PROBLEMS

•**12–1.** A car starts from rest and with constant acceleration achieves a velocity of 15 m/s when it travels a distance of 200 m. Determine the acceleration of the car and the time required.

12–2. A train starts from rest at a station and travels with a constant acceleration of 1 m/s^2. Determine the velocity of the train when $t = 30$ s and the distance traveled during this time.

12–3. An elevator descends from rest with an acceleration of 5 ft/s^2 until it achieves a velocity of 15 ft/s. Determine the time required and the distance traveled.

***12–4.** A car is traveling at 15 m/s, when the traffic light 50 m ahead turns yellow. Determine the required constant deceleration of the car and the time needed to stop the car at the light.

•**12–5.** A particle is moving along a straight line with the acceleration $a = (12t - 3t^{1/2})$ ft/s^2, where t is in seconds. Determine the velocity and the position of the particle as a function of time. When $t = 0$, $v = 0$ and $s = 15$ ft.

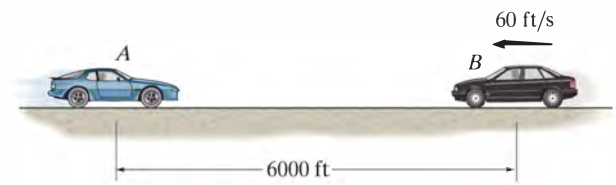
12–6. A ball is released from the bottom of an elevator which is traveling upward with a velocity of 6 ft/s. If the ball strikes the bottom of the elevator shaft in 3 s, determine the height of the elevator from the bottom of the shaft at the instant the ball is released. Also, find the velocity of the ball when it strikes the bottom of the shaft.

12–7. A car has an initial speed of 25 m/s and a constant deceleration of 3 m/s^2. Determine the velocity of the car when $t = 4$ s. What is the displacement of the car during the 4-s time interval? How much time is needed to stop the car?

***12–8.** If a particle has an initial velocity of $v_0 = 12$ ft/s to the right, at $s_0 = 0$, determine its position when $t = 10$ s, if $a = 2$ ft/s^2 to the left.

•**12–9.** The acceleration of a particle traveling along a straight line is $a = k/v$, where k is a constant. If $s = 0, v = v_0$ when $t = 0$, determine the velocity of the particle as a function of time t.

12–10. Car A starts from rest at $t = 0$ and travels along a straight road with a constant acceleration of 6 ft/s^2 until it reaches a speed of 80 ft/s. Afterwards it maintains this speed. Also, when $t = 0$, car B located 6000 ft down the road is traveling towards A at a constant speed of 60 ft/s. Determine the distance traveled by car A when they pass each other.



Prob. 12–10

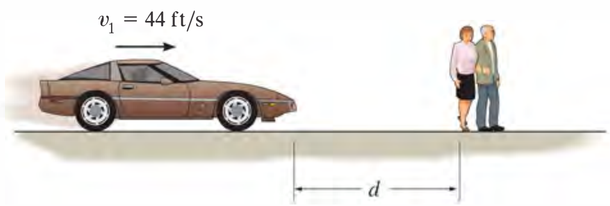
12–11. A particle travels along a straight line with a velocity $v = (12 - 3t^2)$ m/s, where t is in seconds. When $t = 1$ s, the particle is located 10 m to the left of the origin. Determine the acceleration when $t = 4$ s, the displacement from $t = 0$ to $t = 10$ s, and the distance the particle travels during this time period.

***12–12.** A sphere is fired downwards into a medium with an initial speed of 27 m/s. If it experiences a deceleration of $a = (-6t)$ m/s^2, where t is in seconds, determine the distance traveled before it stops.

•**12–13.** A particle travels along a straight line such that in 2 s it moves from an initial position $s_A = +0.5$ m to a position $s_B = -1.5$ m. Then in another 4 s it moves from s_B to $s_C = +2.5$ m. Determine the particle's average velocity and average speed during the 6-s time interval.

12–14. A particle travels along a straight-line path such that in 4 s it moves from an initial position $s_A = -8$ m to a position $s_B = +3$ m. Then in another 5 s it moves from s_B to $s_C = -6$ m. Determine the particle's average velocity and average speed during the 9-s time interval.

12–15. Tests reveal that a normal driver takes about 0.75 s before he or she can *react* to a situation to avoid a collision. It takes about 3 s for a driver having 0.1% alcohol in his system to do the same. If such drivers are traveling on a straight road at 30 mph (44 ft/s) and their cars can decelerate at 2 ft/s^2, determine the shortest stopping distance d for each from the moment they see the pedestrians. *Moral*: If you must drink, please don't drive!



Prob. 12–15

*__12–16.__ As a train accelerates uniformly it passes successive kilometer marks while traveling at velocities of 2 m/s and then 10 m/s. Determine the train's velocity when it passes the next kilometer mark and the time it takes to travel the 2-km distance.

•**12–17.** A ball is thrown with an upward velocity of 5 m/s from the top of a 10-m high building. One second later another ball is thrown vertically from the ground with a velocity of 10 m/s. Determine the height from the ground where the two balls pass each other.

12–18. A car starts from rest and moves with a constant acceleration of 1.5 m/s^2 until it achieves a velocity of 25 m/s. It then travels with constant velocity for 60 seconds. Determine the average speed and the total distance traveled.

12–19. A car is to be hoisted by elevator to the fourth floor of a parking garage, which is 48 ft above the ground. If the elevator can accelerate at 0.6 ft/s^2, decelerate at 0.3 ft/s^2, and reach a maximum speed of 8 ft/s, determine the shortest time to make the lift, starting from rest and ending at rest.

*__12–20.__ A particle is moving along a straight line such that its speed is defined as $v = (-4s^2)$ m/s, where s is in meters. If $s = 2$ m when $t = 0$, determine the velocity and acceleration as functions of time.

•**12–21.** Two particles A and B start from rest at the origin $s = 0$ and move along a straight line such that $a_A = (6t - 3)$ ft/s^2 and $a_B = (12t^2 - 8)$ ft/s^2, where t is in seconds. Determine the distance between them when $t = 4$ s and the total distance each has traveled in $t = 4$ s.

12–22. A particle moving along a straight line is subjected to a deceleration $a = (-2v^3)$ m/s^2, where v is in m/s. If it has a velocity $v = 8$ m/s and a position $s = 10$ m when $t = 0$, determine its velocity and position when $t = 4$ s.

12–23. A particle is moving along a straight line such that its acceleration is defined as $a = (-2v)$ m/s^2, where v is in meters per second. If $v = 20$ m/s when $s = 0$ and $t = 0$, determine the particle's position, velocity, and acceleration as functions of time.

*__12–24.__ A particle starts from rest and travels along a straight line with an acceleration $a = (30 - 0.2v)$ ft/s^2, where v is in ft/s. Determine the time when the velocity of the particle is $v = 30$ ft/s.

•**12–25.** When a particle is projected vertically upwards with an initial velocity of v_0, it experiences an acceleration $a = -(g + kv^2)$, where g is the acceleration due to gravity, k is a constant and v is the velocity of the particle. Determine the maximum height reached by the particle.

12–26. The acceleration of a particle traveling along a straight line is $a = (0.02e^t)$ m/s^2, where t is in seconds. If $v = 0$, $s = 0$ when $t = 0$, determine the velocity and acceleration of the particle at $s = 4$ m.

12–27. A particle moves along a straight line with an acceleration of $a = 5/(3s^{1/3} + s^{5/2})$ m/s^2, where s is in meters. Determine the particle's velocity when $s = 2$ m, if it starts from rest when $s = 1$ m. Use Simpson's rule to evaluate the integral.

*__12–28.__ If the effects of atmospheric resistance are accounted for, a falling body has an acceleration defined by the equation $a = 9.81[1 - v^2(10^{-4})]$ m/s^2, where v is in m/s and the positive direction is downward. If the body is released from rest at a very *high altitude*, determine (a) the velocity when $t = 5$ s, and (b) the body's terminal or maximum attainable velocity (as $t \to \infty$).

•**12–29.** The position of a particle along a straight line is given by $s = (1.5t^3 - 13.5t^2 + 22.5t)$ ft, where t is in seconds. Determine the position of the particle when $t = 6$ s and the total distance it travels during the 6-s time interval. *Hint:* Plot the path to determine the total distance traveled.

12–30. The velocity of a particle traveling along a straight line is $v = v_0 - ks$, where k is constant. If $s = 0$ when $t = 0$, determine the position and acceleration of the particle as a function of time.

12–31. The acceleration of a particle as it moves along a straight line is given by $a = (2t - 1)\ \text{m/s}^2$, where t is in seconds. If $s = 1$ m and $v = 2$ m/s when $t = 0$, determine the particle's velocity and position when $t = 6$ s. Also, determine the total distance the particle travels during this time period.

***12–32.** Ball A is thrown vertically upward from the top of a 30-m-high-building with an initial velocity of 5 m/s. At the same instant another ball B is thrown upward from the ground with an initial velocity of 20 m/s. Determine the height from the ground and the time at which they pass.

•**12–33.** A motorcycle starts from rest at $t = 0$ and travels along a straight road with a constant acceleration of 6 ft/s^2 until it reaches a speed of 50 ft/s. Afterwards it maintains this speed. Also, when $t = 0$, a car located 6000 ft down the road is traveling toward the motorcycle at a constant speed of 30 ft/s. Determine the time and the distance traveled by the motorcycle when they pass each other.

12–34. A particle moves along a straight line with a velocity $v = (200s)$ mm/s, where s is in millimeters. Determine the acceleration of the particle at $s = 2000$ mm. How long does the particle take to reach this position if $s = 500$ mm when $t = 0$?

■**12–35.** A particle has an initial speed of 27 m/s. If it experiences a deceleration of $a = (-6t)\ \text{m/s}^2$, where t is in seconds, determine its velocity, after it has traveled 10 m. How much time does this take?

***12–36.** The acceleration of a particle traveling along a straight line is $a = (8 - 2s)\ \text{m/s}^2$, where s is in meters. If $v = 0$ at $s = 0$, determine the velocity of the particle at $s = 2$ m, and the position of the particle when the velocity is maximum.

•**12–37.** Ball A is thrown vertically upwards with a velocity of v_0. Ball B is thrown upwards from the same point with the same velocity t seconds later. Determine the elapsed time $t < 2v_0/g$ from the instant ball A is thrown to when the balls pass each other, and find the velocity of each ball at this instant.

12–38. As a body is projected to a high altitude above the earth's *surface,* the variation of the acceleration of gravity with respect to altitude y must be taken into account. Neglecting air resistance, this acceleration is determined from the formula $a = -g_0[R^2/(R + y)^2]$, where g_0 is the constant gravitational acceleration at sea level, R is the radius of the earth, and the positive direction is measured upward. If $g_0 = 9.81\ \text{m/s}^2$ and $R = 6356$ km, determine the minimum initial velocity (escape velocity) at which a projectile should be shot vertically from the earth's surface so that it does not fall back to the earth. *Hint:* This requires that $v = 0$ as $y \to \infty$.

12–39. Accounting for the variation of gravitational acceleration a with respect to altitude y (see Prob. 12–38), derive an equation that relates the velocity of a freely falling particle to its altitude. Assume that the particle is released from rest at an altitude y_0 from the earth's surface. With what velocity does the particle strike the earth if it is released from rest at an altitude $y_0 = 500$ km? Use the numerical data in Prob. 12–38.

***12–40.** When a particle falls through the air, its initial acceleration $a = g$ diminishes until it is zero, and thereafter it falls at a constant or terminal velocity v_f. If this variation of the acceleration can be expressed as $a = (g/v^2{}_f)(v^2{}_f - v^2)$, determine the time needed for the velocity to become $v = v_f/2$. Initially the particle falls from rest.

•**12–41.** A particle is moving along a straight line such that its position from a fixed point is $s = (12 - 15t^2 + 5t^3)$ m, where t is in seconds. Determine the total distance traveled by the particle from $t = 1$ s to $t = 3$ s. Also, find the average speed of the particle during this time interval.

12

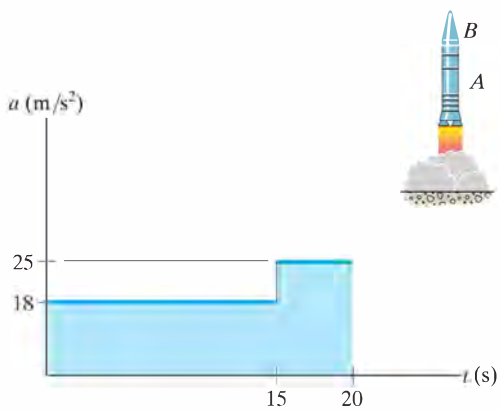
PROBLEMS

12–42. The speed of a train during the first minute has been recorded as follows:

t (s)	0	20	40	60
v (m/s)	0	16	21	24

Plot the $v-t$ graph, approximating the curve as straight-line segments between the given points. Determine the total distance traveled.

12–43. A two-stage missile is fired vertically from rest with the acceleration shown. In 15 s the first stage A burns out and the second stage B ignites. Plot the $v-t$ and $s-t$ graphs which describe the two-stage motion of the missile for $0 \le t \le 20$ s.



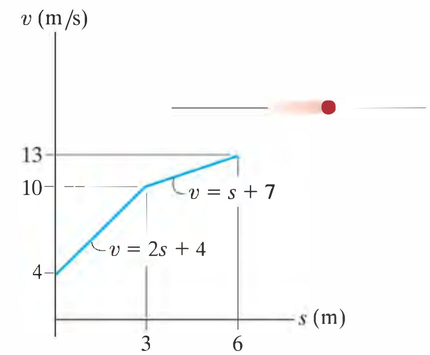
Prob. 12–43

***12–44.** A freight train starts from rest and travels with a constant acceleration of 0.5 ft/s^2. After a time t' it maintains a constant speed so that when $t = 160$ s it has traveled 2000 ft. Determine the time t' and draw the v–t graph for the motion.

•12–45. If the position of a particle is defined by $s = [2 \sin (\pi/5)t + 4]$ m, where t is in seconds, construct the $s-t$, $v-t$, and $a-t$ graphs for $0 \le t \le 10$ s.

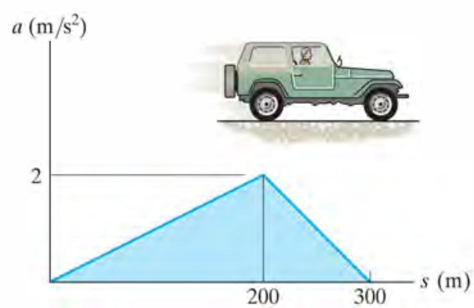
12–46. A train starts from station A and for the first kilometer, it travels with a uniform acceleration. Then, for the next two kilometers, it travels with a uniform speed. Finally, the train decelerates uniformly for another kilometer before coming to rest at station B. If the time for the whole journey is six minutes, draw the v–t graph and determine the maximum speed of the train.

12–47. The particle travels along a straight line with the velocity described by the graph. Construct the $a-s$ graph.



Prob. 12–47

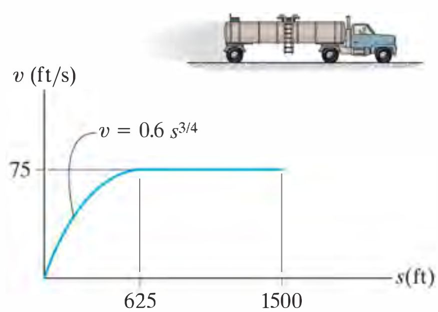
***12–48.** The a–s graph for a jeep traveling along a straight road is given for the first 300 m of its motion. Construct the v–s graph. At $s = 0$, $v = 0$.



