EXERCISES AND PROBLEMS

Exercises

Section 2.1 Uniform Motion

1. ‖ Alan leaves Los Angeles at 9:00 a.m. to drive to San Francisco, 400 miles away. He travels at a steady speed of 55 mph. Beth leaves Los Angeles at 9:30 a.m. and drives at a steady speed of 60 mph.
   a. Who gets to San Francisco first?
   b. How long does the first person to reach have to wait for the second to arrive?

2. ‖ Julie drives 120 miles to her grandmother's house. She covers half the distance at 40 mph and the other half at 60 mph. On her return trip, she drives half the time at 40 mph and the rest at 60 mph.
   a. What is Julie's average speed on the way to her grandmother's house?
   b. What is her average speed on the return trip?

3. ‖ Larry leaves home at 9:05 and runs at constant speed to the lamppost seen in **FIGURE EX2.3**. He reaches the lamppost at 9:07, immediately turns, and runs to the tree. Larry arrives at the tree at 9:10.
   a. What is Larry's average velocity, in m/min, during each of these two intervals?
   b. What is Larry's average velocity for the entire run?
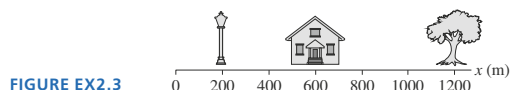
FIGURE EX2.3

4. ‖ **FIGURE EX2.4** is the position-versus-time graph of a jogger. What is the jogger's velocity at $t = 10$ s, at $t = 25$ s, and at $t = 35$ s?
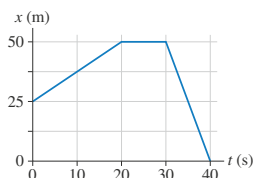
FIGURE EX2.4

Section 2.2 Instantaneous Velocity

Section 2.3 Finding Position from Velocity

5. ‖ **FIGURE EX2.5** shows the position graph of a particle.
   a. Draw the particle's velocity graph for the interval 0 s $\leq t \leq 4$ s.
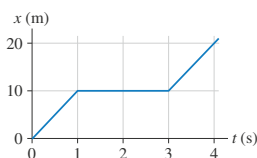   b. Does this particle have a turning point or points? If so, at what time or times?
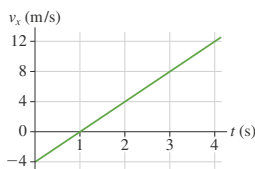
FIGURE EX2.5

FIGURE EX2.6

6. ‖ A particle starts from $x_0 = 10$ m at $t_0 = 0$ s and moves with the velocity graph shown in **FIGURE EX2.6**.
   a. Does this particle have a turning point? If so, at what time?
   b. What is the object's position at $t = 2$ s and 4 s?

7. ‖ **FIGURE EX2.7** is a somewhat idealized graph of the velocity of BIO blood in the ascending aorta during one beat of the heart. Approximately how far, in cm, does the blood move during one beat?
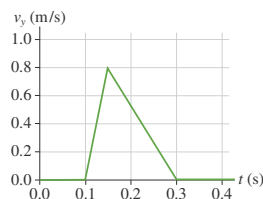
FIGURE EX2.7

8. ‖ **FIGURE EX2.8** shows the velocity graph for a particle having initial position $x_0 = 0$ m at $t_0 = 0$ s. At what time or times is the particle found at $x = 35$ m?
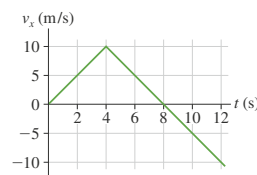
FIGURE EX2.8

Section 2.4 Motion with Constant Acceleration

9. ‖ **FIGURE EX2.9** shows the velocity graph of a particle. Draw the particle's acceleration graph for the interval 0 s $\leq t \leq 4$ s.
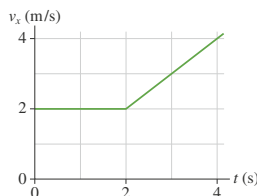
FIGURE EX2.9

10. ‖ **FIGURE EX2.7** showed the velocity graph of blood in the aorta. BIO What is the blood's acceleration during each phase of the motion, speeding up and slowing down?

