


EXERCISES AND PROBLEMS

The  icon in front of a problem indicates that the problem can be done on a Dynamics Worksheet. Dynamics Worksheets are found at the back of the *Student Workbook*. If you use a worksheet, draw a motion diagram in the Physical Representation section, establish your coordinate system and symbols in the Pictorial Representation section, then solve the problem in the Mathematical Representation section.

Exercises

Section 2.1 Motion in One Dimension

- Figure Ex2.1 shows a motion diagram of a car traveling down a street. The camera took one frame every second. A distance scale is provided.
 - Measure the x -value of the car at each dot. Place your data in a table, similar to Table 2.1, showing each position and the instant of time at which it occurred.
 - Make a position-versus-time graph for the ball. Because you have data only at certain instants of time, your graph should consist of dots that are not connected together.

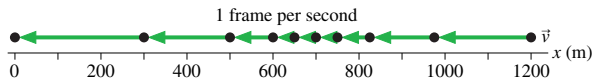


FIGURE EX2.1

- For each motion diagram, determine the sign (positive or negative) of the position, the velocity, and the acceleration.

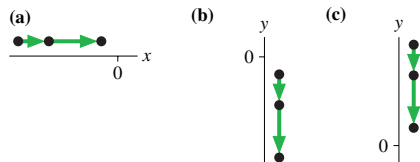


FIGURE EX2.2

- Write a short description of the motion of a real object for which this would be a realistic position-versus-time graph.

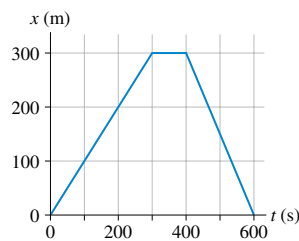


FIGURE EX2.3

- Write a short description of the motion of a real object for which this would be a realistic position-versus-time graph.

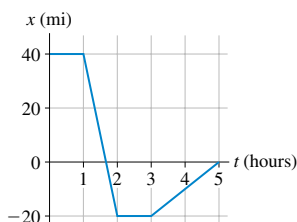


FIGURE EX2.4

Section 2.2 Uniform Motion

- A car starts at the origin and moves with velocity $\vec{v} = (10 \text{ m/s, northeast})$. How far from the origin will the car be after traveling for 45 s?
- Larry leaves home at 9:05 and runs at constant speed to the lamppost. He reaches the lamppost at 9:07, immediately turns, and runs to the tree. Larry arrives at the tree at 9:10.
 - What is Larry's average velocity during each of these two intervals?
 - What is the average velocity for Larry's entire run?

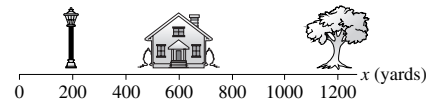


FIGURE EX2.6

- Alan leaves Los Angeles at 8:00 A.M. to drive to San Francisco, 400 mi away. He travels at a steady 50 mph. Beth leaves Los Angeles at 9:00 A.M. and drives a steady 60 mph.
 - Who gets to San Francisco first?
 - How long does the first to arrive have to wait for the second?
- A bicyclist has the position-versus-time graph shown. What is the bicyclist's velocity at $t = 10 \text{ s}$, at $t = 25 \text{ s}$, and at $t = 35 \text{ s}$?

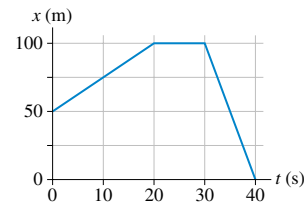


FIGURE EX2.8

- Julie drives 100 mi to Grandmother's house. On the way to Grandmother's, Julie drives half the *distance* at 40 mph and half the distance at 60 mph. On her return trip, she drives half the *time* at 40 mph and half the time at 60 mph.
 - What is Julie's average speed on the way to Grandmother's house?
 - What is her average speed on the return trip?

Section 2.3 Instantaneous Velocity

Section 2.4 Finding Position from Velocity

- Figure Ex2.10 shows the position graph of a particle.
 - Draw the particle's velocity graph for the interval $0 \text{ s} \leq t \leq 4 \text{ s}$.
 - Does this particle have a turning point or points? If so, at what time or times?

