HAPTER 5 REVIEW

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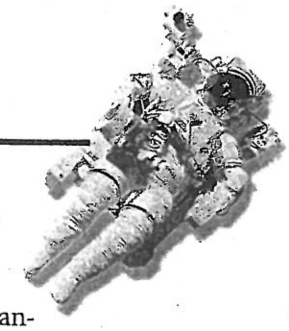
Summary



5.1 Graphing Motion in One Dimension

- Position-time graphs can be used to find the velocity and position of an object, and where and when two objects meet.
- A description of motion can be obtained by interpreting graphs, and graphs can be drawn from descriptions of motion.
- Equations that describe the position of an object moving at constant velocity can be written based on word and graphical representations of problems.

5.2 Graphing Velocity in One Dimension

- Instantaneous velocity is the slope of the tangent to the curve on a position-time graph.
- Velocity-time graphs can be used to determine the velocity of an object and the time when two objects have the same velocity.
- The area under the curve on a velocity-time graph is displacement.

5.3 Acceleration

- The acceleration of an object is the slope of the curve on a velocity-time graph.
- The slope of the tangent to the curve on a v-t graph is the instantaneous acceleration of the object.
- Velocity-time graphs and motion diagrams can be used to find the sign of the acceleration.
- Both graphs and equations can be used to find the velocity of an object undergoing constant acceleration.
- Three different equations give the displacement of an object under constant acceleration, depending on what quantities are known.
- The mathematical model completes the solution of motion problems.
- Results obtained by solving a problem must be tested to find out whether they are reasonable.

5.4 Free Fall

- The magnitude of the acceleration due to gravity ($g = 9.80\ m/s^2$) is always a positive quantity. The sign of acceleration depends upon the choice of the coordinate system.
- Motion equations can be used to solve problems involving freely falling objects.

Reviewing Concepts

Section 5.1

1. A walker and a runner leave your front door at the same time. They move in the same direction at different constant velocities. Describe the position-time graphs of each.
2. What does the slope of the tangent to the curve on a position-time graph measure?

Section 5.2

3. If you know the positions of an object at two points along its path, and you also know the time it took to get from one point to the other, can you determine the particle's instantaneous velocity? Its average velocity? Explain.
4. What quantity is represented by the area under a velocity-time curve?
5. **Figure 5–20** shows the velocity-time graph for an automobile on a test track. Describe how the velocity changes with time.

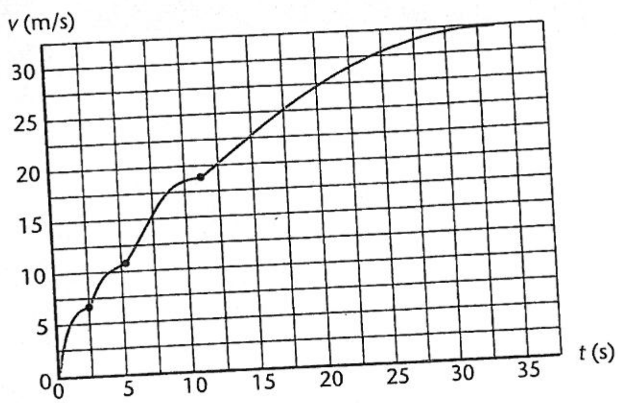


FIGURE 5–20

Section 5.3

6. What does the slope of the tangent to the curve on a velocity-time graph measure?
7. A car is traveling on an interstate highway.
   a. Can the car have a negative velocity and a positive acceleration at the same time? Explain.
   b. Can the car's velocity change signs while it is traveling with constant acceleration? Explain.
8. Can the velocity of an object change when its acceleration is constant? If so, give an example. If not, explain.
9. If the velocity-time curve is a straight line parallel to the t-axis, what can you say about the acceleration?
10. If you are given a table of velocities of an object at various times, how could you find out if the acceleration of the object is constant?
11. Write a summary of the equations for position, velocity, and time for an object experiencing uniformly accelerated motion.

Section 5.4

12. Explain why an aluminum ball and a steel ball of similar size and shape, dropped from the same height, reach the ground at the same time.
13. Give some examples of falling objects for which air resistance cannot be ignored.
14. Give some examples of falling objects for which air resistance can be ignored.