11. ‖ **FIGURE EX2.11** shows the velocity graph of a particle moving along the x-axis. Its initial position is $x_0 = 2.0$ m at $t_0 = 0$ s. At $t = 2.0$ s, what are the particle's (a) position, (b) velocity, and (c) acceleration?
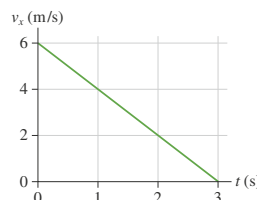
FIGURE EX2.11

12. ‖ **FIGURE EX2.12** shows the velocity-versus-time graph for a particle moving along the *x*-axis. Its initial position is $x_0 = 2.0$ m at $t_0 = 0$ s.
    a. What are the particle's position, velocity, and acceleration at $t = 1.0$ s?
    b. What are the particle's position, velocity, and acceleration at $t = 3.0$ s?
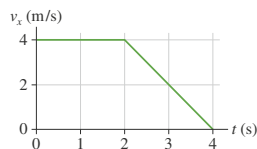

FIGURE EX2.12

13. ‖ a. What constant acceleration, in SI units, must a car have to go from zero to 60 mph in 10 s?
    b. How far has the car traveled when it reaches 60 mph? Give your answer both in SI units and in feet.

14. ‖ A jet plane is cruising at 280 m/s when suddenly the pilot turns the engines to full throttle. After traveling 4 km, the jet moves at a speed of 380 m/s. What is the jet's acceleration, assuming it to be a constant acceleration?

15. ‖ a. How many days will it take a spaceship to accelerate to the speed of light $(3.0 \times 10^8$ m/s) with the acceleration g?
    b. How far will it travel during this interval?
    c. What fraction of a light year is your answer to part b? A light year is the distance light travels in one year.

    | **NOTE** We know, from Einstein's theory of relativity, that no object can travel at the speed of light. So this problem, while interesting and instructive, is not realistic.

16. ‖ When you sneeze, the air in your lungs accelerates from rest
    BIO to 175 km/h in approximately 0.6 s. What is the acceleration of the air in m/s²?

17. ‖ A speed skater moving across frictionless ice at 8 m/s hits a 10-m-wide patch of rough ice. She then slows down steadily, and continues at 5 m/s. What is her acceleration on the rough ice?

18. ‖ A Porsche challenges a Honda to a 400 m race. Because the Porsche's acceleration of 3.5 m/s² is larger than the Honda's 3.0 m/s², the Honda gets a 1.0 s head start. Who wins? By how many seconds?

19. ‖ A car starts from rest at a stop sign. It accelerates at 8 m/s² for 5 s coasts for 3 s and then slows down at the rate of 4 m/s² for the next stop sign. How far apart are the stop signs?

Section 2.5 Free Fall

20. | Ball bearings are made by letting spherical drops of molten metal fall inside a tall tower—called a "shot tower"—and solidify as they fall.
    a. If a bearing needs 5 s to solidify enough for impact, how high must the tower be?
    b. What is the bearing's impact velocity

21. ‖ A student standing on the ground throws a ball straight up. The ball leaves the student's hand with a speed of 15 m/s when the hand is 2.0 m above the ground. How long is the ball in the air before it hits the ground? (The student moves her hand out of the way.)

22. ‖ A rock is tossed straight up from ground level with a speed of 20 m/s. When it returns, it falls into a hole 10 m deep.
    a. What is the rock's velocity as it hits the bottom of the hole?
    b. How long is the rock in the air, from the instant it is released until it hits the bottom of the hole?

