**CHAPTER 3**

**Kinematics in Two or Three Dimensions; Vectors**

**Windows OS**

**Problems**

**3–2 to 3–5 Vector Addition; Unit Vectors**

**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.

**1.** (I) A car is driven 225 km west and then 78 km southwest (45°). What is the displacement of the car from the point of origin (magnitude and direction)? Draw a diagram.

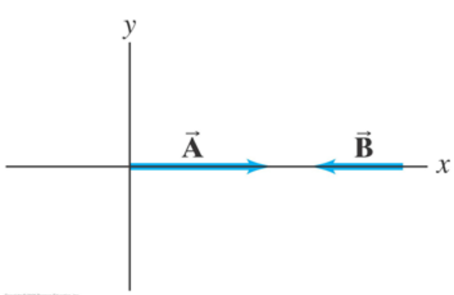
**2.** (I) A delivery truck travels 28 blocks north, 16 blocks east, and 26 blocks south. What is its final displacement from the origin? Assume the blocks are equal length.

**3.** (I) If $V_x = 7.80$ units and $V_y = -6.4$ units, determine the magnitude and direction of $\vec{\mathbf{V}}$.

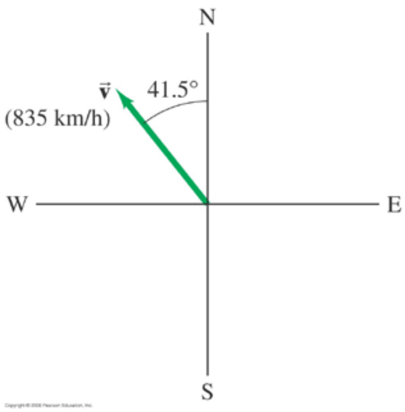
**4.** (II) Graphically determine the resultant of the following three vector displacements: (1) 24 m, 36° north of east; (2) 18 m, 37° east of north; and (3) 26 m, 33° west of south.

**5.** (II) $\vec{\mathbf{V}}$ is a vector 24.8 units in magnitude and points at an angle of 23.4° above the negative *x* axis. (*a*) Sketch this vector. (*b*) Calculate $V_x$ 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.]

**6.** (II) Figure 3–36 shows two vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$, whose magnitudes are $A = 6.8$ units and $B = 5.5$ units. Determine $\vec{\mathbf{C}}$ if (*a*) $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$, (*b*) $\vec{\mathbf{C}} = \vec{\mathbf{A}} - \vec{\mathbf{B}}$, (*c*) $\vec{\mathbf{C}} = \vec{\mathbf{B}} - \vec{\mathbf{A}}$. Give the magnitude and direction for each.



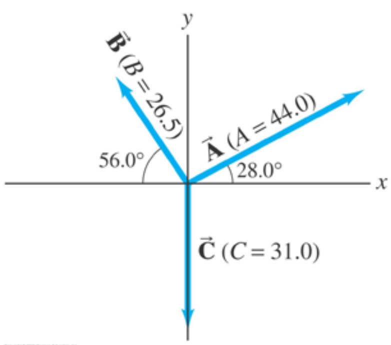
**7.** (II) An airplane is traveling 835 km / h in a direction 41.5° west of north (Fig. 3–37). (*a*) Find the components of the velocity vector in the northerly and westerly directions. (*b*) How far north and how far west has the plane traveled after 2.50 h?




**8.** (II) Let $\vec{\mathbf{V}}_1 = 2\ 6.0\hat{\mathbf{i}} + 8.0\hat{\mathbf{j}}$ and $\vec{\mathbf{V}}_2 = 4.5\hat{\mathbf{i}} - 5.0\hat{\mathbf{j}}$. Determine the magnitude and direction of (*a*) $\vec{\mathbf{V}}_1$, (*b*) $\vec{\mathbf{V}}_2$, (*c*) $\vec{\mathbf{V}}_1 + \vec{\mathbf{V}}_2$ and (*d*) $\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1$.

**9.** (II) (*a*) Determine the magnitude and direction of the sum of the three vectors $\vec{\mathbf{V}}_1 = 4.0\hat{\mathbf{i}} - 8.0\hat{\mathbf{j}}$, $\vec{\mathbf{V}}_2 = \hat{\mathbf{i}} + \hat{\mathbf{j}}$, and $\mathbf{V_3} = -\ 2.0\ \mathbf{i} + 4.0\ \mathbf{j}$ (*b*) Determine $\vec{\mathbf{V}}_1 - \vec{\mathbf{V}}_2 + \vec{\mathbf{V}}_3$.

**10.** (II) Three vectors are shown in Fig. 3–38. 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 *x* axis.




**11.** (II) (*a*) Given the vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ shown in Fig. 3–38, 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.

**12.** (II) Determine the vector $\vec{\mathbf{A}} - \vec{\mathbf{C}}$, given the vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{C}}$ in Fig. 3–38.

**13.** (II) For the vectors shown in Fig. 3 – 38, determine (*a*) $\vec{\mathbf{B}} - 2\vec{\mathbf{A}}$, (*b*) $2\vec{\mathbf{A}} - 3\vec{\mathbf{B}} + 2\vec{\mathbf{C}}$.

