CHAPTER 2 Summary

BIG IDEA The motion of an object can be described and predicted using known relationships between the following variables: displacement, velocity, acceleration, and time.

SECTION 1 Displacement and Velocity

KEY TERMS

frame of reference
displacement
average velocity
instantaneous velocity

- Displacement is a change of position in a certain direction, not the total distance traveled.
- The average velocity of an object during some time interval is equal to the displacement of the object divided by the time interval. Like displacement, velocity has both a magnitude (called speed) and a direction.
- The average velocity is equal to the slope of the straight line connecting the initial and final points on a graph of the position of the object versus time.

SECTION 2 Acceleration

KEY TERM

acceleration

- The average acceleration of an object during a certain time interval is equal to the change in the object's velocity divided by the time interval. Acceleration has both magnitude and direction.
- The direction of the acceleration is not always the same as the direction of the velocity. The direction of the acceleration depends on the direction of the motion and on whether the velocity is increasing or decreasing.
- The average acceleration is equal to the slope of the straight line connecting the initial and final points on the graph of the velocity of the object versus time.
- The equations in **Figure 2.6** are valid whenever acceleration is constant.

SECTION 3 Falling Objects

KEY TERM

free fall

- An object thrown or dropped in the presence of Earth's gravity experiences a constant acceleration directed toward the center of Earth. This acceleration is called the free-fall acceleration, or the acceleration due to gravity.
- Free-fall acceleration is the same for all objects, regardless of mass.
- The value for free-fall acceleration on Earth's surface used in this book is $a_g = -g = -9.81$ m/s^2. The direction of the free-fall acceleration is considered to be negative because the object accelerates toward Earth.

VARIABLE SYMBOLS

Quantities		Units	
x	position	m	meters
Δx	displacement	m	meters
y	position	m	meters
Δy	displacement	m	meters
v	velocity	m/s	meters per second
a	acceleration	m/s^2	meters per second^2

Problem Solving

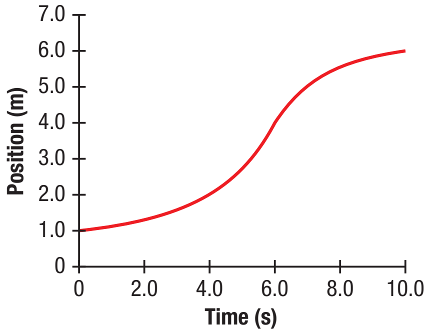
See **Appendix D: Equations** for a summary of the equations introduced in this chapter. If you need more problem-solving practice, see **Appendix I: Additional Problems.**

CHAPTER 2 Review

Displacement and Velocity

REVIEWING MAIN IDEAS

1. On the graph below, what is the total distance traveled during the recorded time interval? What is the displacement?



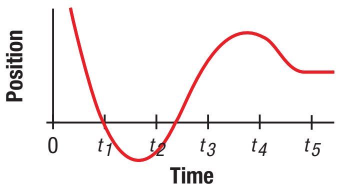
2. On a position-time graph such as the one above, what represents the instantaneous velocity?

3. The position-time graph for a bug crawling along a line is shown in item 4 below. Determine whether the velocity is positive, negative, or zero at each of the times marked on the graph.

4. Use the position-time graph below to answer the following questions:

a. During which time interval(s) is the velocity negative?

b. During which time interval(s) is the velocity positive?



CONCEPTUAL QUESTIONS

5. If the average velocity of a duck is zero in a given time interval, how do you describe the displacement of the duck for that interval?

6. Velocity can be either positive or negative or zero, depending on displacement. The time interval, Δt, is always positive. Why?

PRACTICE PROBLEMS

For problems 7–11, see Sample Problem A.

7. A school bus takes 0.530 h to reach the school from your house. If the average velocity of the bus is 19.0 km/h to the east, what is the displacement?

8. An Olympic runner completes a marathon in 2.00 h, 9.00 min, 21.0 s. If the average speed of this runner is 5.436 m/s, what is the marathon distance?

