

## Guided Practice

### CRITICAL THINKING about the Lesson

- True or False? If  $b^2 = a$ , then  $b$  is a square root of  $a$ . True
- Which statements are true? Give an example of each true statement.
  - A number can have no real square root. True,  $-1$
  - A number can have only one square root. True,  $0$
  - A number can have two different square roots. True,  $25$  has  $5$  and  $-5$ .
  - A number can have more than two square roots. False
- Evaluate  $\sqrt{25}$ ,  $-\sqrt{25}$ , and  $\pm\sqrt{25}$ .  
 $5, -5, \pm 5$
- Find the numbers represented by  
 $3 \pm \sqrt{(-3)^2 - 4(\frac{1}{2})(-8)}$ .  $8$  and  $-2$
- Is  $\sqrt{2}$  irrational? Is  $\frac{144}{99}$  a square root of  $2$ ? Is  $\frac{7064}{4995}$  a square root of  $2$ ? Explain.  
 Yes; no; no. An irrational number cannot be represented by a fraction

## Independent Practice

In Exercises 7–14, find all square roots of the number. Check your results.

- |                   |                     |            |             |
|-------------------|---------------------|------------|-------------|
| 7. $64$           | 8. $144$            | 9. $-9$    | 10. $0$     |
| 11. $\frac{4}{9}$ | 12. $\frac{25}{16}$ | 13. $0.16$ | 14. $0.25$  |
|                   |                     |            | $0.5, -0.5$ |

In Exercises 15–30, evaluate the expression. Give the exact value if possible. Otherwise, give an approximation to two decimal places.

- |                             |                   |                            |                              |
|-----------------------------|-------------------|----------------------------|------------------------------|
| 15. $-\sqrt{256}$           | 16. $\sqrt{49}$   | 17. $\sqrt{11}$            | 18. $\sqrt{121}$             |
| 19. $\sqrt{100}$            | 20. $-\sqrt{169}$ | 21. $\sqrt{36}$            | 22. $\sqrt{23}$              |
| 23. $\sqrt{42}$             | 24. $\sqrt{0.75}$ | 25. $\sqrt{0.04}$          | 26. $-\sqrt{\frac{25}{100}}$ |
| 27. $\sqrt{\frac{81}{324}}$ | 28. $\sqrt{6.25}$ | 29. $-\sqrt{\frac{1}{64}}$ | 30. $\sqrt{26}$              |
|                             |                   |                            | $5.10$                       |

In Exercises 31–34, evaluate  $\sqrt{b^2 - 4ac}$  for the given values of  $a$ ,  $b$ , and  $c$ .

- |                            |                             |
|----------------------------|-----------------------------|
| 31. $a = 4, b = 5, c = 1$  | 32. $a = -2, b = 8, c = -8$ |
| 33. $a = 3, b = -7, c = 6$ | 34. $a = 12, b = 13, c = 3$ |

**Technology** In Exercises 35–38, use a calculator to evaluate the expression. Round results to two decimal places. Use estimation to check results.

- |                                  |                                 |
|----------------------------------|---------------------------------|
| 35. $\frac{2 \pm 5\sqrt{6}}{2}$  | 36. $\frac{3 \pm 4\sqrt{5}}{4}$ |
| 37. $\frac{7 \pm 3\sqrt{2}}{-1}$ | 38. $\frac{5 \pm 6\sqrt{3}}{3}$ |

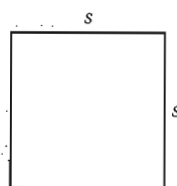
**Geometry** In Exercises 39–42, use the area,  $A$ , to find the length of the indicated side or radius. (Use  $\pi \approx 3.14$ .)

39. Square:  $s = \sqrt{A}$

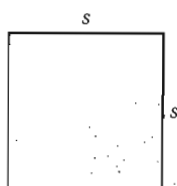
40. Square:  $s = \sqrt{A}$

41. Circle:  $r = \sqrt{\frac{A}{\pi}}$

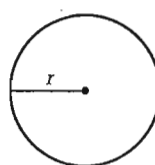
42. Circle:  $r = \sqrt{\frac{A}{\pi}}$



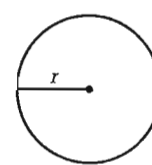
5.2  $A = 27.04$



3.6  $A = 12.96$



4  $A = 50.24$



7  $A = 153.86$

**Biosphere 2** In Exercises 43 and 44, use the following information.

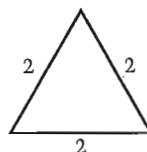
*Biosphere 2, in Arizona, is a large terrarium that covers 3 acres and reaches a height of 10 stories. The structure contains 7 biomes (miniature versions of ecological communities). These include a savanna, freshwater and salt-water marshes, a farm, a desert, and an ocean. To test the possibility of creating miniature "Earth environments" on other planets, 8 people were sealed in Biosphere 2 for 2 years.*



- ✪ 43. Biosphere 2 covers over 130,000 square feet. If its layout was in the shape of a single square, what would be its dimensions?  $\approx 360$  ft by  $\approx 360$  ft
- ✪ 44. The "ocean" in Biosphere 2 has 110,000 cubic feet of sea water and is 25 feet deep. If a square swimming pool was 25 feet deep and held 110,000 cubic feet of water, how long would each side be?  $\approx 66$  ft

**Geometry** In Exercises 45 and 46, use the formula  $h = \frac{1}{2}\sqrt{3}s$  for the height,  $h$ , of an equilateral triangle whose sides are of length  $s$ .

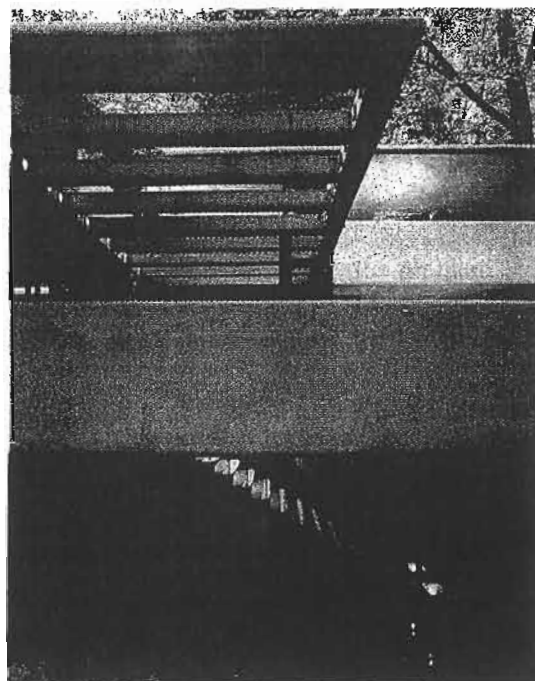
- 45. Find the height of an equilateral triangle with 2-inch sides.  $\sqrt{3}$  in. or  $\approx 1.73$  in.
- ✪ 46. Find the area of an equilateral triangle with 2-inch sides.  $\sqrt{3}$  in.<sup>2</sup> or  $\approx 1.73$  in.<sup>2</sup>



- 47. **Length of a Ladder** A ladder is placed against the trunk of a cherry tree. It reaches a height of 10 feet on the tree. The bottom of the ladder extends 5 feet from the base of the tree. How long is the ladder?  $\approx 11.2$  ft

48. **Fallingwater** How long is the hanging staircase at Fallingwater from the bottom step to the top step?  $\approx 13.9$  ft

*Fallingwater, near Pittsburgh, Pennsylvania, was designed by the American architect Frank Lloyd Wright. One of its many unique features is a hanging staircase that descends from the second floor to the stone steps of the "plunge pool." The staircase is 7 feet high and is cut from a 12-foot-long hole in the stone.*



49. **Diagonal of a Football Field** A football field is 360 feet by 45 feet. How long is the walk from one corner diagonally to the opposite corner?  $\approx 362.8$  ft

50. **Repairing a Gate** The diagonal crossbar of an old wooden gate has rotted. The gate is rectangular, 3 feet by 4 feet. How long is the crossbar? 5 ft

### Integrated Review

**Geometry** What is the unit of measure for  $s$ ?

51.  $s^2 = 64$  square miles miles

52.  $s^2 = 200$  square inches inches

In Exercises 53–56, square the expression.

53.  $-3a$   $9a^2$

54.  $7b$   $49b^2$

55.  $2x^2y$   $4x^4y^2$

56.  $3xy^3$   $9x^2y^6$

In Exercises 57–60, use mental math to solve the equation.

