*** 21.** Describe in words the motion plotted in Fig. 2–28 in terms of v, a, etc. [*Hint*: First try to duplicate the motion plotted by walking or moving your hand.]

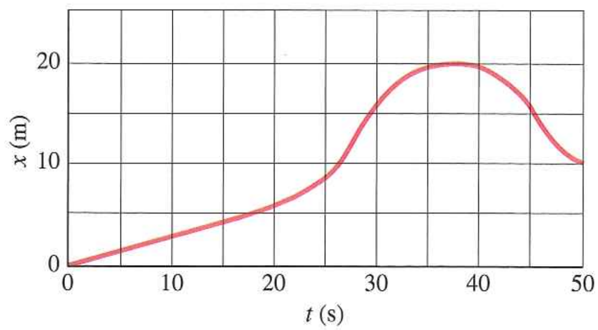

FIGURE 2–28 Question 21, Problems 50, 51, and 55.

*** 22.** Describe in words the motion of the object graphed in Fig. 2–29.

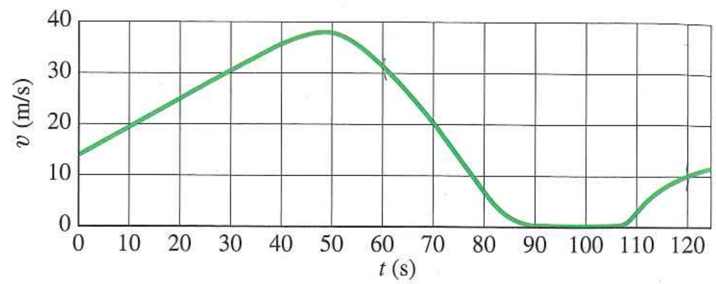

FIGURE 2–29 Question 22, Problems 49 and 54.

Problems

[The Problems at the end of each Chapter are ranked I, II, or III according to estimated difficulty, with (I) Problems being easiest. Level III are meant as challenges for the best students. The Problems are arranged by Section, meaning that the reader should have read up to and including that Section, but not only that Section—Problems often depend on earlier material. Finally, there is a set of unranked "General Problems" not arranged by Section number.]

2–1 to 2–3 Speed and Velocity

1. (I) What must be your car's average speed in order to travel 235 km in 3.25 h?
2. (I) A bird can fly 25 km/h. How long does it take to fly 15 km?
3. (I) If you are driving 110 km/h along a straight road and you look to the side for 2.0 s, how far do you travel during this inattentive period?
4. (I) Convert 35 mi/h to (*a*) km/h, (*b*) m/s, and (*c*) ft/s.
5. (I) A rolling ball moves from $x_1 = 3.4$ cm to $x_2 = -4.2$ cm during the time from $t_1 = 3.0$ s to $t_2 = 6.1$ s. What is its average velocity?
6. (II) A particle at $t_1 = -2.0$ s is at $x_1 = 3.4$ cm and at $t_2 = 4.5$ s is at $x_2 = 8.5$ cm. What is its average velocity? Can you calculate its average speed from these data?
7. (II) You are driving home from school steadily at 95 km/h for 130 km. It then begins to rain and you slow to 65 km/h. You arrive home after driving 3 hours and 20 minutes. (*a*) How far is your hometown from school? (*b*) What was your average speed?
8. (II) According to a rule-of-thumb, every five seconds between a lightning flash and the following thunder gives the distance to the flash in miles. Assuming that the flash of light arrives in essentially no time at all, estimate the speed of sound in m/s from this rule.
9. (II) A person jogs eight complete laps around a quarter-mile track in a total time of 12.5 min. Calculate (*a*) the average speed and (*b*) the average velocity, in m/s.
10. (II) A horse canters away from its trainer in a straight line, moving 116 m away in 14.0 s. It then turns abruptly and gallops halfway back in 4.8 s. Calculate (*a*) its average speed and (*b*) its average velocity for the entire trip, using "away from the trainer" as the positive direction.
11. (II) Two locomotives approach each other on parallel tracks. Each has a speed of 95 km/h with respect to the ground. If they are initially 8.5 km apart, how long will it be before they reach each other? (See Fig. 2–30).