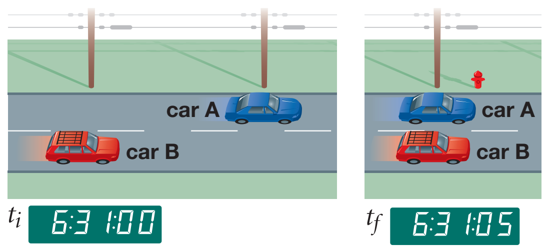
9. Two cars are traveling on a desert road, as shown below. After 5.0 s, they are side by side at the next telephone pole. The distance between the poles is 70.0 m. Identify the following quantities:

a. the displacement of car A after 5.0 s

b. the displacement of car B after 5.0 s

c. the average velocity of car A during 5.0 s

d. the average velocity of car B during 5.0 s



(a) (b)

10. Sally travels by car from one city to another. She drives for 30.0 min at 80.0 km/h, 12.0 min at 105 km/h, and 45.0 min at 40.0 km/h, and she spends 15.0 min eating lunch and buying gas.

a. Determine the average speed for the trip.

b. Determine the total distance traveled.

11. Runner A is initially 6.0 km west of a flagpole and is running with a constant velocity of 9.0 km/h due east. Runner B is initially 5.0 km east of the flagpole and is running with a constant velocity of 8.0 km/h due west. What will be the distance of the two runners from the flagpole when their paths cross? (It is not necessary to convert your answer from kilometers to meters for this problem. You may leave it in kilometers.)

Acceleration

REVIEWING MAIN IDEAS

12. What would be the acceleration of a turtle that is moving with a constant velocity of 0.25 m/s to the right?

13. Sketch the velocity-time graphs for the following motions.

a. a city bus that is moving with a constant velocity

b. a wheelbarrow that is speeding up at a uniform rate of acceleration while moving in the positive direction

c. a tiger that is speeding up at a uniform rate of acceleration while moving in the negative direction

d. an iguana that is slowing down at a uniform rate of acceleration while moving in the positive direction

e. a camel that is slowing down at a uniform rate of acceleration while moving in the negative direction

CONCEPTUAL QUESTIONS

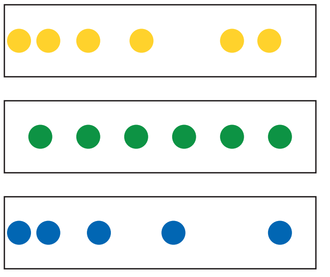
14. If a car is traveling eastward, can its acceleration be westward? Communicate your answer, and use an example in your explanation.

15. The diagrams below show a disk moving from left to right under different conditions. The time interval between images is constant. Assuming that the direction to the right is positive, identify the following types of motion in each photograph. (Some may have more than one type of motion.)

a. the acceleration is positive

b. the acceleration is negative

c. the velocity is constant

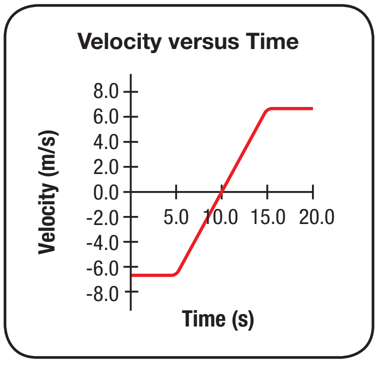


PRACTICE PROBLEMS

For problems 16–17, see Sample Problem B.

16. A car traveling in a straight line has a velocity of +5.0 m/s. After an acceleration of 0.75 m/s^2, the car's velocity is +8.0 m/s. In what time interval did the acceleration occur?

17. The velocity-time graph for an object moving along a straight path is shown below. Find the average accelerations during the time intervals 0.0 s to 5.0 s, 5.0 s to 15.0 s, and 0.0 s to 20.0 s.



For problems 18–19, see Sample Problem C.

18. A bus slows down uniformly from 75.0 km/h (21 m/s) to 0 km/h in 21 s. How far does it travel before stopping?

19. A car accelerates uniformly from rest to a speed of 65 km/h (18 m/s) in 12 s. Find the distance the car travels during this time.

For problems 20–23, see Sample Problem D.

20. A car traveling at +7.0 m/s accelerates at the rate of +0.80 m/s^2 for an interval of 2.0 s. Find v_f.

21. A car accelerates from rest at −3.00 m/s^2.
a. What is the velocity at the end of 5.0 s?
b. What is the displacement after 5.0 s?