57.  $x^2 = 9$  3, -3

58.  $y^2 = 16$  4, -4

59.  $y^3 = 8$  2

60.  $-(x^2) = -36$   
6, -6

### Exploration and Extension

In Exercises 61–64, simplify the positive square root.

The positive square root of an integer that is the product of a *perfect square* and another integer can be simplified using the property  $\sqrt{ab} = \sqrt{a} \cdot \sqrt{b}$ . For example, 12 is the product of 4 and 3, which means that  $\sqrt{12}$  can be written as  $\sqrt{12} = \sqrt{4 \cdot 3} = \sqrt{4} \cdot \sqrt{3} = 2\sqrt{3}$ .

61.  $\sqrt{8}$   $2\sqrt{2}$

62.  $\sqrt{18}$   $3\sqrt{2}$

63.  $\sqrt{27}$   $3\sqrt{3}$

64.  $\sqrt{75}$   $5\sqrt{3}$

# EXERCISES

## Guided Practice

### CRITICAL THINKING about the Lesson

1. Which of the following are quadratic equations?

a.  $-3x + 5 = 0$

b.  $x^2 - 1 = 0$

c.  $x^2 - 3x^3 = 0$

d.  $-3 + 4x + x^2 = 0$

In Exercises 2–4, write in standard form and find the leading coefficient.

2.  $-3x^2 + 5 = 0$  As is,  $-3$

3.  $\frac{1}{2}x^2 + 9x - 3 = 0$  As is,  $\frac{1}{2}$

4.  $-8x - x^2 + 4 = 0$   
 $-x^2 - 8x + 4 = 0, -1$

In Exercises 5–8, solve the equation. If there are no solutions, state the reason.

5.  $x^2 = 17 \pm \sqrt{17}$

6.  $x^2 = 0$

7.  $x^2 = -4$   
 No real solution

8.  $x^2 = 6 \pm \sqrt{6}$

## Independent Practice

In Exercises 9–20, solve the equation.

9.  $x^2 = 9 \pm 3$

10.  $h^2 = 25 \pm 5$

11.  $6x^2 = 600 \pm 10$

16.  $\pm 12$

13.  $3x^2 = 363 \pm 11$

14.  $2b^2 = 98 \pm 7$

15.  $t^2 + 2 = 11 \pm 3$

12.  $\frac{1}{5}x^2 = 5 \pm 5$

16.  $t^2 - 57 = 87$

17.  $\frac{1}{2}x^2 - 1 = 7 \pm 4$

18.  $4y^2 + 7 = 8 \pm \frac{1}{2}$

19.  $2s^2 - 5 = 27 \pm 4$

20.  $81x^2 - 5 = 20$   
 $\pm \frac{5}{9}$

**Technology** In Exercises 21–28, use a calculator to solve the equation. Round the results to two decimal places.

21.  $3x^2 + 2 = 56 \pm 4.24$

22.  $7y^2 - 12 = 23 \pm 2.24$

23.  $2x^2 - 5 = 7 \pm 2.45$

24.  $\frac{2}{3}n^2 - 6 = 2$   
 $\pm 3.46$

25.  $\frac{1}{2}x^2 + 3 = 8 \pm 3.16$

26.  $4x^2 + 9 = 41 \pm 2.83$

27.  $6s^2 - 2 = 0 \pm 0.58$

28.  $5a^2 + 10 = 20$   
 $\pm 1.41$

In Exercises 29–32, an object is dropped from a height  $h$ . How long does it take to reach the ground? (Assume there is no air resistance.)

29.  $h = 64$  feet

30.  $h = 144$  feet

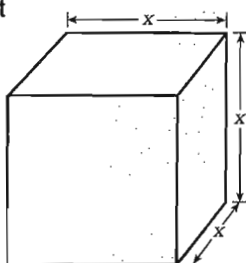
31.  $h = 500$  feet

31.  $\approx 5.59$  seconds

32.  $\approx 6.12$  seconds

32.  $h = 600$  feet

**33. Geometry** The surface area of a cube is 150 square feet. Find the length of each edge. 5 ft

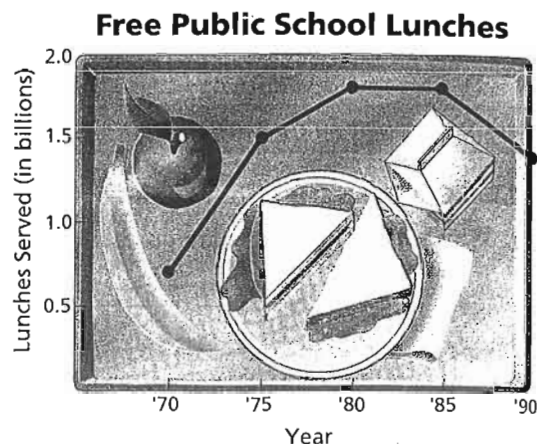


**34. Geometry** The surface area of a sphere is 80 square meters. Find the radius. (Use  $\pi \approx 3.14$ .)  $\approx 2.52$  m

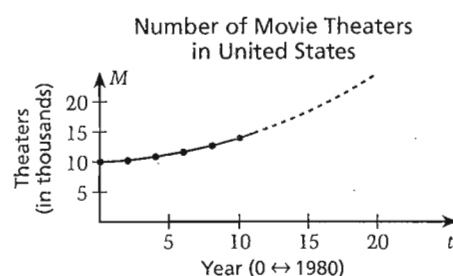
$S = 4\pi r^2$



35. **Free Lunches** The number,  $L$  (in millions), of free lunches served in public schools in the United States from 1970 to 1990 can be modeled by  $L = -7.75t^2 + 1860$ , where  $t$  is the year, with  $t = 0$  corresponding to 1982. During which years were 1736 million free lunches served? During which years were 1364 million free lunches served?  
(Source: U.S. Dept. of Agriculture)  
1978 and 1986, 1974 and 1990

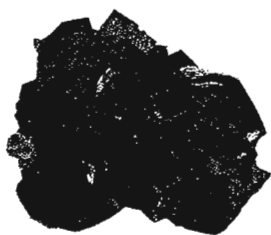


36. **Motion Picture Theaters** The number,  $M$  (in thousands), of motion picture theaters in the United States from 1970 to 1990 can be modeled by  $M = 0.037t^2 + 10$ , where  $t$  is the year, with  $t = 0$  corresponding to 1980. Use this model to estimate the year in which there will be 19.5 thousand motion picture theaters in the United States. 1996



**Hardness of Minerals** In Exercises 37 and 38, use the following information.

Geologists use the Vickers scale to measure the hardness of minerals. The hardness,  $V$ , of a mineral can be determined by hitting the mineral with a wedge-shaped diamond and measuring the depth,  $d$ , of the indentation. A model that relates mineral hardness with the indentation depth in millimeters is  $Vd^2 = 1.89$ .



Fluorite:  $V = 180$



Sulfur:  $V = 40$



Wulfenite:  $V = 85$

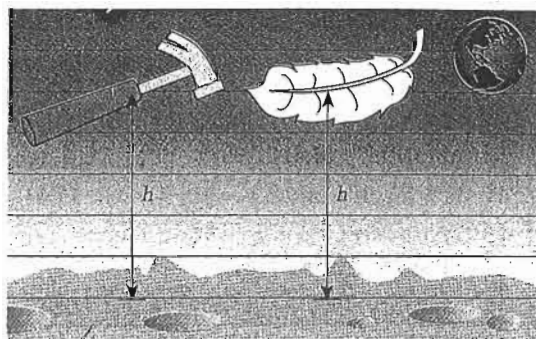
37. Find the depth of the indentation of each of the minerals shown above. 0.10 mm, 0.22 mm, 0.15 mm
38. Which mineral shown above is the hardest? Which is the softest? Why do you think the Vickers scale test uses a diamond to test the hardness of other minerals? Fluorite; sulfur; diamond is the hardest mineral known.

**The Hammer and the Feather** In Exercises 39 and 40, use Example 4 on page 460 and the following information.

In 1971, astronaut David Scott demonstrated that a feather and a hammer fall at the same rate on the moon because the moon has no atmosphere (and hence no air resistance). The height,  $h$  (in feet), of a falling object on the moon is given by

$$h = -\frac{27}{10}t^2 + s.$$

39. If a hammer and feather are dropped 5 feet from the surface of the moon, how long will it take for each to hit the surface?  $\approx 1.36$  seconds
40. On Earth, how long would it take the hammer to hit the ground? Would the feather hit the ground after the same amount of time? Explain. See margin.



### Integrated Review

In Exercises 41–44, evaluate the expression.