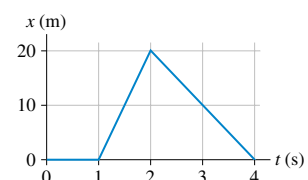


FIGURE EX2.10

11. A particle starts from $x_0 = 10$ m at $t_0 = 0$ and moves with the velocity graph shown in Figure Ex2.11.
- What is the object's position at $t = 2$ s, 3 s, and 4 s?
 - Does this particle have a turning point? If so, at what time?

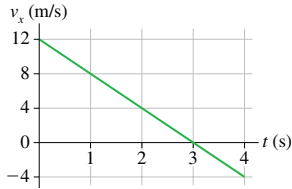


FIGURE EX2.11

Section 2.5 Motion with Constant Acceleration

12. Figure Ex2.12 shows the velocity graph of a particle. Draw the particle's acceleration graph for the interval $0 \text{ s} \leq t \leq 4 \text{ s}$. Give both axes an appropriate numerical scale.

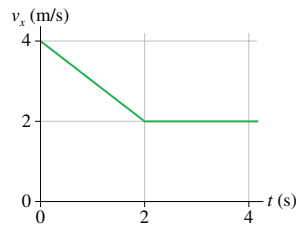


FIGURE EX2.12

13. Figure Ex2.13 shows the velocity graph of a train that starts from the origin at $t = 0$ s.
- Draw position and acceleration graphs for the train.
 - Find the acceleration of the train at $t = 3.0$ s.

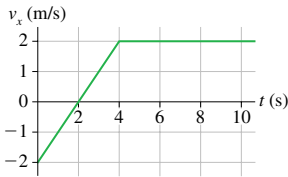


FIGURE EX2.13

14. Figure Ex2.14 shows the velocity graph of a particle moving along the x -axis. Its initial position is $x_0 = 2$ m at $t_0 = 0$ s. At $t = 2$ s, what are the particle's (a) position, (b) velocity, and (c) acceleration?

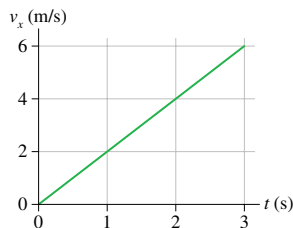


FIGURE EX2.14

- What constant acceleration, in SI units, must a car have to go from zero to 60 mph in 10 s?
 - What fraction of g is this?
 - How far has the car traveled when it reaches 60 mph? Give your answer both in SI units and in feet.
16. A jet plane is cruising at 300 m/s when suddenly the pilot turns the engines up to full throttle. After traveling 4.0 km, the jet is moving with a speed of 400 m/s.
- What is the jet's acceleration, assuming it to be a constant acceleration?
 - Is your answer reasonable? Explain.

17. A speed skater moving across frictionless ice at 8.0 m/s hits a 5.0-m-wide patch of rough ice. She slows steadily, then continues on at 6.0 m/s. What is her acceleration on the rough ice?
- How many days will it take a spaceship to accelerate to the speed of light (3.0×10^8 m/s) with the acceleration g ?
 - How far will it travel during this interval?
 - 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. ◀

Section 2.6 Free Fall

19. 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.
- If a bearing needs 4.0 s to solidify enough for impact, how high must the tower be?
 - What is the bearing's impact velocity?
20. A ball is thrown vertically upward with a speed of 19.6 m/s.
- What is the ball's velocity and its height after 1, 2, 3, and 4 s?
 - Draw the ball's velocity-versus-time graph. Give both axes an appropriate numerical scale.
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 with a speed of 20 m/s. When it returns, it falls into a hole 10 m deep.
- What is the rock's velocity as it hits the bottom of the hole?
 - How long is the rock in the air, from the instant it is released until it hits the bottom of the hole?

Section 2.7 Motion on an Inclined Plane

23. A car traveling at 30 m/s runs out of gas while traveling up a 20° slope. How far up the hill will it coast before starting to roll back down?
24. 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.
- What is the length of the incline?
 - How long does it take him to reach the bottom?