**14.** (II) For the vectors given in Fig. 3 – 38, determine (*a*) $\vec{\mathbf{A}}-\vec{\mathbf{B}}+\vec{\mathbf{C}}$, (*b*) $\vec{\mathbf{A}}+\vec{\mathbf{B}}-\vec{\mathbf{C}}$, and (*c*) $\vec{\mathbf{C}}-\vec{\mathbf{A}}-\vec{\mathbf{B}}$.

**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.** (III) You are given a vector in the *xy* plane that has a magnitude of 90.0 units and a *y* component of 2 55.0 units. (*a*) What are the two possibilities for its *x* component? (*b*) Assuming the *x* component is known to be positive, specify the vector which, if you add it to the original one, would give a resultant vector that is 80.0 units long and points entirely in the 2 $x$ direction.

**3–6 Vector Kinematics**

**17.** (I) The position of a particular particle as a function of time is given by $\vec{\mathbf{r}}=\left(9.60\,t\,\hat{\mathbf{i}}+8.85\,\hat{\mathbf{j}}-1.00\,t^2\,\hat{\mathbf{k}}\right)\mathrm{m}$. Determine the particle's velocity and acceleration as a function of time.

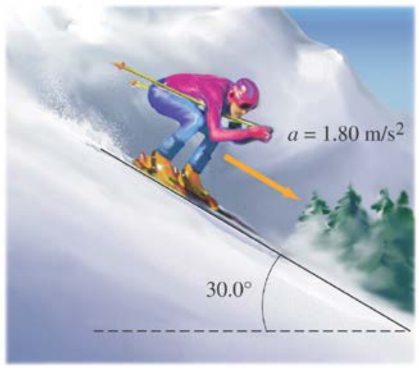
**18.** (I) What was the average velocity of the particle in Problem 17 between $t=1.00\,\mathrm{s}$ and $t=3.00\,\mathrm{s}$? What is the magnitude of the instantaneous velocity at $t=2.00\,\mathrm{s}$?

**19.** (II) What is the shape of the path of the particle of Problem 17?

**20.** (II) A car is moving with speed 18.0 m / s due south at one moment and 27.5 m / s due east 8.00 s later. Over this time interval, determine the magnitude and direction of (*a*) its average velocity, (*b*) its average acceleration. (*c*) What is its average speed. [*Hint:* Can you determine all these from the information given?]

**21.** (II) At $t=0$, a particle starts from rest at $x=0$, $y=0$, and moves in the *xy* plane with an acceleration $\vec{\mathbf{a}}=\left(4.0\,\hat{\mathbf{i}}+3.0\,\hat{\mathbf{j}}\right)\mathrm{m/s^2}$. Determine (*a*) the *x* and *y* components of velocity, (*b*) the speed of the particle, and (*c*) the position of the particle, all as a function of time. (*d*) Evaluate all the above at $t=2.0\,\mathrm{s}$.

**22.** (II) (*a*) A skier is accelerating down a 30.0° hill at $1.80\,\mathrm{m/s^2}$ (Fig. 3–39). 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 325 m?




**23.** (II) An ant walks on a piece of graph paper straight along the *x* axis a distance of 10.0 cm in 2.00 s. It then turns left 30.0° and walks in a straight line another 10.0 cm in 1.80 s. Finally, it turns another 70.0° to the left and walks another 10.0 cm in 1.55 s. Determine (*a*) the *x* and *y* components of the ant's average velocity, and (*b*) its magnitude and direction.

**24.** (II) A particle starts from the origin at $t = 0$ with an initial velocity of 5.0 m / s along the positive $x$ axis. If the acceleration is $\left(2\ 3.0\hat{\mathbf{i}} + 4.5\hat{\mathbf{j}}\right)\text{m/s}^2$, determine the velocity and position of the particle at the moment it reaches its maximum *x* coordinate.

**25.** (II) Suppose the position of an object is given by $\vec{\mathbf{r}} = \left(3.0\,t^2\ \hat{\mathbf{i}} - 6.0\,t^3\ \hat{\mathbf{j}}\right)\text{m}$. (*a*) Determine its velocity $\vec{\mathbf{v}}$ and acceleration $\vec{\mathbf{a}}$, as a function of time. (*b*) Determine $\vec{\mathbf{r}}$ and $\vec{\mathbf{v}}$ at time $t = 2.5\ \text{s}$.

**26.** (II) An object, which is at the origin at time $t = 0$, has initial velocity $\vec{\mathbf{v}}_0 = \left(2\ 14.0\hat{\mathbf{i}} - 7.0\hat{\mathbf{j}}\right)\text{m/s}$ and constant acceleration $\vec{\mathbf{a}} = \left(6.0\hat{\mathbf{i}} + 3.0\hat{\mathbf{j}}\right)\text{m/s}^2$. Find the position $\vec{\mathbf{r}}$ where the object comes to rest (momentarily).