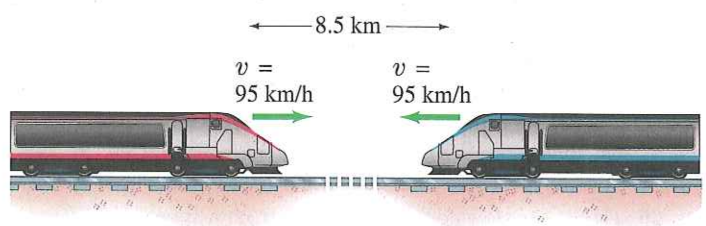

FIGURE 2–30 Problem 11.

12. (II) A car traveling 88 km/h is 110 m behind a truck traveling 75 km/h. How long will it take the car to reach the truck?
13. (II) An airplane travels 3100 km at a speed of 790 km/h, and then encounters a tailwind that boosts its speed to 990 km/h for the next 2800 km. What was the total time for the trip? What was the average speed of the plane for this trip? [*Hint*: Think carefully before using Eq. 2–11d.]
14. (II) Calculate the average speed and average velocity of a complete round-trip in which the outgoing 250 km is covered at 95 km/h, followed by a 1.0-hour lunch break, and the return 250 km is covered at 55 km/h.
15. (III) A bowling ball traveling with constant speed hits the pins at the end of a bowling lane 16.5 m long. The bowler hears the sound of the ball hitting the pins 2.50 s after the ball is released from his hands. What is the speed of the ball? The speed of sound is 340 m/s.

2–4 Acceleration

16. (I) A sports car accelerates from rest to 95 km/h in 6.2 s. What is its average acceleration in m/s^2?
17. (I) A sprinter accelerates from rest to 10.0 m/s in 1.35 s. What is her acceleration (*a*) in m/s^2, and (*b*) in km/h^2?

18. (II) At highway speeds, a particular automobile is capable of an acceleration of about $1.6\ m/s^2$. At this rate, how long does it take to accelerate from 80 km/h to 110 km/h?

19. (II) A sports car moving at constant speed travels 110 m in 5.0 s. If it then brakes and comes to a stop in 4.0 s, what is its acceleration in m/s^2? Express the answer in terms of "g's," where $1.00\ g = 9.80\ m/s^2$.

20. (III) The position of a racing car, which starts from rest at $t = 0$ and moves in a straight line, is given as a function of time in the following Table. Estimate (*a*) its velocity and (*b*) its acceleration as a function of time. Display each in a Table and on a graph.

t (s)	0	0.25	0.50	0.75	1.00	1.50	2.00	2.50
x (m)	0	0.11	0.46	1.06	1.94	4.62	8.55	13.79

t (s)	3.00	3.50	4.00	4.50	5.00	5.50	6.00
x (m)	20.36	28.31	37.65	48.37	60.30	73.26	87.16

2–5 and 2–6 Motion at Constant Acceleration

21. (I) A car accelerates from 13 m/s to 25 m/s in 6.0 s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

22. (I) A car slows down from 23 m/s to rest in a distance of 85 m. What was its acceleration, assumed constant?

23. (I) A light plane must reach a speed of 33 m/s for takeoff. How long a runway is needed if the (constant) acceleration is $3.0\ m/s^2$?

24. (II) A world-class sprinter can burst out of the blocks to essentially top speed (of about 11.5 m/s) in the first 15.0 m of the race. What is the average acceleration of this sprinter, and how long does it take her to reach that speed?

25. (II) A car slows down uniformly from a speed of 21.0 m/s to rest in 6.00 s. How far did it travel in that time?

26. (II) In coming to a stop, a car leaves skid marks 92 m long on the highway. Assuming a deceleration of $7.00\ m/s^2$, estimate the speed of the car just before braking.

27. (II) A car traveling 85 km/h strikes a tree. The front end of the car compresses and the driver comes to rest after traveling 0.80 m. What was the average acceleration of the driver during the collision? Express the answer in terms of "g's," where $1.00\ g = 9.80\ m/s^2$.