41.  $4x^2 + 9x - 14$  when  $x = 3$  49

43.  $-4ac$  when  $a = 5$  and  $c = 2$  -40

42.  $x^2 - 4x + 9$  when  $x = 4$  9

44.  $-16t^2 + s$  when  $s = 4$  and  $t = 4$  -252

In Exercises 45–50, solve for  $x$ .

45.  $2x - 9 = 7$  8

47.  $\frac{1}{4}x + 6 = 8$  8

49.  $\sqrt{x} - 1 = 5$  36

46.  $5x - 9 = 11$  4

48.  $\frac{1}{3}x - 4 = -1$  9

50.  $\sqrt{x} + 3 = 4$  1

### Exploration and Extension

51. Complete the table. Use the points  $(x, y)$  from the table to sketch the graph of  $y = x^2 + 2$ . See margin for graph.

$x$	-3	-2	-1	0	1	2	3
$y$	?	?	?	?	?	?	?

52. The points  $(x_1, 7)$  and  $(x_2, 10)$  are on the graph of the equation given in Exercise 51. What are the  $x$ -coordinates?  $\pm \approx 2.24$ ,  $\pm \approx 2.83$

In Exercises 53 and 54, there are two different ordered pairs  $(x, y)$  that are solutions of the system. Find the two ordered pairs.

53.  $\begin{cases} -5 + 2x^2 = 27 \\ x + y = 4 \end{cases}$  (4, 0), (-4, 8)

54.  $\begin{cases} \frac{1}{3}x^2 + 2 = 5 \\ 2x + y = 4 \end{cases}$  (3, -2), (-3, 10)

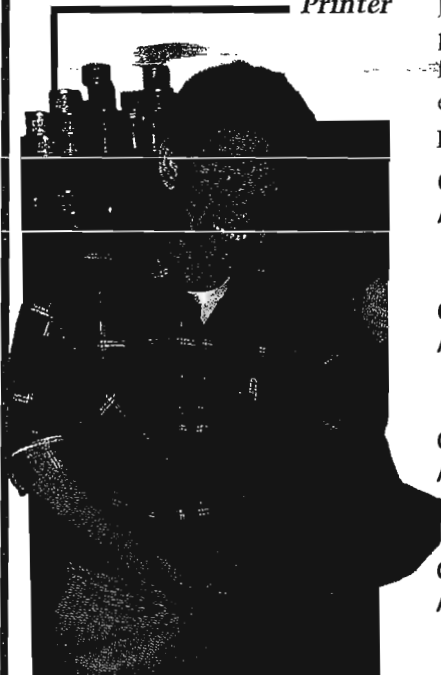
## Mixed Review

3.  $p = \frac{2+q}{1+q}$  4.  $y = \frac{3}{4}x + 5$  15.  $2x^2 + 4x$
- Write the reciprocal of  $a^4$ . (2.7)  $\frac{1}{a^4}$
  - Write the reciprocal of 3. (2.7)  $\frac{1}{3}$
  - Solve  $p(1+q) = 2+q$  for  $p$ . (3.6)
  - Solve  $3x - 4y = -20$  for  $y$ . (3.6)
  - Evaluate  $3x^3 + 2x - 2$  when  $x = -2$ . (1.3)  $-30$
  - Evaluate  $3z^0 + 4z^{-1}$  when  $z = \frac{1}{4}$ . (8.2)  $19$
  - What is the slope of  $y = 5x + 6$ ? (4.4)  $5$
  - What is the slope of  $3y + 2 = 0$ ? (4.4)  $0$
  - Write 1,299,000,000 in scientific notation. (8.4)  $1.299 \times 10^9$  Yes
  - Write 0.000000496 in scientific notation. (8.4)  $4.96 \times 10^{-7}$
  - Is 2 a solution of  $1 + 2x < 4x$ ? (1.5) Yes
  - Is 6 a solution of  $3x - 6 = 10$ ? (1.5) No
  - Write  $10x - 4y = -16$  in slope-intercept form. (4.5)  $y = \frac{5}{2}x + 4$
  - Write  $y = \frac{1}{3}x - 2$  in standard form. (5.5)  $x - 3y = 6$
  - Simplify  $3x(1+x) - x^2 + x$ . (2.6)
  - Simplify  $(x^2y^{-3})^{-2} \cdot x^2y^{-4}$ . (8.1)  $\frac{y^2}{x^2}$
  - Solve  $|x - 3| = 6$ . (4.8)  $-3, 9$
  - Solve  $|2x + 4| \leq 12$ . (4.8)  $-8 \leq x \leq 4$
  - Evaluate  $2.2 \times 10^{-6} \cdot 3.6 \times 10^4$  (8.4)
  - Evaluate  $7.6 \times 10^{-6} \div (2.5 \times 10^8)$ . (8.4)

19.  $7.92 \times 10^{-2}$   
20.  $3.04 \times 10^{-14}$

## Career Interview

### Printer



Jeffrey Wong is the printer at and manager of a printing company. He is involved in all aspects of running the business—from purchasing, to sales, to managing employees. He quotes estimates, sets up business agreements with customers, and processes orders.

#### Q: What led you into this career?

A: I was trained as an engineer. After working in that field for a number of years, I decided to take over the family printing business.

#### Q: Has new technology changed your job experiences?

A: Many new printing machines and equipment have come on the market. Most have built-in functions that can take care of some computations we used to do by hand.

#### Q: Does this mean you don't need to understand math?

A: No. All the functions on a new printer don't mean a thing if I don't know how they can be used, or how they impact on what's happening during a particular process.

#### Q: What would you like to tell kids about math?

A: Often kids think that if they are good in English, then they don't need to worry about math, and vice versa. But we really need to do well in both. English is the vehicle to express your thoughts and feelings; math is the key to meeting everyday needs.

## EXERCISES

### Guided Practice

- **CRITICAL THINKING about the Lesson**
- Write the equation  $y = -3 + 4x - x^2$  in standard form.  $y = -x^2 + 4x - 3$
  - The graph of a quadratic equation is called a ? parabola.
  - How can you use  $a$  to decide whether the graph of  $y = ax^2 + bx + c$  opens up or down? If  $a > 0$ , graph opens up; if  $a < 0$ , graph opens down.
  - True or False?** The axis of symmetry of the graph of  $y = ax^2 + bx + c$  is parallel to the  $y$ -axis (or is the  $y$ -axis).
  - Find the vertex of the graph of  $y = 2x^2 + 4x - 2$ .  $(-1, -4)$
  - Find the axis of symmetry of the graph of  $y = -3x^2 + 3x + 1$ .  $x = \frac{1}{2}$

### Independent Practice

In Exercises 7–12, decide whether the graph of the equation opens up or down. Then find the coordinates of the vertex.

- |  |   |  |
|--|---|--|
| 7. $y = 2x^2 + 4$ Up, $(0, 4)$                         | 8. $y = -5x^2$ Down, $(0, 0)$                                       | 9. $y = \dots$ Down, $(0, 0)$                    |
| 10. $y - 3x^2 = -2x$ Up, $(\frac{1}{3}, -\frac{1}{3})$ | 11. $y + 5x^2 = -x + 10$<br>Down, $(-\frac{1}{10}, \frac{201}{20})$ | 12. $y = 3x + 12$<br>Up, $(-\frac{1}{8}, \dots)$ |

In Exercises 13–18, find the coordinates of the vertex and the equation of the axis of symmetry. See below.

- |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|
| 13. $y = 3x^2 + 2x + 4$  | 14. $y = 2x^2 + 3x + 6$  | 15. $y = -4x^2 - 4x + 8$ |
| 16. $y = 3x^2 - 9x - 12$ | 17. $y = 2x^2 + 7x - 21$ | 18. $y = -x^2 + 4x + 16$ |

In Exercises 19–36, sketch the graph of the equation. Label the vertex. See Additional Answers.

- |                                     |                                      |                                      |
|-------------------------------------|--------------------------------------|--------------------------------------|
| 19. $y = x^2 + x + 2$               | 20. $y = -x^2 + 2x - 1$              | 21. $y = -2x^2 + 6x - 9$             |
| 22. $y = 2x^2 - 3x + 4$             | 23. $y = 6x^2 - 3x + 4$              | 24. $y = 5x^2 + 4x - 5$              |
| 25. $y = 4x^2 - x + 6$              | 26. $y = -3x^2 - x + 7$              | 27. $y = -5x^2 + 2x - 2$             |
| 28. $y = 6x^2 - 4x - 1$             | 29. $y = -3x^2 - 5x + 3$             | 30. $y = -2x^2 - 3x + 2$             |
| 31. $y = x^2 + 6x + 5$              | 32. $y = -4x^2 - 3x + 6$             | ★ 33. $y = -\frac{1}{2}x^2 - 3x + 4$ |
| ★ 34. $y = \frac{1}{3}x^2 + 3x - 2$ | ★ 35. $y = -2x^2 + \frac{1}{3}x - 1$ | ★ 36. $y = 3x^2 - \frac{1}{2}x + 4$  |

**You've Got to Have the Right Angle** In Exercise 37, use the information given in Example 3.

- ★ 37. Natalya Lisovskaya's winning throw in the shot put was at a  $45^\circ$  angle. If the shot had been thrown at a  $40^\circ$  angle or  $50^\circ$  angle, would it have gone farther? Explain. See margin.