Prob. 12–48

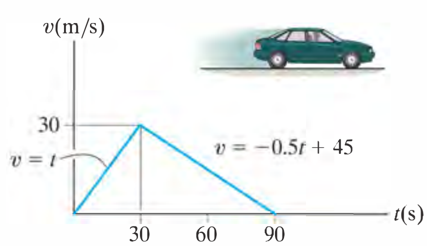
•**12–49.** A particle travels along a curve defined by the equation $s = (t^3 - 3t^2 + 2t)$ m. where t is in seconds. Draw the $s - t$, $v - t$, and $a - t$ graphs for the particle for $0 \le t \le 3$ s.

12–50. A truck is traveling along the straight line with a velocity described by the graph. Construct the a–s graph for $0 \le s \le 1500$ ft.



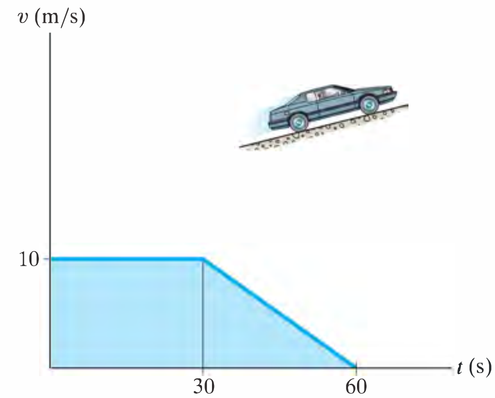
Prob. 12–50

12–51. A car starts from rest and travels along a straight road with a velocity described by the graph. Determine the total distance traveled until the car stops. Construct the s–t and a–t graphs.



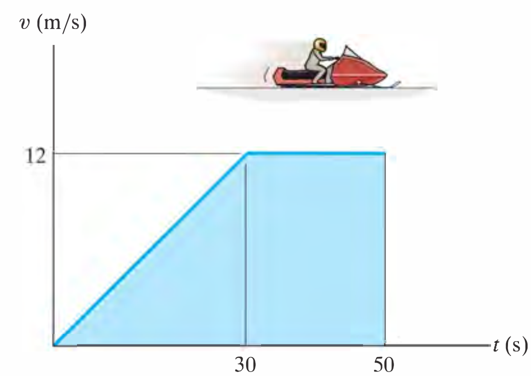
Prob. 12–51

*__12–52.__ A car travels up a hill with the speed shown. Determine the total distance the car travels until it stops ($t = 60$ s). Plot the a–t graph.



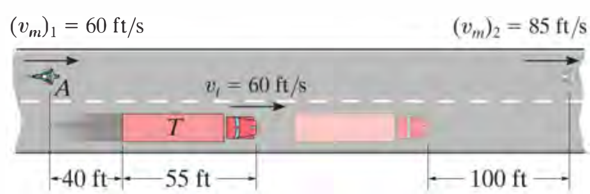
Prob. 12–52

•**12–53.** The snowmobile moves along a straight course according to the v–t graph. Construct the s–t and a–t graphs for the same 50-s time interval. When $t = 0$, $s = 0$.



Prob. 12–53

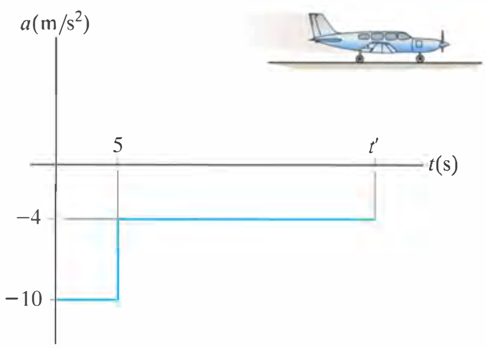
12–54. A motorcyclist at A is traveling at 60 ft/s when he wishes to pass the truck T which is traveling at a constant speed of 60 ft/s. To do so the motorcyclist accelerates at 6 ft/s^2 until reaching a maximum speed of 85 ft/s. If he then maintains this speed, determine the time needed for him to reach a point located 100 ft in front of the truck. Draw the v–t and s–t graphs for the motorcycle during this time.



Prob. 12–54

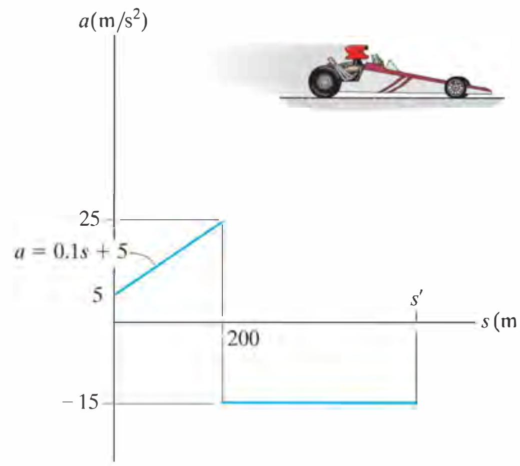
12

12–55. An airplane traveling at 70 m/s lands on a straight runway and has a deceleration described by the graph. Determine the time t' and the distance traveled for it to reach a speed of 5 m/s. Construct the v–t and s–t graphs for this time interval, $0 \le t \le t'$.



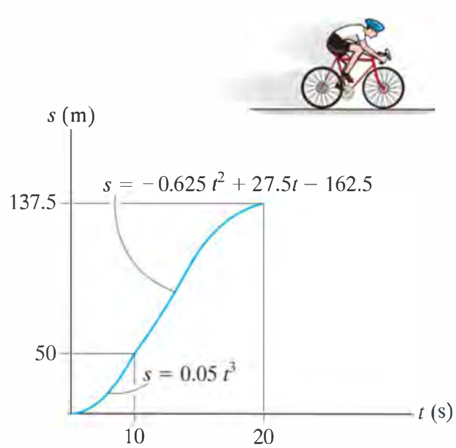
Prob. 12–55

•**12–57.** The dragster starts from rest and travels along a straight track with an acceleration-deceleration described by the graph. Construct the v–s graph for $0 \le s \le s'$, and determine the distance s' traveled before the dragster again comes to rest.



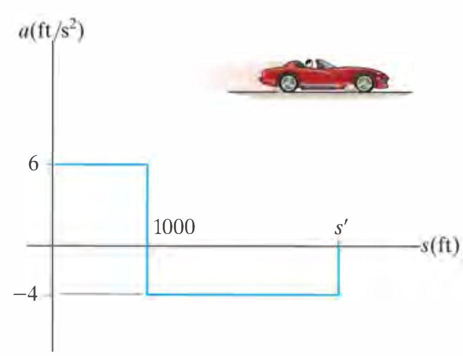
Prob. 12–57

***12–56.** The position of a cyclist traveling along a straight road is described by the graph. Construct the v–t and a–t graphs.



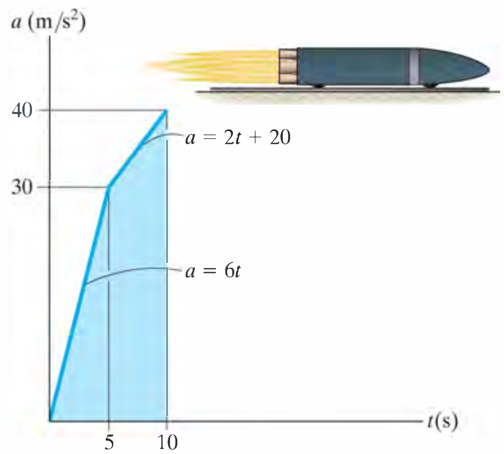
Prob. 12–56

12–58. A sports car travels along a straight road with an acceleration-deceleration described by the graph. If the car starts from rest, determine the distance s' the car travels until it stops. Construct the v–s graph for $0 \le s \le s'$.



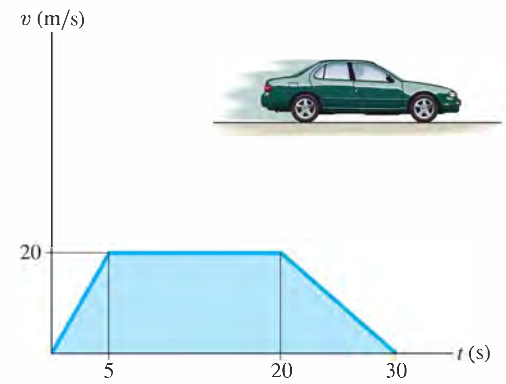
Prob. 12–58

12–59. A missile starting from rest travels along a straight track and for 10 s has an acceleration as shown. Draw the $v-t$ graph that describes the motion and find the distance traveled in 10 s.



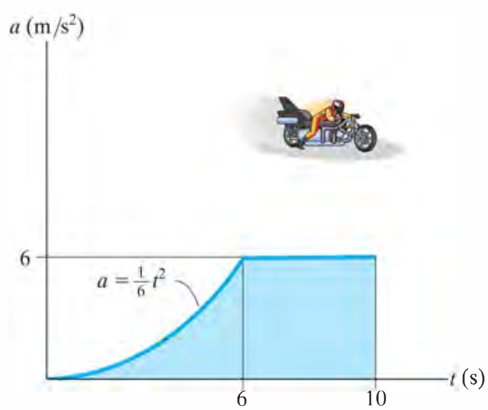
Prob. 12–59

•12–61. The $v-t$ graph of a car while traveling along a road is shown. Draw the $s-t$ and $a-t$ graphs for the motion.



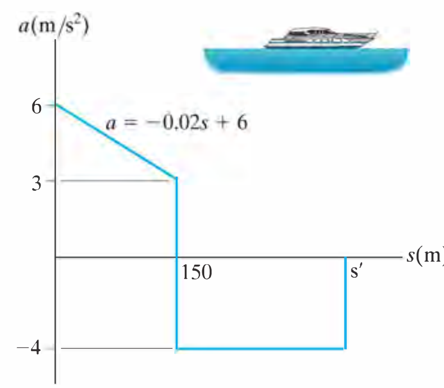
Prob. 12–61

***12–60.** A motorcyclist starting from rest travels along a straight road and for 10 s has an acceleration as shown. Draw the $v-t$ graph that describes the motion and find the distance traveled in 10 s.



Prob. 12–60

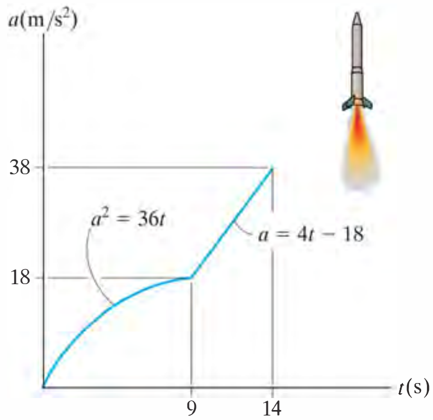
12–62. The boat travels in a straight line with the acceleration described by the $a-s$ graph. If it starts from rest, construct the $v-s$ graph and determine the boat's maximum speed. What distance s' does it travel before it stops?



Prob. 12–62

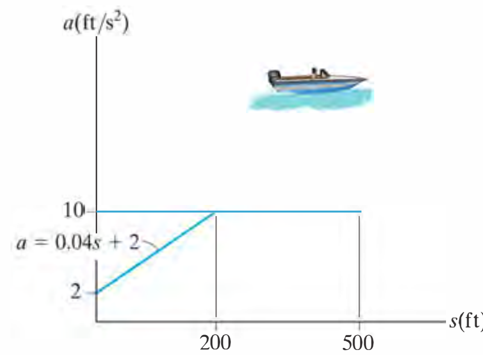
12

12–63. The rocket has an acceleration described by the graph. If it starts from rest, construct the $v-t$ and $s-t$ graphs for the motion for the time interval $0 \leq t \leq 14$ s.



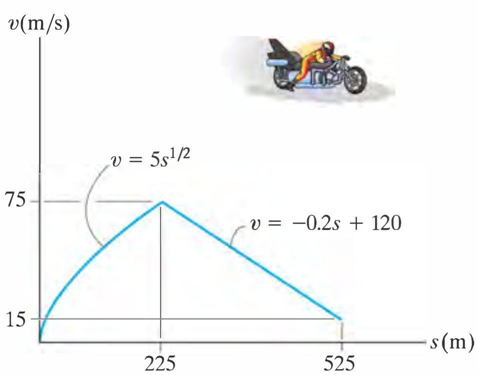
Prob. 12–63

•12–65. The acceleration of the speed boat starting from rest is described by the graph. Construct the $v-s$ graph.



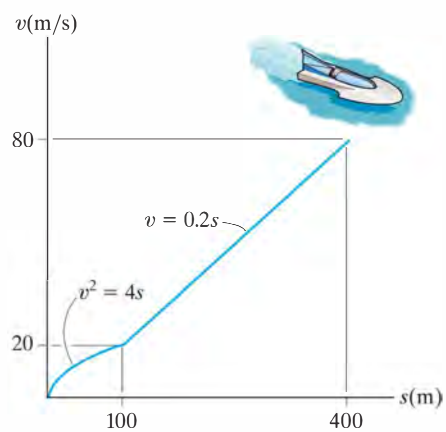
Prob. 12–65

***12–64.** The jet bike is moving along a straight road with the speed described by the $v-s$ graph. Construct the $a-s$ graph.



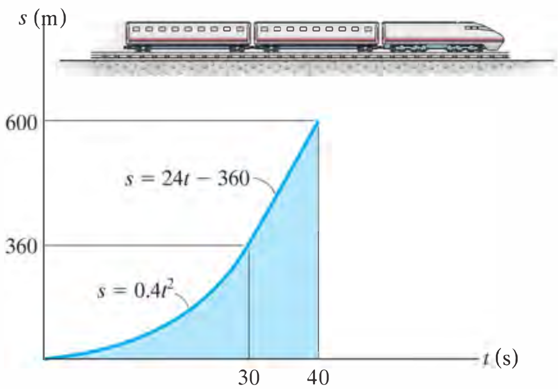
Prob. 12–64

12–66. The boat travels along a straight line with the speed described by the graph. Construct the $s-t$ and $a-s$ graphs. Also, determine the time required for the boat to travel a distance $s = 400$ m if $s = 0$ when $t = 0$.



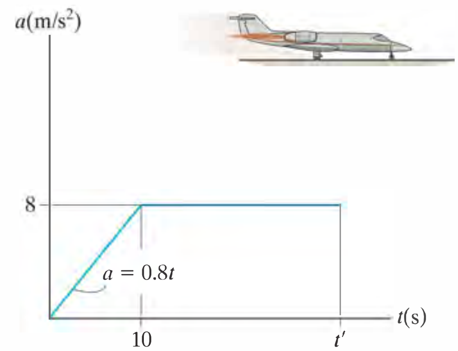
Prob. 12–66

12–67. The s–t graph for a train has been determined experimentally. From the data, construct the v–t and a–t graphs for the motion.



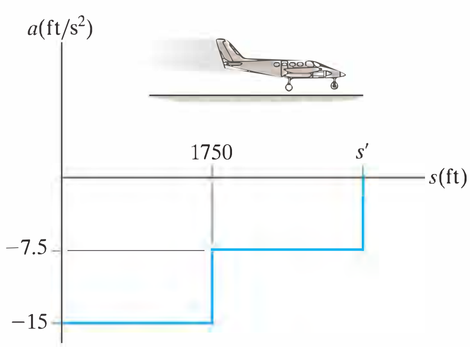
Prob. 12–67

•12–69. The airplane travels along a straight runway with an acceleration described by the graph. If it starts from rest and requires a velocity of 90 m/s to take off, determine the minimum length of runway required and the time t' for take off. Construct the v–t and s–t graphs.