22. A car starts from rest and travels for 5.0 s with a uniform acceleration of +1.5 m/s^2. The driver then applies the brakes, causing a uniform acceleration of −2.0 m/s^2. If the brakes are applied for 3.0 s, how fast is the car going at the end of the braking period, and how far has it gone from its start?

23. A boy sledding down a hill accelerates at 1.40 m/s^2. If he started from rest, in what distance would he reach a speed of 7.00 m/s?

For problems 24–25, see Sample Problem E.

24. A sailboat starts from rest and accelerates at a rate of 0.21 m/s^2 over a distance of 280 m.
a. Find the magnitude of the boat's final velocity.
b. Find the time it takes the boat to travel this distance.

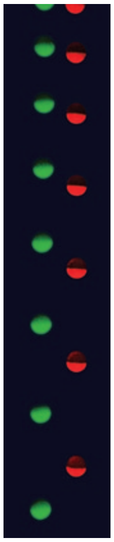
25. An elevator is moving upward at 1.20 m/s when it experiences an acceleration of 0.31 m/s^2 downward, over a distance of 0.75 m. What will be its final velocity?

Falling Objects

REVIEWING MAIN IDEAS

26. A ball is thrown vertically upward.
a. What happens to the ball's velocity while the ball is in the air?
b. What is its velocity when it reaches its maximum altitude?
c. What is its acceleration when it reaches its maximum altitude?
d. What is its acceleration just before it hits the ground?
e. Does its acceleration increase, decrease, or remain constant?

27. The image at right is a strobe photograph of two falling balls released simultaneously. (This motion does not take place in a vacuum.) The time intervals between successive photographs are equal. The ball on the left side is solid, and the ball on the right side is a hollow table-tennis ball. Analyze the motion of both balls in terms of velocity and acceleration.



28. A juggler throws a bowling pin into the air with an initial velocity v_i. Another juggler drops a pin at the same instant. Compare the accelerations of the two pins while they are in the air.

29. A bouquet is thrown upward.
a. Will the value for the bouquet's displacement be the same no matter where you place the origin of the coordinate system?
b. Will the value for the bouquet's velocity be the same?
c. Will the value for the bouquet's acceleration be the same?

PRACTICE PROBLEMS

For problems 30–32, see Sample Problem F.

30. A worker drops a wrench from the top of a tower 80.0 m tall. What is the velocity when the wrench strikes the ground?

31. A peregrine falcon dives at a pigeon. The falcon starts downward from rest with free-fall acceleration. If the pigeon is 76.0 m below the initial position of the falcon, how long does the falcon take to reach the pigeon? Assume that the pigeon remains at rest.

32. A ball is thrown upward from the ground with an initial speed of 25 m/s; at the same instant, a ball is dropped from rest from a building 15 m high. After how long will the balls be at the same height?

Mixed Review

REVIEWING MAIN IDEAS

33. If the average speed of an orbiting space shuttle is 27 800 km/h, determine the time required for it to circle Earth. Assume that the shuttle is orbiting about 320.0 km above Earth's surface and that Earth's radius is 6380 km.

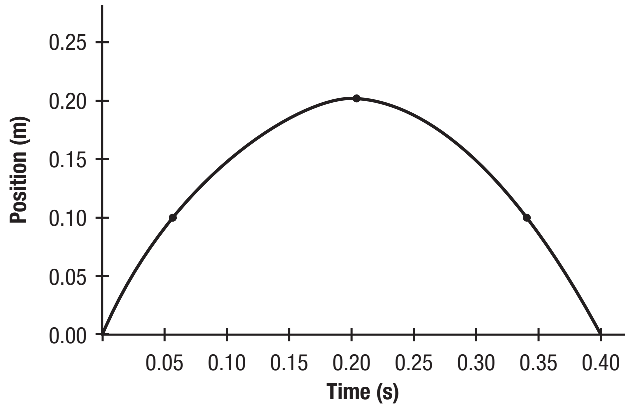
34. A ball is thrown directly upward into the air. The graph below shows the vertical position of the ball with respect to time.

a. How much time does the ball take to reach its maximum height?

b. How much time does the ball take to reach one-half its maximum height?

c. Estimate the slope $\Delta y/\Delta t$ at $t = 0.05$ s, $t = 0.10$ s, $t = 0.15$ s, and $t = 0.20$ s. On your paper, draw a coordinate system with velocity (v) on the y-axis and time (t) on the x-axis. Plot your velocity estimates against time.

d. From your graph, determine what the acceleration on the ball is.