Section 2.8 Instantaneous Acceleration

25. A particle moving along the x -axis has its position described by the function $x = (2t^3 - t + 1)$ m, where t is in s. At $t = 2$ s, what are the particle's (a) position, (b) velocity, and (c) acceleration?
26. A particle moving along the x -axis has its velocity described by the function $v_x = 2t^2$ m/s, where t is in s. Its initial position is $x_0 = 1$ m at $t_0 = 0$ s. At $t = 1$ s, what are the particle's (a) position, (b) velocity, and (c) acceleration?

27. Figure Ex2.27 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?

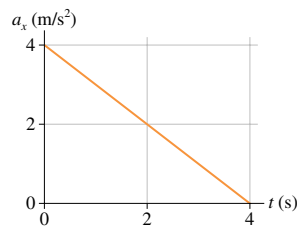


FIGURE EX2.27

Problems

28. Figure P2.28 shows the motion diagram, made at two frames per second, of a ball rolling along a track. The track has a 3.0-m-long sticky section.
- Use the meter stick to measure the positions of the center of the ball. Place your data in a table, similar to Table 2.1, showing each position and the instant of time at which it occurred.
 - Make a position-versus-time graph for the ball. Because you have data only at certain instants of time, your graph should consist of dots that are not connected together.
 - What is the *change* in the ball's position from $t = 0$ s to $t = 1.0$ s?
 - What is the *change* in the ball's position from $t = 2.0$ s to $t = 4.0$ s?
 - What is the ball's velocity before reaching the sticky section?
 - What is the ball's velocity after passing the sticky section?
 - Determine the ball's acceleration on the sticky section of the track.

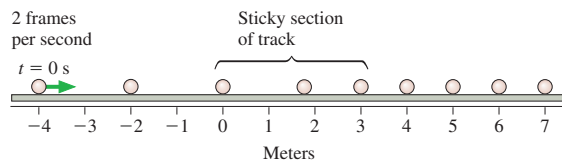


FIGURE P2.28

29. A particle's position on the x -axis is given by the function $x = (t^2 - 4t + 2)$ m, where t is in s.
- Make a position-versus-time graph for the interval $0 \text{ s} \leq t \leq 5 \text{ s}$. Do this by calculating and plotting x every 0.5 s from 0 s to 5 s, then drawing a smooth curve through the points.
 - Determine the particle's velocity at $t = 1.0$ s by drawing the tangent line on your graph and measuring its slope.
 - Determine the particle's velocity at $t = 1.0$ s by evaluating the derivative at that instant. Compare this to your result from part b.
 - Are there any turning points in the particle's motion? If so, at what position or positions?
 - Where is the particle when $v_x = 4.0$ m/s?
 - Draw a motion diagram for the particle.

30. The velocity-versus-time graph is shown for a particle moving along the x -axis. Its initial position is $x_0 = 2.0$ m at $t_0 = 0$ s.
- What are the particle's position, velocity, and acceleration at $t = 1.0$ s?
 - What are the particle's position, velocity, and acceleration at $t = 3.0$ s?

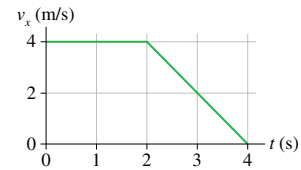


FIGURE P2.30

31. Three particles move along the x -axis, each starting with $v_{0x} = 10$ m/s at $t_0 = 0$ s. 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. Work with the geometry of the graphs, not with kinematic equations.

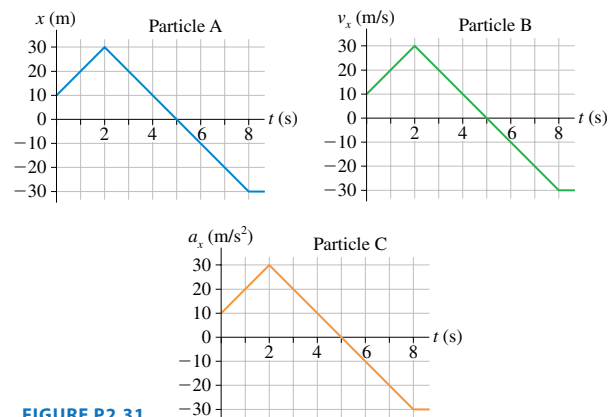


FIGURE P2.31

32. The velocity graph is shown 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? Work with the geometry of the graph, not with kinematic equations.
 - Draw a motion diagram for the particle.