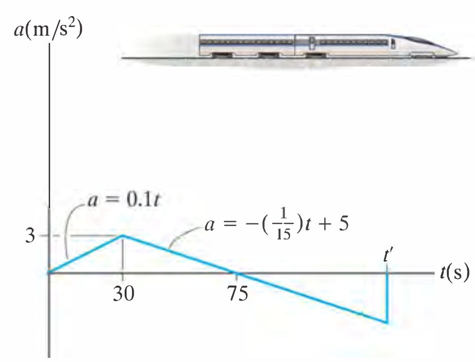
Prob. 12–69

***12–68.** The airplane lands at 250 ft/s on a straight runway and has a deceleration described by the graph. Determine the distance s' traveled before its speed is decreased to 25 ft/s. Draw the s–t graph.



Prob. 12–68

12–70. The a–t graph of the bullet train is shown. If the train starts from rest, determine the elapsed time t' before it again comes to rest. What is the total distance traveled during this time interval? Construct the v–t and s–t graphs.



Prob. 12–70

12

PROBLEMS

12–71. The position of a particle is $\mathbf{r} = \{(3t^3 - 2t)\mathbf{i} - (4t^{1/2} + t)\mathbf{j} + (3t^2 - 2)\mathbf{k}\}$ m, where t is in seconds. Determine the magnitude of the particle's velocity and acceleration when $t = 2$ s.

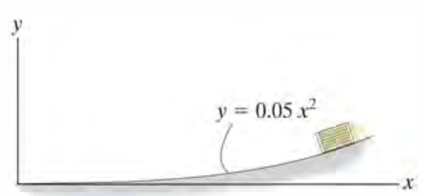
***12–72.** The velocity of a particle is $\mathbf{v} = \{3\mathbf{i} + (6 - 2t)\mathbf{j}\}$ m/s, where t is in seconds. If $\mathbf{r} = \mathbf{0}$ when $t = 0$, determine the displacement of the particle during the time interval $t = 1$ s to $t = 3$ s.

•12–73. A particle travels along the parabolic path $y = bx^2$. If its component of velocity along the y axis is $v_y = ct^2$, determine the x and y components of the particle's acceleration. Here b and c are constants.

12–74. The velocity of a particle is given by $\mathbf{v} = \{16t^2\mathbf{i} + 4t^3\mathbf{j} + (5t + 2)\mathbf{k}\}$ m/s, where t is in seconds. If the particle is at the origin when $t = 0$, determine the magnitude of the particle's acceleration when $t = 2$ s. Also, what is the x, y, z coordinate position of the particle at this instant?

12–75. A particle travels along the circular path $x^2 + y^2 = r^2$. If the y component of the particle's velocity is $v_y = 2r \cos 2t$, determine the x and y components of its acceleration at any instant.

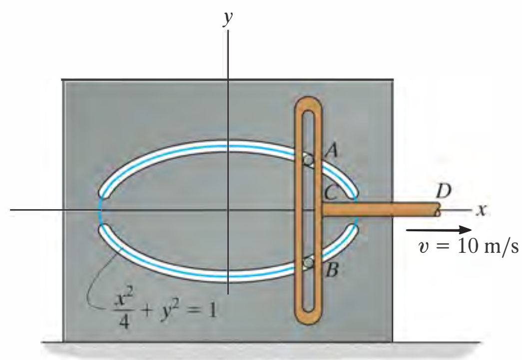
***12–76.** The box slides down the slope described by the equation $y = (0.05x^2)$ m, where x is in meters. If the box has x components of velocity and acceleration of $v_x = -3$ m/s and $a_x = -1.5$ m/s^2 at $x = 5$ m, determine the y components of the velocity and the acceleration of the box at this instant.



Prob. 12–76

•12–77. The position of a particle is defined by $\mathbf{r} = \{5 \cos 2t\, \mathbf{i} + 4 \sin 2t\, \mathbf{j}\}$ m, where t is in seconds and the arguments for the sine and cosine are given in radians. Determine the magnitudes of the velocity and acceleration of the particle when $t = 1$ s. Also, prove that the path of the particle is elliptical.

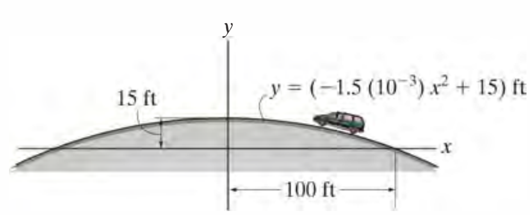
12–78. Pegs A and B are restricted to move in the elliptical slots due to the motion of the slotted link. If the link moves with a constant speed of 10 m/s, determine the magnitude of the velocity and acceleration of peg A when $x = 1$ m.



Prob. 12–78

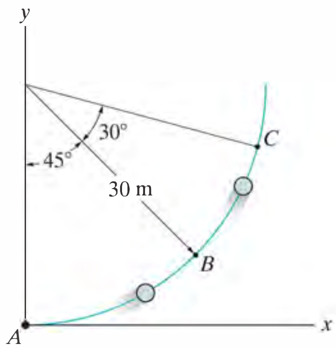
12–79. A particle travels along the path $y^2 = 4x$ with a constant speed of $v = 4$ m/s. Determine the x and y components of the particle's velocity and acceleration when the particle is at $x = 4$ m.

***12–80.** The van travels over the hill described by $y = (-1.5(10^{-3})\, x^2 + 15)$ ft. If it has a constant speed of 75 ft/s, determine the x and y components of the van's velocity and acceleration when $x = 50$ ft.



Prob. 12–80

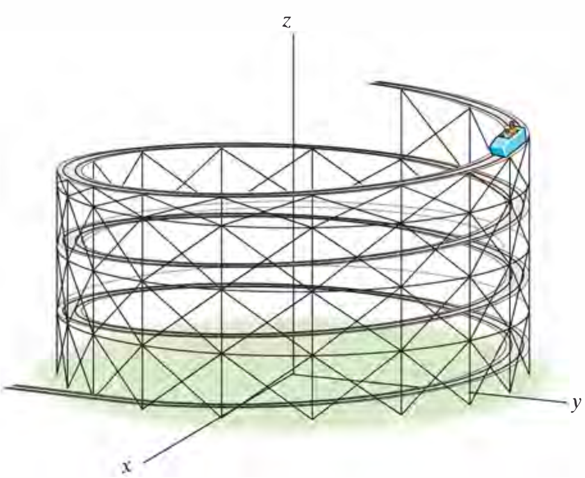
•**12–81.** A particle travels along the circular path from A to B in 1 s. If it takes 3 s for it to go from A to C, determine its *average velocity* when it goes from B to C.



Prob. 12–81

12–82. A car travels east 2 km for 5 minutes, then north 3 km for 8 minutes, and then west 4 km for 10 minutes. Determine the total distance traveled and the magnitude of displacement of the car. Also, what is the magnitude of the average velocity and the average speed?

12–83. The roller coaster car travels down the helical path at constant speed such that the parametric equations that define its position are $x = c \sin kt$, $y = c \cos kt$, $z = h - bt$, where c, h, and b are constants. Determine the magnitudes of its velocity and acceleration.

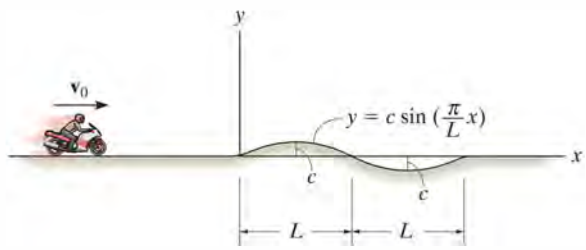


Prob. 12–83

*__12–84.__ The path of a particle is defined by $y^2 = 4kx$, and the component of velocity along the y axis is $v_y = ct$, where both k and c are constants. Determine the x and y components of acceleration when $y = y_0$.

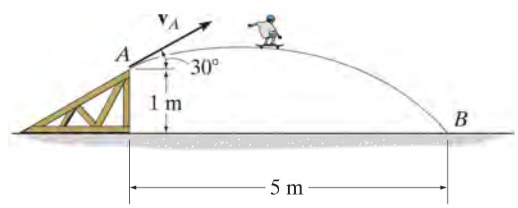
•**12–85.** A particle moves along the curve $y = x - (x^2/400)$, where x and y are in ft. If the velocity component in the x direction is $v_x = 2$ ft/s and remains *constant*, determine the magnitudes of the velocity and acceleration when $x = 20$ ft.

12–86. The motorcycle travels with constant speed v_0 along the path that, for a short distance, takes the form of a sine curve. Determine the x and y components of its velocity at any instant on the curve.



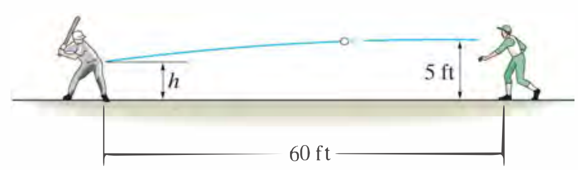
Prob. 12–86

12–87. The skateboard rider leaves the ramp at A with an initial velocity v_A at a 30° angle. If he strikes the ground at B, determine v_A and the time of flight.



Prob. 12–87

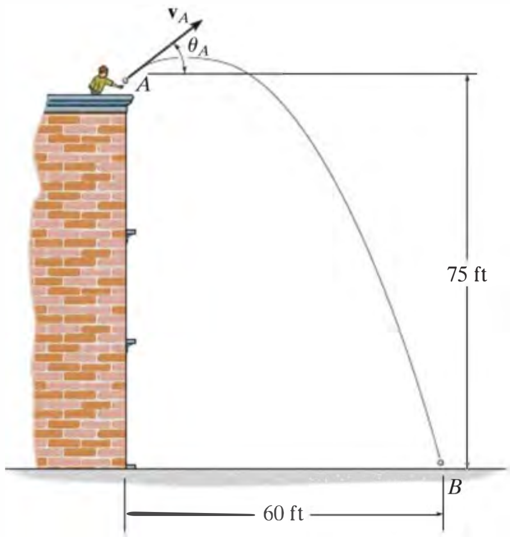
*__12–88.__ The pitcher throws the baseball horizontally with a speed of 140 ft/s from a height of 5 ft. If the batter is 60 ft away, determine the time for the ball to arrive at the batter and the height h at which it passes the batter.



Prob. 12–88

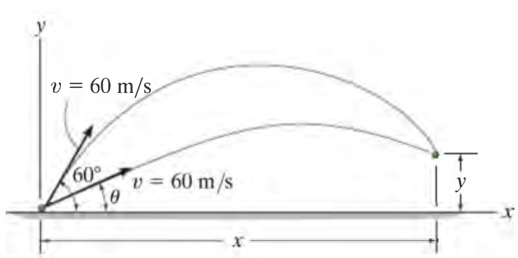
12

•**12–89.** The ball is thrown off the top of the building. If it strikes the ground at B in 3 s, determine the initial velocity v_A and the inclination angle θ_A at which it was thrown. Also, find the magnitude of the ball's velocity when it strikes the ground.



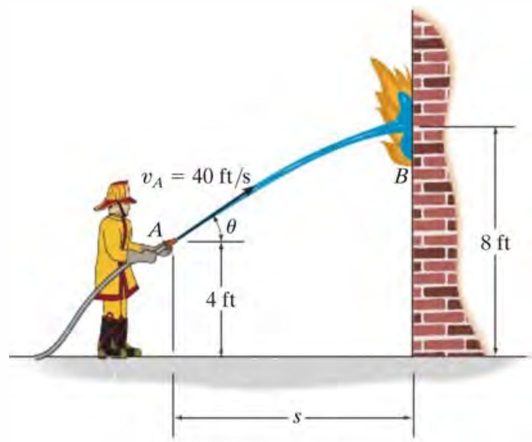
Prob. 12–89

12–90. A projectile is fired with a speed of $v = 60$ m/s at an angle of 60°. A second projectile is then fired with the same speed 0.5 s later. Determine the angle θ of the second projectile so that the two projectiles collide. At what position (x, y) will this happen?



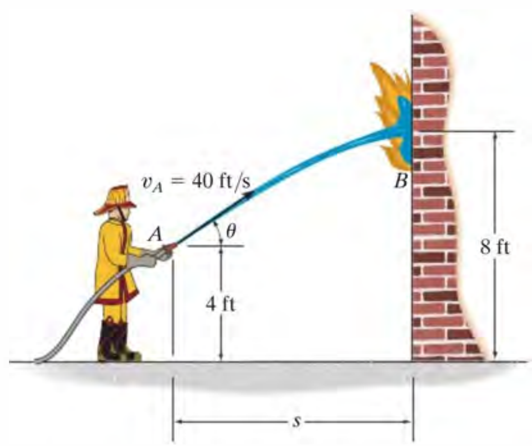
Prob. 12–90

12–91. The fireman holds the hose at an angle $\theta = 30°$ with horizontal, and the water is discharged from the hose at A with a speed of $v_A = 40$ ft/s. If the water stream strikes the building at B, determine his two possible distances s from the building.



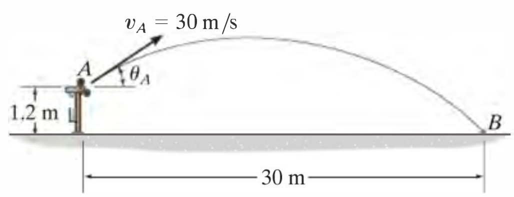
Prob. 12–91

***12–92.** Water is discharged from the hose with a speed of 40 ft/s. Determine the two possible angles θ the fireman can hold the hose so that the water strikes the building at B. Take $s = 20$ ft.



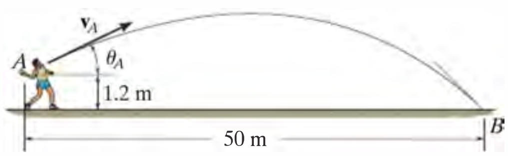
Prob. 12–92

•**12–93.** The pitching machine is adjusted so that the baseball is launched with a speed of $v_A = 30$ m/s. If the ball strikes the ground at B, determine the two possible angles θ_A at which it was launched.



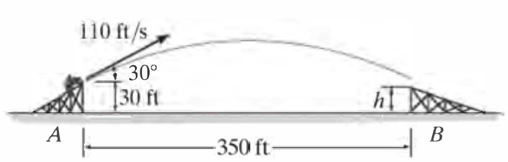
Prob. 12–93

12–94. It is observed that the time for the ball to strike the ground at B is 2.5 s. Determine the speed v_A and angle θ_A at which the ball was thrown.



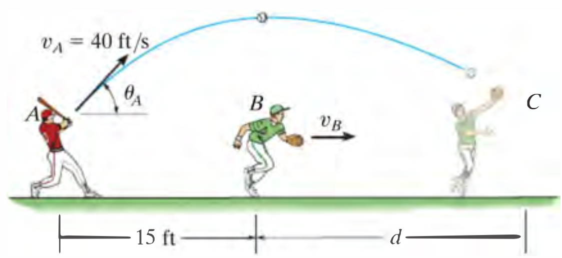
Prob. 12–94

12–95. If the motorcycle leaves the ramp traveling at 110 ft/s, determine the height h ramp B must have so that the motorcycle lands safely.



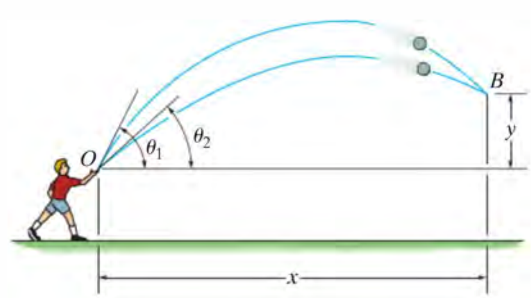
Prob. 12–95

***12–96.** The baseball player A hits the baseball with $v_A = 40$ ft/s and $\theta_A = 60°$. When the ball is directly above of player B he begins to run under it. Determine the constant speed v_B and the distance d at which B must run in order to make the catch at the same elevation at which the ball was hit.