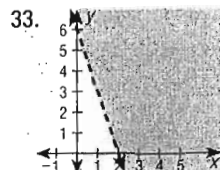
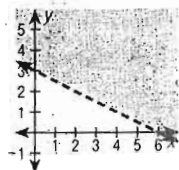
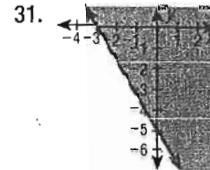
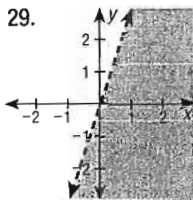
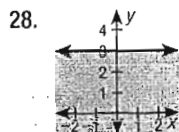
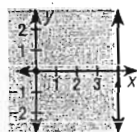
Throw at  $40^\circ$  angle:  $y = -0.0125x^2 + 0.84x + 5$

Throw at  $50^\circ$  angle:  $y = -0.0177x^2 + 1.19x + 5$

- |  |  |   |
|--|--|---|
| 13. $x = -\frac{1}{3}; (-\frac{1}{3}, \frac{11}{3})$ | 14. $x = -\frac{3}{4}; (-\frac{3}{4}, \frac{39}{8})$   | 15. $x = -\frac{1}{2}; (-\frac{1}{2}, 9)$ |
| 16. $x = \frac{3}{2}; (\frac{3}{2}, -\frac{75}{4})$  | 17. $x = -\frac{7}{4}; (-\frac{7}{4}, -\frac{217}{8})$ | 18. $x = 2; (2, 20)$                      |

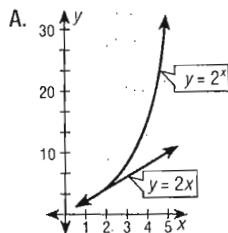


# Lesson 7.7



## CHAPTER 8

### Lesson 8.1

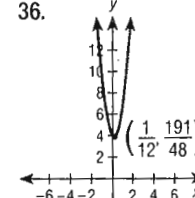
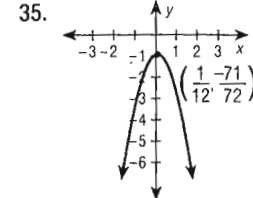
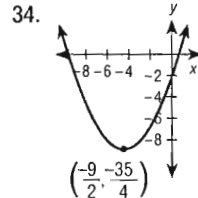
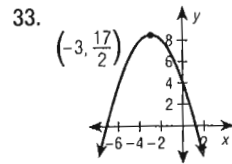
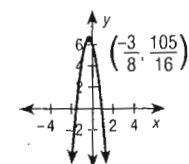
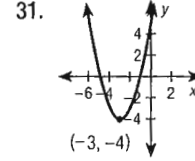
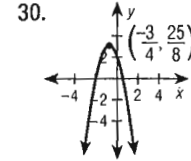
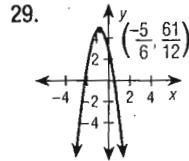
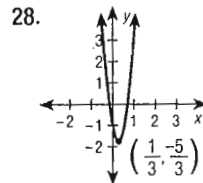
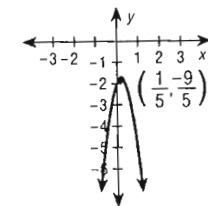
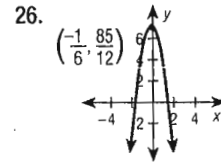
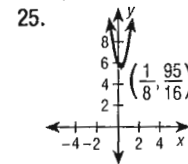
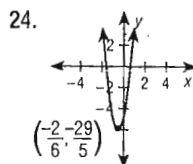
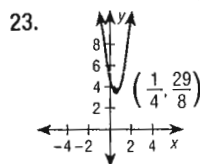
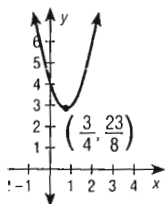
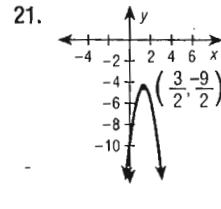
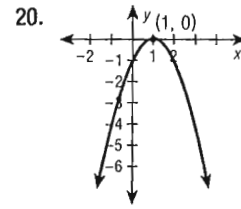
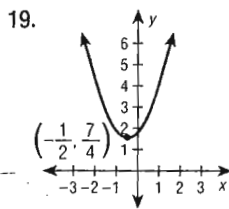
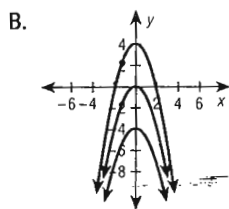
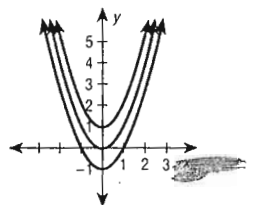


### Lesson 8.5

2. Number of flowers to visit = Number of flowers per pound of honey • Number of pounds of honey
3. Number of flowers to visit =  $n$   
 Number of flowers per pound of honey =  $\frac{(45 \text{ to } 64) \times 10^6}{2.2}$   
 Number of pounds of honey = 500

## CHAPTER 9

### Lesson 9.3

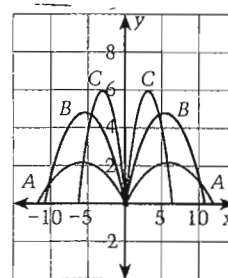


**Water Sprinkler** In Exercises 38 and 39, use the following information.

The paths of the water from a water sprinkler are shown for three different settings.

$$\begin{aligned} 35^\circ: y &= -0.06x^2 + 0.70x + 0.5 & \text{Radii: } \approx 12 \text{ ft,} \\ 60^\circ: y &= -0.16x^2 + 1.73x + 0.5 & \approx 11 \text{ ft, } \approx 6 \text{ ft;} \\ 75^\circ: y &= -0.60x^2 + 3.73x + 0.5 & \text{heights: } \approx 2.5 \text{ ft,} \\ & & \approx 5.2 \text{ ft, } \approx 6.3 \text{ ft} \end{aligned}$$

$x$  and  $y$  are measured in feet.



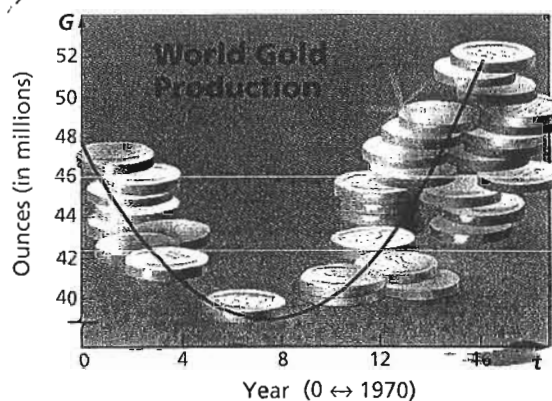
38. Find the height of each vertex and the radius of the region covered by each setting.
39. Do you think there is an angle setting for the sprinkler that will cover a greater area? Use the equation given by  $y = -0.08x^2 + x + 0.5$  to help answer the question. What angle do you think this equation represents? Yes,  $\approx 45^\circ$

**World Production of Gold** In Exercises 40 and 41, use the following information.

From 1970 to 1990, the annual world production,  $G$ , of gold in thousands of ounces, can be modeled by

$$G = 47,974 - 2446t + 167t^2$$

where  $t$  is the year, with  $t = 0$  corresponding to 1970. The graph of this model is shown at the right. (Source: U.S. Bureau of Mines)



40. During which years between 1970 and 1990 was the world production of gold decreasing? During which years was the production increasing? How are these questions related to the vertex of the graph? 1970–1977; 1978–1990; graph decreases to the left of the vertex, increases to the right.