23. ‖ When jumping, a flea accelerates at an astounding 1000 m/s²,
    BIO but over only the very short distance of 0.50 mm. If a flea jumps straight up, and if air resistance is neglected (a rather poor approximation in this situation), how high does the flea go?

24. ‖ A science project involves dropping a watermelon from the Empire State Building to the sidewalk below from a height of 350 m. It so happens that Superman is flying by at the instant the watermelon is dropped. He is headed straight down at a speed of 40 m/s. How fast is the watermelon falling when it passes Superman?

25. ‖| A rock is dropped from the top of a tall building. Its displacement in the last second before it hits the ground is 45% of the entire distance it falls. How tall is the building?

Section 2.6 Motion on an Inclined Plane

26. ‖ A skier is gliding along at 3.0 m/s on horizontal, frictionless snow. He suddenly starts down a 10° incline. His speed at the bottom is 15 m/s.
    a. What is the length of the incline?
    b. How long does it take him to reach the bottom?

27. ‖ A car traveling at 30 m/s runs out of gas while traveling up a 10° slope. How far up the hill will it coast before starting to roll back down?

28. ‖ Santa loses his footing and slides down a frictionless, snowy roof that is tilted at an angle of 30°. If Santa slides 10 m before reaching the edge, what is his speed as he leaves the roof?

29. ‖ A snowboarder glides down a 50-m-long, 15° hill. She then glides horizontally for 10 m before reaching a 25° upward slope. Assume the snow is frictionless.
    a. What is her velocity at the bottom of the hill?
    b. How far can she travel up the 25° slope?

30. ‖ A small child gives a plastic frog a big push at the bottom of a slippery 2.0-m-long, 1.0-m-high ramp, starting it with a speed of 5.0 m/s. What is the frog's speed as it flies off the top of the ramp?

Section 2.7 Instantaneous Acceleration

31. ‖ **FIGURE EX2.31** shows the acceleration-versus-time graph of a particle moving along the *x*-axis. Its initial velocity is $v_{0x} = 8.0$ m/s at $t_0 = 0$ s. What is the particle's velocity at $t = 4.0$ s?
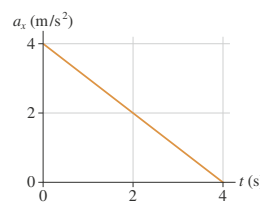
FIGURE EX2.31   **FIGURE EX2.32**

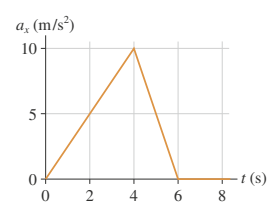32. ‖ **FIGURE EX2.32** shows the acceleration graph for a particle that starts from rest at $t = 0$ s. What is the particle's velocity at $t = 6$ s?

33. | A particle moving along the *x*-axis has its position described
    CALC by the function $x = (3.00t^3 - 3.00t + 5.00)$ m, where *t* is time (in seconds). At $t = 2.00$, what is
    a. the position of the particle;
    b. its velocity;
    c. its acceleration?

34. ‖ A particle moving along the x-axis has its velocity described
CALC by the function, $v_x = 2t^2$ m/s, where t is time (in seconds). Its
initial position is $x_0 = 1$ m at $t_0 = 0$ s. At $t = 1$ s, what is
   a. the position of the particle;
   b. its velocity;
   c. its acceleration?

35. ‖ The position of a particle is given by the function
CALC $x = (2t^3 - 9t^2 + 12)$ m, where t is in s.
   a. At what time or times is $v_x = 0$ m/s?
   b. What are the particle's position and its acceleration at this time(s)?

36. ‖ The position of a particle is given by the function
CALC $x = (2t^3 - 6t^2 + 12)$ m, where t is in s.
   a. At what time does the particle reach its minimum velocity?
      What is $(v_x)_{min}$?
   b. At what time is the acceleration zero?