Prob. 12–96

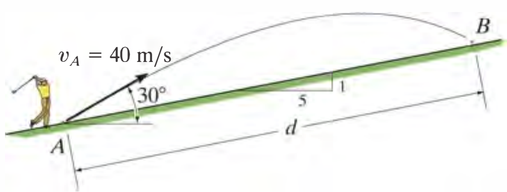
•**12–97.** A boy throws a ball at O in the air with a speed v_0 at an angle θ_1. If he then throws another ball with the same speed v_0 at an angle $\theta_2 < \theta_1$, determine the time between the throws so that the balls collide in mid air at B.



Prob. 12–97

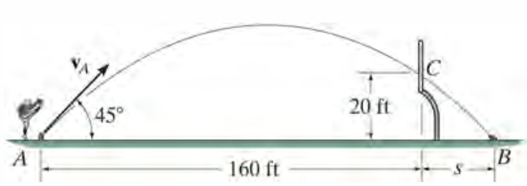
12

12–98. The golf ball is hit at A with a speed of $v_A = 40$ m/s and directed at an angle of 30° with the horizontal as shown. Determine the distance d where the ball strikes the slope at B.



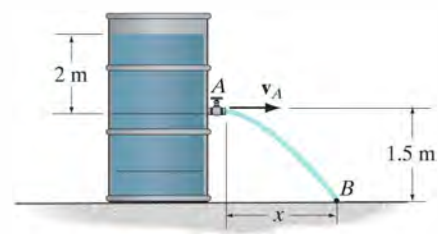
Prob. 12–98

12–99. If the football is kicked at the 45° angle, determine its minimum initial speed v_A so that it passes over the goal post at C. At what distance s from the goal post will the football strike the ground at B?



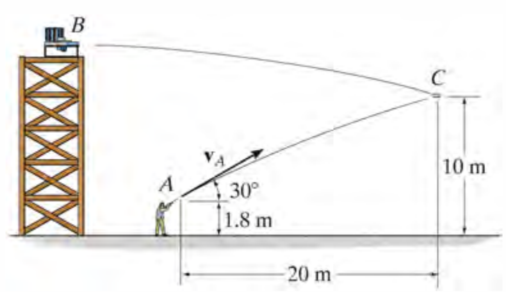
Prob. 12–99

***12–100.** The velocity of the water jet discharging from the orifice can be obtained from $v = \sqrt{2gh}$, where $h = 2$ m is the depth of the orifice from the free water surface. Determine the time for a particle of water leaving the orifice to reach point B and the horizontal distance x where it hits the surface.



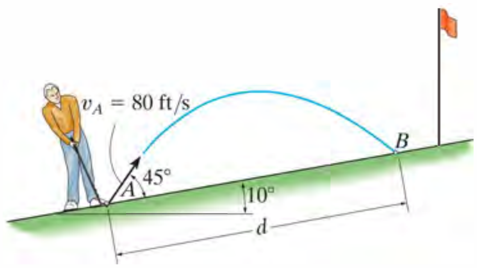
Prob. 12–100

•12–101. A projectile is fired from the platform at B. The shooter fires his gun from point A at an angle of 30°. Determine the muzzle speed of the bullet if it hits the projectile at C.



Prob. 12–101

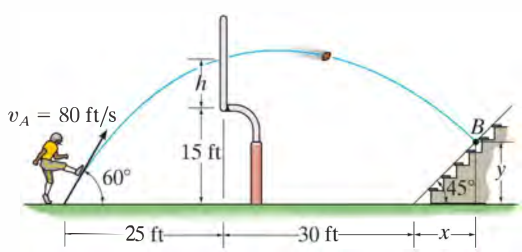
12–102. A golf ball is struck with a velocity of 80 ft/s as shown. Determine the distance d to where it will land.



Prob. 12–102

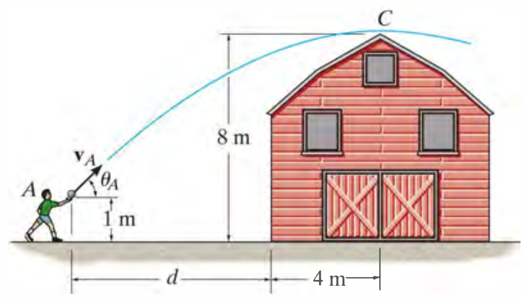
12–103. The football is to be kicked over the goalpost, which is 15 ft high. If its initial speed is $v_A = 80$ ft/s, determine if it makes it over the goalpost, and if so, by how much, h.

***12–104.** The football is kicked over the goalpost with an initial velocity of $v_A = 80$ ft/s as shown. Determine the point B (x, y) where it strikes the bleachers.



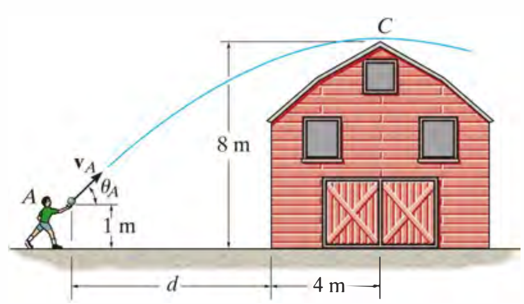
Probs. 12–103/104

•12–105. The boy at A attempts to throw a ball over the roof of a barn with an initial speed of $v_A = 15$ m/s. Determine the angle θ_A at which the ball must be thrown so that it reaches its maximum height at C. Also, find the distance d where the boy should stand to make the throw.



Prob. 12–105

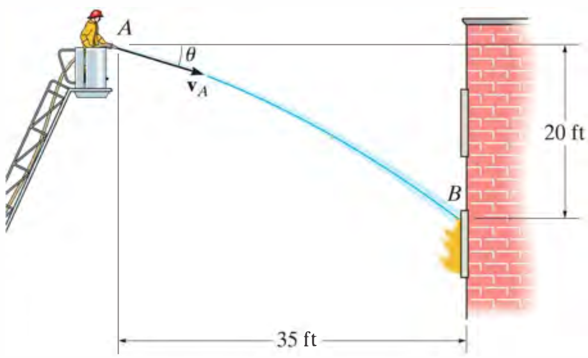
12–106. The boy at A attempts to throw a ball over the roof of a barn such that it is launched at an angle $\theta_A = 40°$. Determine the minimum speed v_A at which he must throw the ball so that it reaches its maximum height at C. Also, find the distance d where the boy must stand so that he can make the throw.



Prob. 12–106

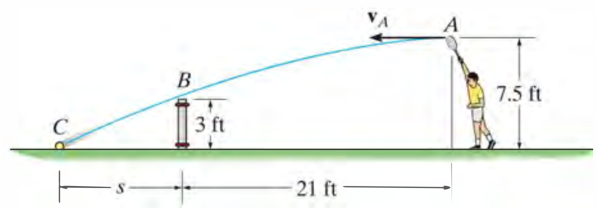
12

12–107. The fireman wishes to direct the flow of water from his hose to the fire at B. Determine two possible angles θ_1 and θ_2 at which this can be done. Water flows from the hose at $v_A = 80$ ft/s.



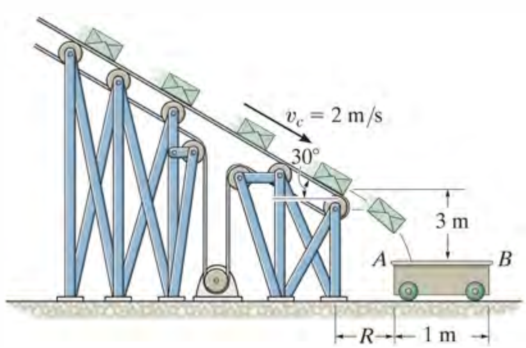
Prob. 12–107

•12–109. Determine the horizontal velocity v_A of a tennis ball at A so that it just clears the net at B. Also, find the distance s where the ball strikes the ground.



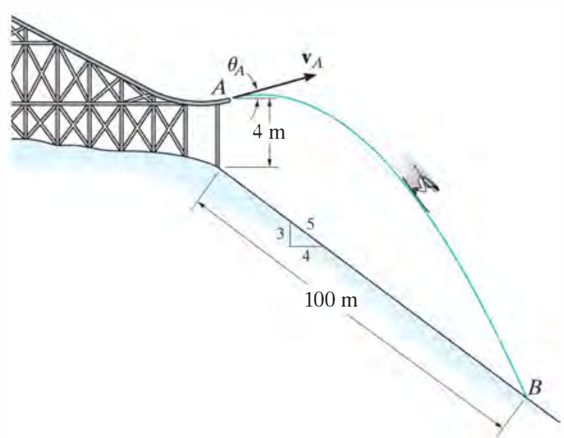
Prob. 12–109

***12–108.** Small packages traveling on the conveyor belt fall off into a l-m-long loading car. If the conveyor is running at a constant speed of $v_C = 2$ m/s, determine the smallest and largest distance R at which the end A of the car may be placed from the conveyor so that the packages enter the car.



Prob. 12–108

12–110. It is observed that the skier leaves the ramp A at an angle $\theta_A = 25°$ with the horizontal. If he strikes the ground at B, determine his initial speed v_A and the time of flight t_{AB}.



Prob. 12–110

PROBLEMS

12–111. When designing a highway curve it is required that cars traveling at a constant speed of 25 m/s must not have an acceleration that exceeds $3\ \text{m/s}^2$. Determine the minimum radius of curvature of the curve.

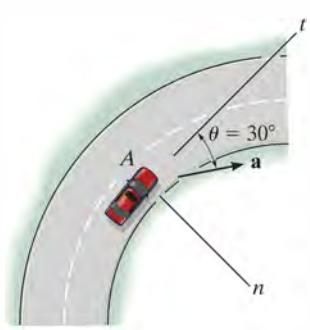
***12–112.** At a given instant, a car travels along a circular curved road with a speed of 20 m/s while decreasing its speed at the rate of $3\ \text{m/s}^2$. If the magnitude of the car's acceleration is $5\ \text{m/s}^2$, determine the radius of curvature of the road.

•12–113. Determine the maximum constant speed a race car can have if the acceleration of the car cannot exceed $7.5\ \text{m/s}^2$ while rounding a track having a radius of curvature of 200 m.

12–114. An automobile is traveling on a horizontal circular curve having a radius of 800 ft. If the acceleration of the automobile is $5\ \text{ft/s}^2$, determine the constant speed at which the automobile is traveling.

12–115. A car travels along a horizontal circular curved road that has a radius of 600 m. If the speed is uniformly increased at a rate of $2000\ \text{km/h}^2$, determine the magnitude of the acceleration at the instant the speed of the car is 60 km/h.

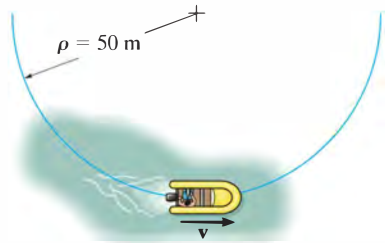
***12–116.** The automobile has a speed of 80 ft/s at point A and an acceleration **a** having a magnitude of $10\ \text{ft/s}^2$, acting in the direction shown. Determine the radius of curvature of the path at point A and the tangential component of acceleration.



Prob. 12–116

•12–117. Starting from rest the motorboat travels around the circular path, $\rho = 50\ \text{m}$, at a speed $v = (0.8t)\ \text{m/s}$, where t is in seconds. Determine the magnitudes of the boat's velocity and acceleration when it has traveled 20 m.

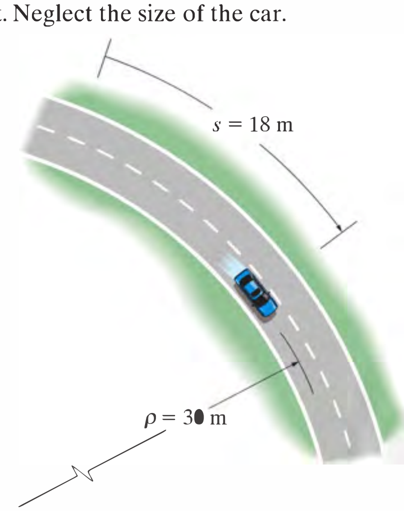
12–118. Starting from rest, the motorboat travels around the circular path, $\rho = 50\ \text{m}$, at a speed $v = (0.2t^2)\ \text{m/s}$, where t is in seconds. Determine the magnitudes of the boat's velocity and acceleration at the instant $t = 3\ \text{s}$.



Probs. 12–117/118

12–119. A car moves along a circular track of radius 250 ft, and its speed for a short period of time $0 \le t \le 2\ \text{s}$ is $v = 3(t + t^2)\ \text{ft/s}$, where t is in seconds. Determine the magnitude of the car's acceleration when $t = 2\ \text{s}$. How far has it traveled in $t = 2\ \text{s}$?

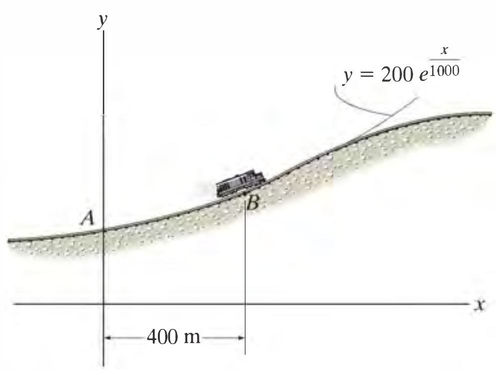
***12–120.** The car travels along the circular path such that its speed is increased by $a_t = (0.5e^t)\ \text{m/s}^2$, where t is in seconds. Determine the magnitudes of its velocity and acceleration after the car has traveled $s = 18\ \text{m}$ starting from rest. Neglect the size of the car.



Prob. 12–120

•12–121. The train passes point B with a speed of 20 m/s which is decreasing at $a_t = -0.5\ \text{m/s}^2$. Determine the magnitude of acceleration of the train at this point.

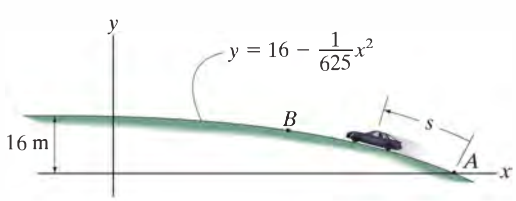
12–122. The train passes point A with a speed of 30 m/s and begins to decrease its speed at a constant rate of $a_t = -0.25\ \text{m/s}^2$. Determine the magnitude of the acceleration of the train when it reaches point B, where $s_{AB} = 412$ m.



Probs. 12–121/122

12–123. The car passes point A with a speed of 25 m/s after which its speed is defined by $v = (25 - 0.15s)$ m/s. Determine the magnitude of the car's acceleration when it reaches point B, where $s = 51.5$ m.

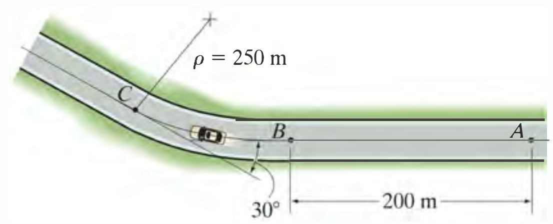
***12–124.** If the car passes point A with a speed of 20 m/s and begins to increase its speed at a constant rate of $a_t = 0.5\ \text{m/s}^2$, determine the magnitude of the car's acceleration when $s = 100$ m.



Probs. 12–123/124

•12–125. When the car reaches point A it has a speed of 25 m/s. If the brakes are applied, its speed is reduced by $a_t = (-\frac{1}{4}t^{1/2})\ \text{m/s}^2$. Determine the magnitude of acceleration of the car just before it reaches point C.

