12. You tie a cricket ball to a string and hang it from a tall pole. The ball is then struck with a cricket bat. Ignoring the mass of the string, what should be the direction of the acceleration if it attains a constant speed along a circular path centering the pole? Which force is responsible for this acceleration?
13. FIGURE Q4.13 shows three points on a steadily rotating wheel.
    a. Rank in order, from largest to smallest, the angular velocities ω_1, ω_2, and ω_3 of these points. Explain.
    b. Rank in order, from largest to smallest, the speeds v_1, v_2, and v_3 of these points. Explain.

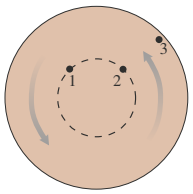


FIGURE Q4.13

14. FIGURE Q4.14 shows four rotating wheels. For each, determine the signs (+ or −) of ω and α.

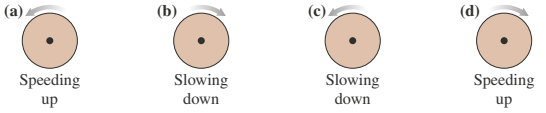


FIGURE Q4.14

15. FIGURE Q4.15 shows a pendulum at one end point of its arc.
    a. At this point, is ω positive, negative, or zero? Explain.
    b. At this point, is α positive, negative, or zero? Explain.

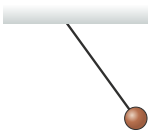


FIGURE Q4.15

EXERCISES AND PROBLEMS

Exercises

Section 4.1 Motion in Two Dimensions

Problems 1 and 2 show a partial motion diagram. For each:
a. Complete the motion diagram by adding acceleration vectors.
b. Write a physics *problem* for which this is the correct motion diagram. Be imaginative! Don't forget to include enough information to make the problem complete and to state clearly what is to be found.

1. |

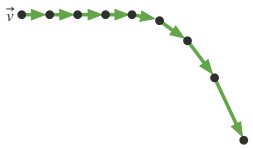


FIGURE EX4.1

2. |

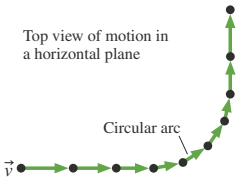
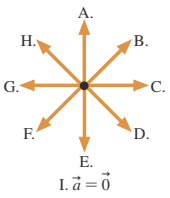


FIGURE EX4.2

Answer Problems 3 through 5 by choosing one of the eight labeled acceleration vectors or selecting option I: $\vec{a} = \vec{0}$.



3. || At this instant, the particle has steady speed and is curving to the right. What is the direction of its acceleration?

FIGURE EX4.3

4. || At this instant, the particle is speeding up and curving upward. What is the direction of its acceleration?

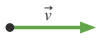


FIGURE EX4.4

5. || At this instant, the particle is speeding up and curving downward. What is the direction of its acceleration?

FIGURE EX4.5

6. || A rocket-powered hockey puck moves on a horizontal frictionless table. FIGURE EX4.6 shows graphs of v_x and v_y, the x- and y-components of the puck's velocity. The puck starts at the origin.
    a. In which direction is the puck moving at $t = 2$ s? Give your answer as an angle from the x-axis.
    b. How far from the origin is the puck at $t = 5$ s?

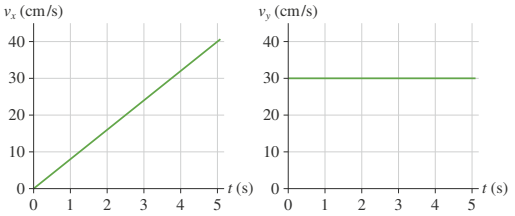


FIGURE EX4.6

7. || A rocket-powered hockey puck moves on a horizontal frictionless table. FIGURE EX4.7 shows graphs of v_x and v_y, the x- and y-components of the puck's velocity. The puck starts at the origin. What is the magnitude of the puck's acceleration at $t = 5$ s?