28. (II) Determine the stopping distances for a car with an initial speed of 95 km/h and human reaction time of 1.0 s, for an acceleration (*a*) $a = -4.0\ m/s^2$; (*b*) $a = -8.0\ m/s^2$.

29. (III) Show that the equation for the stopping distance of a car is $d_S = v_0 t_R - v_0^2/(2a)$, where v_0 is the initial speed of the car, t_R is the driver's reaction time, and a is the constant acceleration (and is negative).

30. (III) A car is behind a truck going 25 m/s on the highway. The car's driver looks for an opportunity to pass, guessing that his car can accelerate at $1.0\ m/s^2$. He gauges that he has to cover the 20-m length of the truck, plus 10 m clear room at the rear of the truck and 10 m more at the front of it. In the oncoming lane, he sees a car approaching, probably also traveling at 25 m/s. He estimates that the car is about 400 m away. Should he attempt the pass? Give details.

31. (III) A runner hopes to complete the 10,000-m run in less than 30.0 min. After exactly 27.0 min, there are still 1100 m to go. The runner must then accelerate at $0.20\ m/s^2$ for how many seconds in order to achieve the desired time?

32. (III) A person driving her car at 45 km/h approaches an intersection just as the traffic light turns yellow. She knows that the yellow light lasts only 2.0 s before turning red, and she is 28 m away from the near side of the intersection (Fig. 2–31). Should she try to stop, or should she speed up to cross the intersection before the light turns red? The intersection is 15 m wide. Her car's maximum deceleration is $-5.8\ m/s^2$, whereas it can accelerate from 45 km/h to 65 km/h in 6.0 s. Ignore the length of her car and her reaction time.

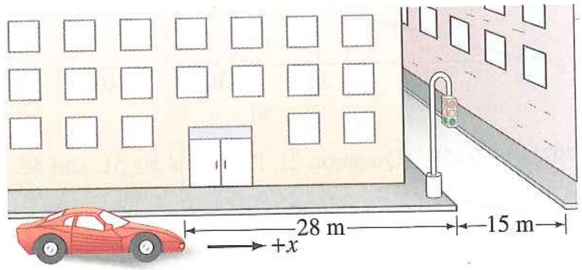

FIGURE 2–31 Problem 32.

2–7 Falling Objects [neglect air resistance]

33. (I) A stone is dropped from the top of a cliff. It hits the ground below after 3.25 s. How high is the cliff?

34. (I) If a car rolls gently ($v_0 = 0$) off a vertical cliff, how long does it take it to reach 85 km/h?

35. (I) Estimate (*a*) how long it took King Kong to fall straight down from the top of the Empire State Building (380 m high), and (*b*) his velocity just before "landing"?

36. (II) A baseball is hit nearly straight up into the air with a speed of 22 m/s. (*a*) How high does it go? (*b*) How long is it in the air?

37. (II) A ballplayer catches a ball 3.0 s after throwing it vertically upward. With what speed did he throw it, and what height did it reach?

38. (II) An object starts from rest and falls under the influence of gravity. Draw graphs of (*a*) its speed and (*b*) the distance it has fallen, as a function of time from $t = 0$ to $t = 5.00$ s. Ignore air resistance.

39. (II) A helicopter is ascending vertically with a speed of 5.20 m/s. At a height of 125 m above the Earth, a package is dropped from a window. How much time does it take for the package to reach the ground? [*Hint*: The package's initial speed equals the helicopter's.]

40. (II) For an object falling freely from rest, show that the distance traveled during each successive second increases in the ratio of successive odd integers (1, 3, 5, etc.). This was first shown by Galileo. See Figs. 2–18 and 2–21.

41. (II) If air resistance is neglected, show (algebraically) that a ball thrown vertically upward with a speed v_0 will have the same speed, v_0, when it comes back down to the starting point.

42. (II) A stone is thrown vertically upward with a speed of 18.0 m/s. (*a*) How fast is it moving when it reaches a height of 11.0 m? (*b*) How long is required to reach this height? (*c*) Why are there two answers to (*b*)?

43. (III) Estimate the time between each photoflash of the apple in Fig. 2–18 (or number of photoflashes per second). Assume the apple is about 10 cm in diameter. [*Hint*: Use two apple positions, but not the unclear ones at the top.]