**27.** (II) A particle's position as a function of time $t$ is given by $\vec{\mathbf{r}} = \left(5.0\,t + 6.0\,t^2\right)\text{m}\hat{\mathbf{i}} + \left(7.0 - 3.0\,t^3\right)\text{m}\hat{\mathbf{j}}$. At $t = 5.0\ \text{s}$, find the magnitude and direction of the particle's displacement vector D$\vec{\mathbf{r}}$ relative to the point $\vec{\mathbf{r}}_0 = \left(0.0\hat{\mathbf{i}} + 7.0\hat{\mathbf{j}}\right)\text{m}$.

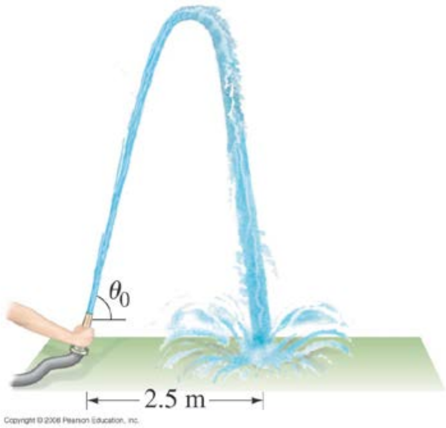
**3–7 and 3–8 Projectile Motion (neglect air resistance)**

**28.** (I) A tiger leaps horizontally from a 7.5-m-high rock with a speed of 3.2 m / s. How far from the base of the rock will she land?

**29.** (I) A diver running 2.3 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?

**30.** (II) Estimate 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.

**31.** (II) A fire hose held near the ground shoots water at a speed of 6.5 m / s. At what angle(s) should the nozzle point in order that the water land 2.5 m away (Fig. 3–40)? Why are there two different angles? Sketch the two trajectories.




**32.** (II) A ball is thrown horizontally from the roof of a building 9.0 m tall and lands 9.5 m from the base. What was the ball's initial speed?

**33.** (II) A football is kicked at ground level with a speed of 18.0 m / s at an angle of 38.0° to the horizontal. How much later does it hit the ground?

**34.** (II) A ball thrown horizontally at 23.7 m / s from the roof of a building lands 31.0 m from the base of the building. How high is the building?

**35.** (II) A shot-putter throws the shot $(\text{mass} = 7.3\,\text{kg})$ with an initial speed of 14.4 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 2.10 m above the ground.

**36.** (II) Show that the time required for a projectile to reach its highest point is equal to the time for it to return to its original height if air resistance is neglible.

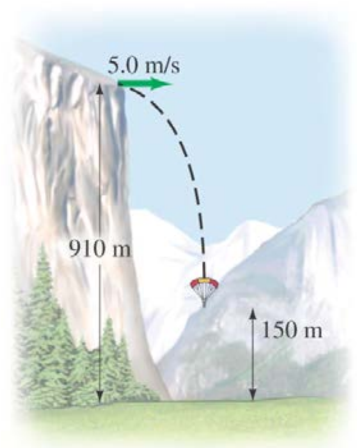
**37.** (II) You buy a plastic dart gun, and being a clever physics student you decide to do a quick calculation to find its maximum horizontal range. You shoot the gun straight up, and it takes 4.0 s for the dart to land back at the barrel. What is the maximum horizontal range of your gun?

**38.** (II) A baseball is hit with a speed of 27.0 m / s at an angle of 45.0°. It lands on the flat roof of a 13.0-m-tall nearby building. If the ball was hit when it was 1.0 m above the ground, what horizontal distance does it travel before it lands on the building?

**39.** (II) In Example 3–11 we chose the $x$ axis to the right and $y$ axis up. Redo this problem by defining the $x$ axis to the left and $y$ axis down, and show that the conclusion remains the same — the football lands on the ground 40.5 m to the right of where it departed the punter's foot.

**40.** (II) A grasshopper hops down a level road. On each hop, the grasshopper launches itself at angle $\theta_o = 45°$ and achieves a range $R = 1.0\text{ m}$. What is the average horizontal speed of the grasshopper as it progresses down the road? Assume that the time spent on the ground between hops is negligible.

**41.** (II) Extreme-sports enthusiasts have been known to jump off the top of El Capitan, a sheer granite cliff of height 910 m in Yosemite National Park. Assume a jumper runs horizontally off the top of El Capitan with speed $5.0\text{ m}/\text{s}$ and enjoys a freefall until she is 150 m above the valley floor, at which time she opens her parachute (Fig. 3–41). (*a*) How long is the jumper in freefall? Ignore air resistance. (*b*) It is important to be as far away from the cliff as possible before opening the parachute. How far from the cliff is this jumper when she opens her chute?