Problems

37. ‖ Particles A, B, and C move along the x-axis. Particle C has
an initial velocity of 10 m/s. In FIGURE P2.37, the graph for A is a
position-versus-time graph; the graph for B is a velocity-versus-
time graph; the graph for C is an acceleration-versus-time graph.
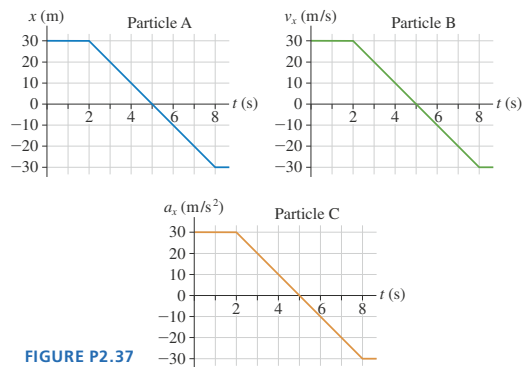Find each particle's velocity at $t = 7.0$ s.

FIGURE P2.37

38. ‖ A block is suspended from a spring, pulled down, and released.
The block's position-versus-time graph is shown in FIGURE P2.38.
   a. At what times is the velocity zero? At what times is the veloc-
      ity most positive? Most negative?
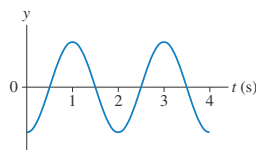   b. Draw a reasonable velocity-versus-time graph.

FIGURE P2.38

39. ‖ A particle's velocity is described by the function
CALC $v_x = (t^2 - 7t + 10)$ m/s, where t is in s.
   a. At what times does the particle reach its turning points?
   b. What is the particle's acceleration at each of the turning points?

40. ‖‖ A particle's velocity is described by the function $v_x = kt^2$ m/s,
CALC where k is a constant and t is in s. The particle's position at $t_0 = 0$ s
is $x_0 = -9.0$ m. At $t_1 = 3.0$ s, the particle is at $x_1 = 9.0$ m.
Determine the value of the constant k. Be sure to include the
proper units.

41. ‖ A particle's acceleration is described by the function
CALC $a_x = (10 - t)$ m/s^2, where t is in s. Its initial conditions are
$x_0 = 0$ m and $v_{0x} = 0$ m/s at $t = 0$ s.
   a. At what time is the velocity again zero?
   b. What is the particle's position at that time?

42. ‖ A particle's velocity is given by the function
CALC $v_x = (2.0 \text{ m/s})\sin(\pi t)$, where t is in s.
   a. What is the first time after $t = 0$ s when the particle reaches
      a turning point?
   b. What is the particle's acceleration at that time?

43. ‖ A ball rolls along the smooth track shown in FIGURE P2.43.
Each segment of the track is straight, and the ball passes smoothly
from one segment to the next without changing speed or leaving
the track. Draw three vertically stacked graphs showing posi-
tion, velocity, and acceleration versus time. Each graph should
have the same time axis, and the proportions of the graph should
be qualitatively correct. Assume that the ball has enough speed
to reach the top.

FIGURE P2.43

44. ‖ Draw position, velocity, and acceleration graphs for the ball
shown in FIGURE P2.44. See Problem 43 for more information.

FIGURE P2.44

45. ‖ FIGURE P2.45 shows a set of kinematic graphs for a ball rolling
on a track. All segments of the track are straight lines, but some
may be tilted. Draw a picture of the track and also indicate the
ball's initial condition.