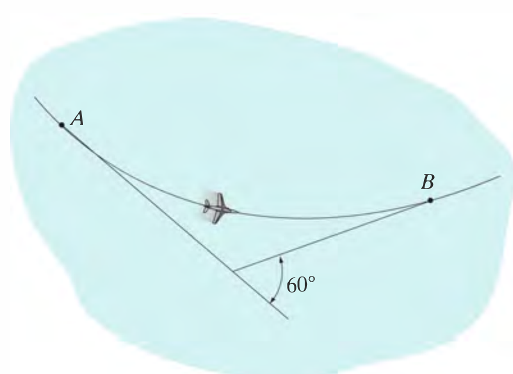
12–126. When the car reaches point A, it has a speed of 25 m/s. If the brakes are applied, its speed is reduced by $a_t = (0.001s - 1)\ \text{m/s}^2$. Determine the magnitude of acceleration of the car just before it reaches point C.



Probs. 12–125/126

12–127. Determine the magnitude of acceleration of the airplane during the turn. It flies along the horizontal circular path AB in 40 s, while maintaining a constant speed of 300 ft/s.

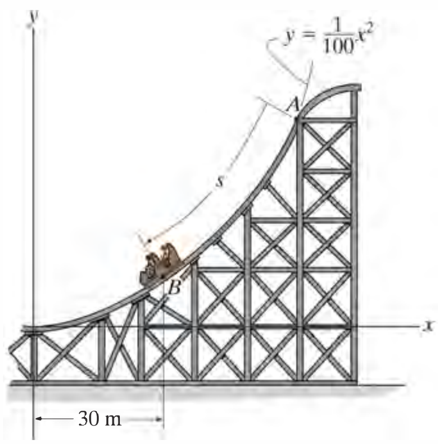
***12–128.** The airplane flies along the horizontal circular path AB in 60 s. If its speed at point A is 400 ft/s, which decreases at a rate of $a_t = (-0.1t)\ \text{ft/s}^2$, determine the magnitude of the plane's acceleration when it reaches point B.



Probs. 12–127/128

•12–129. When the roller coaster is at B, it has a speed of 25 m/s, which is increasing at $a_t = 3\ \text{m/s}^2$. Determine the magnitude of the acceleration of the roller coaster at this instant and the direction angle it makes with the x axis.

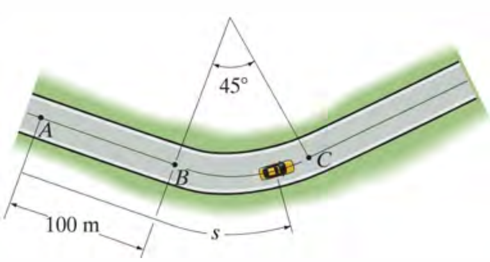
12–130. If the roller coaster starts from rest at A and its speed increases at $a_t = (6 - 0.06s)\ \text{m/s}^2$, determine the magnitude of its acceleration when it reaches B where $s_B = 40$ m.



Probs. 12–129/130

12–131. The car is traveling at a constant speed of 30 m/s. The driver then applies the brakes at A and thereby reduces the car's speed at the rate of $a_t = (-0.08v)\ \text{m/s}^2$, where v is in m/s. Determine the acceleration of the car just before it reaches point C on the circular curve. It takes 15 s for the car to travel from A to C.

***12–132.** The car is traveling at a speed of 30 m/s. The driver applies the brakes at A and thereby reduces the speed at the rate of $a_t = \left(-\frac{1}{8}t\right)\ \text{m/s}^2$, where t is in seconds. Determine the acceleration of the car just before it reaches point C on the circular curve. It takes 15 s for the car to travel from A to C.

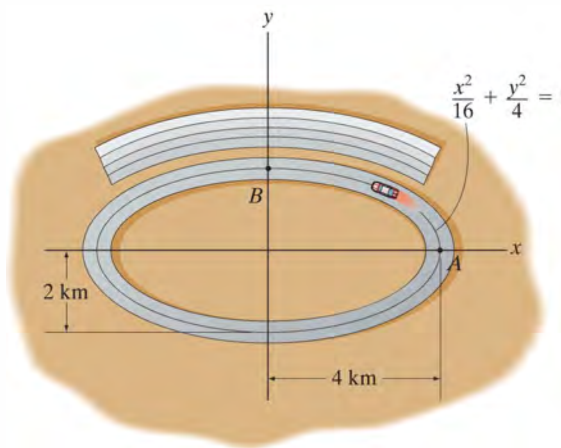


Probs. 12–131/132

•12–133. A particle is traveling along a circular curve having a radius of 20 m. If it has an initial speed of 20 m/s and then begins to decrease its speed at the rate of $a_t = (-0.25s)\ \text{m/s}^2$, determine the magnitude of the acceleration of the particle two seconds later.

12–134. A racing car travels with a constant speed of 240 km/h around the elliptical race track. Determine the acceleration experienced by the driver at A.

12–135. The racing car travels with a constant speed of 240 km/h around the elliptical race track. Determine the acceleration experienced by the driver at B.



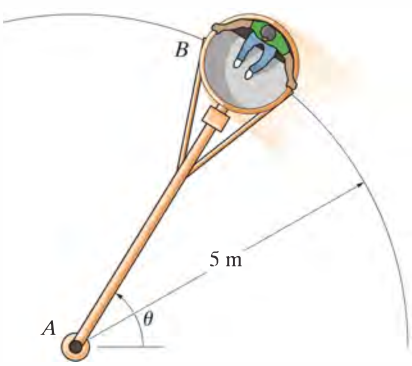
Probs. 12–134/135

***12–136.** The position of a particle is defined by $\mathbf{r} = \{2\sin(\frac{\pi}{4})t\mathbf{i} + 2\cos(\frac{\pi}{4})t\mathbf{j} + 3t\mathbf{k}\}$ m, where t is in seconds. Determine the magnitudes of the velocity and acceleration at any instant.

•12–137. The position of a particle is defined by $\mathbf{r} = \{t^3\mathbf{i} + 3t^2\mathbf{j} + 8t\mathbf{k}\}$ m, where t is in seconds. Determine the magnitude of the velocity and acceleration and the radius of curvature of the path when $t = 2$ s.

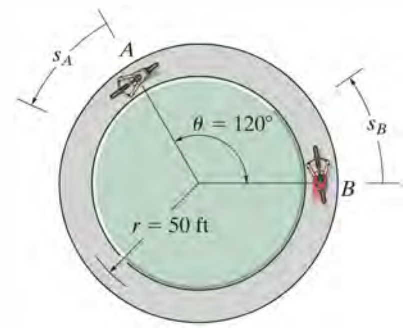
12–138. Car B turns such that its speed is increased by $(a_t)_B = (0.5e^t)\ \text{m/s}^2$, where t is in seconds. If the car starts from rest when $\theta = 0°$, determine the magnitudes of its velocity and acceleration when the arm AB rotates $\theta = 30°$. Neglect the size of the car.

12–139. Car B turns such that its speed is increased by $(a_t)_B = (0.5e^t)\ \text{m/s}^2$, where t is in seconds. If the car starts from rest when $\theta = 0°$, determine the magnitudes of its velocity and acceleration when $t = 2$ s. Neglect the size of the car.



Probs. 12–138/139

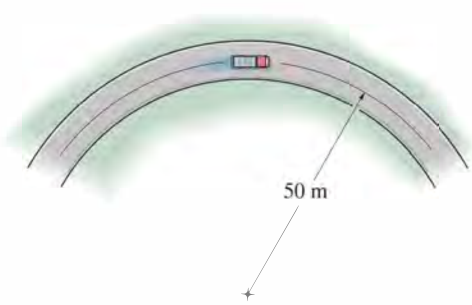
12–142. Two cyclists, A and B, are traveling counterclockwise around a circular track at a constant speed of 8 ft/s at the instant shown. If the speed of A is increased at $(a_t)_A = (s_A)\ \text{ft/s}^2$, where s_A is in feet, determine the distance measured counterclockwise along the track from B to A between the cyclists when $t = 1$ s. What is the magnitude of the acceleration of each cyclist at this instant?



Prob. 12–142

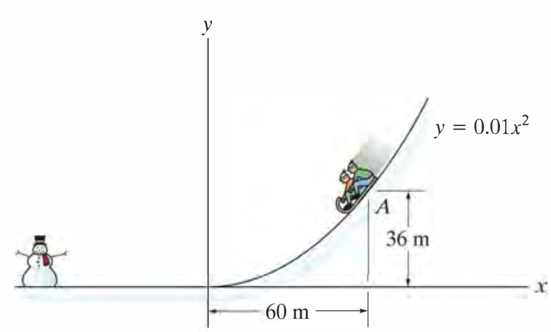
***12–140.** The truck travels at a speed of 4 m/s along a circular road that has a radius of 50 m. For a short distance from $s = 0$, its speed is then increased by $a_t = (0.05s)\ \text{m/s}^2$, where s is in meters. Determine its speed and the magnitude of its acceleration when it has moved $s = 10$ m.

•12–141. The truck travels along a circular road that has a radius of 50 m at a speed of 4 m/s. For a short distance when $t = 0$, its speed is then increased by $a_t = (0.4t)\ \text{m/s}^2$, where t is in seconds. Determine the speed and the magnitude of the truck's acceleration when $t = 4$ s.



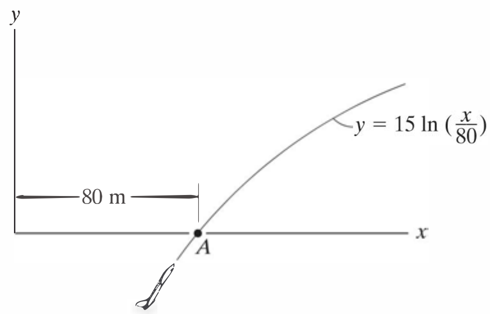
Probs. 12–140/141

12–143. A toboggan is traveling down along a curve which can be approximated by the parabola $y = 0.01x^2$. Determine the magnitude of its acceleration when it reaches point A, where its speed is $v_A = 10$ m/s, and it is increasing at the rate of $(a_t)_A = 3\ \text{m/s}^2$.



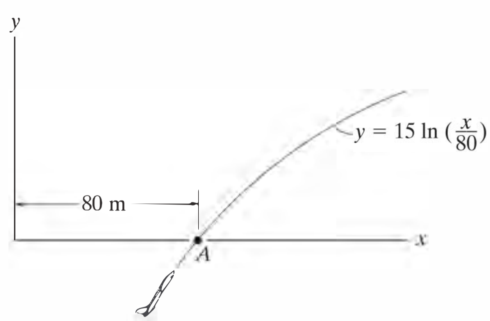
Prob. 12–143

***12–144.** The jet plane is traveling with a speed of 120 m/s which is decreasing at $40\ \text{m/s}^2$ when it reaches point A. Determine the magnitude of its acceleration when it is at this point. Also, specify the direction of flight, measured from the x axis.



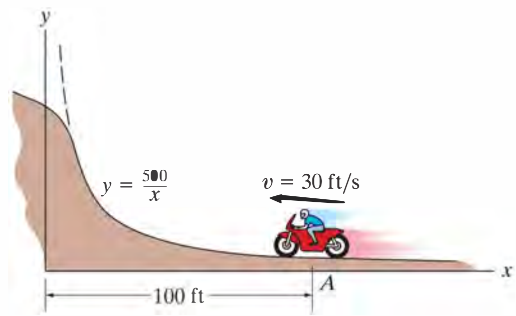
Prob. 12–144

•12–145. The jet plane is traveling with a constant speed of 110 m/s along the curved path. Determine the magnitude of the acceleration of the plane at the instant it reaches point A ($y = 0$).



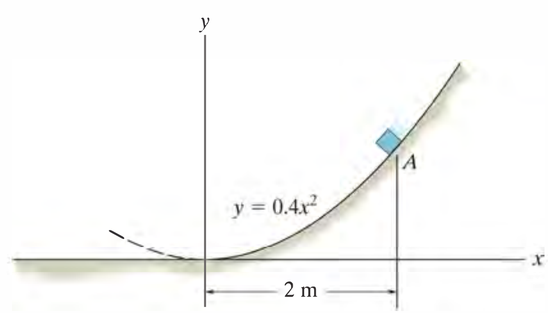
Prob. 12–145

12–146. The motorcyclist travels along the curve at a constant speed of 30 ft/s. Determine his acceleration when he is located at point A. Neglect the size of the motorcycle and rider for the calculation.



Prob. 12–146

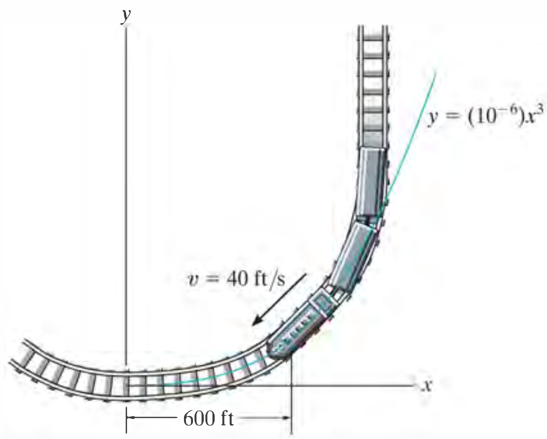
12–147. The box of negligible size is sliding down along a curved path defined by the parabola $y = 0.4x^2$. When it is at A ($x_A = 2$ m, $y_A = 1.6$ m), the speed is $v_B = 8$ m/s and the increase in speed is $dv_B/dt = 4\ \text{m/s}^2$. Determine the magnitude of the acceleration of the box at this instant.



Prob. 12–147

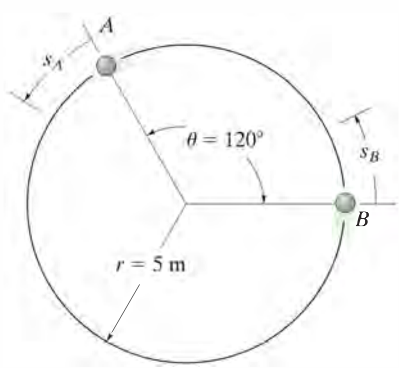
12

*12–148. A spiral transition curve is used on railroads to connect a straight portion of the track with a curved portion. If the spiral is defined by the equation $y = (10^{-6})x^3$, where x and y are in feet, determine the magnitude of the acceleration of a train engine moving with a constant speed of 40 ft/s when it is at point $x = 600$ ft.



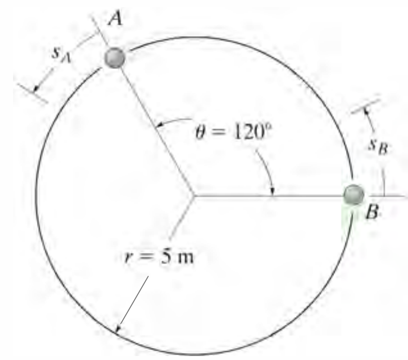
Prob. 12–148

•12–149. Particles A and B are traveling counter-clockwise around a circular track at a constant speed of 8 m/s. If at the instant shown the speed of A begins to increase by $(a_t)_A = (0.4s_A)$ m/s^2, where s_A is in meters, determine the distance measured counterclockwise along the track from B to A when $t = 1$ s. What is the magnitude of the acceleration of each particle at this instant?



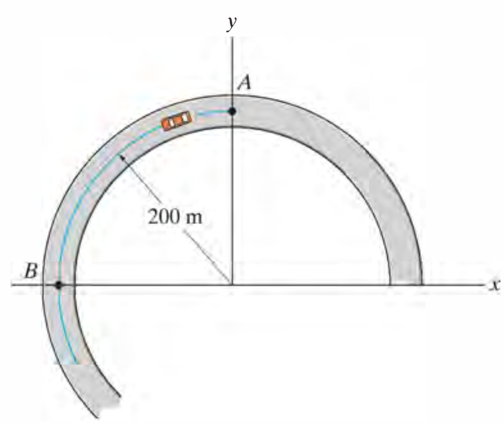
Prob. 12–149

12–150. Particles A and B are traveling around a circular track at a speed of 8 m/s at the instant shown. If the speed of B is increasing by $(a_t)_B = 4$ m/s^2, and at the same instant A has an increase in speed of $(a_t)_A = 0.8t$ m/s^2, determine how long it takes for a collision to occur. What is the magnitude of the acceleration of each particle just before the collision occurs?