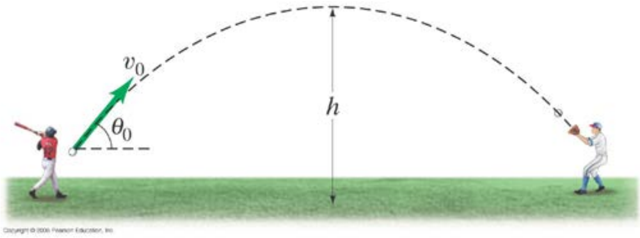



**42.** (II) Here is something to try at a sporting event. Show that the maximum height $h$ attained by an object projected into the air, such as a baseball, football, or soccer ball, is approximately given by

$$h < 1.2\,t^2\text{ m},$$

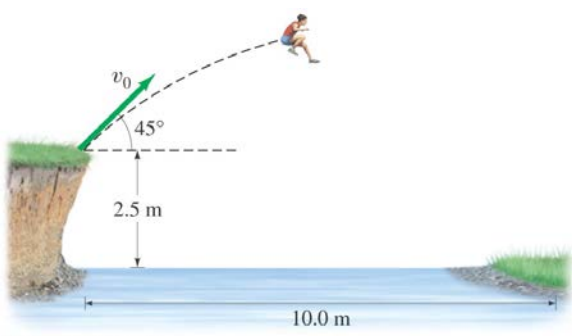
where $t$ is the total time of flight for the object in seconds. Assume that the object returns to the same level as that from which it was launched, as in Fig. 3–42. For example, if you count to find that a baseball was in the air for $t = 5.0\text{ s}$, the maximum height attained was

$h = 1.23\,(5.0)^2 = 30\text{ m}$. The beauty of this relation is that $h$ can be determined without knowledge of the launch speed $y_0$ or launch angle $u_0$.



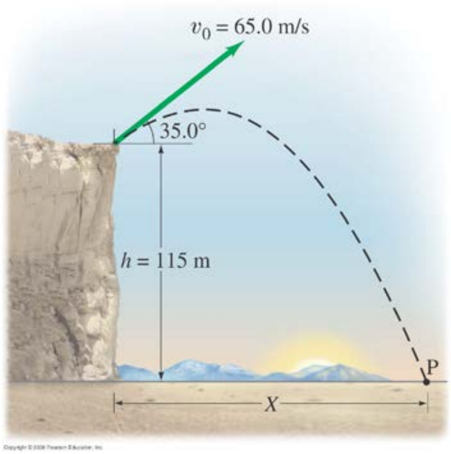

**43.** (II) The pilot of an airplane traveling 170 km / h wants to drop supplies to flood victims isolated on a patch of land 150 m below. The supplies should be dropped how many seconds before the plane is directly overhead?

**44.** (II) (*a*) A long jumper leaves the ground at 45° above the horizontal and lands 8.0 m away. What is her "takeoff" speed $y_0$ ? (*b*) Now she is out on a hike and comes to the left bank of a river. There is no bridge and the right bank is 10.0 m away horizontally and 2.5 m, vertically below. If she long jumps from the edge of the left bank at 45° with the speed calculated in (*a*), how long, or short, of the opposite bank will she land (Fig. 3–43)?




**45.** (II) 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, $\vec{\mathbf{v}}_0$; (*b*) the maximum height reached; and (*c*) the velocity $\vec{y}_f$ with which she enters the water.

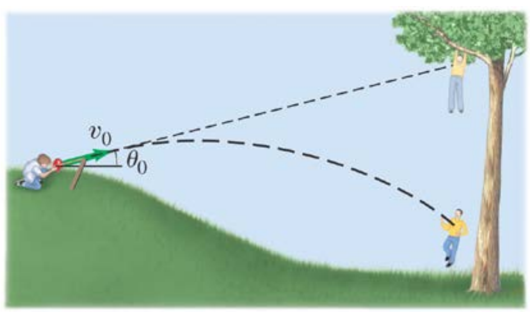
**46.** (II) A projectile is shot from the edge of a cliff 115 m above ground level with an initial speed of 65.0 m / s at an angle of 35.0° with the horizontal, as shown in Fig. 3–44. (*a*) Determine the time taken by the projectile to hit point P at ground level. (*b*) Determine the distance *X* of point P from the base of the vertical 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.



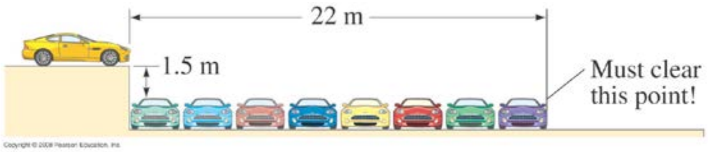

**47.** (II) Suppose the kick in Example 3–7 is attempted 36.0 m from the goalposts, whose crossbar is 3.00 m above the ground. If the football is directed perfectly between the goalposts, will it pass over the bar and be a field goal? Show why or why not. If not, from what horizontal distance must this kick be made if it is to score?

**48.** (II) Exactly 3.0 s after a projectile is fired into the air from the ground, it is observed to have a velocity $\vec{\mathbf{v}} = \left(8.6\,\hat{\mathbf{i}} + 4.8\,\hat{\mathbf{j}}\right)$ m/s, where the *x* axis is horizontal and the *y* axis is positive upward. Determine (*a*) the horizontal range of the projectile, (*b*) its maximum height above the ground, and (*c*) its speed and angle of motion just before it strikes the ground.