FIGURE P2.45   FIGURE P2.46
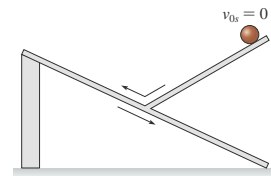
46. ‖ FIGURE P2.46 shows a set of kinematic graphs for a ball rolling
on a track. All segments of the track are straight lines, but some
may be tilted. Draw a picture of the track and also indicate the
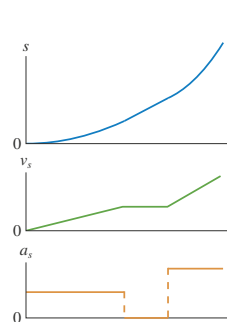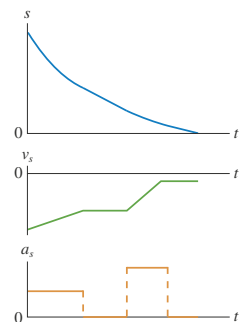ball's initial condition.

47. ‖ The takeoff speed for an Airbus A320 jetliner is 80 m/s. Velocity data measured during takeoff are as shown.

t (s)	v_x (m/s)
0	0
10	23
20	46
30	69

   a. Is the jetliner's acceleration constant during takeoff? Explain.
   b. At what time do the wheels leave the ground?
   c. For safety reasons, in case of an aborted takeoff, the runway must be three times the takeoff distance. Can an A320 take off safely on a 2.5-mi-long runway?

48. ‖ You are driving to the grocery store at 20 m/s. You are 110 m from an intersection when the traffic light turns red. Assume that your reaction time is 0.50 s and that your car brakes with constant acceleration. What magnitude braking acceleration will bring you to a stop exactly at the intersection?

49. ‖ You're driving down the highway late one night at 20 m/s when a deer steps onto the road 35 m in front of you. Your reaction time before stepping on the brakes is 0.50 s, and the maximum deceleration of your car is 10 m/s².
   a. How much distance is between you and the deer when you come to a stop?
   b. What is the maximum speed you could have and still not hit the deer?

50. ‖ Two cars are driving at the same constant speed on a straight road, with car 1 in front of car 2. Car 1 suddenly starts to brake with constant acceleration and stops in 10 m. At the instant car 1 comes to a stop, car 2 begins to brake with the same acceleration. It comes to a halt just as it reaches the back of car 1. What was the separation between the cars before they starting braking?

51. ‖ You are playing miniature golf at the golf course shown in **FIGURE P2.51**. Due to the fake plastic grass, the ball decelerates at 1.0 m/s² when rolling horizontally and at 6.0 m/s² on the slope. What is the slowest speed with which the ball can leave your golf club if you wish to make a hole in one?
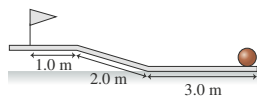

FIGURE P2.51

52. ‖ The minimum stopping distance for a car traveling at a speed of 30 m/s is 60 m, including the distance traveled during the driver's reaction time of 0.50 s. What is the minimum stopping distance for the same car traveling at a speed of 40 m/s?

53. ‖ A cheetah spots a Thomson's gazelle, its preferred prey, and
BIO leaps into action, quickly accelerating to its top speed of 30 m/s, the highest of any land animal. However, a cheetah can maintain this extreme speed for only 15 s before having to let up. The cheetah is 170 m from the gazelle as it reaches top speed, and the gazelle sees the cheetah at just this instant. With negligible reaction time, the gazelle heads directly away from the cheetah, accelerating at 4.6 m/s² for 5.0 s, then running at constant speed. Does the gazelle escape? If so, by what distance is the gazelle in front when the cheetah gives up?

54. ‖ You are at a train station, standing next to the train at the front of the first car. The train starts moving with constant acceleration, and 5.0 s later the back of the first car passes you. How long does it take after the train starts moving until the back of the seventh car passes you? All cars are the same length.

55. ‖‖ A 200 kg weather rocket is loaded with 100 kg of fuel and fired straight up. It accelerates upward at 30 m/s² for 30 s, then runs out of fuel. Ignore any air resistance effects.
   a. What is the rocket's maximum altitude?
   b. How long is the rocket in the air before hitting the ground?

