


FIGURE 3–47 Problem 67.

67. A projectile is launched from ground level to the top of a cliff which is 195 m away and 155 m high (see Fig. 3–47). If the projectile lands on top of the cliff 7.6 s after it is fired, find the initial velocity of the projectile (magnitude and direction). Neglect air resistance.

68. (*a*) A skier is accelerating down a 30.0° hill at $1.80\ m/s^2$ (Fig. 3–48). What is the vertical component of her acceleration? (*b*) How long will it take her to reach the bottom of the hill, assuming she starts from rest and accelerates uniformly, if the elevation change is 335 m?

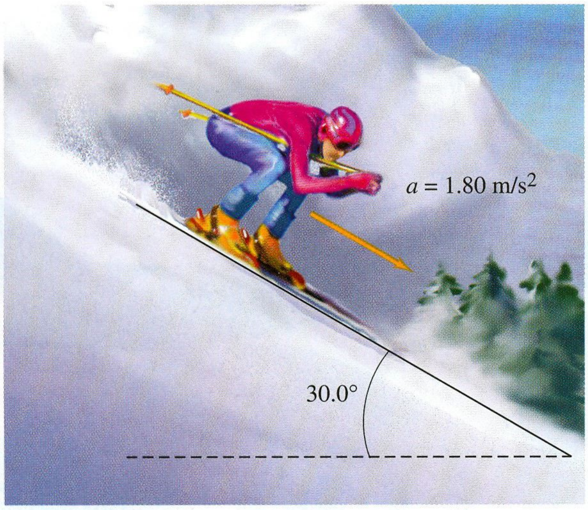


FIGURE 3–48 Problem 68.

69. A basketball leaves a player's hands at a height of 2.10 m above the floor. The basket is 2.60 m above the floor. The player likes to shoot the ball at a 38.0° angle. If the shot is made from a horizontal distance of 11.00 m and must be accurate to ± 0.22 m (horizontally), what is the range of initial speeds allowed to make the basket?

70. A high diver leaves the end of a 5.0-m-high diving board and strikes the water 1.3 s later, 3.0 m beyond the end of the board. Considering the diver as a particle, determine (*a*) her initial velocity, $\vec{v}_0$, (*b*) the maximum height reached, and (*c*) the velocity $\vec{v}_f$ with which she enters the water.

71. A stunt driver wants to make his car jump over eight cars parked side by side below a horizontal ramp (Fig. 3–49). (*a*) With what minimum speed must he drive off the horizontal ramp? The vertical height of the ramp is 1.5 m above the cars, and the horizontal distance he must clear is 20 m. (*b*) If the ramp is now tilted upward, so that "takeoff angle" is 10° above the horizontal, what is the new minimum speed?

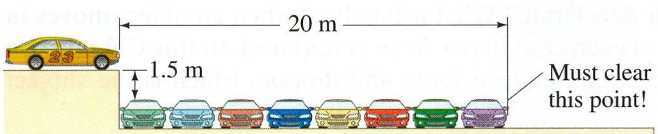


FIGURE 3–49 Problem 71.

72. A batter hits a fly ball which leaves the bat 0.90 m above the ground at an angle of 61° with an initial speed of 28 m/s heading toward centerfield. Ignore air resistance. (*a*) How far from home plate would the ball land if not caught? (*b*) The ball is caught by the centerfielder who, starting at a distance of 105 m from home plate, runs straight toward home plate at a constant speed and makes the catch at ground level. Find his speed.

73. At $t = 0$ a batter hits a baseball with an initial speed of 32 m/s at a 55° angle to the horizontal. An outfielder is 85 m from the batter at $t = 0$, and, as seen from home plate, the line of sight to the outfielder makes a horizontal angle of 22° with the plane in which the ball moves (see Fig. 3–50). What speed and direction must the fielder take in order to catch the ball at the same height from which it was struck? Give angle with respect to the outfielder's line of sight to home plate.

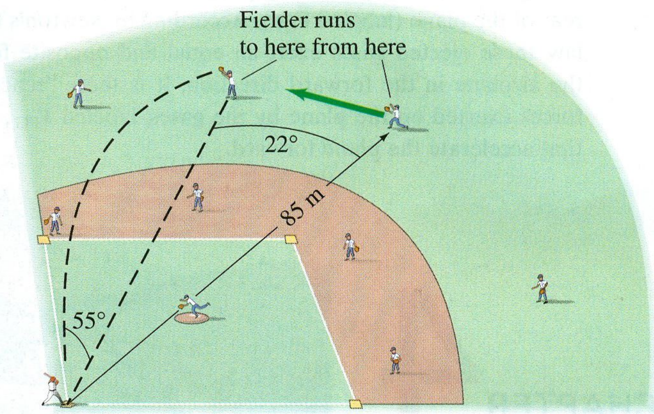


FIGURE 3–50 Problem 73.

74. A ball is shot from the top of a building with an initial velocity of 18 m/s at an angle $\theta = 42°$ above the horizontal. (*a*) What are the *x* and *y* components of the initial velocity? (*b*) If a nearby building is the same height and 55 m away, how far below the top of the building will the ball strike the nearby building?

75. You buy a plastic dart gun, and being a clever physics student you decide to do a quick calculation to find its maximum horizontal range. You shoot the gun straight up, and it takes 4.0 s for the dart to land back at the barrel. What is the maximum horizontal range of your gun?

Answers to Exercises

A: When the two vectors D_1 and D_2 point in the same direction.

B: $3\sqrt{2} = 4.24$.

C: They hit at the same time.

D: Both balls reach the same height; therefore they are in the air for the same length of time.

E: (*b*).