Applying Concepts

15. **Figure 5–20** shows the velocity-time graph of an accelerating car. The three "notches" in the curve occur where the driver changes gears.
    a. Describe the changes in velocity and acceleration of the car while in first gear.
    b. Is the acceleration just before a gear change larger or smaller than the acceleration just after the change? Explain your answer.
16. Explain how you would walk to produce each of the position-time graphs in **Figure 5–21.**

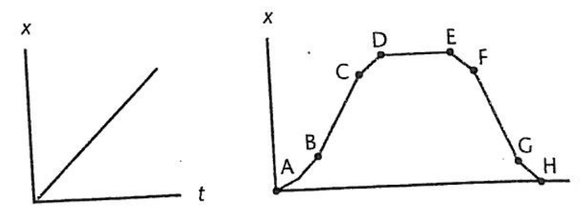


FIGURE 5–21

17. Use **Figure 5–20** to determine during what time interval the acceleration is largest and during what time interval the acceleration is smallest.
18. Solve the equation $v = v_0 + at$ for acceleration.
19. **Figure 5–22** is a position-time graph of two people running.
    a. Describe the position of runner A relative to runner B at the y-intercept.
    b. Which runner is faster?
    c. What occurs at point P and beyond?

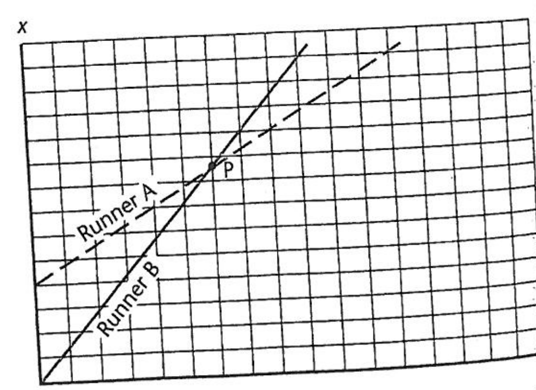
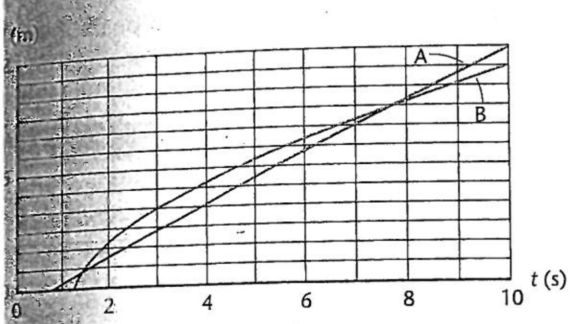


FIGURE 5–22



URE 5–23

Figure 5–23 is a position-time graph of the motion of two cars on a road.

a. At what time(s) does one car pass the other?

b. Which car is moving faster at 7.0 s?

c. At what time(s) do the cars have the same velocity?

d. Over what time interval is car B speeding up all the time?

e. Over what time interval is car B slowing down all the time?

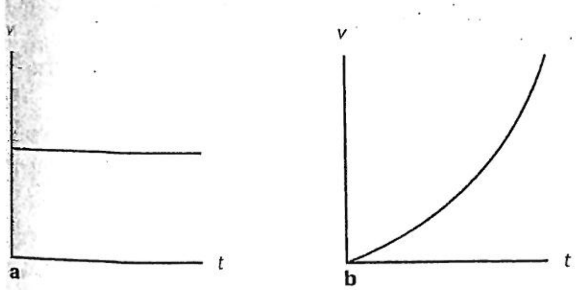
Look at **Figure 5–24.**

a. What kind of motion is represented by **a?**

b. What does the area under the curve represent?

c. What kind of motion is represented by **b?**

d. What does the area under the curve represent?



URE 5–24

22. An object shot straight up rises for 7.0 s before it reaches its maximum height. A second object falling from rest takes 7.0 s to reach the ground. Compare the displacements of the two objects during this time interval.

23. Describe the changes in the velocity of a ball thrown straight up into the air. Then describe the changes in the ball's acceleration.