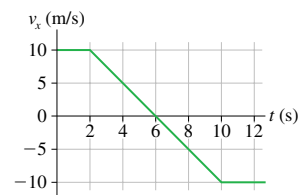


FIGURE P2.32

33. The acceleration graph is shown for a particle that starts from rest at $t = 0$ s. Determine the object's velocity at times $t = 0$ s, 2 s, 4 s, 6 s, and 8 s.

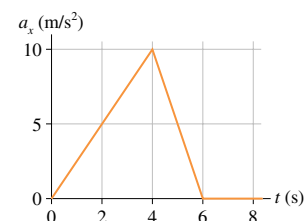


FIGURE P2.33

34. A block is suspended from a spring, pulled down, and released. The block's position-versus-time graph is shown in Figure P2.34.
- At what times is the velocity zero? At what times is the velocity most positive? Most negative?
 - Draw a reasonable velocity-versus-time graph.

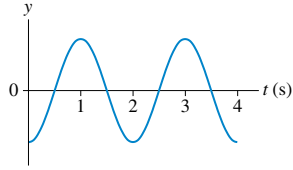


FIGURE P2.34

35. The acceleration graph is shown for a particle that starts from rest at $t = 0$ s.
- Draw the particle's velocity graph over the interval $0 \text{ s} \leq t \leq 10 \text{ s}$. Include an appropriate numerical scale on both axes.
 - Describe, in words, how the velocity graph would differ if the particle had an initial velocity of 2.0 m/s .

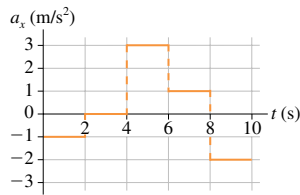


FIGURE P2.35

36. Drop a rubber ball or a tennis ball from a height of about 25 cm ($\approx 1 \text{ ft}$) and watch carefully as it bounces. Then draw a position graph, a velocity graph, and an acceleration graph from the instant you drop the ball until it returns to its maximum height. Stack your three graphs vertically so that the time axes are aligned with each other. Pay particular attention to the time when the ball is in contact with the ground. This is a short interval of time, but it's not zero.
37. The position of a particle is given by the function $x = (2t^3 - 9t^2 + 12) \text{ m}$, where t is in s.
- At what time or times is $v_x = 0 \text{ m/s}$?
 - What are the particle's position and its acceleration at this time(s)?
38. An object starts from rest at $x = 0 \text{ m}$ at time $t = 0 \text{ s}$. Five seconds later, at $t = 5.0 \text{ s}$, the object is observed to be at $x = 40.0 \text{ m}$ and to have velocity $v_x = 11 \text{ m/s}$.
- Was the object's acceleration uniform or nonuniform? Explain your reasoning.
 - Sketch the velocity-versus-time graph implied by these data. Is the graph a straight line or curved? If curved, is it concave upward or downward?
39. A particle's velocity is described by the function $v_x = kt^2 \text{ m/s}$, where k is a constant and t is in s. The particle's position at $t_0 = 0 \text{ s}$ is $x_0 = -9.0 \text{ m}$. At $t_1 = 3.0 \text{ s}$, the particle is at $x_1 = 9.0 \text{ m}$. Determine the value of the constant k . Be sure to include the proper units.
40. A particle's acceleration is described by the function $a_x = (10 - t) \text{ m/s}^2$, where t is in s. Its initial conditions are $x_0 = 0 \text{ m}$ and $v_{0x} = 0 \text{ m/s}$ at $t = 0 \text{ s}$.
- At what time is the velocity again zero?
 - What is the particle's position at that time?
41. A ball rolls along the frictionless track shown. 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 position, 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.