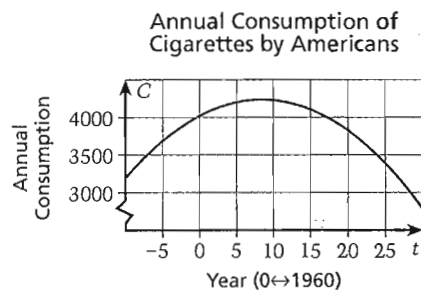
In Exercise 42, use the following information.

From 1950 to 1990, the average annual consumption,  $C$ , of cigarettes per American (18 or older) can be modeled by

$$C = 4024.5 + 51.4t - 3.1t^2$$

where  $t$  is the year, with  $t = 0$  corresponding to 1960. The graph of the model is shown at the right. (Source: U.S. Centers for Disease Control)

41. The United States used to be on the *gold standard*, which had the effect of keeping the price of gold artificially low. In 1971, the United States went off the gold standard. How did this affect the world production of gold? It decreased gold production.



42. From 1966 on, all cigarette packages were required by law to carry a health warning. Did the warnings have any effect? Explain. Answers will vary. Yes, a decrease in consumption began in 1968.

## Integrated Review

In Exercises 43–48, solve the equation.

43.  $16 + t^2 = 32 \pm 4$

44.  $s^2 - 40 = -4 \pm 6$

45.  $2m^2 - 30 = 20 \pm 5$

46.  $24 = 4n^2 - 12 \pm 3$

47.  $12 + 3a^2 = 2a^2 + 16 \pm 2$

48.  $6a^2 = 3a^2 + 108 \pm 6$

In Exercises 49–54, match each equation with its graph.

49.  $y = x^2 - 2x + 3$

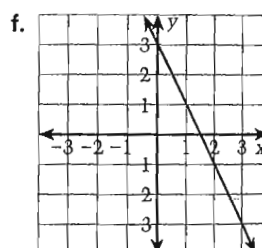
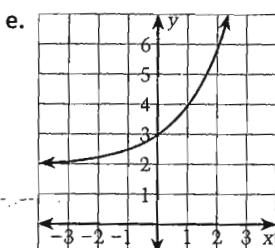
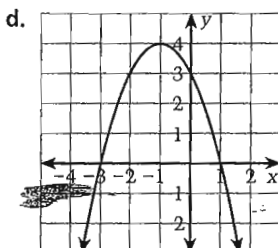
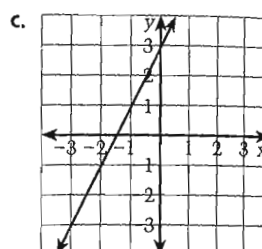
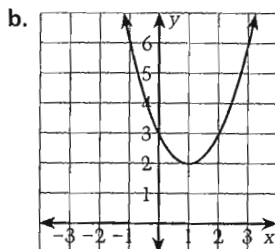
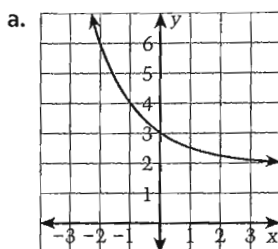
50.  $y = 2x + 3$

51.  $y = 3 - 2x$

52.  $y = 2^x + 2$

53.  $y = -x^2 - 2x + 3$

54.  $y = 2^{-x} + 2$



In Exercises 55–60, evaluate the expression. If necessary, use a calculator and round the result to two decimal places.

55.  $-4ac$ ,  $a = \frac{1}{2}$ ,  $c = 12$

56.  $-4ac$ ,  $a = -2$ ,  $c = 7$

57.  $b^2 - 4ac$ ,  $a = 6$ ,  $b = 6$ ,  $c = 1$

58.  $b^2 - 4ac$ ,  $a = -5$ ,  $b = 3$ ,  $c = 1$

59.  $\sqrt{b^2 - 4ac}$ ,  $a = 8$ ,  $b = -10$ ,  $c = 2$

60.  $\sqrt{b^2 - 4ac}$ ,  $a = 6.2$ ,  $b = 12.1$ ,  $c = -4.3$   
15.91

## Exploration and Extension

See Additional Answers for graphs.

In Exercises 61–63, sketch the graphs of all three equations on the same coordinate plane. Describe how the three graphs are related. See below.

★ 61.  $\begin{cases} y = x^2 - x + 1 \\ y = x^2 - x + 3 \\ y = x^2 - x - 2 \end{cases}$

★ 62.  $\begin{cases} y = x^2 + x + 1 \\ y = \frac{1}{2}x^2 + x + 1 \\ y = 2x^2 + x + 1 \end{cases}$

★ 63.  $\begin{cases} y = x^2 - 2x + 1 \\ y = x^2 - 4x + 4 \\ y = x^2 - 6x + 9 \end{cases}$

64. Use the result of Exercise 61 to describe how a change in the value of  $c$  changes the graph of  $y = ax^2 + bx + c$ .  
The greater the value of  $c$ , the higher the graph.

65. Use the result of Exercise 62 to describe how a change in the value of  $a$  changes the graph of  $y = ax^2 + bx + c$ .  
The greater the value of  $|a|$ , the narrower the graph.

61. Each graph has its vertex on  $x = \frac{1}{2}$ ; each graph opens upward; the greater the constant term the higher up the graph is.

# EXERCISES

## Guided Practice

### CRITICAL THINKING about the Lesson

1. **True or False?** The quadratic formula states that the solutions of the equation  $ax^2 + bx + c = 0$  are "the opposite of  $b$ , plus or minus the square root of  $b$  minus  $4ac$ , all divided by  $2a$ ." **False**
2. Describe the two models for vertical motion. See top of page 474.
3. State the values of  $a$ ,  $b$ , and  $c$  from the standard form of the equation  $5 = 6 + 9x - x^2$ .  $a = -1$ ,  $b = 9$ ,  $c = 1$
4. Solve  $x^2 + x - 2 = 0$ .  $1, -2$
5. Sketch the graph of  $y = x^2 + x - 2$  and label the  $x$ -intercepts. See Additional Answers.
6. Describe the relationship between the  $x$ -intercepts found in Exercise 5 and the solutions found in Exercise 4. They are the same.

## Independent Practice

In Exercises 7–10, write the quadratic equation in standard form.

7.  $-3x^2 + 5x = 9$   $-3x^2 + 5x - 9 = 0$
8.  $5 - 2x + x^2 = 0$   $x^2 - 2x + 5 = 0$
9.  $-4 + 3x + x^2 = 5$   $x^2 + 3x - 9 = 0$
10.  $9x - 7x^2 = 16$   $-7x^2 + 9x - 16 = 0$

In Exercises 11–14, find the value of  $b^2 - 4ac$  for the equation.

11.  $2x^2 - 3x - 1 = 0$  17
12.  $4x^2 + 4x + 1 = 0$  0
13.  $3x^2 - 2x - 5 = 0$  64
14.  $x^2 - 11x + 30 = 0$  1
18.  $3 + \sqrt{2} \approx 4.41$ ,  $3 - \sqrt{2} \approx 1.59$

In Exercises 15–20, use the quadratic formula to solve the equation.

15.  $4x^2 - 13x + 3 = 0$   $3, \frac{1}{4}$
16.  $3y^2 + 11y + 10 = 0$   $-\frac{5}{3}, -2$
17.  $2x^2 + 7x + 3 = 0$
18.  $x^2 - 6x + 7 = 0$
19.  $5y^2 + 2y - 2 = 0$
20.  $2x^2 + 4x - 3 = 0$
- 19–20. See below.
21.  $\frac{-10 + \sqrt{70}}{6} \approx -0.27$
- $\frac{-10 - \sqrt{70}}{6} \approx -3.06$

In Exercises 21–26, solve the quadratic equation by the most convenient method (finding square roots or the quadratic formula). Explain why you chose your method.

21.  $6x^2 + 20x + 5 = 0$
22.  $t^2 = 27$   $\sqrt{27} \approx 5.20$ ,  $-\sqrt{27} \approx -5.20$
23.  $x^2 - 625 = 0$  25, -25
24.  $4u^2 - 49 = 0$   $\frac{7}{2}, -\frac{7}{2}$
25.  $-2x^2 + 6x + 1 = 0$
26.  $x^2 + 14x + 49 = 0$  -7

In Exercises 27–32, find the  $x$ -intercepts of the graph of the equation.