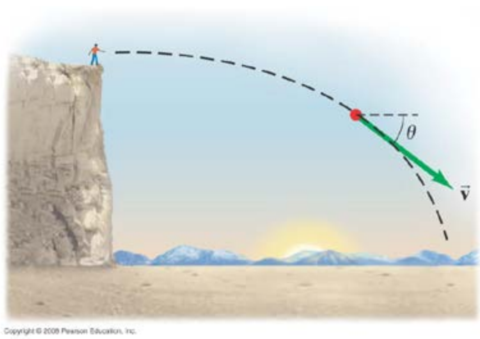
**49.** (II) Revisit Example 3–9, and assume that the boy with the slingshot is *below* the boy in the tree (Fig. 3–45) and so aims *upward*, directly at the boy in the tree. Show that again the boy in the tree makes the wrong move by letting go at the moment the water balloon is shot.




**50.** (II) A stunt driver wants to make his car jump over 8 cars parked side by side below a horizontal ramp (Fig. 3–46). (*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 22 m. (*b*) If the ramp is now tilted upward, so that "takeoff angle" is 7.0° above the horizontal, what is the new minimum speed?




**51.** (II) A ball is thrown horizontally from the top of a cliff with initial speed $v_0$ (at $t = 0$). At any moment, its direction of motion makes an angle $\theta$ to the horizontal (Fig. 3–47). Derive a formula for $\theta$ as a function of time, $t$, as the ball follows a projectile's path.

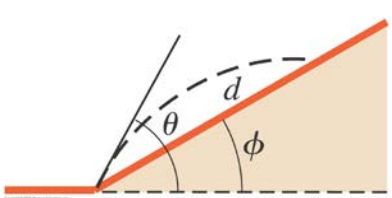



**52.** (II) At what projection angle will the range of a projectile equal its maximum height?

**53.** (II) A projectile is fired with an initial speed of 46.6 m / s at an angle of 42.2° 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.

**54.** (II) An athlete executing a long jump leaves the ground at a 27.0° angle and lands 7.80 m away. (*a*) What was the takeoff speed? (*b*) If this speed were increased by just 5.0%, how much longer would the jump be?

**55.** (III) A person stands at the base of a hill that is a straight incline making an angle $\phi$ with the horizontal (Fig. 3–48). For a given initial speed $v_0$, at what angle $\theta$ (to the horizontal) should objects be thrown so that the distance *d* they land up the hill is as large as possible?

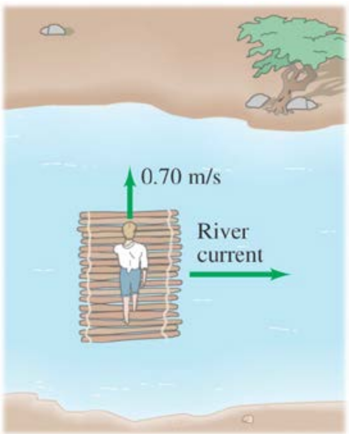



**56.** (III) Derive a formula for the horizontal range *R*, of a projectile when it lands at a height *h* above its initial point. (For $h < 0$, it lands a distance $-h$ below the starting point.) Assume it is projected at an angle $\theta_0$ with initial speed $v_0$.

### 3–9 Relative Velocity

**57.** (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 2.0 m / s while the ship is moving ahead at 8.5 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?

**58.** (I) Huck Finn walks at a speed of 0.70 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 1.50 m / s relative to the river bank (Fig. 3–49). What is Huck's velocity (speed and direction) relative to the river bank?

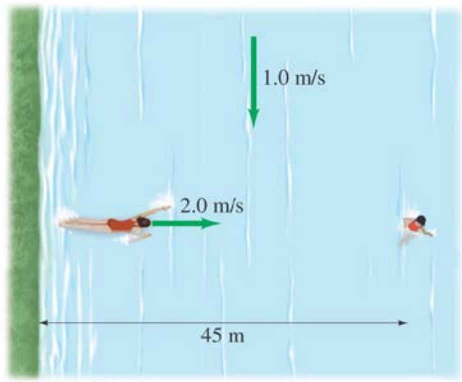





**59.** (II) Determine the speed of the boat with respect to the shore in Example 3–14.

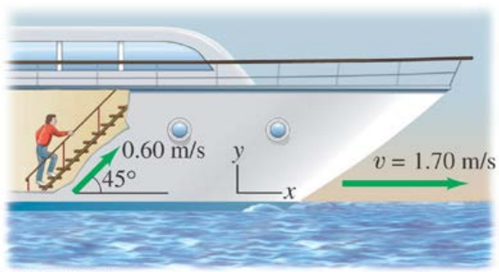
**60.** (II) Two planes approach each other head-on. Each has a speed of 780 km / h, and they spot each other when they are initially 12.0 km apart. How much time do the pilots have to take evasive action?

**61.** (II) A child, who is 45 m from the bank of a river, is being carried helplessly downstream by the river's swift current of 1.0 m / s. As the child passes a lifeguard on the river's bank, the lifeguard starts swimming in a straight line until she reaches the child at a point downstream (Fig. 3–50). If the lifeguard can swim at a speed of 2.0 m / s relative to the water, how long does it take her to reach the child? How far downstream does the lifeguard intercept the child?