24. The value of g on the moon is 1/6 of its value on Earth.

a. Will a ball dropped by an astronaut hit the surface of the moon with a smaller, equal, or larger speed than that of a ball dropped from the same height to Earth?

b. Will it take more, less, or equal time to fall?

25. Planet Dweeb has three times the gravitational acceleration of Earth. A ball is thrown vertically upward with the same initial velocity on Earth and on Dweeb.

a. How does the maximum height reached by the ball on Dweeb compare to the maximum height on Earth?

b. If the ball on Dweeb were thrown with three times greater initial velocity, how would that affect your answer to **a?**

26. Rock A is dropped from a cliff; rock B is thrown upward from the same position.

a. When they reach the ground at the bottom of the cliff, which rock has a greater velocity?

b. Which has a greater acceleration?

c. Which arrives first?

Problems

Section 5.1

LEVEL 1

27. Light from the sun reaches Earth in 8.3 min. The velocity of light is 3.00×10^8 m/s. How far is Earth from the sun?

28. You and a friend each drive 50 km. You travel at 90 km/h; your friend travels at 95 km/h. How long will your friend wait for you at the end of the trip?

TABLE 5–3	
Distance versus Time	
Time (s)	**Distance (m)**
0.0	0.0
1.0	2.0
2.0	8.0
3.0	18.0
4.0	32.9
5.0	50.0

29. The total distance a steel ball rolls down an incline at various times is given in **Table 5–3.**
- **a.** Draw a position-time graph of the motion of the ball. When setting up the axes, use five divisions for each 10 m of travel on the *d*-axis. Use five divisions for 1 s of time on the *t*-axis.
- **b.** What type of curve is the line of the graph?
- **c.** What distance has the ball rolled at the end of 2.2 s?

30. A cyclist maintains a constant velocity of +5.0 m/s. At time $t = 0.0$, the cyclist is +250 m from point A.
- **a.** Plot a position-time graph of the cyclist's location from point A at 10.0-s intervals for 60.0 s.
- **b.** What is the cyclist's position from point A at 60.0 s?
- **c.** What is the displacement from the starting position at 60.0 s?

31. From the position-time graph in **Figure 5–25,** construct a table showing the average velocity of the object during each 10-s interval over the entire 100 s.

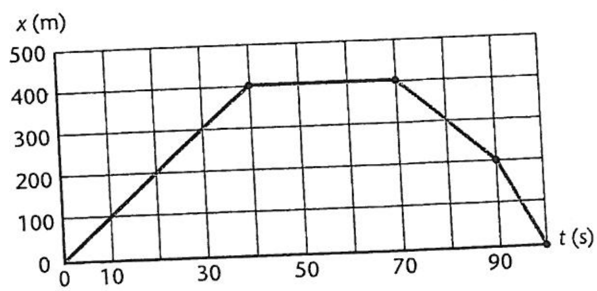


FIGURE 5–25

32. Plot the data in **Table 5–4** on a position-time graph. Find the average velocity in the time interval between 0.0 s and 5.0 s.

TABLE 5–4	
Position versus Time	
Clock Reading, *t* (s)	**Position, *d* (m)**
0.0	30
1.0	30
2.0	35
3.0	45
4.0	60
5.0	70

LEVEL 2

33. You drive a car for 2.0 h at 40 km/h, then for another 2.0 h at 60 km/h.
- **a.** What is your average velocity?
- **b.** Do you get the same answer if you drive 100 km at each of the two speeds?

34. Use the position-time graph in **Figure 5–25** to find how far the object travels
- **a.** between $t = 0$ s and $t = 40$ s.
- **b.** between $t = 40$ s and $t = 70$ s.
- **c.** between $t = 90$ s and $t = 100$ s.

35. Do this problem on a worksheet. Both car A and car B leave school when a clock reads zero. Car A travels at a constant 75 km/h, and car B travels at a constant 85 km/h.
- **a.** Draw a position-time graph showing the motion of both cars.
- **b.** How far are the two cars from school when the clock reads 2.0 h? Calculate the distances using the equation for motion and show them on your graph.
- **c.** Both cars passed a gas station 120 km from the school. When did each car pass the gas station? Calculate the times and show them on your graph.