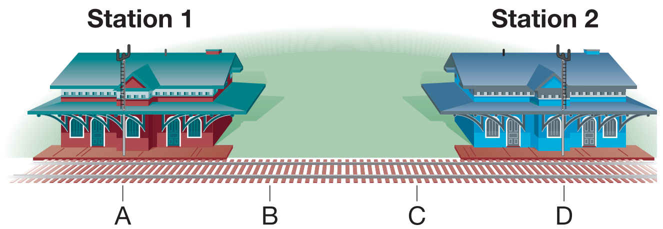


35. A train travels between stations 1 and 2, as shown below. The engineer of the train is instructed to start from rest at station 1 and accelerate uniformly between points A and B, then coast with a uniform velocity between points B and C, and finally accelerate uniformly between points C and D until the train stops at station 2. The distances AB, BC, and CD are all equal, and it takes 5.00 min to travel between the two stations. Assume that the uniform accelerations have the same magnitude, even when they are opposite in direction.

a. How much of this 5.00 min period does the train spend between points A and B?

b. How much of this 5.00 min period does the train spend between points B and C?

c. How much of this 5.00 min period does the train spend between points C and D?



36. Two students are on a balcony 19.6 m above the street. One student throws a ball vertically downward at 14.7 m/s. At the same instant, the other student throws a ball vertically upward at the same speed. The second ball just misses the balcony on the way down.

a. What is the difference in the time the balls spend in the air?

b. What is the velocity of each ball as it strikes the ground?

c. How far apart are the balls 0.800 s after they are thrown?

37. A rocket moves upward, starting from rest, with an acceleration of $+29.4\ m/s^2$ for 3.98 s. It runs out of fuel at the end of the 3.98 s but does not stop. How high does it rise above the ground?

38. Two cars travel westward along a straight highway, one at a constant velocity of 85 km/h and the other at a constant velocity of 115 km/h.

a. Assuming that both cars start at the same point, how much sooner does the faster car arrive at a destination 16 km away?

b. How far must the cars travel for the faster car to arrive 15 min before the slower car?

39. A small first-aid kit is dropped by a rock climber who is descending steadily at 1.3 m/s. After 2.5 s, what is the velocity of the first-aid kit, and how far is the kit below the climber?

40. A small fish is dropped by a pelican that is rising steadily at 0.50 m/s.

a. After 2.5 s, what is the velocity of the fish?

b. How far below the pelican is the fish after 2.5 s?

41. A ranger in a national park is driving at 56 km/h when a deer jumps onto the road 65 m ahead of the vehicle. After a reaction time of t s, the ranger applies the brakes to produce an acceleration of $-3.0\ m/s^2$. What is the maximum reaction time allowed if the ranger is to avoid hitting the deer?

42. A speeder passes a parked police car at 30.0 m/s. The police car starts from rest with a uniform acceleration of 2.44 m/s^2. (Assume that the police car starts at the exact moment the car passes by.)
- **a.** How much time passes before the speeder is overtaken by the police car?
- **b.** How far does the speeder get before being overtaken by the police car?

43. An ice sled powered by a rocket engine starts from rest on a large frozen lake and accelerates at $+13.0\ m/s^2$. At t_1 the rocket engine is shut down and the sled moves with constant velocity v until t_2. The total distance traveled by the sled is 5.30×10^3 m, and the total time is 90.0 s. Find t_1, t_2, and v.

44. At the 5800 m mark, the sled in the previous question begins to accelerate at $-7.0\ m/s^2$. Use your answers from item 43 to answer the following questions.
- **a.** What is the final position of the sled when it comes to rest?
- **b.** How long does it take for the sled to come to rest?

45. A tennis ball with a velocity of +10.0 m/s to the right is thrown perpendicularly at a wall. After striking the wall, the ball rebounds in the opposite direction with a velocity of −8.0 m/s to the left. If the ball is in contact with the wall for 0.012 s, what is the average acceleration of the ball while it is in contact with the wall?

46. A parachutist descending at a speed of 10.0 m/s loses a shoe at an altitude of 50.0 m.
- **a.** When does the shoe reach the ground?
- **b.** What is the velocity of the shoe just before it hits the ground?