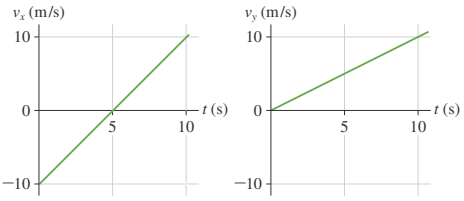


FIGURE EX4.7

8. || CALC A particle's trajectory is described by $x = \left(\frac{1}{2}t^3 - 2t^2\right)$ m and $y = \left(\frac{1}{2}t^2 - 2t\right)$ m, where t is in s.
   a. What are the particle's position and speed at $t = 0$ s and $t = 4$ s?
   b. What is the particle's direction of motion, measured as an angle from the x-axis, at $t = 0$ s and $t = 4$ s?
9. | CALC A particle moving in the xy-plane has velocity $\vec{v} = (2t\hat{i} + (3 - t^2)\hat{j})$ m/s, where t is in s. What is the particle's acceleration vector at $t = 4$ s?
10. || CALC You have a remote-controlled car that has been programmed to have velocity $\vec{v} = (-3t\hat{i} + 2t^2\hat{j})$ m/s, where t is in s. At $t = 0$ s, the car is at $\vec{r}_0 = (3.0\hat{i} + 2.0\hat{j})$ m. What are the car's (a) position vector and (b) acceleration vector at $t = 2.0$ s?

Section 4.2 Projectile Motion

11. || A ball thrown horizontally at 20 m/s travels a horizontal distance of 40 m before hitting the ground. From what height was the ball thrown?
12. | A physics student on Planet Exidor throws a ball, and it follows the parabolic trajectory shown in FIGURE EX4.12. The ball's position is shown at 1 s intervals until $t = 3$ s. At $t = 1$ s, the ball's velocity is $\vec{v} = (2.0\,\hat{i} + 2.0\,\hat{j})$ m/s.
   a. Determine the ball's velocity at $t = 0$ s, 2 s, and 3 s.
   b. What is the value of g on Planet Exidor?
   c. What was the ball's launch angle?

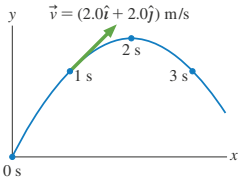


FIGURE EX4.12

13. || A supply plane needs to drop a package of food to scientists working on a glacier in Greenland. The plane flies 80 m above the glacier at a speed of 100 m/s. How far short of the target should it drop the package?
14. || A rifle is aimed horizontally at a target 50 m away. The bullet hits 2 cm below the target.
   a. What was the bullet's flight time?
   b. What was the bullet's speed as it left the barrel?
15. || In the Olympic shotput event, an athlete throws the shot with an initial speed of 12.0 m/s at a 40.0° angle from the horizontal. The shot leaves her hand at a height of 1.80 m above the ground. How far does the shot travel?
16. || On the Apollo 14 mission to the moon, astronaut Alan Shepard hit a golf ball with a 6 iron. The free-fall acceleration on the moon is 1/6 of its value on earth. Suppose he hit the ball with a speed of 25 m/s at an angle 30° above the horizontal.
   a. How much farther did the ball travel on the moon than it would have on earth?
   b. For how much more time was the ball in flight?
17. ||| A friend of yours is a baseball player and wants to determine his pitching speed. You have him stand on a ledge and throw the ball horizontally from an elevation of 6 m above the ground. The ball lands 40 m away. What is his pitching speed?

Section 4.3 Relative Motion

18. || A boat takes 2 hours to travel 20 km down a river, and 4 hours to return. How fast is the river flowing?
19. || When the moving sidewalk at the airport is broken, as it often seems to be, it takes you 50 s to walk from your gate to baggage claim. When it is working and you stand on the moving sidewalk the entire way, without walking, it takes 75 s to travel the same distance. How long will it take you to travel from the gate to baggage claim if you walk while riding on the moving sidewalk?
20. | Mary needs to row her boat across a river 100 m wide that is flowing to the east at a speed of 2 m/s. Mary can row with a speed of 4 m/s.
   a. If Mary points her boat due north, how far will she be from her intended landing spot when she reaches the opposite shore?
   b. What is her speed with respect to the shore?
21. | A kayaker needs to paddle north across an 80-m-wide harbor. The tide is going out, creating a current that flows to the east at 3 m/s. The kayaker can paddle with a speed of 4 m/s.
   a. In which direction should he paddle in order to travel straight across the harbor?
   b. How long will it take him to cross the harbor?
22. || Susan, driving north at 60 mph, and Trent, driving east at 45 mph, are approaching an intersection. What is Trent's speed relative to Susan's reference frame?