36. Draw a position-time graph for two cars driving to the beach, which is 50 km from school. At noon Car A leaves a store 10 km closer to the beach than the school is and drives at 40 km/h. Car B starts from school at 12:30 P.M. and drives at 100 km/h. When does each car get to the beach?

37. Two cars travel along a straight road. When a stopwatch reads $t = 0.00$ h, car A is at $d_A =$ 48.0 km moving at a constant 36.0 km/h. Later, when the watch reads $t = 0.50$ h, car B is at $d_B = 0.00$ km moving at 48.0 km/h. Answer the following questions, first, graphically by creating a position-time graph, and second, algebraically by writing down equations for the positions d_A and d_B as a function of the stopwatch time, t.
   a. What will the watch read when car B passes car A?
   b. At what position will car B pass car A?
   c. When the cars pass, how long will it have been since car A was at the reference point?

38. A car is moving down a street at 55 km/h. A child suddenly runs into the street. If it takes the driver 0.75 s to react and apply the brakes, how many meters will the car have moved before it begins to slow down?

Section 5.2

LEVEL 1

39. Refer to **Figure 5–23** to find the instantaneous speed for
   a. car B at 2.0 s.
   b. car B at 9.0 s.
   c. car A at 2.0 s.

40. Refer to **Figure 5–26** to find the distance the moving object travels between
   a. $t = 0$ s and $t = 5$ s.
   b. $t = 5$ s and $t = 10$ s.
   c. $t = 10$ s and $t = 15$ s.
   d. $t = 0$ s and $t = 25$ s.

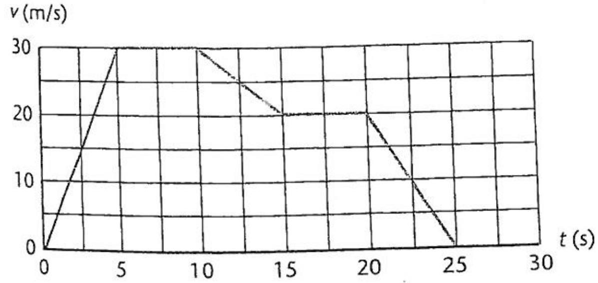


FIGURE 5–26

41. Find the instantaneous speed of the car in **Figure 5–20** at 15 s.

42. You ride your bike for 1.5 h at an average velocity of 10 km/h, then for 30 min at 15 km/h. What is your average velocity?

LEVEL 2

43. Plot a velocity-time graph using the information in **Table 5–5,** then answer the questions.
   a. During what time interval is the object speeding up? Slowing down?
   b. At what time does the object reverse direction?
   c. How does the average acceleration of the object in the interval between 0 s and 2 s differ from the average acceleration in the interval between 7 s and 12 s?

TABLE 5–5

Velocity versus Time

Time (s)	Velocity (m/s)	Time (s)	Velocity (m/s)
0.0	4.0	7.0	12.0
1.0	8.0	8.0	8.0
2.0	12.0	9.0	4.0
3.0	14.0	10.0	0.0
4.0	16.0	11.0	−4.0
5.0	16.0	12.0	−8.0
6.0	14.0		

Section 5.3

LEVEL 1

44. Find the uniform acceleration that causes a car's velocity to change from 32 m/s to 96 m/s in an 8.0-s period.

45. Use **Figure 5–26** to find the acceleration of the moving object
   a. during the first 5 s of travel.
   b. between the fifth and the tenth second of travel.
   c. between the tenth and the 15th second of travel.
   d. between the 20th and 25th second of travel.

46. A car with a velocity of 22 m/s is accelerated uniformly at the rate of 1.6 m/s^2 for 6.8 s. What is its final velocity?

47. A supersonic jet flying at 145 m/s is accelerated uniformly at the rate of 23.1 m/s^2 for 20.0 s.
   a. What is its final velocity?
   b. The speed of sound in air is 331 m/s. How many times the speed of sound is the plane's final speed?