Prob. 12–150

12–151. The race car travels around the circular track with a speed of 16 m/s. When it reaches point A it increases its speed at $a_t = (\frac{4}{3}v^{1/4})$ m/s^2, where v is in m/s. Determine the magnitudes of the velocity and acceleration of the car when it reaches point B. Also, how much time is required for it to travel from A to B?



Prob. 12–151

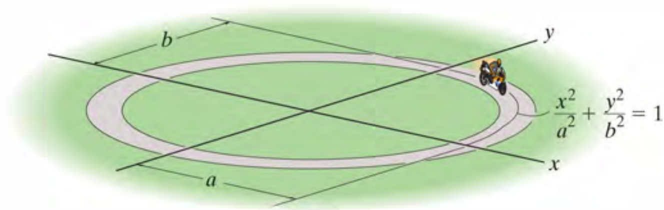
***12–152.** A particle travels along the path $y = a + bx + cx^2$, where a, b, c are constants. If the speed of the particle is constant, $v = v_0$, determine the x and y components of velocity and the normal component of acceleration when $x = 0$.

•12–153. The ball is kicked with an initial speed $v_A = 8$ m/s at an angle $\theta_A = 40°$ with the horizontal. Find the equation of the path, $y = f(x)$, and then determine the normal and tangential components of its acceleration when $t = 0.25$ s.

12–154. The motion of a particle is defined by the equations $x = (2t + t^2)$ m and $y = (t^2)$ m, where t is in seconds. Determine the normal and tangential components of the particle's velocity and acceleration when $t = 2$ s.

12–155. The motorcycle travels along the elliptical track at a constant speed v. Determine the greatest magnitude of the acceleration if $a > b$.

Prob. 12–153

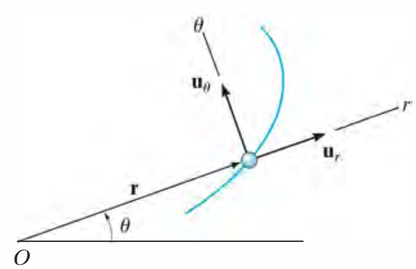


Prob. 12–155

12.8 Curvilinear Motion: Cylindrical Components

Sometimes the motion of the particle is constrained on a path that is best described using cylindrical coordinates. If motion is restricted to the plane, then polar coordinates are used.

Polar Coordinates. We can specify the location of the particle shown in Fig. 12–30*a* using a *radial coordinate* r, which extends outward from the fixed origin O to the particle, and a *transverse coordinate* θ, which is the counterclockwise angle between a fixed reference line and the r axis. The angle is generally measured in degrees or radians, where 1 rad = $180°/\pi$. The positive directions of the r and θ coordinates are defined by the unit vectors $\mathbf{u}_r$ and $\mathbf{u}_\theta$, respectively. Here $\mathbf{u}_r$ is in the direction of increasing r when θ is held fixed, and $\mathbf{u}_\theta$ is in a direction of increasing θ when r is held fixed. Note that these directions are perpendicular to one another.



Position

(a)

Fig. 12–30

PROBLEMS

***12–156.** A particle moves along a circular path of radius 300 mm. If its angular velocity is $\dot{\theta} = (2t^2)$ rad/s, where t is in seconds, determine the magnitude of the particle's acceleration when $t = 2$ s.

•12–157. A particle moves along a circular path of radius 300 mm. If its angular velocity is $\dot{\theta} = (3t^2)$ rad/s, where t is in seconds, determine the magnitudes of the particle's velocity and acceleration when $\theta = 45°$. The particle starts from rest when $\theta = 0°$.

12–158. A particle moves along a circular path of radius 5 ft. If its position is $\theta = (e^{0.5t})$ rad, where t is in seconds, determine the magnitude of the particle's acceleration when $\theta = 90°$.

12–159. The position of a particle is described by $r = (t^3 + 4t - 4)$ m and $\theta = (t^{3/2})$ rad, where t is in seconds. Determine the magnitudes of the particle's velocity and acceleration at the instant $t = 2$ s.

***12–160.** The position of a particle is described by $r = (300e^{-0.5t})$ mm and $\theta = (0.3t^2)$ rad, where t is in seconds. Determine the magnitudes of the particle's velocity and acceleration at the instant $t = 1.5$ s.

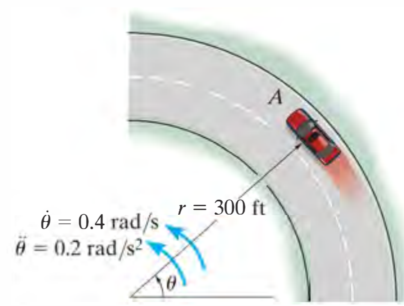
•12–161. An airplane is flying in a straight line with a velocity of 200 mi/h and an acceleration of 3 mi/h^2. If the propeller has a diameter of 6 ft and is rotating at an angular rate of 120 rad/s, determine the magnitudes of velocity and acceleration of a particle located on the tip of the propeller.

12–162. A particle moves along a circular path having a radius of 4 in. such that its position as a function of time is given by $\theta = (\cos 2t)$ rad, where t is in seconds. Determine the magnitude of the acceleration of the particle when $\theta = 30°$.

12–163. A particle travels around a limaçon, defined by the equation $r = b - a \cos \theta$, where a and b are constants. Determine the particle's radial and transverse components of velocity and acceleration as a function of θ and its time derivatives.

***12–164.** A particle travels around a lituus, defined by the equation $r^2\theta = a^2$, where a is a constant. Determine the particle's radial and transverse components of velocity and acceleration as a function of θ and its time derivatives.

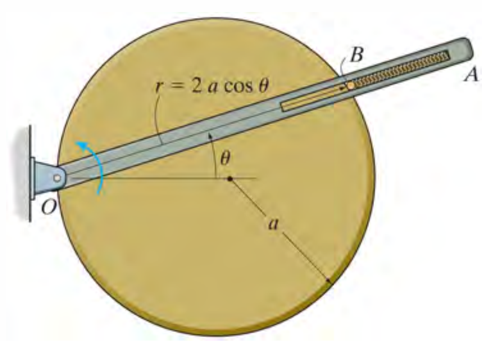
•12–165. A car travels along the circular curve of radius $r = 300$ ft. At the instant shown, its angular rate of rotation is $\dot{\theta} = 0.4$ rad/s, which is increasing at the rate of $\ddot{\theta} = 0.2$ rad/s^2. Determine the magnitudes of the car's velocity and acceleration at this instant.



Prob. 12–165

12–166. The slotted arm OA rotates counterclockwise about O with a constant angular velocity of $\dot{\theta}$. The motion of pin B is constrained such that it moves on the fixed circular surface and along the slot in OA. Determine the magnitudes of the velocity and acceleration of pin B as a function of θ.

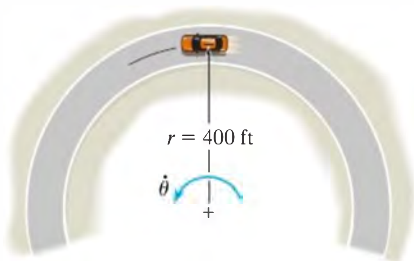
12–167. The slotted arm OA rotates counterclockwise about O such that when $\theta = \pi/4$, arm OA is rotating with an angular velocity of $\dot{\theta}$ and an angular acceleration of $\ddot{\theta}$. Determine the magnitudes of the velocity and acceleration of pin B at this instant. The motion of pin B is constrained such that it moves on the fixed circular surface and along the slot in OA.



Probs. 12–166/167

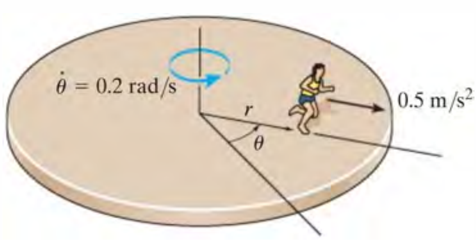
*12–168. The car travels along the circular curve having a radius $r = 400$ ft. At the instant shown, its angular rate of rotation is $\dot{\theta} = 0.025$ rad/s, which is decreasing at the rate $\ddot{\theta} = -0.008$ rad/s^2. Determine the radial and transverse components of the car's velocity and acceleration at this instant and sketch these components on the curve.

•12–169. The car travels along the circular curve of radius $r = 400$ ft with a constant speed of $v = 30$ ft/s. Determine the angular rate of rotation $\dot{\theta}$ of the radial line r and the magnitude of the car's acceleration.



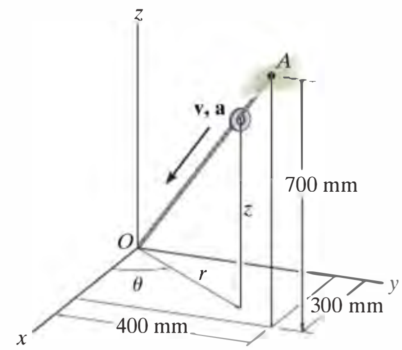
Probs. 12–168/169

12–170. Starting from rest, the boy runs outward in the radial direction from the center of the platform with a constant acceleration of 0.5 m/s^2. If the platform is rotating at a constant rate $\dot{\theta} = 0.2$ rad/s, determine the radial and transverse components of the velocity and acceleration of the boy when $t = 3$ s. Neglect his size.



Prob. 12–170

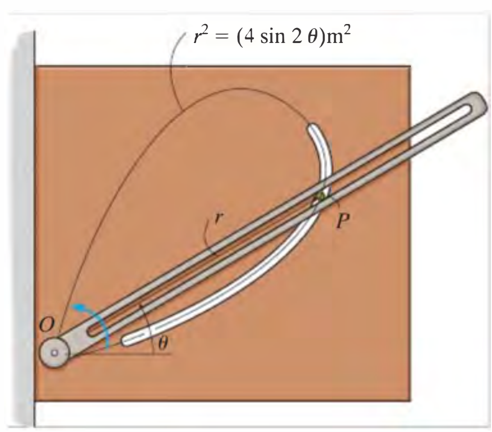
12–171. The small washer slides down the cord OA. When it is at the midpoint, its speed is 200 mm/s and its acceleration is 10 mm/s^2. Express the velocity and acceleration of the washer at this point in terms of its cylindrical components.



Prob. 12–171

*12–172. If arm OA rotates counterclockwise with a constant angular velocity of $\dot{\theta} = 2$ rad/s, determine the magnitudes of the velocity and acceleration of peg P at $\theta = 30°$. The peg moves in the fixed groove defined by the lemniscate, and along the slot in the arm.

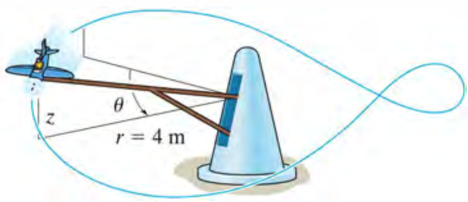
•12–173. The peg moves in the curved slot defined by the lemniscate, and through the slot in the arm. At $\theta = 30°$, the angular velocity is $\dot{\theta} = 2$ rad/s, and the angular acceleration is $\ddot{\theta} = 1.5$ rad/s^2. Determine the magnitudes of the velocity and acceleration of peg P at this instant.



Probs. 12–172/173

12

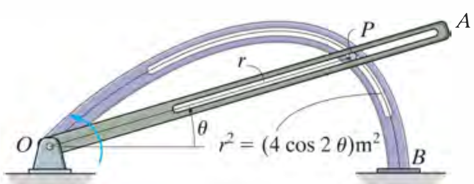
12–174. The airplane on the amusement park ride moves along a path defined by the equations $r = 4$ m, $\theta = (0.2t)$ rad, and $z = (0.5 \cos \theta)$ m, where t is in seconds. Determine the cylindrical components of the velocity and acceleration of the airplane when $t = 6$ s.



Prob. 12–174

12–175. The motion of peg P is constrained by the lemniscate curved slot in OB and by the slotted arm OA. If OA rotates counterclockwise with a constant angular velocity of $\dot{\theta} = 3$ rad/s, determine the magnitudes of the velocity and acceleration of peg P at $\theta = 30°$.

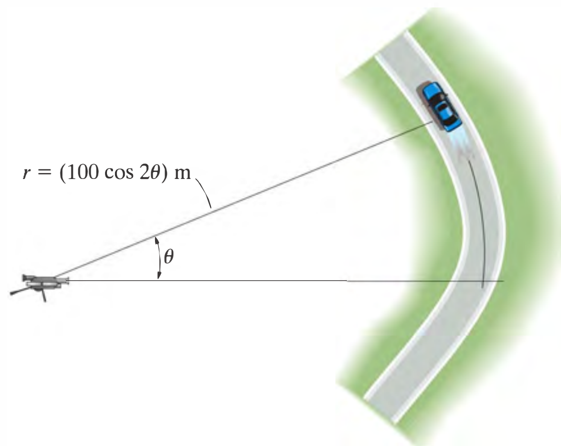
***12–176.** The motion of peg P is constrained by the lemniscate curved slot in OB and by the slotted arm OA. If OA rotates counterclockwise with an angular velocity of $\dot{\theta} = (3t^{3/2})$ rad/s, where t is in seconds, determine the magnitudes of the velocity and acceleration of peg P at $\theta = 30°$. When $t = 0, \theta = 0°$.



Probs. 12–175/176

•12–177. The driver of the car maintains a constant speed of 40 m/s. Determine the angular velocity of the camera tracking the car when $\theta = 15°$.

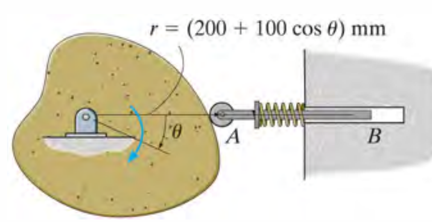
12–178. When $\theta = 15°$, the car has a speed of 50 m/s which is increasing at 6 m/s^2. Determine the angular velocity of the camera tracking the car at this instant.



Probs. 12–177/178

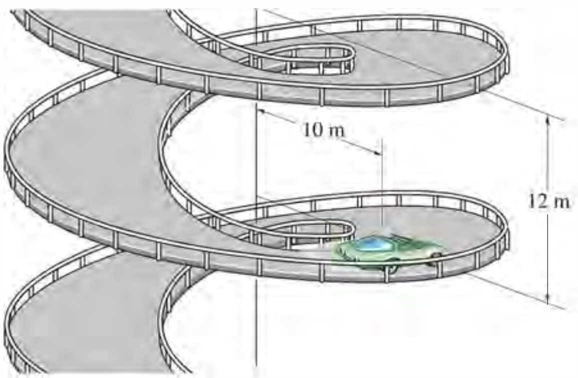
12–179. If the cam rotates clockwise with a constant angular velocity of $\dot{\theta} = 5$ rad/s, determine the magnitudes of the velocity and acceleration of the follower rod AB at the instant $\theta = 30°$. The surface of the cam has a shape of limaçon defined by $r = (200 + 100 \cos \theta)$ mm.

***12–180.** At the instant $\theta = 30°$, the cam rotates with a clockwise angular velocity of $\dot{\theta} = 5$ rad/s and and angular acceleration of $\ddot{\theta} = 6$ rad/s^2. Determine the magnitudes of the velocity and acceleration of the follower rod AB at this instant. The surface of the cam has a shape of a limaçon defined by $r = (200 + 100 \cos \theta)$ mm.