Section 4.4 Uniform Circular Motion

23. || FIGURE EX4.23 shows the angular-velocity-versus-time graph for a particle moving in a circle. How many revolutions does the object make during the first 4 s?

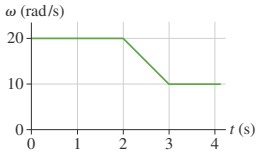


FIGURE EX4.23

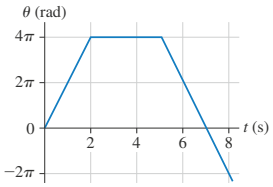


FIGURE EX4.24

24. | FIGURE EX4.24 shows the angular-position-versus-time graph for a particle moving in a circle. What is the particle's angular velocity at (a) $t = 1$ s, (b) $t = 4$ s, and (c) $t = 7$ s?
25. || FIGURE EX4.25 shows the angular-velocity-versus-time graph for a particle moving in a circle, starting from $\theta_0 = 0$ rad at $t = 0$ s. Draw the angular-position-versus-time graph. Include an appropriate scale on both axes.

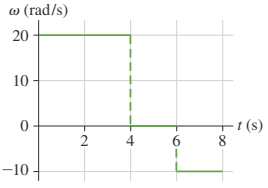


FIGURE EX4.25

26. || The earth's radius is about 4000 miles. Kampala, the capital of Uganda, and Singapore are both nearly on the equator. The distance between them is 5000 miles. The flight from Kampala to Singapore takes 9.0 hours. What is the plane's angular velocity with respect to the earth's surface? Give your answer in °/h.
27. | An old-fashioned single-play vinyl record rotates on a turntable at 72 rotations per minute.
   a. What is the angular velocity in rad/s?
   b. What is the period of the motion?

28. || As the earth rotates, what is the speed of (a) a physics student in Miami, Florida, at latitude 26°, and (b) a physics student in Fairbanks, Alaska, at latitude 65°? Ignore the revolution of the earth around the sun. The radius of the earth is 6400 km.
29. | How fast must a plane fly along the earth's equator so that the sun stands still relative to the passengers? In which direction must the plane fly, east to west or west to east? Give your answer in both km/h and mph. The earth's radius is 6400 km.
30. || A mountain 3200 m high is located on the equator. How much faster does a mountaineer at the peak move because of the earth's rotation relative to a sunbather at a nearby beach? The earth's radius is 6400 km.

Section 4.5 Centripetal Acceleration

31. | BIO Peregrine falcons are known for their maneuvering ability. In a tight circular turn, a falcon can attain a centripetal acceleration 1.5 times the free-fall acceleration. What is the radius of the turn if the falcon is flying at 25 m/s?
32. | BIO To withstand "g-forces" of up to 10 g's, caused by suddenly pulling out of a steep dive, fighter jet pilots train on a "human centrifuge." 10 g's is an acceleration of 98 m/s^2. If the length of the centrifuge arm is 12 m, at what speed is the rider moving when she experiences 10 g's?
33. || The radius of the earth's very nearly circular orbit around the sun is 1.5×10^{11} m. Find the magnitude of the earth's (a) velocity, (b) angular velocity, and (c) centripetal acceleration as it travels around the sun. Assume a year of 365 days.
34. || A speck of dust on a spinning DVD has a centripetal acceleration of 20 m/s^2.
    a. What is the acceleration of a different speck of dust that is twice as far from the center of the disk?
    b. What would be the acceleration of the first speck of dust if the disk's angular velocity was doubled?
35. || Your roommate is working on his bicycle and has the bike upside down. He spins the 60-cm-diameter wheel, and you notice that a pebble stuck in the tread goes by three times every second. What are the pebble's speed and acceleration?

Section 4.6 Nonuniform Circular Motion

36. | FIGURE EX4.36 shows the angular velocity graph of the crankshaft in a car. What is the crankshaft's angular acceleration at (a) $t = 1$ s, (b) $t = 3$ s, and (c) $t = 5$ s?