47. A mountain climber stands at the top of a 50.0 m cliff hanging over a calm pool of water. The climber throws two stones vertically 1.0 s apart and observes that they cause a single splash when they hit the water. The first stone has an initial velocity of +2.0 m/s.
- **a.** How long after release of the first stone will the two stones hit the water?
- **b.** What is the initial velocity of the second stone when it is thrown?
- **c.** What will the velocity of each stone be at the instant both stones hit the water?

48. A model rocket is launched straight upward with an initial speed of 50.0 m/s. It accelerates with a constant upward acceleration of 2.00 m/s^2 until its engines stop at an altitude of 150 m.
- **a.** What is the maximum height reached by the rocket?
- **b.** When does the rocket reach maximum height?
- **c.** How long is the rocket in the air?

49. A professional racecar driver buys a car that can accelerate at $+5.9\ m/s^2$. The racer decides to race against another driver in a souped-up stock car. Both start from rest, but the stock-car driver leaves 1.0 s before the driver of the racecar. The stock car moves with a constant acceleration of $+3.6\ m/s^2$.
- **a.** Find the time it takes the racecar driver to overtake the stock-car driver.
- **b.** Find the distance the two drivers travel before they are side by side.
- **c.** Find the velocities of both cars at the instant they are side by side.

50. Two cars are traveling along a straight line in the same direction, the lead car at 25 m/s and the other car at 35 m/s. At the moment the cars are 45 m apart, the lead driver applies the brakes, causing the car to have an acceleration of $-2.0\ m/s^2$.
- **a.** How long does it take for the lead car to stop?
- **b.** Assume that the driver of the chasing car applies the brakes at the same time as the driver of the lead car. What must the chasing car's minimum negative acceleration be to avoid hitting the lead car?
- **c.** How long does it take the chasing car to stop?

51. One swimmer in a relay race has a 0.50 s lead and is swimming at a constant speed of 4.00 m/s. The swimmer has 20.0 m to swim before reaching the end of the pool. A second swimmer moves in the same direction as the leader. What constant speed must the second swimmer have in order to catch up to the leader at the end of the pool?

ALTERNATIVE ASSESSMENT

1. Can a boat moving eastward accelerate to the west? What happens to the boat's velocity? Name other examples of objects accelerating in the direction opposite their motion, including one with numerical values. Create diagrams and graphs.

2. Two stones are thrown from a cliff at the same time with the same speed, one upward and one downward. Which stone, if either, hits the ground first? Which, if either, hits with the higher speed? In a group discussion, make your best argument for each possible prediction. Set up numerical examples, and solve them to test your prediction.

3. Research typical values for velocities and acceleration of various objects. Include many examples, such as different animals, means of transportation, sports, continental drift, light, subatomic particles, and planets. Organize your findings for display on a poster or some other form.

4. The study of various motions in nature requires devices for measuring periods of time. Prepare a presentation on a specific type of clock, such as water clocks, sand clocks, pendulum clocks, wind-up clocks, atomic clocks, or biological clocks. Who invented or discovered the clock? What scale of time does it measure? What are the principles or phenomena behind each clock? Can they be calibrated?

5. Research Galileo's work on falling bodies. What did he want to demonstrate? What opinions or theories was he trying to refute? What arguments did he use to persuade others that he was right? Did he depend on experiments, logic, findings of other scientists, or other approaches?

GRAPHING CALCULATOR PRACTICE

Motion in One Dimension

At what speed does a falling hailstone travel? Does the speed depend on the distance that the hailstone falls?

In this graphing calculator activity, you will have the opportunity to answer these questions. Your calculator will display two graphs: one for displacement (distance fallen) versus time and the other for speed versus time. These two graphs correspond to the following two equations:

$$Y_1 = 4.9X^2$$
$$Y_2 = 9.8X$$

You should be able to use the table below to correlate these equations with those for an accelerating object that starts from rest.

Motion Equations for an Object with Constant Acceleration That Started from Rest
$\Delta x = \frac{1}{2} v_f \Delta t$
$v_f = a\Delta t$
$\Delta x = \frac{1}{2} a(\Delta t)^2$
$v_f^2 = 2a\Delta x$

Go online to HMHScience.com to find the skillsheet and program for this graphing calculator activity.