44. (III) A falling stone takes 0.28 s to travel past a window 2.2 m tall (Fig. 2–32). From what height above the top of the window did the stone fall?

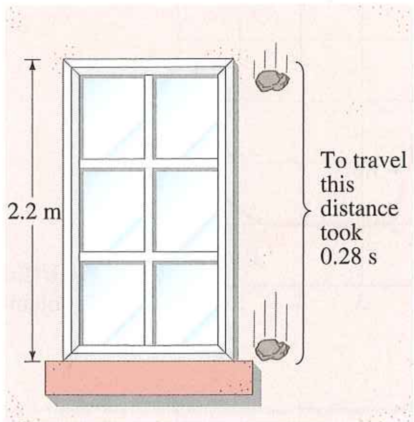

FIGURE 2–32 Problem 44.

45. (III) A rock is dropped from a sea cliff, and the sound of it striking the ocean is heard 3.2 s later. If the speed of sound is 340 m/s, how high is the cliff?

46. (III) Suppose you adjust your garden hose nozzle for a hard stream of water. You point the nozzle vertically upward at a height of 1.5 m above the ground (Fig. 2–33). When you quickly move the nozzle away from the vertical, you hear the water striking the ground next to you for another 2.0 s. What is the water speed as it leaves the nozzle?

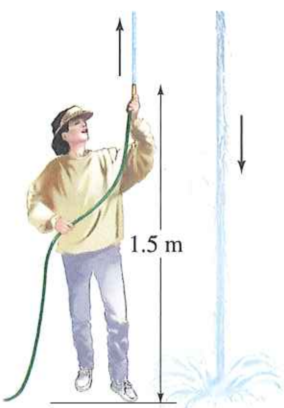

FIGURE 2–33 Problem 46.

47. (III) A stone is thrown vertically upward with a speed of 12.0 m/s from the edge of a cliff 70.0 m high (Fig. 2–34). (*a*) How much later does it reach the bottom of the cliff? (*b*) What is its speed just before hitting? (*c*) What total distance did it travel?

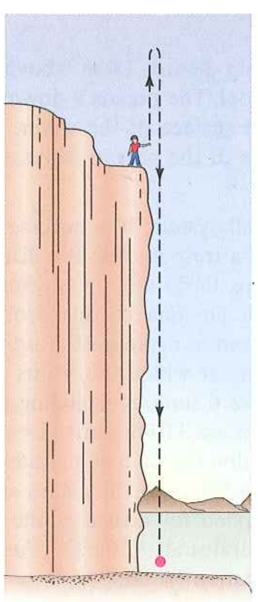

FIGURE 2–34 Problem 47.

48. (III) A baseball is seen to pass upward by a window 28 m above the street with a vertical speed of 13 m/s. If the ball was thrown from the street, (*a*) what was its initial speed, (*b*) what altitude does it reach, (*c*) when was it thrown, and (*d*) when does it reach the street again?

* 2–8 Graphical Analysis

* 49. (I) Figure 2–29 shows the velocity of a train as a function of time. (*a*) At what time was its velocity greatest? (*b*) During what periods, if any, was the velocity constant? (*c*) During what periods, if any, was the acceleration constant? (*d*) When was the magnitude of the acceleration greatest?

* 50. (II) The position of a rabbit along a straight tunnel as a function of time is plotted in Fig. 2–28. What is its instantaneous velocity (*a*) at $t = 10.0\,\mathrm{s}$ and (*b*) at $t = 30.0\,\mathrm{s}$? What is its average velocity (*c*) between $t = 0$ and $t = 5.0\,\mathrm{s}$, (*d*) between $t = 25.0\,\mathrm{s}$ and $t = 30.0\,\mathrm{s}$, and (*e*) between $t = 40.0\,\mathrm{s}$ and $t = 50.0\,\mathrm{s}$?

* 51. (II) In Fig. 2–28, (*a*) during what time periods, if any, is the velocity constant? (*b*) At what time is the velocity greatest? (*c*) At what time, if any, is the velocity zero? (*d*) Does the object move in one direction or in both directions during the time shown?