27.  $y = x^2 + 2x + 15$  None
28.  $y = x^2 - 6x - 7$  7, -1
29.  $y = x^2 + x - 20$  4, -5
30.  $y = x^2 + 8x + 12$  -2, -6
31.  $y = x^2 + x - \frac{3}{4}$   $\frac{1}{2}, -\frac{3}{2}$
32.  $y = x^2 + \frac{7}{3}x - 2\frac{2}{3}$  -3
25.  $\frac{3 + \sqrt{11}}{2} \approx 3.16$ ,  $\frac{3 - \sqrt{11}}{2} \approx -0.16$

19.  $\frac{-1 + \sqrt{11}}{5} \approx 0.46$ ;  $\frac{-1 - \sqrt{11}}{5} \approx -0.86$  20.  $\frac{-2 + \sqrt{10}}{2} \approx 0.58$ ;  $\frac{-2 - \sqrt{10}}{2} \approx -2.58$

$$0 = -16t^2 + 1053$$

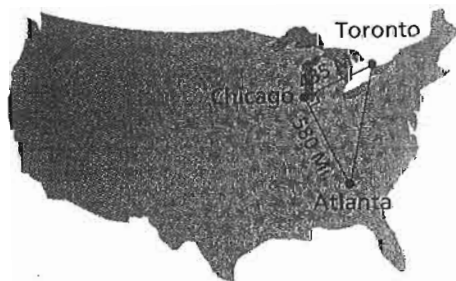
33. **Royal Gorge Bridge** If a rock was dropped from the Royal Gorge Bridge into the Arkansas River, how long would it take for the rock to hit the water?  $\approx 8.18$  (Assume there is no air resistance.) Do you think there is a regulation *against* dropping objects off this bridge? Explain your answer. See margin.

34. **Royal Gorge Bridge** How much sooner would the rock reach the Arkansas River if it was thrown straight down with an initial speed of 30 feet per second?  $\approx 0.9$  seconds

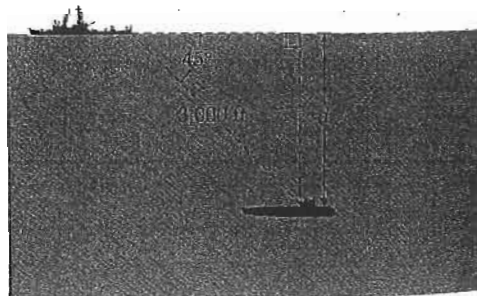
35. **The Owl and the Mouse** An owl is circling a field at a height of 100 feet and sees a mouse. The owl folds its wings and begins to dive with an initial speed of 10 feet per second. Estimate the time the mouse has to escape. 2.2 seconds

36. **Play It Again in Metric** An owl is circling a field at a height of 30.5 meters and sees a mouse. The owl folds its wings and begins to dive with an initial speed of 3 meters per second. Estimate the time the mouse has to escape. (Use the vertical motion model  $h = -4.9t^2 + vt + s$ , where  $h$  is height in meters,  $v$  is initial velocity in meters per second, and  $s$  is initial height in meters.) 2.2 seconds

37. **Flying Time** The cities of Chicago, Atlanta, and Toronto approximate the vertices of a right triangle. How long would it take a plane flying at 500 miles per hour to fly from Atlanta to Toronto? 1.45 hours



38. **Depth of a Submarine** The sonar of a Navy cruiser detects a submarine that is 3000 feet from the cruiser. The angle between the water surface and the submarine is  $45^\circ$ . How deep is the submarine?  $\approx 2121$  ft



39. **Population of Mexico** The population,  $P$  (in thousands), of Mexico between 1930 and 1990 can be modeled by

$$P = 19.2t^2 + 31.6t + 16964.5$$

where  $t$  is the year, with  $t = 0$  corresponding to 1930. Find the year in which the population of Mexico will reach 100,000,000. Demonstrate your result graphically. 1994 See margin.



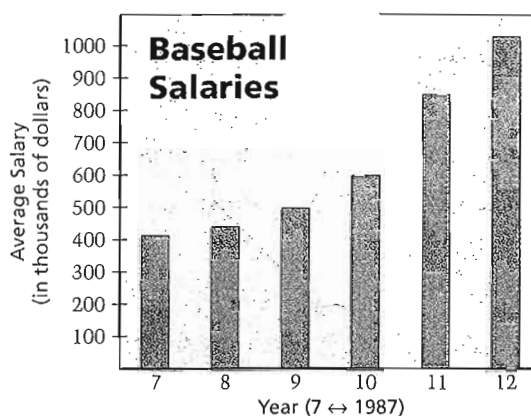
The Royal Gorge Bridge near Canon City, Colorado, is the highest suspension bridge in the world. The bridge is 1053 feet above the Arkansas River.

40. **Baseball Salaries** The average salary  $S$  (in thousands) of major league baseball players between 1987 and 1992 can be modeled by

$$S = 27.4t^2 - 394.5t + 1831.3$$

where  $t$  is the year, with  $t = 7$  corresponding to 1987. During which year was the average salary about \$500,000? Does your algebraic solution agree with the graph?

(Source: Major League Baseball Players Association)  
1989, yes



### Integrated Review

In Exercises 41 and 42, evaluate the expression.

41.  $\sqrt{16 - 4(3)(1)}$  2

42.  $\sqrt{36 - 4(2)(-4)}$   $\sqrt{68} \approx 8.25$

In Exercises 43–45, check whether the number is a solution of the equation.

43.  $2x^2 - 4x + 9 = 9$ , 2 Is

44.  $3x^2 + 3x + 4 = 12$ , -2 Is not

45.  $x^2 - 9x + 7 = 11$ , 6 Is not

In Exercises 46–48, sketch the graph of the equation. Label the  $x$ -intercepts on the graph. See Additional Answers.

46.  $y = x^2 + 4x - 45$

47.  $y = x^2 - x - 6$

48.  $y = 2x^2 - 7x + 3$

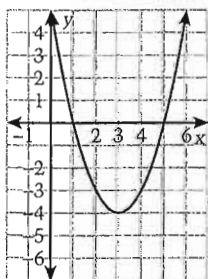
### Exploration and Extension

In Exercises 49 and 50, find the axis of symmetry of each graph and show that it lies midway between the two  $x$ -intercepts of the graph. Show how you could use this “two-part” form of the quadratic formula,

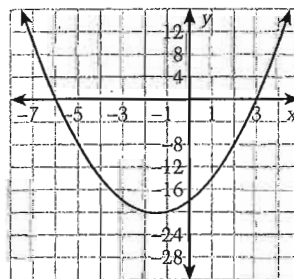
$$x = \frac{-b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a},$$

to find the distance between the axis of symmetry of a parabola and either of its  $x$ -intercepts. See margin.

49.  $y = x^2 - 6x + 5$



50.  $y = x^2 + 3x - 18$



## Mid-Chapter SELF-TEST

Take this test as you would take a test in class. The answers to the exercises are given in the back of the book.

In Exercises 1–6, find all square roots of the number. (9.1)

- |                                      |                                   |                      |
|--------------------------------------|-----------------------------------|----------------------|
| 1. $64 \pm 8$                        | 2. $121 \pm 11$                   | 3. $0.0064 \pm 0.08$ |
| 4. $\frac{49}{100} \pm \frac{7}{10}$ | 5. $\frac{1}{81} \pm \frac{1}{9}$ | 6. $0.01 \pm 0.1$    |

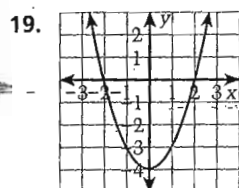
In Exercises 7–12, evaluate the square root. Give the exact value, if possible. Otherwise, give an approximation to two decimal places. (9.1)

- |                         |                         |                        |
|-------------------------|-------------------------|------------------------|
| 7. $\sqrt{4} \ 2$       | 8. $\sqrt{1} \ 1$       | 9. $\sqrt{8} \ 2.83$   |
| 10. $\sqrt{2.25} \ 1.5$ | 11. $\sqrt{0.1} \ 0.32$ | 12. $\sqrt{50} \ 7.07$ |

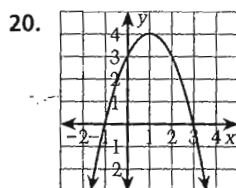
In Exercises 13–18, solve the equation. (9.2)

- |  |   |   |
|--|---|---|
| 13. $\frac{1}{3}x^2 - 27 = 0 \pm 9$                          | 14. $25x^2 - 37 = 588 \pm 5$                | 15. $7x^2 - 81 = 31 \pm 4$                            |
| 16. $\frac{3}{4}x^2 - 3 = 51 \pm \sqrt{72} \approx \pm 8.49$ | 17. $x^2 - \frac{1}{4} = 6 \pm \frac{5}{2}$ | 18. $x^2 + 37 = 199 \pm \sqrt{162} \approx \pm 12.73$ |