Probs. 12–179/180

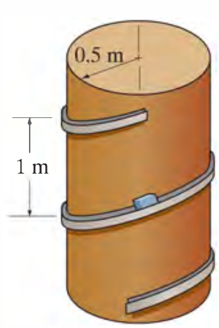
•**12–181.** The automobile travels from a parking deck down along a cylindrical spiral ramp at a constant speed of $v = 1.5$ m/s. If the ramp descends a distance of 12 m for every full revolution, $\theta = 2\pi$ rad, determine the magnitude of the car's acceleration as it moves along the ramp, $r = 10$ m. *Hint:* For part of the solution, note that the tangent to the ramp at any point is at an angle of $\phi = \tan^{-1}(12/[2\pi(10)]) = 10.81°$ from the horizontal. Use this to determine the velocity components v_θ and v_z, which in turn are used to determine $\dot{\theta}$ and $\dot{z}$.



Prob. 12–181

12–182. The box slides down the helical ramp with a constant speed of $v = 2$ m/s. Determine the magnitude of its acceleration. The ramp descends a vertical distance of 1 m for every full revolution. The mean radius of the ramp is $r = 0.5$ m.

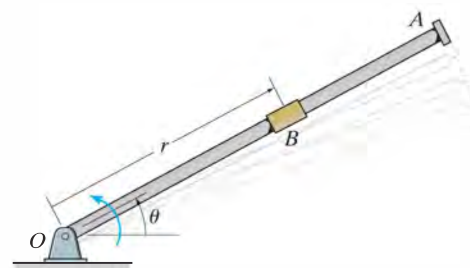
12–183. The box slides down the helical ramp which is defined by $r = 0.5$ m, $\theta = (0.5t^3)$ rad, and $z = (2 - 0.2t^2)$ m, where t is in seconds. Determine the magnitudes of the velocity and acceleration of the box at the instant $\theta = 2\pi$ rad.



Probs. 12–182/183

***12–184.** Rod OA rotates counterclockwise with a constant angular velocity of $\dot{\theta} = 6$ rad/s. Through mechanical means collar B moves along the rod with a speed of $\dot{r} = (4t^2)$ m/s, where t is in seconds. If $r = 0$ when $t = 0$, determine the magnitudes of velocity and acceleration of the collar when $t = 0.75$ s.

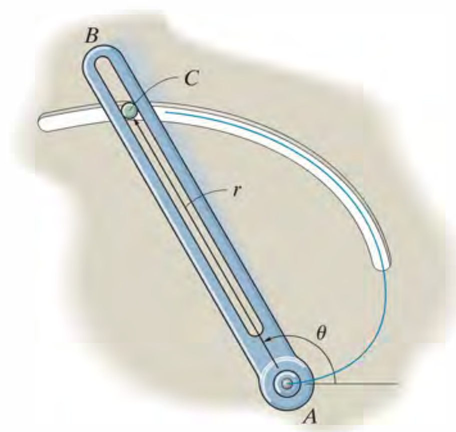
•**12–185.** Rod OA is rotating counterclockwise with an angular velocity of $\dot{\theta} = (2t^2)$ rad/s. Through mechanical means collar B moves along the rod with a speed of $\dot{r} = (4t^2)$ m/s. If $\theta = 0$ and $r = 0$ when $t = 0$, determine the magnitudes of velocity and acceleration of the collar at $\theta = 60°$.



Probs. 12–184/185

12–186. The slotted arm AB drives pin C through the spiral groove described by the equation $r = a\theta$. If the angular velocity is constant at $\dot{\theta}$, determine the radial and transverse components of velocity and acceleration of the pin.

12–187. The slotted arm AB drives pin C through the spiral groove described by the equation $r = (1.5\,\theta)$ ft, where θ is in radians. If the arm starts from rest when $\theta = 60°$ and is driven at an angular velocity of $\dot{\theta} = (4t)$ rad/s, where t is in seconds, determine the radial and transverse components of velocity and acceleration of the pin C when $t = 1$ s.

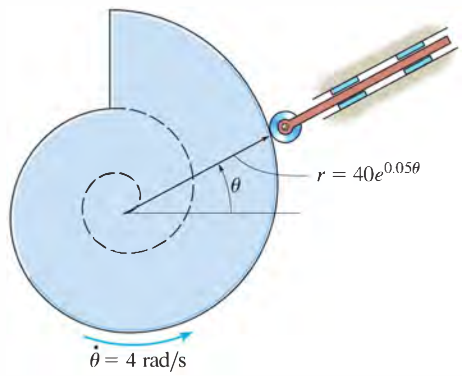


Probs. 12–186/187

12

***12–188.** The partial surface of the cam is that of a logarithmic spiral $r = (40e^{0.05\theta})$ mm, where θ is in radians. If the cam rotates at a constant angular velocity of $\dot{\theta} = 4$ rad/s, determine the magnitudes of the velocity and acceleration of the point on the cam that contacts the follower rod at the instant $\theta = 30°$.

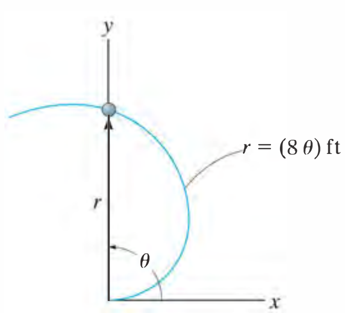
•12–189. Solve Prob. 12–188, if the cam has an angular acceleration of $\ddot{\theta} = 2$ rad/s^2 when its angular velocity is $\dot{\theta} = 4$ rad/s at $\theta = 30°$.



Probs. 12–188/189

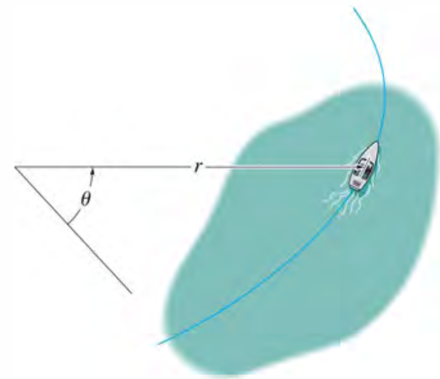
12–190. A particle moves along an Archimedean spiral $r = (8\theta)$ ft, where θ is given in radians. If $\dot{\theta} = 4$ rad/s (constant), determine the radial and transverse components of the particle's velocity and acceleration at the instant $\theta = \pi/2$ rad. Sketch the curve and show the components on the curve.

12–191. Solve Prob. 12–190 if the particle has an angular acceleration $\ddot{\theta} = 5$ rad/s^2 when $\dot{\theta} = 4$ rad/s at $\theta = \pi/2$ rad.



Probs. 12–190/191

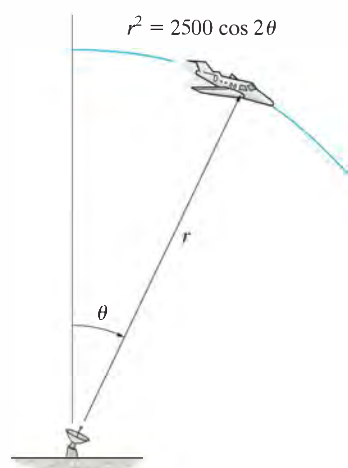
***12–192.** The boat moves along a path defined by $r^2 = [10(10^3)\cos 2\theta]$ ft^2, where θ is in radians. If $\theta = (0.4t^2)$ rad, where t is in seconds, determine the radial and transverse components of the boat's velocity and acceleration at the instant $t = 1$ s.



Prob. 12–192

•12–193. A car travels along a road, which for a short distance is defined by $r = (200/\theta)$ ft, where θ is in radians. If it maintains a constant speed of $v = 35$ ft/s, determine the radial and transverse components of its velocity when $\theta = \pi/3$ rad.

12–194. For a short time the jet plane moves along a path in the shape of a lemniscate, $r^2 = (2500\cos 2\theta)$ km^2. At the instant $\theta = 30°$, the radar tracking device is rotating at $\dot{\theta} = 5(10^{-3})$ rad/s with $\ddot{\theta} = 2(10^{-3})$ rad/s^2. Determine the radial and transverse components of velocity and acceleration of the plane at this instant.

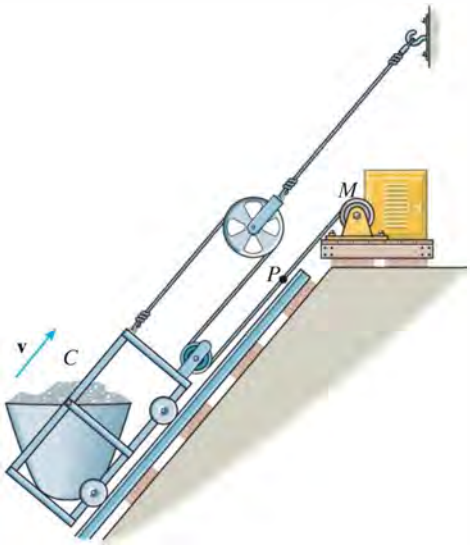


Prob. 12–194

12

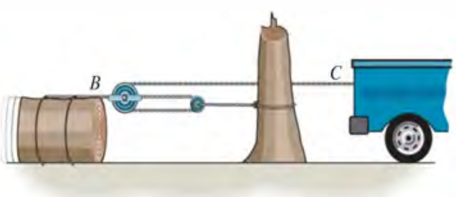
PROBLEMS

12–195. The mine car C is being pulled up the incline using the motor M and the rope-and-pulley arrangement shown. Determine the speed v_P at which a point P on the cable must be traveling toward the motor to move the car up the plane with a constant speed of $v = 2$ m/s.



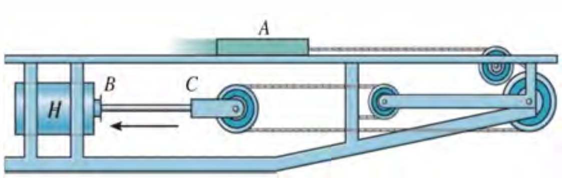
Prob. 12–195

***12–196.** Determine the displacement of the log if the truck at C pulls the cable 4 ft to the right.



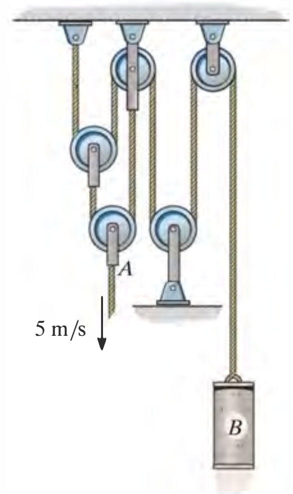
Prob. 12–196

•**12–197.** If the hydraulic cylinder H draws in rod BC at 2 ft/s, determine the speed of slider A.



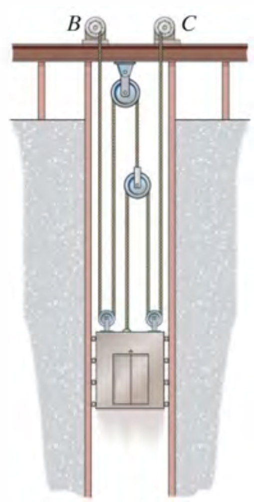
Prob. 12–197

12–198. If end A of the rope moves downward with a speed of 5 m/s, determine the speed of cylinder B.



Prob. 12–198

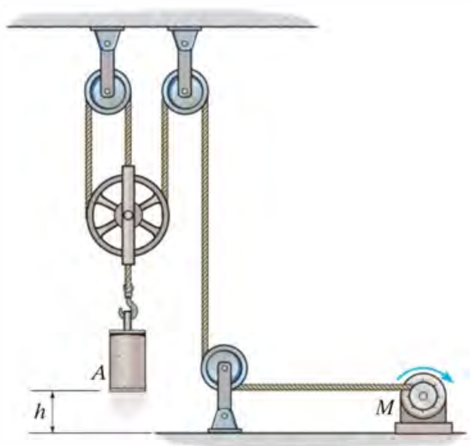
12–199. Determine the speed of the elevator if each motor draws in the cable with a constant speed of 5 m/s.



Prob. 12–199

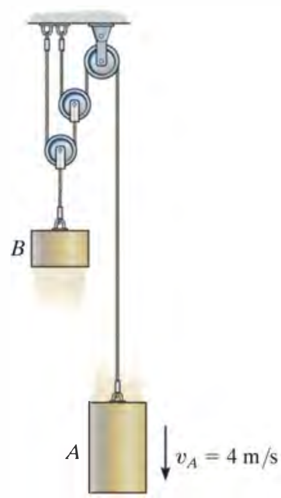
***12–200.** Determine the speed of cylinder A, if the rope is drawn towards the motor M at a constant rate of 10 m/s.

•12–201. If the rope is drawn towards the motor M at a speed of $v_M = (5t^{3/2})$ m/s, where t is in seconds, determine the speed of cylinder A when $t = 1$ s.



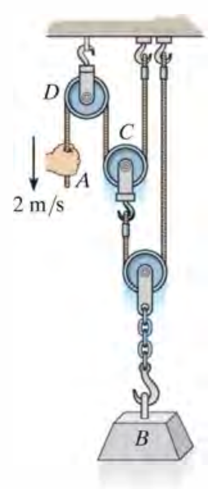
Probs. 12–200/201

12–203. Determine the speed of B if A is moving downwards with a speed of $v_A = 4$ m/s at the instant shown.



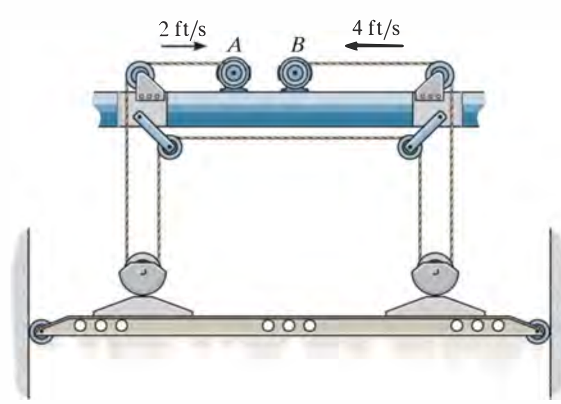
Prob. 12–203

12–202. If the end of the cable at A is pulled down with a speed of 2 m/s, determine the speed at which block B rises.



Prob. 12–202

***12–204.** The crane is used to hoist the load. If the motors at A and B are drawing in the cable at a speed of 2 ft/s and 4 ft/s, respectively, determine the speed of the load.



Prob. 12–204

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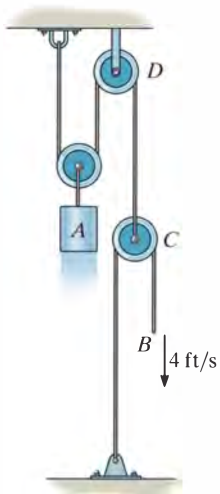
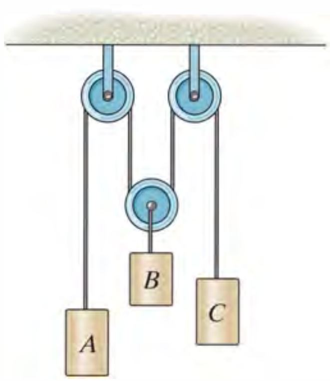
•**12–205.** The cable at B is pulled downwards at 4 ft/s, and the speed is decreasing at 2 ft/s^2. Determine the velocity and acceleration of block A at this instant.



Prob. 12–205

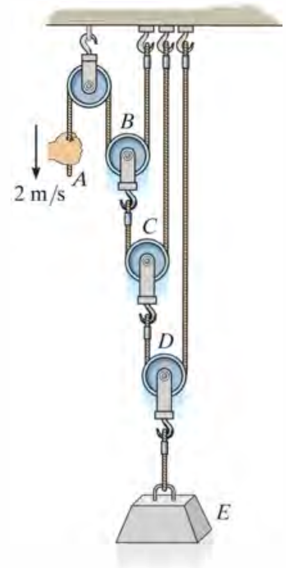
12–206. If block A is moving downward with a speed of 4 ft/s while C is moving up at 2 ft/s, determine the speed of block B.