56. ‖‖ A 1000 kg weather rocket is launched straight up. The rocket motor provides a constant acceleration for 16 s, then the motor stops. The rocket altitude 20 s after launch is 5100 m. You can ignore any effects of air resistance. What was the rocket's acceleration during the first 16 s?

57. ‖‖ A lead ball is dropped into a lake from a diving board 5.0 m above the water. After entering the water, it sinks to the bottom with a constant velocity equal to the velocity with which it hit the water. The ball reaches the bottom 3.0 s after it is released. How deep is the lake?

58. ‖ A hotel elevator ascends 200 m with a maximum speed of 5.0 m/s. Its acceleration and deceleration both have a magnitude of 1.0 m/s².
   a. How far does the elevator move while accelerating to full speed from rest?
   b. How long does it take to make the complete trip from bottom to top?

59. ‖ A basketball player can jump to a height of 55 cm. How far above the floor can he jump in an elevator that is descending at a constant 1.0 m/s?

60. ‖ You are 9.0 m from the door of your bus, behind the bus, when it pulls away with an acceleration of 1.0 m/s². You instantly start running toward the still-open door at 4.5 m/s.
   a. How long does it take for you to reach the open door and jump in?
   b. What is the maximum time you can wait before starting to run and still catch the bus?

61. ‖ Ann and Carol are driving their cars along the same straight road. Carol is located at $x = 2.4$ mi at $t = 0$ h and drives at a steady 36 mph. Ann, who is traveling in the same direction, is located at $x = 0.0$ mi at $t = 0.50$ h and drives at a steady 50 mph.
   a. At what time does Ann overtake Carol?
   b. What is their position at this instant?
   c. Draw a position-versus-time graph showing the motion of both Ann and Carol.

62. ‖ Amir starts riding his bike up a 200-m-long slope at a speed of 18 km/h, decelerating at 0.20 m/s² as he goes up. At the same instant, Becky starts down from the top at a speed of 6.0 km/h, accelerating at 0.40 m/s² as she goes down. How far has Amir ridden when they pass?

63. ‖ A very slippery block of ice slides down a smooth ramp tilted at angle θ. The ice is released from rest at vertical height h above the bottom of the ramp. Find an expression for the speed of the ice at the bottom.

64. ‖ Bob is driving the getaway car after the big bank robbery. He's going 50 m/s when his headlights suddenly reveal a nail strip that the cops have placed across the road 150 m in front of him. If Bob can stop in time, he can throw the car into reverse and escape. But if he crosses the nail strip, all his tires will go flat and he will be caught. Bob's reaction time before he can hit the brakes is 0.60 s, and his car's maximum deceleration is 10 m/s². Does Bob stop before or after the nail strip? By what distance?

65. ‖ One game at the amusement park has you push a puck up a long, frictionless ramp. You win a stuffed animal if the puck, at its highest point, comes to within 10 cm of the end of the ramp without going off. You give the puck a push, releasing it with a speed of 5.0 m/s when it is 8.5 m from the end of the ramp. The puck's speed after traveling 3.0 m is 4.0 m/s. How far is it from the end when it stops?

66. ‖ A motorist is driving at 20 m/s when she sees that a traffic light 200 m ahead has just turned red. She knows that this light stays red for 15 s, and she wants to reach the light just as it turns green again. It takes her 1.0 s to step on the brakes and begin slowing. What is her speed as she reaches the light at the instant it turns green?

67. ‖ Nicole throws a ball straight up. Chad watches the ball from a window 5.0 m above the point where Nicole released it. The ball passes Chad on the way up, and it has a speed of 10 m/s as it passes him on the way back down. How fast did Nicole throw the ball?

68. ‖ David is driving a steady 30 m/s when he passes Tina, who is sitting in her car at rest. Tina begins to accelerate at a steady 2.0 m/s^2 at the instant when David passes.
   a. How far does Tina drive before passing David?
   b. What is her speed as she passes him?