48. Determine the final velocity of a proton that has an initial velocity of 2.35×10^5 m/s, and then is accelerated uniformly in an electric field at the rate of -1.10×10^{12} m/s^2 for 1.50×10^{-7} s.

49. Determine the displacement of a plane that is uniformly accelerated from 66 m/s to 88 m/s in 12 s.

50. How far does a plane fly in 15 s while its velocity is changing from 145 m/s to 75 m/s at a uniform rate of acceleration?

51. A car moves at 12 m/s and coasts up a hill with a uniform acceleration of -1.6 m/s^2.
   a. How far has it traveled after 6.0 s?
   b. How far has it gone after 9.0 s?

52. A plane travels 5.0×10^2 m while being accelerated uniformly from rest at the rate of 5.0 m/s^2. What final velocity does it attain?

53. A race car can be slowed with a constant acceleration of -11 m/s^2.
   a. If the car is going 55 m/s, how many meters will it take to stop?
   b. How many meters will it take to stop a car going twice as fast?

54. An engineer must design a runway to accommodate airplanes that must reach a ground velocity of 61 m/s before they can take off. These planes are capable of being accelerated uniformly at the rate of 2.5 m/s^2.
   a. How long will it take the planes to reach takeoff speed?
   b. What must be the minimum length of the runway?

55. Engineers are developing new types of guns that might someday be used to launch satellites as if they were bullets. One such gun can give a small object a velocity of 3.5 km/s, moving it through only 2.0 cm.
   a. What acceleration does the gun give this object?
   b. Over what time interval does the acceleration take place?

56. Highway safety engineers build soft barriers so that cars hitting them will slow down at a safe rate. A person wearing a seat belt can withstand an acceleration of -300 m/s^2. How thick should barriers be to safely stop a car that hits a barrier at 110 km/h?

57. A baseball pitcher throws a fastball at a speed of 44 m/s. The acceleration occurs as the pitcher holds the ball in his hand and moves it through an almost straight-line distance of 3.5 m. Calculate the acceleration, assuming it is uniform. Compare this acceleration to the acceleration due to gravity, 9.80 m/s^2.

LEVEL 2

58. Rocket-powered sleds are used to test the responses of humans to acceleration. Starting from rest, one sled can reach a speed of 444 m/s in 1.80 s and can be brought to a stop again in 2.15 s.
   a. Calculate the acceleration of the sled when starting, and compare it to the magnitude of the acceleration due to gravity, 9.80 m/s^2.
   b. Find the acceleration of the sled when braking and compare it to the magnitude of the acceleration due to gravity.

59. Draw a velocity-time graph for each of the graphs in **Figure 5–27.**

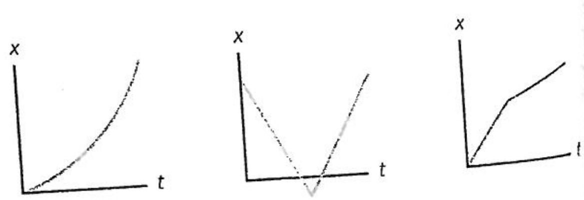


FIGURE 5–27

60. The velocity of an automobile changes over an 8.0-s time period as shown in **Table 5–6.**
   a. Plot the velocity-time graph of the motion.
   b. Determine the displacement of the car during the first 2.0 s.
   c. What displacement does the car have during the first 4.0 s?
   d. What displacement does the car have during the entire 8.0 s?
   e. Find the slope of the line between $t = 0.0$ s and $t = 4.0$ s. What does this slope represent?
   f. Find the slope of the line between $t = 5.0$ s and $t = 7.0$ s. What does this slope indicate?