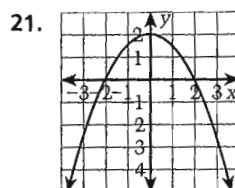
In Exercises 19–22, determine the vertex and x-intercepts of the graph. (9.3)



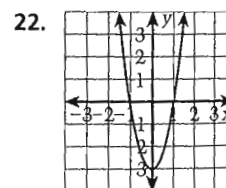
(0, -4); 2, -2



(1, 4); -1, 3



(0, 2); 2, -2



(0, -3); 1, -1

In Exercises 23–26, solve the equation. (9.4)

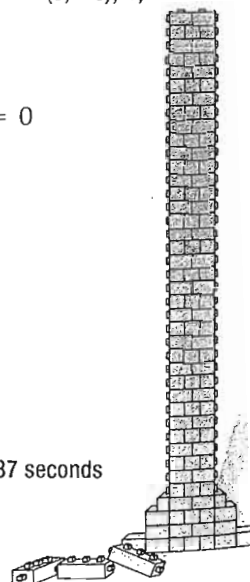
- |  |                               |
|--|-------------------------------|
| 23. $x^2 - x - 30 = 0 \ 6, -5$                       | 24. $-x^2 - 8x - 16 = 0 \ -4$ |
| 25. $-x^2 + 3x + 2 = 0 \ 25\text{--}26.$ See margin. | 26. $x^2 + 5x - 2 = 0$        |

27. **Geometry** The legs of a right triangle are 3 inches and 4 inches. What is the length of the hypotenuse? (9.1) 5 in.

28. **Geometry** The volume of a box with a square base and a height of 14 centimeters is 1400 cubic centimeters. What is the length of an edge of the base? (9.2) 10 cm

29. You are trying to build the world's tallest tower of interlocking toy blocks. (The record is  $59\frac{1}{2}$  feet.) When your tower is 30 feet tall, the bag holding the loose blocks is knocked off the top of the tower. How many seconds did it take for the bag to hit the floor? (9.2)  $\approx 1.37$  seconds

30. If the bag of blocks in Exercise 29 is thrown down with an initial velocity of 10 feet per second, how many seconds does it take for it to hit the floor? (9.4)  $\approx 1.09$  seconds



## EXERCISES

### Guided Practice

#### CRITICAL THINKING about the Lesson

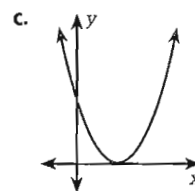
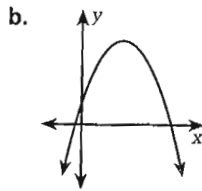
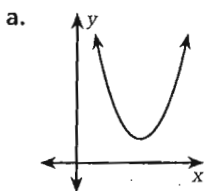
- Write the quadratic formula and circle the part that is called the  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$  discriminant.
- Explain how the discriminant can be used to determine the number of solutions of  $ax^2 + bx + c = 0$ . See margin.
- Find the discriminant of  $3x^2 - 2x - 5 = 0$ . How many solutions does this equation have? 64, 2

In Exercises 4–6, match the discriminant with the graph.

4.  $b^2 - 4ac = 3b$

5.  $b^2 - 4ac = 0$

6.  $b^2 - 4ac = -2a$



### Independent Practice

In Exercises 7–12, decide how many solutions the equation has.

7.  $2x^2 + 3x - 2 = 0$  25

8.  $x^2 - 2x + 4 = 0$  None -12

9.  $-2x^2 + 4x - 2 = 0$   $d=0$  1

10.  $-\frac{1}{2}x^2 + x + 3 = 0$  7

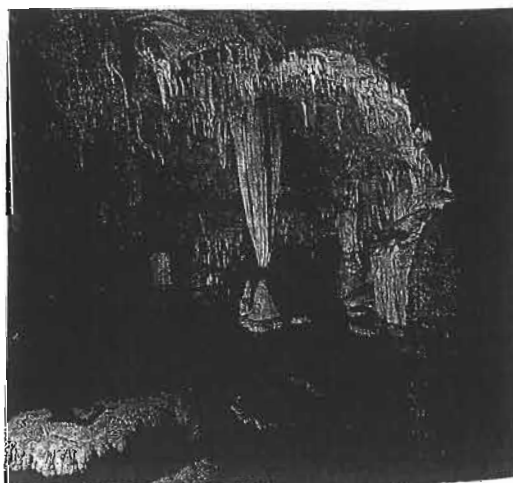
11.  $5x^2 - 2x + 3 = 0$  None -56

12.  $3x^2 - 6x + 3 = 0$  1  $d=0$

13. **Spelunking** You and a friend are spelunking (exploring caves) in a section of the Onondaga Cave in Missouri. The two of you are standing beneath a ledge that is 15 feet high. Your friend can throw a grappling hook upward with an initial velocity of 30 feet per second. Will the grappling hook reach the ledge when it is thrown? Explain.

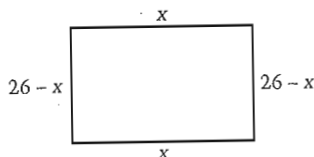
14. **Spelunking, Part II** While you and your friend are attempting to reach the ledge, some other spelunkers join you. They see the trouble you are having and suggest that your friend stand on a foot-high rock to throw the hook. Would this help? Explain.  
Yes, the discriminant would then be positive.

Onondaga Cave, in Leasburg, Missouri

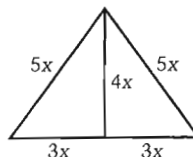




15. **Geometry** Is it possible for a rectangle with a perimeter of 52 centimeters to have an area of 148.75 square centimeters? Explain. Yes, the discriminant is positive.



16. **Geometry** The area of the isosceles triangle is 192 square meters. What is its perimeter? 64 m



**Dunking the Ball** In Exercises 17 and 18, use the vertical motion model:  $h = -16t^2 + vt + s$ .

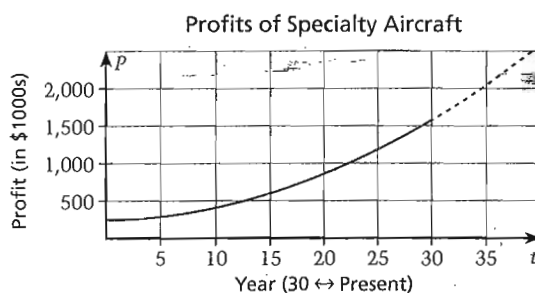
Chun and R.J. are playing basketball. Chun can jump with an initial velocity of 13 feet per second and needs to jump 2.6 feet to dunk the basketball. R.J. can jump with an initial velocity of 15 feet per second and needs to jump 3.6 feet to dunk the ball.

17. Can Chun dunk the ball? Can R.J.? Justify your answers. Yes, the discriminant is positive; no, the discriminant is negative.
18. Suppose that Chun can jump with an initial velocity of 12.5 feet per second and R.J. can jump with an initial velocity of 15.5 feet per second. How, if at all, would this change your answers to Exercise 17? Chun cannot dunk, R.J. can.

19. **Business as Usual?** For the past 30 years, profits of Specialty Aircraft have increased as shown in the graph. The profits can be modeled by

$$P = 1.4t^2 + 2.2t + 258,$$

where  $t = 30$  represents the present year and  $P$  is in thousands of dollars. Now, you have been elected president of the company, and the board of directors expects you to increase annual profits by at least 10% per year for five years. Should you follow the previous president's strategies or do you need to make some changes? Explain. See margin.

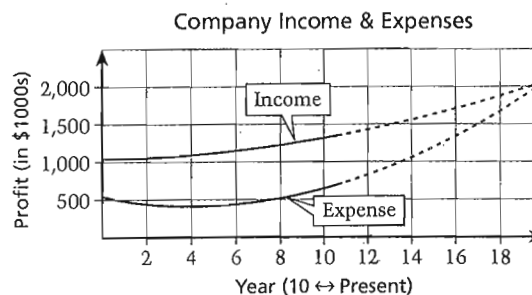


20. **Profit or Loss?** Your company's income and expenses for the past ten years can be modeled as follows.

$$I = 2.3t^2 + 4.8t + 1049 \quad \text{Income}$$

$$E = 6.5t^2 - 54.4t + 546 \quad \text{Expenses}$$

$I$  and  $E$  are measured in thousands of dollars. Describe your company's profit record for the past ten years. How do the next ten years look? See margin.