69. ‖ A cat is sleeping on the floor in the middle of a 3.0-m-wide room when a barking dog enters with a speed of 1.50 m/s. As the dog enters, the cat (as only cats can do) immediately accelerates at 0.85 m/s^2 toward an open window on the opposite side of the room. The dog (all bark and no bite) is a bit startled by the cat and begins to slow down at 0.10 m/s^2 as soon as it enters the room. How far is the cat in front of the dog as it leaps through the window?

70. ‖‖ Water drops fall from the edge of a roof at a steady rate. A fifth drop starts to fall just as the first drop hits the ground. At this instant, the second and third drops are exactly at the bottom and top edges of a 1.00-m-tall window. How high is the edge of the roof?

71. ‖‖ I was driving along at 20 m/s, trying to change a CD and not watching where I was going. When I looked up, I found myself 45 m from a railroad crossing. And wouldn't you know it, a train moving at 30 m/s was only 60 m from the crossing. In a split second, I realized that the train was going to beat me to the crossing and that I didn't have enough distance to stop. My only hope was to accelerate enough to cross the tracks before the train arrived. If my reaction time before starting to accelerate was 0.50 s, what minimum acceleration did my car need for me to be here today writing these words?

72. ‖ As an astronaut visiting Planet X, you're assigned to measure the free-fall acceleration. Getting out your meter stick and stop watch, you time the fall of a heavy ball from several heights. Your data are as follows:

Height (m)	Fall time (s)
0.0	0.00
1.0	0.54
2.0	0.72
3.0	0.91
4.0	1.01
5.0	1.17

Analyze these data to determine the free-fall acceleration on Planet X. Your analysis method should involve fitting a straight line to an appropriate graph, similar to the analysis in Example 2.14.

73. ‖ Your goal in laboratory is to launch a ball of mass m straight up so that it reaches exactly height h above the top of the launching tube. You and your lab partners will earn fewer points if the ball goes too high or too low. The launch tube uses compressed air to accelerate the ball over a distance d, and you have a table of data telling you how to set the air compressor to achieve a desired acceleration. Find an expression for the acceleration that will earn you maximum points.

74. ‖ When a 1984 Alfa Romeo Spider sports car accelerates at
CALC the maximum possible rate, its motion during the first 20 s is extremely well modeled by the simple equation

$$v_x^2 = \frac{2P}{m} t$$

where $P = 3.6 \times 10^4$ watts is the car's power output, $m = 1200$ kg is its mass, and v_x is in m/s. That is, the square of the car's velocity increases linearly with time.
   a. Find an algebraic expression in terms of P, m, and t for the car's acceleration at time t.
   b. What is the car's speed at $t = 2$ s and $t = 10$ s?
   c. Evaluate the acceleration at $t = 2$ s and $t = 10$ s.

75. ‖ The two masses in **FIGURE P2.75** slide on frictionless wires. They are connected by a pivoting rigid rod of length L. Prove that $v_{2x} = -v_{1y} \tan\theta$.
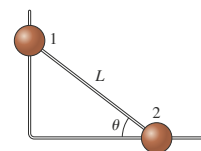

FIGURE P2.75

In Problems 76 through 79, you are given the kinematic equation or equations that are used to solve a problem. For each of these, you are to:
   a. Write a *realistic* problem for which this is the correct equation(s). Be sure that the answer your problem requests is consistent with the equation(s) given.
   b. Draw the pictorial representation for your problem.
   c. Finish the solution of the problem.