TABLE 5–6
Velocity versus Time

Time (s)	Velocity (m/s)	Time (s)	Velocity (m/s)
0.0	0.0	5.0	20.0
1.0	4.0	6.0	20.0
2.0	8.0	7.0	20.0
3.0	12.0	8.0	20.0
4.0	16.0		

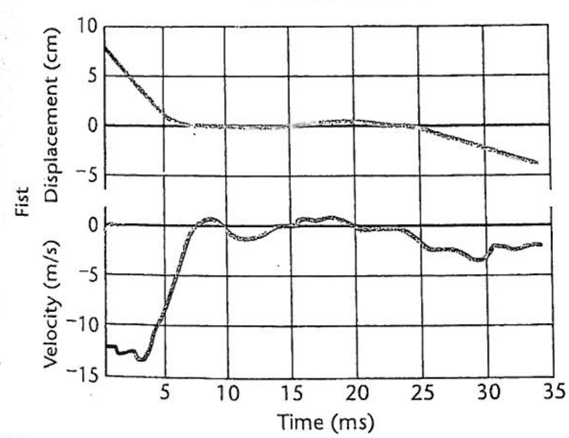


FIGURE 5-28

61. **Figure 5–28** shows the position-time and velocity-time graphs of a karate expert's fist as it breaks a wooden board.
   a. Use the velocity-time graph to describe the motion of the expert's fist during the first 10 ms.
   b. Estimate the slope of the velocity-time graph to determine the acceleration of the fist when it suddenly stops.
   c. Express the acceleration as a multiple of the gravitational acceleration, $g = 9.80\ m/s^2$.
   d. Determine the area under the velocity-time curve to find the displacement of the fist in the first 6 ms. Compare this with the position-time graph.

62. The driver of a car going 90.0 km/h suddenly sees the lights of a barrier 40.0 m ahead. It takes the driver 0.75 s to apply the brakes, and the average acceleration during braking is $-10.0\ m/s^2$.
   a. Determine whether the car hits the barrier.
   b. What is the maximum speed at which the car could be moving and not hit the barrier 40.0 m ahead? Assume that the acceleration rate doesn't change.

63. The data in **Table 5–7,** taken from a driver's handbook, show the distance a car travels when it brakes to a halt from a specific initial velocity.

TABLE 5–7
Initial Velocity versus Braking Distance

Initial Velocity (m/s)	Braking Distance (m)
11	10
15	20
20	34
25	50
29	70

   a. Plot the braking distance versus the initial velocity. Describe the shape of the curve.
   b. Plot the braking distance versus the square of the initial velocity. Describe the shape of the curve.
   c. Calculate the slope of your graph from part **b.** Find the value and units of the quantity 1/slope.
   d. Does this curve agree with the equation $v_0^2 = -2ad$? What is the value of a?

64. As a traffic light turns green, a waiting car starts with a constant acceleration of $6.0\ m/s^2$. At the instant the car begins to accelerate, a truck with a constant velocity of 21 m/s passes in the next lane.

a. How far will the car travel before it overtakes the truck?
b. How fast will the car be traveling when it overtakes the truck?

65. Use the information given in problem 64.
a. Draw velocity-time and position-time graphs for the car and truck.
b. Do the graphs confirm the answer you calculated for problem 64?

Section 5.4

LEVEL 1

66. An astronaut drops a feather from 1.2 m above the surface of the moon. If the acceleration of gravity on the moon is 1.62 m/s^2 downward, how long does it take the feather to hit the moon's surface?

67. A stone falls freely from rest for 8.0 s.
a. Calculate the stone's velocity after 8.0 s.
b. What is the stone's displacement during this time?

68. A student drops a penny from the top of a tower and decides that she will establish a coordinate system in which the direction of the penny's motion is positive. What is the sign of the acceleration of the penny?

69. A bag is dropped from a hovering helicopter. When the bag has fallen 2.0 s,
a. what is the bag's velocity?
b. how far has the bag fallen?

70. A weather balloon is floating at a constant height above Earth when it releases a pack of instruments.
a. If the pack hits the ground with a velocity of −73.5 m/s, how far did the pack fall?
b. How long did it take for the pack to fall?

71. During a baseball game, a batter hits a high pop-up. If the ball remains in the air for 6.0 s, how high does it rise? **Hint:** Calculate the height using the second half of the trajectory.

LEVEL 2

72. **Table 5–8** gives the positions and velocities of a ball at the end of each second for the first 5.0 s of free fall from rest.
a. Use the data to plot a velocity-time graph.
b. Use the data in the table to plot a position-time graph.
c. Find the slope of the curve at the end of 2.0 s and 4.0 s on the position-time graph. Do the values agree with the table of velocity?
d. Use the data in the table to plot a position-versus-time-squared graph. What type of curve is obtained?
e. Find the slope of the line at any point. Explain the significance of the value.
f. Does this curve agree with the equation $d = 1/2\, gt^2$?