12–207. If block A is moving downward at 6 ft/s while block C is moving down at 18 ft/s, determine the speed of block B.



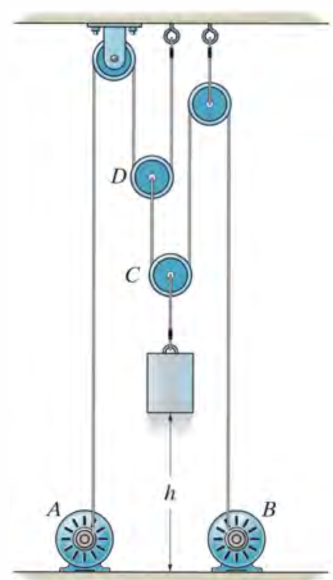
Probs. 12–206/207

***12–208.** If the end of the cable at A is pulled down with a speed of 2 m/s, determine the speed at which block E rises.



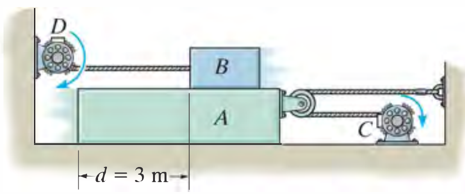
Prob. 12–208

•**12–209.** If motors at A and B draw in their attached cables with an acceleration of $a = (0.2t)$ m/s^2, where t is in seconds, determine the speed of the block when it reaches a height of $h = 4$ m, starting from rest at $h = 0$. Also, how much time does it take to reach this height?



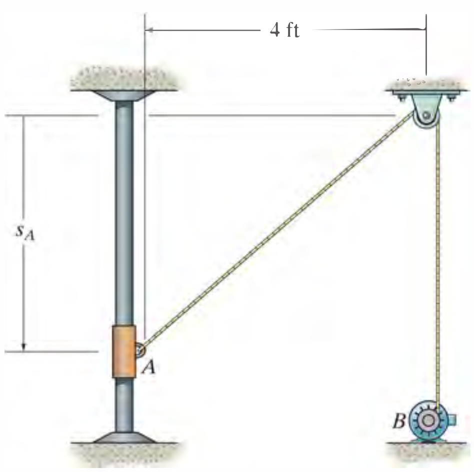
Prob. 12–209

12–210. The motor at C pulls in the cable with an acceleration $a_C = (3t^2)\ \text{m/s}^2$, where t is in seconds. The motor at D draws in its cable at $a_D = 5\ \text{m/s}^2$. If both motors start at the same instant from rest when $d = 3$ m, determine (a) the time needed for $d = 0$, and (b) the velocities of blocks A and B when this occurs.



Prob. 12–210

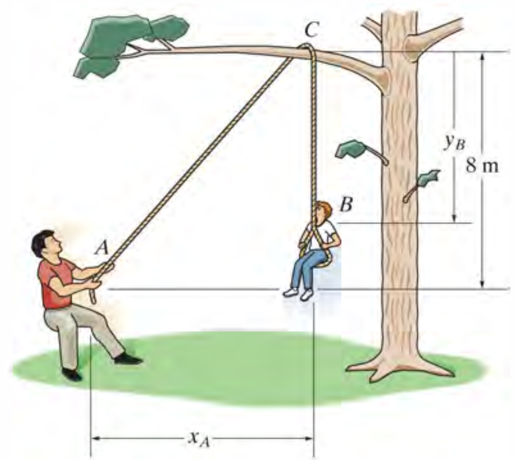
12–211. The motion of the collar at A is controlled by a motor at B such that when the collar is at $s_A = 3$ ft it is moving upwards at 2 ft/s and decreasing at 1 ft/s^2. Determine the velocity and acceleration of a point on the cable as it is drawn into the motor B at this instant.



Prob. 12–211

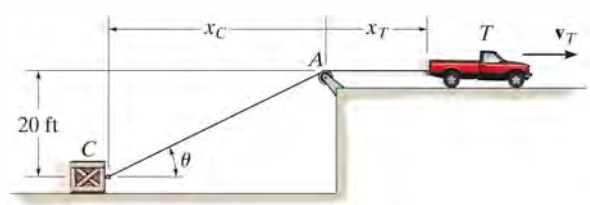
*__12–212.__ The man pulls the boy up to the tree limb C by walking backward at a constant speed of 1.5 m/s. Determine the speed at which the boy is being lifted at the instant $x_A = 4$ m. Neglect the size of the limb. When $x_A = 0$, $y_B = 8$ m, so that A and B are coincident, i.e., the rope is 16 m long.

•**12–213.** The man pulls the boy up to the tree limb C by walking backward. If he starts from rest when $x_A = 0$ and moves backward with a constant acceleration $a_A = 0.2\ \text{m/s}^2$, determine the speed of the boy at the instant $y_B = 4$ m. Neglect the size of the limb. When $x_A = 0$, $y_B = 8$ m, so that A and B are coincident, i.e., the rope is 16 m long.



Probs. 12–212/213

12–214. If the truck travels at a constant speed of $v_T = 6$ ft/s, determine the speed of the crate for any angle θ of the rope. The rope has a length of 100 ft and passes over a pulley of negligible size at A. *Hint:* Relate the coordinates x_T and x_C to the length of the rope and take the time derivative. Then substitute the trigonometric relation between x_C and θ.



Prob. 12–214

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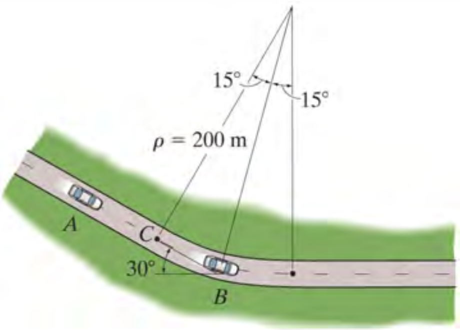
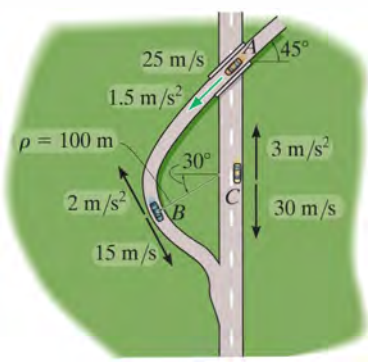
12–215. At the instant shown, car A travels along the straight portion of the road with a speed of 25 m/s. At this same instant car B travels along the circular portion of the road with a speed of 15 m/s. Determine the velocity of car B relative to car A.



Prob. 12–215

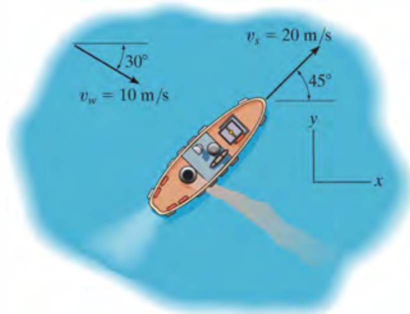
***12–216.** Car A travels along a straight road at a speed of 25 m/s while accelerating at 1.5 m/s^2. At this same instant car C is traveling along the straight road with a speed of 30 m/s while decelerating at 3 m/s^2. Determine the velocity and acceleration of car A relative to car C.

•**12–217.** Car B is traveling along the curved road with a speed of 15 m/s while decreasing its speed at 2 m/s^2. At this same instant car C is traveling along the straight road with a speed of 30 m/s while decelerating at 3 m/s^2. Determine the velocity and acceleration of car B relative to car C.



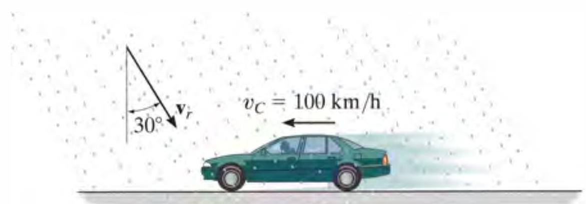
Probs. 12–216/217

12–218. The ship travels at a constant speed of $v_s = 20$ m/s and the wind is blowing at a speed of $v_w = 10$ m/s, as shown. Determine the magnitude and direction of the horizontal component of velocity of the smoke coming from the smoke stack as it appears to a passenger on the ship.



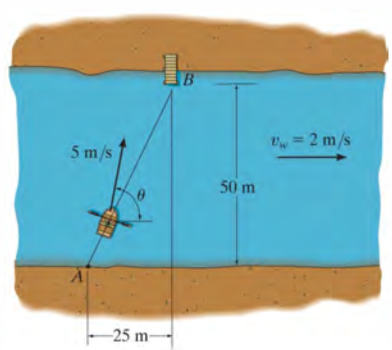
Prob. 12–218

12–219. The car is traveling at a constant speed of 100 km/h. If the rain is falling at 6 m/s in the direction shown, determine the velocity of the rain as seen by the driver.



Prob. 12–219

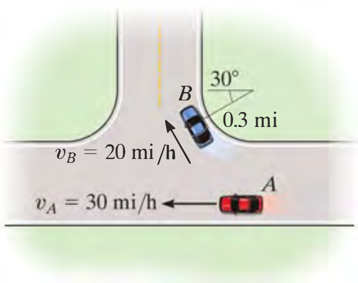
***12–220.** The man can row the boat in still water with a speed of 5 m/s. If the river is flowing at 2 m/s, determine the speed of the boat and the angle θ he must direct the boat so that it travels from A to B.



Prob. 12–220

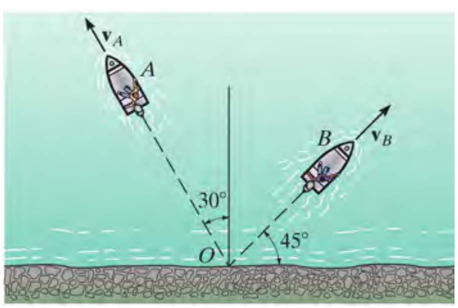
•**12–221.** At the instant shown, cars A and B travel at speeds of 30 mi/h and 20 mi/h, respectively. If B is increasing its speed by 1200 mi/h^2, while A maintains a constant speed, determine the velocity and acceleration of B with respect to A.

12–222. At the instant shown, cars A and B travel at speeds of 30 m/h and 20 mi/h, respectively. If A is increasing its speed at 400 mi/h^2 whereas the speed of B is decreasing at 800 mi/h^2, determine the velocity and acceleration of B with respect to A.



Probs. 12–221/222

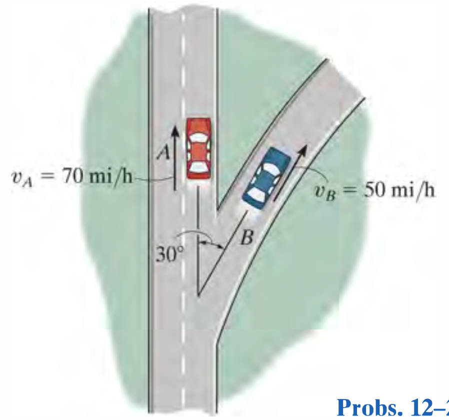
12–223. Two boats leave the shore at the same time and travel in the directions shown. If $v_A = 20$ ft/s and $v_B = 15$ ft/s, determine the velocity of boat A with respect to boat B. How long after leaving the shore will the boats be 800 ft apart?



Prob. 12–223

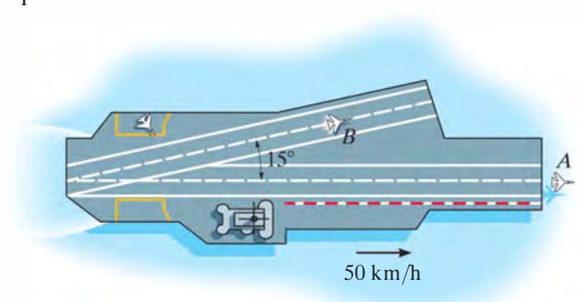
*__12–224.__ At the instant shown, cars A and B travel at speeds of 70 mi/h and 50 mi/h, respectively. If B is increasing its speed by 1100 mi/h^2, while A maintains a constant speed, determine the velocity and acceleration of B with respect to A. Car B moves along a curve having a radius of curvature of 0.7 mi.

•**12–225.** At the instant shown, cars A and B travel at speeds of 70 mi/h and 50 mi/h, respectively. If B is decreasing its speed at 1400 mi/h^2 while A is increasing its speed at 800 mi/h^2, determine the acceleration of B with respect to A. Car B moves along a curve having a radius of curvature of 0.7 mi.



Probs. 12–224/225

12–226. An aircraft carrier is traveling forward with a velocity of 50 km/h. At the instant shown, the plane at A has just taken off and has attained a forward horizontal air speed of 200 km/h, measured from still water. If the plane at B is traveling along the runway of the carrier at 175 km/h in the direction shown, determine the velocity of A with respect to B.

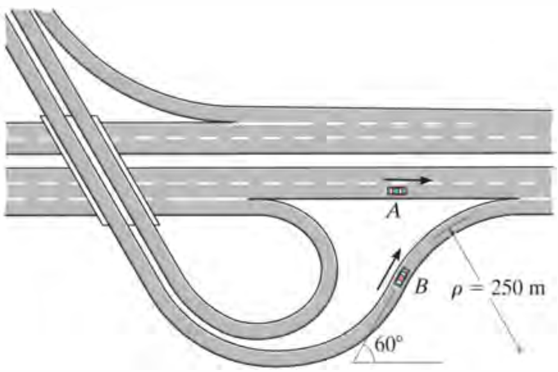


Prob. 12–226

12–227. A car is traveling north along a straight road at 50 km/h. An instrument in the car indicates that the wind is directed towards the east. If the car's speed is 80 km/h, the instrument indicates that the wind is directed towards the north-east. Determine the speed and direction of the wind.

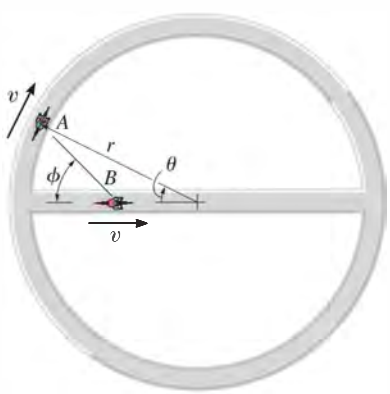
12

*12–228. At the instant shown car A is traveling with a velocity of 30 m/s and has an acceleration of 2 m/s^2 along the highway. At the same instant B is traveling on the trumpet interchange curve with a speed of 15 m/s, which is decreasing at 0.8 m/s^2. Determine the relative velocity and relative acceleration of B with respect to A at this instant.



Prob. 12–228

•12–229. Two cyclists A and B travel at the same constant speed v. Determine the velocity of A with respect to B if A travels along the circular track, while B travels along the diameter of the circle.

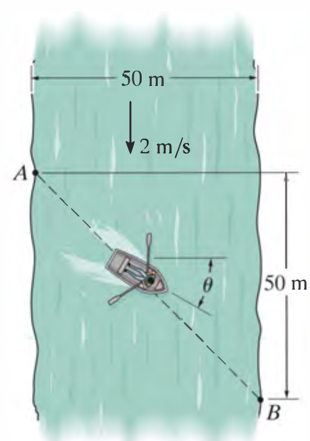


Prob. 12–229

12–230. A man walks at 5 km/h in the direction of a 20-km/h wind. If raindrops fall vertically at 7 km/h in *still air*, determine the direction in which the drops appear to fall with respect to the man. Assume the horizontal speed of the raindrops is equal to that of the wind.

Prob. 12–230

12–231. A man can row a boat at 5 m/s in still water. He wishes to cross a 50-m-wide river to point B, 50 m downstream. If the river flows with a velocity of 2 m/s, determine the speed of the boat and the time needed to make the crossing.



Prob. 12–231