76. $64 \text{ m} = 0 \text{ m} + (32 \text{ m/s})(4 \text{ s} - 0 \text{ s}) + \frac{1}{2}a_x(4 \text{ s} - 0 \text{ s})^2$

77. $(10 \text{ m/s})^2 = v_{0y}^2 - 2(9.8 \text{ m/s}^2)(10 \text{ m} - 0 \text{ m})$

78. $(0 \text{ m/s})^2 = (5 \text{ m/s})^2 - 2(9.8 \text{ m/s}^2)(\sin 10°)(x_1 - 0 \text{ m})$

79. $v_{1x} = 0 \text{ m/s} + (20 \text{ m/s}^2)(5 \text{ s} - 0 \text{ s})$
   $x_1 = 0 \text{ m} + (0 \text{ m/s})(5 \text{ s} - 0 \text{ s}) + \frac{1}{2}(20 \text{ m/s}^2)(5 \text{ s} - 0 \text{ s})^2$
   $x_2 = x_1 + v_{1x}(10 \text{ s} - 5 \text{ s})$

Challenge Problems

80. ‖‖‖ A rocket is launched straight up with constant acceleration. Four seconds after liftoff, a bolt falls off the side of the rocket. The bolt hits the ground 6.0 s later. What was the rocket's acceleration?

81. ‖‖‖ Careful measurements have been made of Olympic sprinters in the 100 meter dash. A simple but reasonably accurate model is that a sprinter accelerates at 3.6 m/s^2 for $3\frac{1}{3}$ s, then runs at constant velocity to the finish line.
   a. What is the race time for a sprinter who follows this model?
   b. A sprinter could run a faster race by accelerating faster at the beginning, thus reaching top speed sooner. If a sprinter's top speed is the same as in part a, what acceleration would he need to run the 100 meter dash in 9.9 s?
   c. By what percent did the sprinter need to increase his acceleration in order to decrease his time by 1%?

82. ⦀ Careful measurements have been made of Olympic sprinters
CALC in the 100 meter dash. A quite realistic model is that the sprint-
er's velocity is given by

$$v_x = a(1 - e^{-bt})$$

where t is in s, v_x is in m/s, and the constants a and b are char-
acteristic of the sprinter. Sprinter Carl Lewis's run at the 1987
World Championships is modeled with $a = 11.81$ m/s and
$b = 0.6887$ s^{-1}.

a. What was Lewis's acceleration at $t = 0$ s, 2.00 s, and 4.00 s?
b. Find an expression for the distance traveled at time t.
c. Your expression from part b is a transcendental equation,
meaning that you can't solve it for t. However, it's not hard to
use trial and error to find the time needed to travel a specific
distance. To the nearest 0.01 s, find the time Lewis needed to
sprint 100.0 m. His official time was 0.01 s more than your
answer, showing that this model is very good, but not perfect.

83. ⦀ A sprinter can accelerate with constant acceleration for 4.0 s
before reaching top speed. He can run the 100 meter dash in 10.0 s.
What is his speed as he crosses the finish line?

84. ⦀ A rubber ball is shot straight up from the ground with speed v_0.
Simultaneously, a second rubber ball at height h directly above
the first ball is dropped from rest.

a. At what height above the ground do the balls collide? Your an-
swer will be an *algebraic expression* in terms of h, v_0, and g.
b. What is the maximum value of h for which a collision occurs
before the first ball falls back to the ground?
c. For what value of h does the collision occur at the instant
when the first ball is at its highest point?

85. ⦀ The Starship Enterprise returns from warp drive to ordinary
space with a forward speed of 50 km/s. To the crew's great sur-
prise, a Klingon ship is 100 km directly ahead, traveling in the
same direction at a mere 20 km/s. Without evasive action, the
Enterprise will overtake and collide with the Klingons in just
slightly over 3.0 s. The Enterprise's computers react instantly to
brake the ship. What magnitude acceleration does the Enterprise
need to just barely avoid a collision with the Klingon ship?
Assume the acceleration is constant.

Hint: Draw a position-versus-time graph showing the motions
of both the Enterprise and the Klingon ship. Let $x_0 = 0$ km be
the location of the Enterprise as it returns from warp drive. How
do you show graphically the situation in which the collision is
"barely avoided"? Once you decide what it looks like graphically,
express that situation mathematically.