* 52. (II) A certain type of automobile can accelerate approximately as shown in the velocity–time graph of Fig. 2–35. (The short flat spots in the curve represent shifting of the gears.) (*a*) Estimate the average acceleration of the car in second gear and in fourth gear. (*b*) Estimate how far the car traveled while in fourth gear.

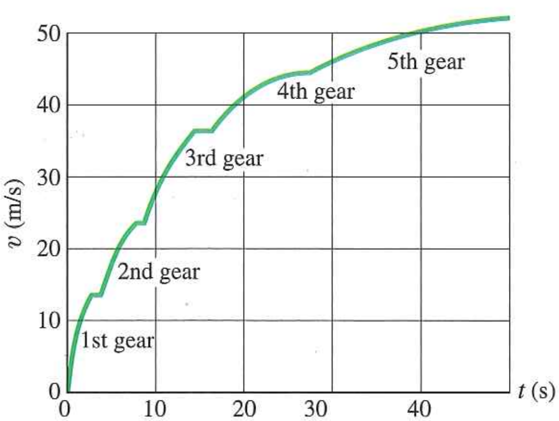

FIGURE 2–35 Problems 52 and 53. The velocity of an automobile as a function of time, starting from a dead stop. The jumps in the curve represent gear shifts.

* 53. (II) Estimate the average acceleration of the car in the previous Problem (Fig. 2–35) when it is in (*a*) first, (*b*) third, and (*c*) fifth gear. (*d*) What is its average acceleration through the first four gears?

* 54. (II) In Fig. 2–29, estimate the distance the object traveled during (*a*) the first minute, and (*b*) the second minute.

* 55. (II) Construct the v vs. t graph for the object whose displacement as a function of time is given by Fig. 2–28.

* 56. (II) Figure 2–36 is a position versus time graph for the motion of an object along the x axis. Consider the time interval from A to B. (*a*) Is the object moving in the positive or negative direction? (*b*) Is the object speeding up or slowing down? (*c*) Is the acceleration of the object positive or negative? Now consider the time interval from D to E. (*d*) Is the object moving in the positive or negative direction? (*e*) Is the object speeding up or slowing down? (*f*) Is the acceleration of the object positive or negative? (*g*) Finally, answer these same three questions for the time interval from C to D.

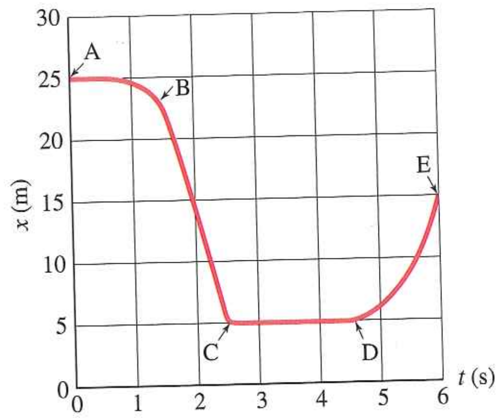

FIGURE 2–36 Problem 56.

General Problems

57. A person jumps from a fourth-story window 15.0 m above a firefighter's safety net. The survivor stretches the net 1.0 m before coming to rest, Fig. 2–37. (*a*) What was the average deceleration experienced by the survivor when she was slowed to rest by the net? (*b*) What would you do to make it "safer" (that is, to generate a smaller deceleration): would you stiffen or loosen the net? Explain.

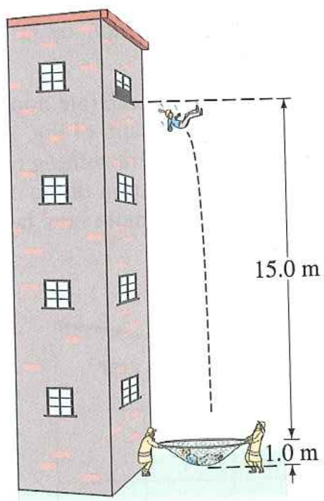

FIGURE 2–37 Problem 57.

58. The acceleration due to gravity on the Moon is about one-sixth what it is on Earth. If an object is thrown vertically upward on the Moon, how many times higher will it go than it would on Earth, assuming the same initial velocity?