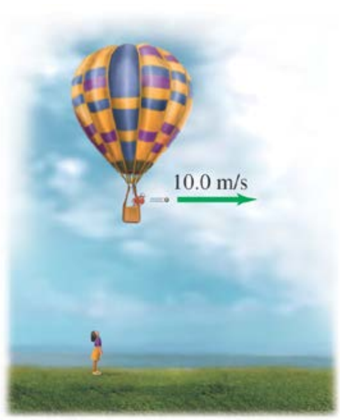




**62.** (II) A passenger on a boat moving at 1.70 m / s on a still lake walks up a flight of stairs at a speed of 0.60 m / s, Fig. 3–51. The stairs are angled at 45° pointing in the direction of motion as shown. Write the vector velocity of the passenger relative to the water.




**63.** (II) A person in the passenger basket of a hot-air balloon throws a ball horizontally outward from the basket with speed 10.0 m / s (Fig. 3–52). What initial velocity (magnitude and direction) does the ball have relative to a person standing on the ground (*a*) if the hot-air balloon is rising at 5.0 m / s relative to the ground during this throw, (*b*) if the hot-air balloon is descending at 5.0 m / s relative to the ground.





**64.** (II) An airplane is heading due south at a speed of 580 km / h. If a wind begins blowing from the southwest at a speed of 90.0 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 it will be after 11.0 min if the pilot takes no corrective action. [*Hint*: First draw a diagram.]

**65.** (II) In what direction should the pilot aim the plane in Problem 64 so that it will fly due south?

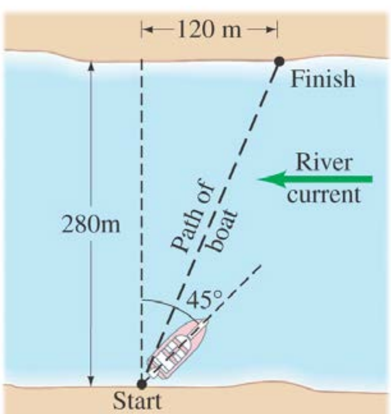
**66.** (II) Two cars approach a street corner at right angles to each other (see Fig. 3–35). Car 1 travels at 35 km / h and car 2 at 45 km / h. What is the relative velocity of car 1 as seen by car 2? What is the velocity of car 2 relative to car 1?

**67.** (II) A swimmer is capable of swimming 0.60 m / s in still water. (*a*) If she aims her body directly across a 55-m-wide river whose current is 0.50 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?

**68.** (II) (*a*) At what upstream angle must the swimmer in Problem 67 aim, if she is to arrive at a point directly across the stream? (*b*) How long will it take her?

**69.** (II) A motorboat whose speed in still water is 3.40 m / s must aim upstream at an angle of 19.5° (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. 3–31.)

**70.** (II) A boat, whose speed in still water is 2.70 m / s, must cross a 280-m-wide river and arrive at a point 120 m upstream from where it starts (Fig. 3–53). To do so, the pilot must head the boat at a 45.0° upstream angle. What is the speed of the river's current?





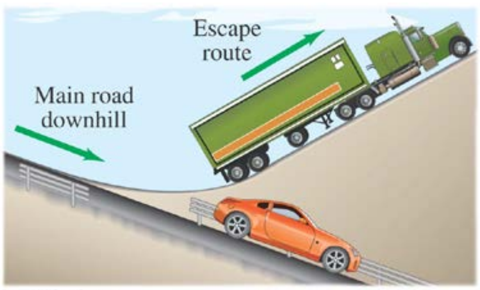

**71.** (III) An airplane, whose air speed is 580 km / h, is supposed to fly in a straight path 38.0° N of E. But a steady 72 km / h wind is blowing from the north. In what direction should the plane head?

## General Problems

**72.** Two vectors, $\vec{\mathbf{V}}_1$ and $\vec{\mathbf{V}}_2$, add to a resultant $\vec{\mathbf{V}} = \vec{\mathbf{V}}_1 + \vec{\mathbf{V}}_2$. Describe $\vec{\mathbf{V}}_1$ and $\vec{\mathbf{V}}_2$ if (*a*) $V = V_1 + V_2$, (*b*) $V^2 = V_1^2 + V_2^2$, (*c*) $V_1 + V_2 = V_1 - V_2$.

**73.** A plumber steps out of his truck, walks 66 m east and 35 m south, and then takes an elevator 12 m 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; also give the magnitude and angles, with respect to the *x* axis, in the vertical and horizontal plane. Assume *x* is east, *y* is north, and *z* is up.

**74.** 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 26°, calculate the horizontal and vertical components of the acceleration of a truck that slowed from 110 km / h to rest in 7.0 s. See Fig. 3–54.

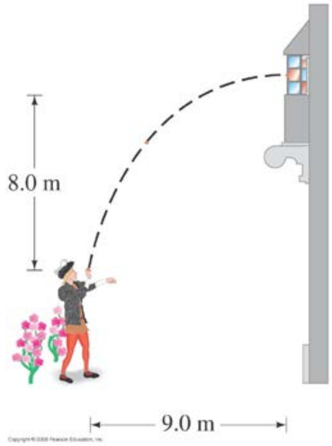





**75.** A light plane is headed due south with a speed relative to still air of 185 km / h. After 1.00 h, the pilot notices that they have covered only 135 km and their direction is not south but southeast (45.0°). What is the wind velocity?