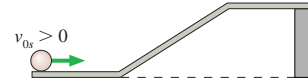


FIGURE P2.41

42. Draw position, velocity, and acceleration graphs for the ball shown here. See Problem 41 for more information.

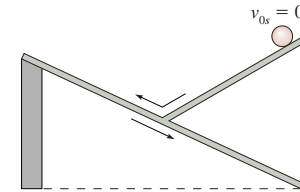


FIGURE P2.42

43. Draw position, velocity, and acceleration graphs for the ball shown here. See Problem 41 for more information. The ball changes direction but not speed as it bounces from the reflecting wall.

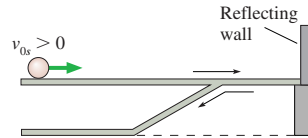


FIGURE P2.43

44. Figure P2.44 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.

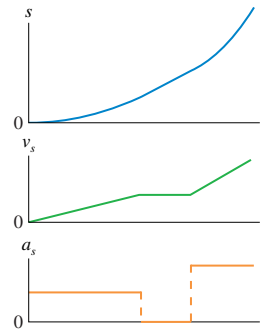


FIGURE P2.44

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.

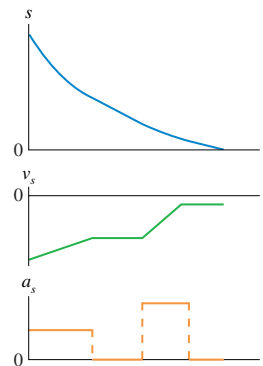


FIGURE P2.45

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.

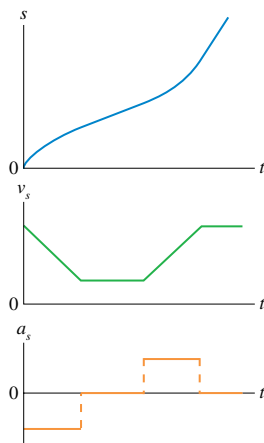


FIGURE P2.46

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

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

- What is the takeoff speed in miles per hour?
 - Is the jetliner's acceleration constant during takeoff? Explain.
 - At what time do the wheels leave the ground?
 - 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. Does a real automobile have constant acceleration? Measured data for a Porsche 944 Turbo at maximum acceleration is as follows:

t (s)	v_s (mph)
0	0
2	28
4	46
6	60
8	70
10	78

- Make a graph of velocity versus time. Based on your graph, is the acceleration constant? Explain.
- Draw a smooth curve through the points on your graph, then use your graph to estimate the car's acceleration at 2.0 s and 8.0 s. Give your answer in SI units.
- Use your graph to estimate the distance traveled in the first 10 s.

Hint: Approximate the curve with five steps, each of width $\Delta t = 2$ s. Let the height of each step be the average of the velocities at the beginning and end of the step.

49. A driver has a reaction time of 0.50 s, and the maximum deceleration of her car is 6.0 m/s^2 . She is driving at 20 m/s when suddenly she sees an obstacle in the road 50 m in front of her. Can she stop the car in time to avoid a collision?
50. 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.
- How far are you from the intersection when you begin to apply the brakes?
 - What acceleration will bring you to rest right at the intersection?
 - How long does it take you to stop?
51. 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?
 - Draw a position-versus-time graph for the motion of the car in part a. Assume the car is at $x_0 = 0$ m when the driver first sees the emergency situation ahead that calls for a rapid halt.
52. 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 0.5 s, and the maximum deceleration of your car is 10 m/s^2 .
- How much distance is between you and the deer when you come to a stop?
 - What is the maximum speed you could have and still not hit the deer?
53. A 200kg weather rocket is loaded with 100 kg of fuel and fired straight up. It accelerates upward at 30 m/s^2 for 30 s, then runs out of fuel. Ignore any air resistance effects.
- What is the rocket's maximum altitude?
 - How long is the rocket in the air?
 - Draw a velocity-versus-time graph for the rocket from liftoff until it hits the ground.
54. A 1000kg 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?
 - What is the rocket's speed as it passes through a cloud 5100 m above the ground?
55. 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?
56. A hotel elevator ascends 200 m at maximum speed of 5 m/s. Its acceleration and deceleration both have a magnitude of 1.0 m/s^2 .
- How far does the elevator move while accelerating to full speed from rest?
 - How long does it take to make the complete trip from bottom to top?
57. A car starts from rest at a stop sign. It accelerates at 4.0 m/s^2 for 6 seconds, coasts for 2 s, and then slows down at a rate of 3.0 m/s^2 for the next stop sign. How far apart are the stop signs?