TABLE 5–8
Position and Velocity in Free Fall

Time (s)	Position (m)	Velocity (m/s)
0.0	0.0	0.0
1.0	−4.9	−9.8
2.0	−19.6	−19.6
3.0	−44.1	−29.4
4.0	−78.4	−39.2
5.0	−122.5	−49.0

73. The same helicopter in problem 69 is rising at 5.0 m/s when the bag is dropped. After 2.0 s,
a. what is the bag's velocity?
b. how far has the bag fallen?
c. how far below the helicopter is the bag?

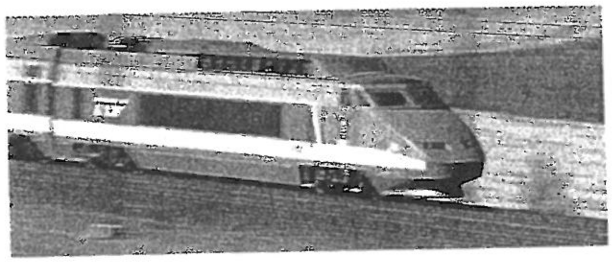
74. The helicopter in problems 69 and 73 now descends at 5.0 m/s as the bag is released. After 2.0 s,
a. what is the bag's velocity?
b. how far has the bag fallen?
c. how far below the helicopter is the bag?

75. What is common to the answers to problems 69, 73, and 74?

76. A tennis ball is dropped from 1.20 m above the ground. It rebounds to a height of 1.00 m.
a. With what velocity does it hit the ground?
b. With what velocity does it leave the ground?
c. If the tennis ball were in contact with the ground for 0.010 s, find its acceleration while touching the ground. Compare the acceleration to *g*.

Critical Thinking Problems

77. An express train, traveling at 36.0 m/s, is accidentally sidetracked onto a local train track. The express engineer spots a local train exactly 1.00×10^2 m ahead on the same track and traveling in the same direction. The local engineer is unaware of the situation. The express engineer jams on the brakes and slows the express at a constant rate of 3.00 m/s^2. If the speed of the local train is 11.0 m/s, will the express train be able to stop in time or will there be a collision? To solve this problem, take the position of the express train when it first sights the local train as a point of origin. Next, keeping in mind that the local train has exactly a 1.00×10^2 m lead, calculate how far each train is from the origin at the end of the 12.0 s it would take the express train to stop.
    - **a.** On the basis of your calculations, would you conclude that a collision will occur?
    - **b.** The calculations you made do not allow for the possibility that a collision might take place before the end of the 12 s required for the express train to come to a halt. To check this, take the position of the express train when it first sights the local train as the point of origin and calculate the position of each train at the end of each second after sighting. Make a table showing the distance of each train from the origin at the end of each second. Plot these positions on the same graph and draw two lines. Use your graph to check your answer to part **a.**
78. Which has the greater acceleration: a car that increases its speed from 50 to 60 km/h, or a bike that goes from 0 to 10 km/h in the same time? Explain.
79. You plan a car trip on which you want to average 90 km/h. You cover the first half of the distance at an average speed of only 48 km/h. What must your average speed be in the second half of the trip to meet your goal? Is this reasonable? Note that the velocities are based on half the distance, not half the time.



Going Further

Applying Calculators Members of a physics class stood 25 m apart and used stopwatches to measure the time a car driving down the highway passed each person. The data they compiled are shown in **Table 5–9.**

TABLE 5–9
Position versus Time

Time (s)	Position (m)	Time (s)	Position (m)
0.0	0.0	5.9	125.0
1.3	25.0	7.0	150.0
2.7	50.0	8.6	175.0
3.6	75.0	10.3	200.0
5.1	100.0		

Use a graphing calculator to fit a line to a position-time graph of the data and to plot this line. Be sure to set the display range of the graph so that all the data fit on it. Find the slope of the line. What was the speed of the car?

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