**76.** 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.

**77.** 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 8.0 m below her window and 9.0 m from the base of the wall (Fig. 3–55). How fast are the pebbles going when they hit her window?

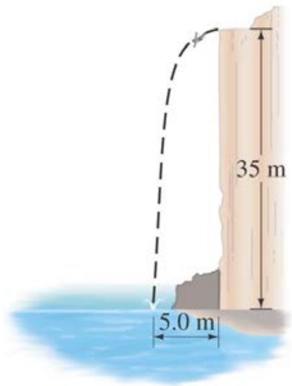



**78.** Raindrops make an angle u with the vertical when viewed through a moving train window (Fig. 3–56). If the speed of the train is $y_T$, what is the speed of the raindrops in the reference frame of the Earth in which they are assumed to fall vertically?


**79.** 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 32 m, estimate the acceleration due to gravity on the surface of the Moon. (We neglect air resistance in both cases, but on the Moon there is none.)

**80.** A hunter aims directly at a target (on the same level) 68.0 m away. (*a*) If the bullet leaves the gun at a speed of 175 m / s, by how much will it miss the target? (*b*) At what angle should the gun be aimed so the target will be hit?

**81.** 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. 3–57. What minimum pushoff speed is necessary to clear the rocks? How long are they in the air?

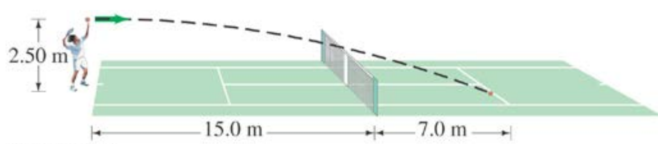




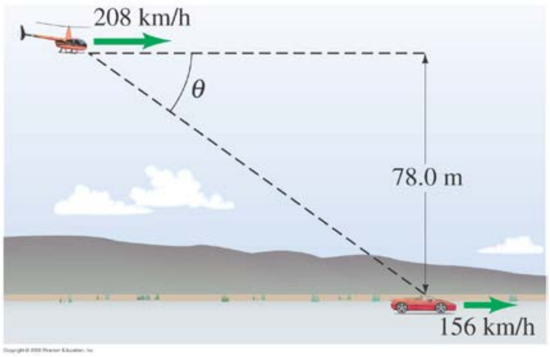
**82.** When Babe Ruth hit a homer over the 8.0-m-high right-field fence 98 m from home plate, roughly what was the minimum speed of the ball when it left the bat? Assume the ball was hit 1.0 m above the ground and its path initially made a 36° angle with the ground.

**83.** The speed of a boat in still water is y. 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, and (*b*) directly across the river and back. We must assume $u <$ y; why?

**84.** 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. 3–58.



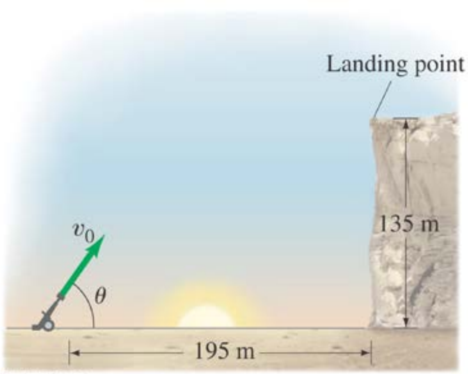

**85.** Spymaster Chris, flying a constant 208 km / h horizontally in a low-flying helicopter, wants to drop secret documents into her contact's open car which is traveling 156 km / h on a level highway 78.0 m below. At what angle (with the horizontal) should the car be in her sights when the packet is released (Fig. 3–59)?




**86.** A basketball leaves a player's hands at a height of 2.10 m above the floor. The basket is 3.05 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 6 0.22 m (horizontally), what is the range of initial speeds allowed to make the basket?

**87.** A particle has a velocity of $\vec{\mathbf{v}} = \left(2\ 2.0\hat{\mathbf{i}} + 3.5t\,\hat{\mathbf{j}}\right)$ m/s. The particle starts at $\vec{\mathbf{r}} = \left(1.5\hat{\mathbf{i}} - 3.1\hat{\mathbf{j}}\right)$ m at $t = 0$. Give the position and acceleration as a function of time. What is the shape of the resulting path?

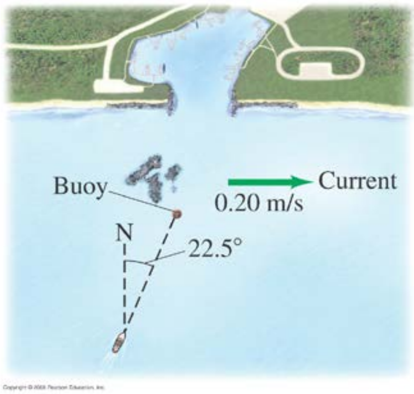
**88.** A projectile is launched from ground level to the top of a cliff which is 195 m away and 135 m high (see Fig. 3–60). If the projectile lands on top of the cliff 6.6 s after it is fired, find the initial velocity of the projectile (magnitude and direction). Neglect air resistance.