FIGURE EX4.36

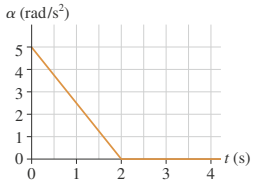


FIGURE EX4.37

37. || FIGURE EX4.37 shows the angular acceleration graph of a turntable that starts from rest. What is the turntable's angular velocity at (a) $t = 1$ s, (b) $t = 2$ s, and (c) $t = 3$ s?
38. || FIGURE EX4.38 shows the angular-velocity-versus-time graph for a particle moving in a circle. How many revolutions does the object make during the first 4 s?

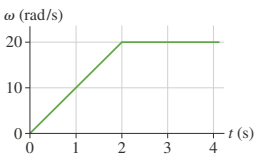


FIGURE EX4.38

39. || A wheel initially rotating at 60 rpm experiences the angular acceleration shown in FIGURE EX4.39. What is the wheel's angular velocity, in rpm, at $t = 3.0$ s?

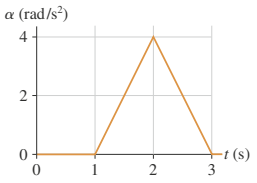


FIGURE EX4.39

40. || A 5.0-m-diameter merry-go-round is initially turning with a 4.0 s period. It slows down and stops in 20 s.
    a. Before slowing, what is the speed of a child on the rim?
    b. How many revolutions does the merry-go-round make as it stops?
41. || An electric fan goes from rest to 1800 rpm in 4.0 s. What is its angular acceleration?
42. || A bicycle wheel is rotating at 50 rpm when the cyclist begins to pedal harder, giving the wheel a constant angular acceleration of 0.50 rad/s^2.
    a. What is the wheel's angular velocity, in rpm, 10 s later?
    b. How many revolutions does the wheel make during this time?
43. || Starting from rest, a DVD steadily accelerates to 500 rpm in 1.0 s, rotates at this angular speed for 3.0 s, then steadily decelerates to a halt in 2.0 s. How many revolutions does it make?

Problems

44. ||| A spaceship maneuvering near Planet Zeta is located at $\vec{r} = (600\hat{\imath} - 400\hat{\jmath} + 200\hat{k}) \times 10^3$ km, relative to the planet, and traveling at $\vec{v} = 9500\hat{\imath}$ m/s. It turns on its thruster engine and accelerates with $\vec{a} = (40\hat{\imath} - 20\hat{k})$ m/s^2 for 35 min. What is the spaceship's position when the engine shuts off? Give your answer as a position vector measured in km.
45. ||| CALC A particle moving in the xy-plane has velocity $\vec{v}_0 = v_{0x}\hat{\imath} + v_{0y}\hat{\jmath}$ at $t = 0$. It undergoes acceleration $\vec{a} = bt\hat{\imath} - cv_y\hat{\jmath}$, where b and c are constants. Find an expression for the particle's velocity at a later time t.
46. || A projectile's horizontal range over level ground is $v_0^2 \sin 2\theta/g$. At what launch angle or angles will the projectile land at half of its maximum possible range?
47. || a. A projectile is launched with speed v_0 and angle θ. Derive an expression for the projectile's maximum height h.
    b. A baseball is hit with a speed of 33.6 m/s. Calculate its height and the distance traveled if it is hit at angles of 30.0°, 45.0°, and 60.0°.
48. ||| CALC A projectile is launched from ground level at angle θ and speed v_0 into a headwind that causes a constant horizontal acceleration of magnitude a opposite the direction of motion.
    a. Find an expression in terms of a and g for the launch angle that gives maximum range.
    b. What is the angle for maximum range if a is 10% of g?
49. ||| BIO A gray kangaroo can bound across level ground with each jump carrying it 10 m from the takeoff point. Typically the kangaroo leaves the ground at a 20° angle. If this is so:
    a. What is its takeoff speed?
    b. What is its maximum height above the ground?
50. || A ball is thrown toward a cliff of height h with a speed of 30 m/s and an angle of 60° above horizontal. It lands on the edge of the cliff 4.0 s later.
    a. How high is the cliff?
    b. What was the maximum height of the ball?
    c. What is the ball's impact speed?