59. A person who is properly constrained by an over-the-shoulder seat belt has a good chance of surviving a car collision if the deceleration does not exceed about 30 "g's" ($1.0\ g = 9.8\ \mathrm{m/s^2}$). Assuming uniform deceleration of this value, calculate the distance over which the front end of the car must be designed to collapse if a crash brings the car to rest from 100 km/h.

60. Agent Bond is standing on a bridge, 12 m above the road below, and his pursuers are getting too close for comfort. He spots a flatbed truck approaching at 25 m/s, which he measures by knowing that the telephone poles the truck is passing are 25 m apart in this country. The bed of the truck is 1.5 m above the road, and Bond quickly calculates how many poles away the truck should be when he jumps down from the bridge onto the truck to make his getaway. How many poles is it?

61. Suppose a car manufacturer tested its cars for front-end collisions by hauling them up on a crane and dropping them from a certain height. (*a*) Show that the speed just before a car hits the ground, after falling from rest a vertical distance H, is given by $\sqrt{2gH}$. What height corresponds to a collision at (*b*) 60 km/h? (*c*) 100 km/h?

62. Every year the Earth travels about 10^9 km as it orbits the Sun. What is Earth's average speed in km/h?

63. A 95-m-long train begins uniform acceleration from rest. The front of the train has a speed of 25 m/s when it passes a railway worker who is standing 180 m from where the front of the train started. What will be the speed of the last car as it passes the worker? (See Fig. 2–38.)

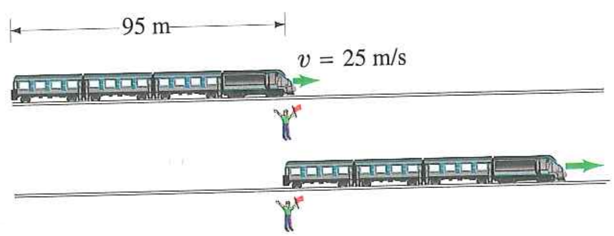

FIGURE 2–38 Problem 63.

64. A person jumps off a diving board 4.0 m above the water's surface into a deep pool. The person's downward motion stops 2.0 m below the surface of the water. Estimate the average deceleration of the person while under the water.

65. In the design of a rapid transit system, it is necessary to balance the average speed of a train against the distance between stops. The more stops there are, the slower the train's average speed. To get an idea of this problem, calculate the time it takes a train to make a 9.0-km trip in two situations: (*a*) the stations at which the trains must stop are 1.8 km apart (a total of 6 stations, including those at the ends); and (*b*) the stations are 3.0 km apart (4 stations total). Assume that at each station the train accelerates at a rate of $1.1\ \mathrm{m/s^2}$ until it reaches 90 km/h, then stays at this speed until its brakes are applied for arrival at the next station, at which time it decelerates at $-2.0\ \mathrm{m/s^2}$. Assume it stops at each intermediate station for 20 s.

66. Pelicans tuck their wings and free fall straight down when diving for fish. Suppose a pelican starts its dive from a height of 16.0 m and cannot change its path once committed. If it takes a fish 0.20 s to perform evasive action, at what minimum height must it spot the pelican to escape? Assume the fish is at the surface of the water.

67. In putting, the force with which a golfer strikes a ball is planned so that the ball will stop within some small distance of the cup, say, 1.0 m long or short, in case the putt is missed. Accomplishing this from an uphill lie (that is, putting downhill, see Fig. 2–39) is more difficult than from a downhill lie. To see why, assume that on a particular green the ball decelerates constantly at $2.0\ \text{m/s}^2$ going downhill, and constantly at $3.0\ \text{m/s}^2$ going uphill. Suppose we have an uphill lie 7.0 m from the cup. Calculate the allowable range of initial velocities we may impart to the ball so that it stops in the range 1.0 m short to 1.0 m long of the cup. Do the same for a downhill lie 7.0 m from the cup. What in your results suggests that the downhill putt is more difficult?