**89.** In hot pursuit, Agent Logan of the FBI must get directly across a 1200-m-wide river in minimum time. The river's current is 0.80 m / s, he can row a boat at 1.60 m / s, and he can run 3.00 m / s. Describe the path he should take (rowing plus running along the shore) for the minimum crossing time, and determine the minimum time.

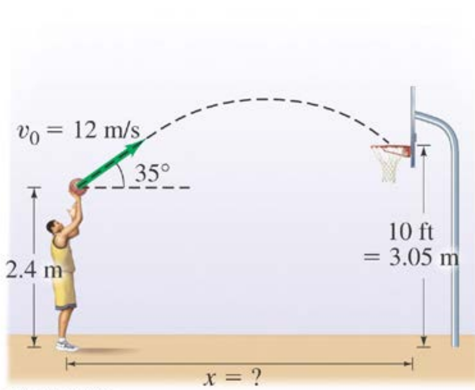
**90.** A boat can travel 2.20 m / s in still water. (*a*) If the boat points its prow directly across a stream whose current is 1.30 m / s, what is the velocity (magnitude and direction) of the boat relative to the shore? (*b*) What will be the position of the boat, relative to its point of origin, after 3.00 s?

**91.** A boat is traveling where there is a current of 0.20 m / s east (Fig. 3–61). To avoid some offshore rocks, the boat must clear a buoy that is NNE (22.5°) and 3.0 km away. The boat's speed through still water is 2.1 m / s. If the boat wants to pass the buoy 0.15 km on its right, at what angle should the boat head?



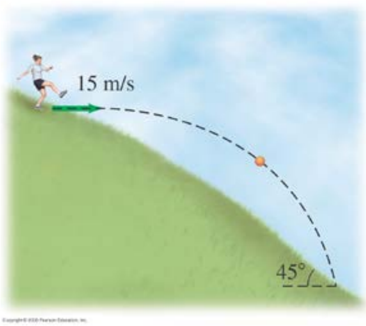

**92.** A child runs down a 12° hill and then suddenly jumps upward at a 15° angle above horizontal and lands 1.4 m down the hill as measured along the hill. What was the child's initial speed?

**93.** A basketball is shot from an initial height of 2.4 m (Fig. 3–62) with an initial speed $y_0 = 12$ m/s directed at an angle $u_0 = 358$ above the horizontal. (*a*) How far from the basket was the player if he made a basket? (*b*) At what angle to the horizontal did the ball enter the basket?




**94.** 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 37° to the horizontal. Estimate the speed of the snowflakes relative to the car and relative to the ground.

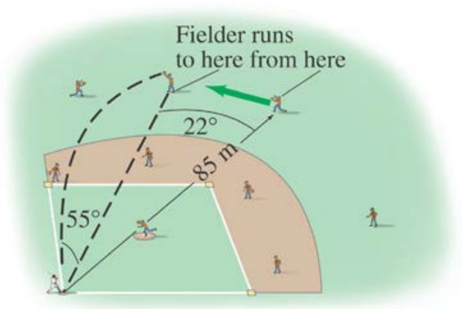
**95.** A rock is kicked horizontally at 15 m / s from a hill with a 45° slope (Fig. 3–63). How long does it take for the rock to hit the ground?




**96.** 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.

**97.** A ball is shot from the top of a building with an initial velocity of 18 m / s at an angle $u = 428$above the horizontal. (*a*) What are the horizontal and vertical 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?

**98.** At $t = 0$ a batter hits a baseball with an initial speed of 28 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. 3–64). What speed and direction must the fielder take to catch the ball at the same height from which it was struck? Give the angle with respect to the outfielder's line of sight to home plate.




***Numerical/Computer**

***99.** (II) Students shoot a plastic ball horizontally from a projectile launcher. They measure the distance $x$ the ball travels horizontally, the distance $y$ the ball falls vertically, and the total time $t$ the ball is in the air for six different heights of the projectile launcher. Here is their data.

| **Time,** $t$ **(s)** | **Horizontal distance,** $x$ **(m)** | **Vertical distance,** $y$ **(m)** |
|---|---|---|
| 0.217 | 0.642 | 0.260 |
| 0.376 | 1.115 | 0.685 |
| 0.398 | 1.140 | 0.800 |
| 0.431 | 1.300 | 0.915 |
| 0.478 | 1.420 | 1.150 |
| 0.491 | 1.480 | 1.200 |

(*a*) Determine the best-fit straight line that represents $x$ as a function of $t$. What is the initial speed of the ball obtained from the best-fit straight line? (*b*) Determine the best-fit quadratic equation that represents $y$ as a function of $t$. What is the acceleration of the ball in the vertical direction?

***100.** (III) A shot-putter throws from a height $h = 2.1\,\text{m}$ above the ground as shown in Fig. 3 – 65, with an initial speed of $y_0 = 13.5\,\text{m/s}$. (*a*) Derive a relation that describes how the distance traveled *d* depends on the release angle $u_0$. (*b*) Using the given values for $y_0$ and *h*, use a graphing calculator or computer to plot *d* vs. $u_0$. According to your plot, what value for $u_0$ maximizes *d*?