58. A car accelerates at 2.0 m/s^2 along a straight road. It passes two marks that are 30 m apart at times $t = 4.0 \text{ s}$ and $t = 5.0 \text{ s}$. What was the car's initial velocity?
59. 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?
60. Ann and Carol are driving their cars along the same straight road. Carol is located at $x = 2.4 \text{ mi}$ at $t = 0$ hours and drives at a steady 36 mph. Ann, who is traveling in the same direction, is located at $x = 0.0 \text{ mi}$ at $t = 0.50$ hours and drives at a steady 50 mph.
- At what time does Ann overtake Carol?
 - What is their position at this instant?
 - Draw a position-versus-time graph showing the motion of both Ann and Carol.
61. A ball rolls along the smooth track shown in the figure with an initial speed of 5.0 m/s . Assume that the ball turns all the corners smoothly, with no loss of speed.
- What is the ball's speed as it goes over the top?
 - What is its speed when it reaches the level track on the right side?
 - By what percentage does the ball's final speed differ from its initial speed? Is this surprising?

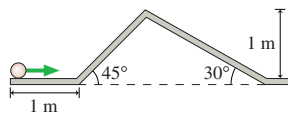


FIGURE P2.61

62. A toy train is pushed forward and released at $x_0 = 2.0 \text{ m}$ with a speed of 2.0 m/s . It rolls at a steady speed for 2.0 s , then one wheel begins to stick. The train comes to a stop 6.0 m from its starting point. What is the train's acceleration after its wheel begins to stick?
63. 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/s^2 . Is Bob in jail?
64. 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 8.50 m from the end of the ramp. The puck's speed after traveling 3.0 m is 4.0 m/s . Are you a winner?
65. A professional skier's *initial* acceleration on fresh snow is 90% of the acceleration expected on a frictionless, inclined plane, the loss being due to friction. Due to air resistance, his acceleration slowly decreases as he picks up speed. The speed record on a mountain in Oregon is 180 kilometers per hour at the bottom of a 25° slope that drops 200 m .
- What exit speed could a skier reach in the absence of air resistance?
 - What percentage of this ideal speed is lost to air resistance?
66. Heather and Jerry are standing on a bridge 50 m above a river. Heather throws a rock straight down with a speed of 20 m/s . Jerry, at exactly the same instant of time, throws a rock straight up with the same speed. Ignore air resistance.
- How much time elapses between the first splash and the second splash?
 - Which rock has the faster speed as it hits the water?
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. 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?
69. 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.
- How far does Tina drive before passing David?
 - What is her speed as she passes him?
70. A Porsche challenges a Honda to a 400-m race. Because the Porsche's acceleration of 3.5 m/s^2 is larger than the Honda's 3.0 m/s^2 , the Honda gets a 50-m head start. Both cars start accelerating at the same instant. Who wins?
71. 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. Does the dog catch the cat before the cat is able to leap through the window?
72. You want to visit your friend in Seattle during spring break. To save money, you decide to travel there by train. Unfortunately, your physics final exam took the full 3 hours, so you are late in arriving at the train station. You run as fast as you can, but just as you reach the platform you see your train, 30 m ahead of you down the platform, begin to accelerate at 1.0 m/s^2 . You chase after the train at your maximum speed of 8.0 m/s , but there's a barrier 50 m ahead. Will you be able to leap onto the back step of the train before you crash into the barrier?
73. 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?