51. || A tennis player hits a ball 2.0 m above the ground. The ball leaves his racquet with a speed of 20.0 m/s at an angle 5.0° above the horizontal. The horizontal distance to the net is 7.0 m, and the net is 1.0 m high. Does the ball clear the net? If so, by how much? If not, by how much does it miss?
52. || You are target shooting using a toy gun that fires a small ball at a speed of 15 m/s. When the gun is fired at an angle of 30° above horizontal, the ball hits the bull's-eye of a target at the same height as the gun. Then the target distance is halved. At what angle must you aim the gun to hit the bull's-eye in its new position? (Mathematically there are two solutions to this problem; the physically reasonable answer is the smaller of the two.)
53. || A 35 g steel ball is held by a ceiling-mounted electromagnet 3.5 m above the floor. A compressed-air cannon sits on the floor, 4.0 m to one side of the point directly under the ball. When a button is pressed, the ball drops and, simultaneously, the cannon fires a 25 g plastic ball. The two balls collide 1.0 m above the floor. What was the launch speed of the plastic ball?
54. || You are watching an archery tournament when you start wondering how fast an arrow is shot from the bow. Remembering your physics, you ask one of the archers to shoot an arrow parallel to the ground. You find the arrow stuck in the ground 60 m away, making a 3.0° angle with the ground. How fast was the arrow shot?
55. || You're 6.0 m from one wall of the house seen in **FIGURE P4.55**. You want to toss a ball to your friend who is 6.0 m from the opposite wall. The throw and catch each occur 1.0 m above the ground.
    a. What minimum speed will allow the ball to clear the roof?
    b. At what angle should you toss the ball?

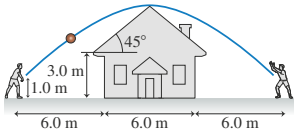


FIGURE P4.55

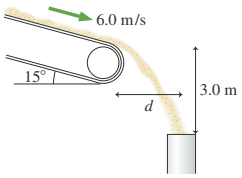


FIGURE P4.56

56. || Sand moves without slipping at 6.0 m/s down a conveyer that is tilted at 15°. The sand enters a pipe 3.0 m below the end of the conveyer belt, as shown in **FIGURE P4.56**. What is the horizontal distance d between the conveyer belt and the pipe?
57. || A stunt man drives a car at a speed of 20 m/s off a 30-m-high cliff. The road leading to the cliff is inclined upward at an angle of 20°.
    a. How far from the base of the cliff does the car land?
    b. What is the car's impact speed?
58. ||| BIO A javelin thrower standing at rest holds the center of the javelin behind her head, then accelerates it through a distance of 70 cm as she throws. She releases the javelin 2.0 m above the ground traveling at an angle of 30° above the horizontal. Top-rated javelin throwers do throw at about a 30° angle, not the 45° you might have expected, because the biomechanics of the arm allow them to throw the javelin much faster at 30° than they would be able to at 45°. In this throw, the javelin hits the ground 62 m away. What was the acceleration of the javelin during the throw? Assume that it has a constant acceleration.
59. || A rubber ball is dropped onto a ramp that is tilted at 20°, as shown in **FIGURE P4.59**. A bouncing ball obeys the "law of reflection," which says that the ball leaves the surface at the same angle it approached the surface. The ball's next bounce is 3.0 m to the right of its first bounce. What is the ball's rebound speed on its first bounce?