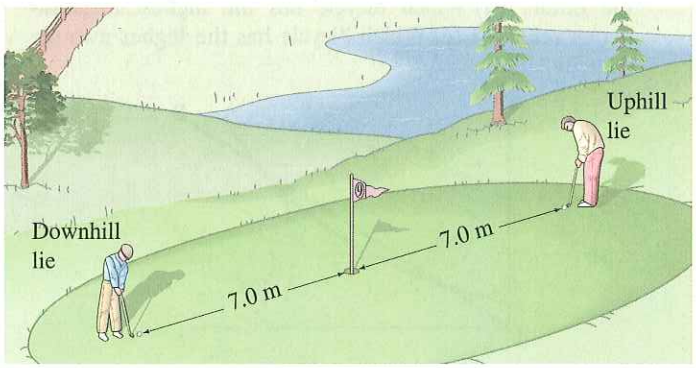

FIGURE 2–39 Problem 67. Golf on Wednesday morning.

68. A fugitive tries to hop on a freight train traveling at a constant speed of 6.0 m/s. Just as an empty box car passes him, the fugitive starts from rest and accelerates at $a = 4.0\ \text{m/s}^2$ to his maximum speed of 8.0 m/s. (*a*) How long does it take him to catch up to the empty box car? (*b*) What is the distance traveled to reach the box car?

69. A stone is dropped from the roof of a high building. A second stone is dropped 1.50 s later. How far apart are the stones when the second one has reached a speed of 12.0 m/s?

70. A race car driver must average 200.0 km/h over the course of a time trial lasting ten laps. If the first nine laps were done at 198.0 km/h, what average speed must be maintained for the last lap?

71. A bicyclist in the Tour de France crests a mountain pass as he moves at 18 km/h. At the bottom, 4.0 km farther, his speed is 75 km/h. What was his average acceleration (in m/s^2) while riding down the mountain?

72. Two children are playing on two trampolines. The first child can bounce up one-and-a-half times higher than the second child. The initial speed up of the second child is 5.0 m/s. (*a*) Find the maximum height the second child reaches. (*b*) What is the initial speed of the first child? (*c*) How long was the first child in the air?

73. An automobile traveling 95 km/h overtakes a 1.10-km-long train traveling in the same direction on a track parallel to the road. If the train's speed is 75 km/h, how long does it take the car to pass it, and how far will the car have traveled in this time? See Fig. 2–40. What are the results if the car and train are traveling in opposite directions?

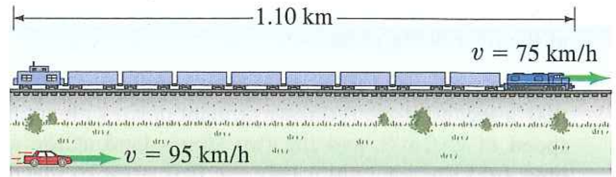

FIGURE 2–40 Problem 73.

74. A baseball pitcher throws a baseball with a speed of 44 m/s. In throwing the baseball, the pitcher accelerates the ball through a displacement of about 3.5 m, from behind the body to the point where it is released (Fig. 2–41). Estimate the average acceleration of the ball during the throwing motion.

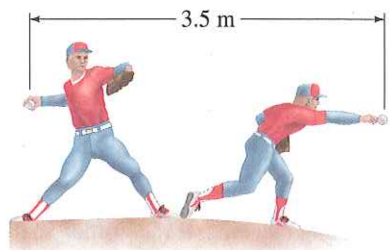

FIGURE 2–41 Problem 74.

75. A rocket rises vertically, from rest, with an acceleration of $3.2\ \text{m/s}^2$ until it runs out of fuel at an altitude of 1200 m. After this point, its acceleration is that of gravity, downward. (*a*) What is the velocity of the rocket when it runs out of fuel? (*b*) How long does it take to reach this point? (*c*) What maximum altitude does the rocket reach? (*d*) How much time (total) does it take to reach maximum altitude? (*e*) With what velocity does the rocket strike the Earth? (*f*) How long (total) is it in the air?

76. Consider the street pattern shown in Fig. 2–42. Each intersection has a traffic signal, and the speed limit is 50 km/h. Suppose you are driving from the west at the speed limit. When you are 10 m from the first intersection, all the lights turn green. The lights are green for 13 s each. (*a*) Calculate the time needed to reach the third stoplight. Can you make it through all three lights without stopping? (*b*) Another car was stopped at the first light when all the lights turned green. It can accelerate at the rate of $2.0\ \text{m/s}^2$ to the speed limit. Can the second car make it through all three lights without stopping?