In Problems 74 through 77 you are given the kinematic equation or equations that are used to solve a problem. For each of these, you are to

- 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.
- Draw the motion diagram and the pictorial representation for your problem.
- Finish the solution of the problem.

$$74. 64 \text{ m} = 0 \text{ m} + (32 \text{ m/s})(4 \text{ s} - 0 \text{ s}) + \frac{1}{2}a_x(4 \text{ s} - 0 \text{ s})^2$$



$$75. (10 \text{ m/s})^2 = v_{0y}^2 - 2(9.8 \text{ m/s}^2)(10 \text{ m} - 0 \text{ m})$$



$$76. (0 \text{ m/s})^2 = (5 \text{ m/s})^2 - 2(9.8 \text{ m/s}^2)(\sin 10^\circ)(x_1 - 0 \text{ m})$$



$$77. v_{1x} = 0 \text{ m/s} + (20 \text{ m/s}^2)(5 \text{ s} - 0 \text{ s})$$

$$x_1 = 0 \text{ m} + (0 \text{ m/s})(5 \text{ s} - 0 \text{ s}) + \frac{1}{2}(20 \text{ m/s}^2)(5 \text{ s} - 0 \text{ s})^2$$

$$x_2 = x_1 + v_{1x}(10 \text{ s} - 5 \text{ s})$$

Challenge Problems

78. Jill has just gotten out of her car in the grocery store parking lot. The parking lot is on a hill and is tilted 3° . Fifty meters downhill from Jill, a little old lady lets go of a fully loaded shopping cart. The cart, with frictionless wheels, starts to roll straight downhill. Jill immediately starts to sprint after the cart with her top acceleration of 2.0 m/s^2 . How far has the cart rolled before Jill catches it?
79. As a science project, you drop a watermelon off the top of the Empire State Building, 320 m above the sidewalk. It so happens that Superman flies by at the instant you release the watermelon. Superman is headed straight down with a speed of 35 m/s . How fast is the watermelon going when it passes Superman?
80. Your school science club has devised a special event for homecoming. You've attached a rocket to the rear of a small car that has been decorated in the blue-and-gold school colors. The rocket provides a constant acceleration for 9.0 s . As the rocket shuts off, a parachute opens and slows the car at a rate of 5.0 m/s^2 . The car passes the judges' box in the center of the

grandstand, 990 m from the starting line, exactly 12 s after you fire the rocket. What is the car's speed as it passes the judges?

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 $3\frac{1}{3} \text{ s}$, then runs at constant velocity to the finish line.
- What is the race time for a sprinter who follows this model?
 - 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 ?
 - By what percent did the sprinter need to increase his acceleration in order to decrease his time by 1% ?
82. A sprinter can accelerate with constant acceleration for 4.0 s before reaching top speed. He can run the 100-meter dash in 10 s . What is his speed as he crosses the finish line?
83. The Starship Enterprise returns from warp drive to ordinary space with a forward speed of 50 km/s . To the crew's great surprise, 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 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 $x_0 = 0 \text{ km}$ 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.

STOP TO THINK ANSWERS

Stop to Think 2.1: d. The particle starts with positive x and moves to negative x .

Stop to Think 2.2: c. The velocity is the slope of the position graph. The slope is positive and constant until the position graph crosses the axis, then positive but decreasing, and finally zero when the position graph is horizontal.

Stop to Think 2.3: b. A constant positive v_x corresponds to a linearly increasing x , starting from $x_i = -10 \text{ m}$. The constant negative v_x then corresponds to a linearly decreasing x .

Stop to Think 2.4: a or b. The velocity is constant while $a = 0$, it decreases linearly while a is negative. Graphs a, b, and c all have

the same acceleration, but only graphs a and b have a positive initial velocity that represents a particle moving to the right.

Stop to Think 2.5: d. The acceleration vector $\vec{a}_{||}$ points downhill (negative s -direction) and has the constant value $-g \sin \theta$ throughout the motion.

Stop to Think 2.6: c. Acceleration is the slope of the graph. The slope is zero at B. Although the graph is steepest at A, the slope at that point is negative, and so $a_A < a_B$. Only C has a positive slope, so $a_C > a_B$.