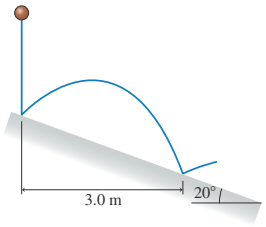


FIGURE P4.59

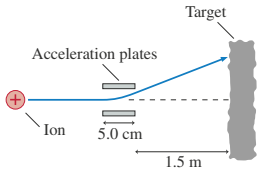


FIGURE P4.60

60. ||| BIO You are asked to consult for the city's research hospital, where a group of doctors is investigating the bombardment of cancer tumors with high-energy ions. As **FIGURE P4.60** shows, ions are fired directly toward the center of the tumor at speeds of 5.0×10^6 m/s. To cover the entire tumor area, the ions are deflected sideways by passing them between two charged metal plates that accelerate the ions perpendicular to the direction of their initial motion. The acceleration region is 5.0 cm long, and the ends of the acceleration plates are 1.5 m from the target. What sideways acceleration is required to deflect an ion 2.0 cm to one side?
61. || Ships A and B leave port together. For the next two hours, ship A travels at 20 mph in a direction 30° west of north while ship B travels 20° east of north at 25 mph.
    a. What is the distance between the two ships two hours after they depart?
    b. What is the speed of ship A as seen by ship B?
62. || While driving north at 25 m/s during a rainstorm you notice that the rain makes an angle of 38° with the vertical. While driving back home moments later at the same speed but in the opposite direction, you see that the rain is falling straight down. From these observations, determine the speed and angle of the raindrops relative to the ground.
63. || You've been assigned the task of using a shaft encoder—a device that measures the angle of a shaft or axle and provides a signal to a computer—to analyze the rotation of an engine crankshaft under certain conditions. The table lists the crankshaft's angles over a 0.6 s interval.

Time (s)	Angle (rad)
0.0	0.0
0.1	2.0
0.2	3.2
0.3	4.3
0.4	5.3
0.5	6.1
0.6	7.0

Is the crankshaft rotating with uniform circular motion? If so, what is its angular velocity in rpm? If not, is the angular acceleration positive or negative?

64. || A circular track has several concentric rings where people can run at their leisure. Phil runs on the outermost track with radius r_P while Annie runs on an inner track with radius $r_A = 0.80r_P$. The runners start side by side, along a radial line, and run at the same speed in a counterclockwise direction. How many revolutions has Annie made when Annie's and Phil's velocity vectors point in opposite directions for the first time?

65. ||| A typical laboratory centrifuge rotates at 4000 rpm. Test tubes have to be placed into a centrifuge very carefully because of the very large accelerations.
    a. What is the acceleration at the end of a test tube that is 10 cm from the axis of rotation?
    b. For comparison, what is the magnitude of the acceleration a test tube would experience if dropped from a height of 1.0 m and stopped in a 1.0-ms-long encounter with a hard floor?
66. || BIO Astronauts use a centrifuge to simulate the acceleration of a rocket launch. The centrifuge takes 30 s to speed up from rest to its top speed of 1 rotation every 1.3 s. The astronaut is strapped into a seat 6.0 m from the axis.
    a. What is the astronaut's tangential acceleration during the first 30 s?
    b. How many g's of acceleration does the astronaut experience when the device is rotating at top speed? Each 9.8 m/s^2 of acceleration is 1 g.
67. || Communications satellites are placed in a circular orbit where they stay directly over a fixed point on the equator as the earth rotates. These are called *geosynchronous orbits*. The radius of the earth is 6.37×10^6 m, and the altitude of a geosynchronous orbit is 3.58×10^7 m ($\approx$22,000 miles). What are (a) the speed and (b) the magnitude of the acceleration of a satellite in a geosynchronous orbit?
68. || A computer hard disk 8.0 cm in diameter is initially at rest. A small dot is painted on the edge of the disk. The disk accelerates at 600 rad/s^2 for $\frac{1}{2}$s, then coasts at a steady angular velocity for another $\frac{1}{2}$s.
    a. What is the speed of the dot at $t = 1.0$ s?
    b. Through how many revolutions has the disk turned?
69. || A high-speed drill rotating ccw at 2400 rpm comes to a halt in 2.5 s.
    a. What is the magnitude of the drill's angular acceleration?
    b. How many revolutions does it make as it stops?
70. || A turbine is spinning at 3800 rpm. Friction in the bearings is so low that it takes 10 min to coast to a stop. How many revolutions does the turbine make while stopping?
71. || Your 64-cm-diameter car tire is rotating at 3.5 rev/s when suddenly you press down hard on the accelerator. After traveling 200 m, the tire's rotation has increased to 6.0 rev/s. What was the tire's angular acceleration? Give your answer in rad/s^2.
72. || CALC The angular velocity of a process control motor is $\omega = \left(20 - \frac{1}{2}t^2\right)$ rad/s, where t is in seconds.
    a. At what time does the motor reverse direction?
    b. Through what angle does the motor turn between $t = 0$ s and the instant at which it reverses direction?
73. || A Ferris wheel of radius R speeds up with angular acceleration α starting from rest. Find an expression for the (a) velocity and (b) centripetal acceleration of a rider after the Ferris wheel has rotated through angle $\Delta\theta$.
74. || CALC A 6.0-cm-diameter gear rotates with angular velocity $\omega = \left(2.0 + \frac{1}{2}t^2\right)$ rad/s, where t is in seconds. At $t = 4.0$ s, what are:
    a. The gear's angular acceleration?
    b. The tangential acceleration of a tooth on the gear?
75. || CALC A painted tooth on a spinning gear has angular acceleration $\alpha = (20 - t)$ rad/s^2, where t is in s. Its initial angular velocity, at $t = 0$ s, is 300 rpm. What is the tooth's angular velocity in rpm at $t = 20$ s?
76. ||| A car starts from rest on a curve with a radius of 120 m and accelerates tangentially at 1.0 m/s^2. Through what angle will the car have traveled when the magnitude of its total acceleration is 2.0 m/s^2?
77. ||| A long string is wrapped around a 6.0-cm-diameter cylinder, initially at rest, that is free to rotate on an axle. The string is then pulled with a constant acceleration of 1.5 m/s^2 until 1.0 m of string has been unwound. If the string unwinds without slipping, what is the cylinder's angular speed, in rpm, at this time?