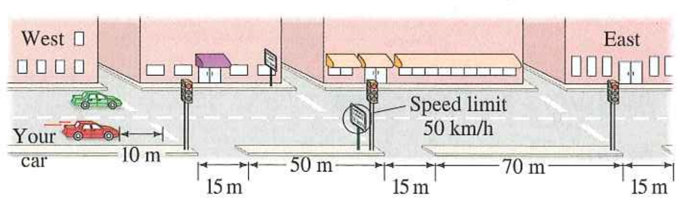

FIGURE 2–42 Problem 76.

77. A police car at rest, passed by a speeder traveling at a constant 120 km/h, takes off in hot pursuit. The police officer catches up to the speeder in 750 m, maintaining a constant acceleration. (*a*) Qualitatively plot the position vs. time graph for both cars from the police car's start to the catch-up point. Calculate (*b*) how long it took the police officer to overtake the speeder, (*c*) the required police car acceleration, and (*d*) the speed of the police car at the overtaking point.

78. A stone is dropped from the roof of a building; 2.00 s after that, a second stone is thrown straight down with an initial speed of 25.0 m/s, and the two stones land at the same time. (*a*) How long did it take the first stone to reach the ground? (*b*) How high is the building? (*c*) What are the speeds of the two stones just before they hit the ground?

79. Two stones are thrown vertically up at the same time. The first stone is thrown with an initial velocity of 11.0 m/s from a 12th-floor balcony of a building and hits the ground after 4.5 s. With what initial velocity should the second stone be thrown from a 4th-floor balcony so that it hits the ground at the same time as the first stone? Make simple assumptions, like equal-height floors.

80. If there were no air resistance, how long would it take a free-falling parachutist to fall from a plane at 3200 m to an altitude of 350 m, where she will pull her ripcord? What would her speed be at 350 m? (In reality, the air resistance will restrict her speed to perhaps 150 km/h.)

81. A fast-food restaurant uses a conveyor belt to send the burgers through a grilling machine. If the grilling machine is 1.1 m long and the burgers require 2.5 min to cook, how fast must the conveyor belt travel? If the burgers are spaced 15 cm apart, what is the rate of burger production (in burgers/min)?

82. Bill can throw a ball vertically at a speed 1.5 times faster than Joe can. How many times higher will Bill's ball go than Joe's?

83. You stand at the top of a cliff while your friend stands on the ground below you. You drop a ball from rest and see that it takes 1.2 s for the ball to hit the ground below. Your friend then picks up the ball and throws it up to you, such that it just comes to rest in your hand. What is the speed with which your friend threw the ball?

84. Two students are asked to find the height of a particular building using a barometer. Instead of using the barometer as an altitude-measuring device, they take it to the roof of the building and drop it off, timing its fall. One student reports a fall time of 2.0 s, and the other, 2.3 s. How much difference does the 0.3 s make for the estimates of the building's height?

* 85. Figure 2–43 shows the position vs. time graph for two bicycles, A and B. (*a*) Is there any instant at which the two bicycles have the same velocity? (*b*) Which bicycle has the larger acceleration? (*c*) At which instant(s) are the bicycles passing each other? Which bicycle is passing the other? (*d*) Which bicycle has the highest instantaneous velocity? (*e*) Which bicycle has the higher average velocity?

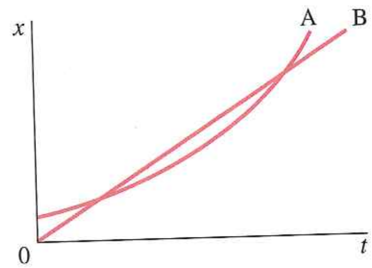

FIGURE 2–43 Problem 85.

Answers to Exercises

A: (*b*).
B: (*a*) +; (*b*) −; (*c*) −; (*d*) +.
C: (*c*).
D: 4.9 m/s^2.
E: That plane on which a smooth ball will not roll; or perpendicular to vertical.