In Problems 78 through 80 you are given the equations that are used to solve a problem. For each of these, you are to
a. Write a realistic problem for which these are the correct equations. Be sure that the answer your problem requests is consistent with the equations given.
b. Finish the solution of the problem, including a pictorial representation.

78. $100 \text{ m} = 0 \text{ m} + (50\cos\theta \text{ m/s})t_1$
    $0 \text{ m} = 0 \text{ m} + (50\sin\theta \text{ m/s})t_1 - \frac{1}{2}(9.80 \text{ m/s}^2){t_1}^2$
79. $v_x = -(6.0\cos 45°) \text{ m/s} + 3.0 \text{ m/s}$
    $v_y = (6.0 \sin 45°) \text{ m/s} + 0 \text{ m/s}$
    $100 \text{ m} = v_y t_1, x_1 = v_x t_1$
80. $2.5 \text{ rad} = 0 \text{ rad} + \omega_i(10 \text{ s}) + \left((1.5 \text{ m/s}^2)/2(50 \text{ m})\right)(10 \text{ s})^2$
    $\omega_f = \omega_i + \left((1.5 \text{ m/s}^2)/(50 \text{ m})\right)(10 \text{ s})$

Challenge Problems

81. ||| In one contest at the county fair, seen in FIGURE CP4.81, a spring-loaded plunger launches a ball at a speed of 3.0 m/s from one corner of a smooth, flat board that is tilted up at a 20° angle. To win, you must make the ball hit a small target at the adjacent corner, 2.50 m away. At what angle θ should you tilt the ball launcher?

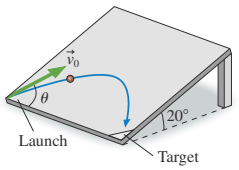


FIGURE CP4.81

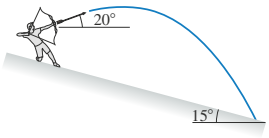


FIGURE CP4.82

82. ||| An archer standing on a 15° slope shoots an arrow 20° above the horizontal, as shown in FIGURE CP4.82. How far down the slope does the arrow hit if it is shot with a speed of 50 m/s from 1.75 m above the ground?
83. ||| A skateboarder starts up a 1.0-m-high, 30° ramp at a speed of 7.0 m/s. The skateboard wheels roll without friction. At the top she leaves the ramp and sails through the air. How far from the end of the ramp does the skateboarder touch down?
84. ||| CALC A cannon on a train car fires a projectile to the right with speed v_0, relative to the train, from a barrel elevated at angle θ. The cannon fires just as the train, which had been cruising to the right along a level track with speed v_{train}, begins to accelerate with acceleration a, which can be either positive (speeding up) or negative (slowing down). Find an expression for the angle at which the projectile should be fired so that it lands as far as possible from the cannon. You can ignore the small height of the cannon above the track.
85. ||| A child in danger of drowning in a river is being carried downstream by a current that flows uniformly with a speed of 2.0 m/s. The child is 200 m from the shore and 1500 m upstream of the boat dock from which the rescue team sets out. If their boat speed is 8.0 m/s with respect to the water, at what angle from the shore should the pilot leave the shore to go directly to the child?