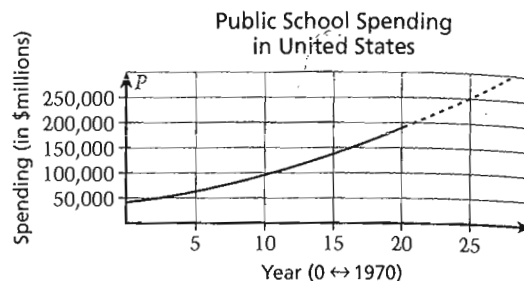


- 21. Public School Spending** For 1970 to 1990 in the United States, public school (K–12) spending can be modeled by

$$P = 195t^2 + 3480t + 41,540 \quad 2001\text{--}2002$$

where  $P$  is in millions of dollars and  $t = 0$  corresponds to 1970. Use the model to predict when annual spending will reach \$350 billion.

(Source: U.S. National Center for Education)

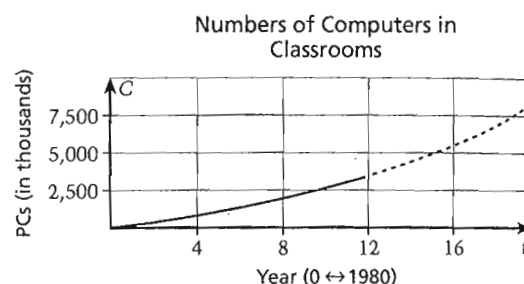


- 22. Computers in the Classroom** For 1980 to 1990, the number of personal computers in grades K–12 (public and private) can be modeled by

$$C = 16t^2 + 96t$$

where  $C$  is in thousands of computers and  $t = 0$  corresponds to 1980. Use the model to find when 5 million computers will be used in grades K–12. 1994–1995

(Source: Future Computing/Data Inc.)

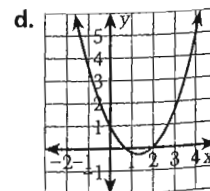
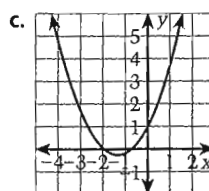
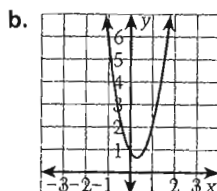
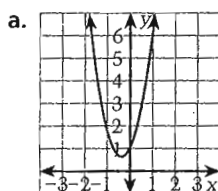


## Integrated Review

- 23. College Entrance Exam Sample** If  $\frac{1}{x+2} = \frac{1}{2}$ , then  $x = \boxed{?}$   
 a. 2    b. 1    c. 0    d. -1    e. -2
- 24. College Entrance Exam Sample** If  $x = -3$ , then  $(x+3)^2 - 3x = \boxed{?}$   
 a. -6    b. -3    c. 0    d. 6    e. 9
- 25. Estimation—Powers of Ten** Which is the best estimate of the time it takes an object to fall 100 feet?  
 a. 0.3 second    b. 3 seconds    c. 30 seconds    d. 300 seconds
- 26. Estimation—Powers of Ten** Which is the best estimate of distance between Providence, Rhode Island, and San Diego, California?  
 a. 250 miles    b. 2500 miles    c. 25,000 miles    d. 250,000 miles

In Exercises 27–30, match the equation with its graph.

27.  $y = 3x^2 - 2x + 1$     28.  $y = \frac{3}{4}x^2 + 2x + 1$     29.  $y = \frac{3}{4}x^2 - 2x + 1$     30.  $y = 3x^2 + 2x + 1$



## Exploration and Extension

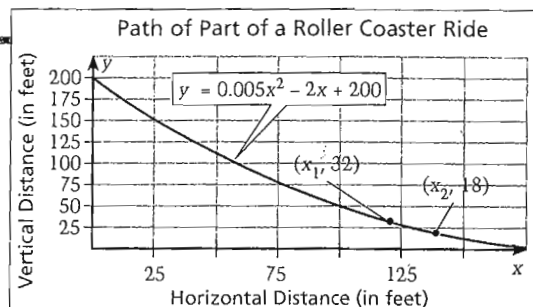
**Roller Coaster** In Exercises 31–34, use the following information.

You are riding on a roller coaster whose path can be modeled by

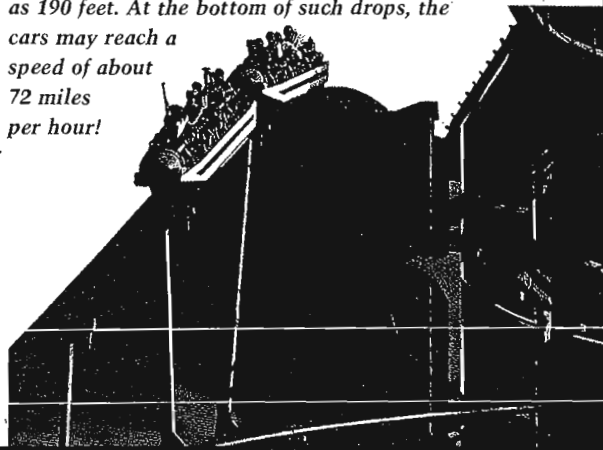
$$y = 0.005x^2 - 2x + 200$$

where  $x$  and  $y$  are measured in feet. When  $t = 0$  seconds, you are at the point  $(0, 200)$ .

31. When  $t = 4$  seconds, the  $y$ -coordinate of your location is 32. What is the  $x$ -coordinate of your location?  $x = 120$
32. When  $t = 4.23$  seconds, the  $y$ -coordinate of your location is 18. What is the  $x$ -coordinate of your location?  $x = 140$
33. Use the Pythagorean theorem to approximate the length of the track between the two points  $(x_1, 32)$  and  $(x_2, 18)$ .  $\approx 24.4$  feet
34. What was your average speed between the two points?  $\approx 106.1$  feet per second



Roller coasters may include vertical drops of as much as 190 feet. At the bottom of such drops, the cars may reach a speed of about 72 miles per hour!



## Mixed REVIEW

1. Find the quotient of  $x^2y$  and  $xy^2$ . (1.3)  $\frac{x}{y}$
2. Find the sum of  $\frac{3}{7}$  and  $\frac{1}{2}$ . (1.1)  $\frac{13}{14}$
3. Evaluate  $|x| - \sqrt{x}$  when  $x = 9$ . 6 (2.1, 9.1)
4. Evaluate  $|3y + 2| - \frac{1}{2}y$  when  $y = -6$ . (2.1) 19
5. What is the opposite of  $-\frac{6}{7}$ ? (2.1)  $\frac{6}{7}$
6. What is the opposite of  $-a^3$ ? (2.1)  $a^3$
7. Sketch the graph of  $|3x - 3| - 6 = y$ . (4.7) See margin.
8. Sketch the graph of  $y = -\frac{1}{2}x - 2$ . (4.5) See margin.
9. Evaluate  $4[(3 \div 2) + \frac{1}{2}]$ . (1.1) 8
10. Evaluate  $(3x - 2)\frac{1}{2} + 2x$  when  $x = 4$ . (1.4) 13
11. Is  $(4, 6)$  a solution of  $2x + 3y = 26$ ? Yes (1.5)
12. Is  $(0, 3)$  a solution of  $4x - 3y \leq 5x + 1$ ? (6.5) Yes
13. Solve  $|x + \frac{1}{4}| - 8 < 0$ . (6.4)  $-\frac{33}{4} < x < \frac{31}{4}$
14. Solve  $\frac{1}{3}(6x - 1) > 2$ . (6.1)  $x > \frac{7}{6}$

In Exercises 15–20, write an equation for the indicated line. (5.2, 5.3) See margin.

15. Slope  $m = -\frac{1}{2}$ , through point  $(3, -1)$
16. Slope  $m = 5$ , through point  $(8, -6)$
17. Slope  $m = 0$ , through point  $(-3, 6)$
18. Through two points:  $(3, -5)$ ,  $(3, 7)$
19. Through two points:  $(44, 28)$ ,  $(33, 17)$
20. Through two points:  $(-8, -3)$ ,  $(-5, -5)$

## Chapter REVIEW

In Exercises 1–8, evaluate the expression. Give the exact value if possible. Otherwise give an approximation to two decimal places. (9.1)

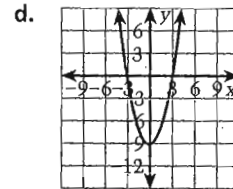
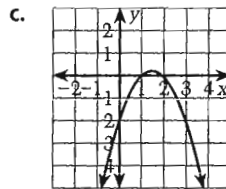
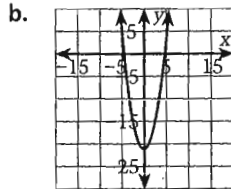
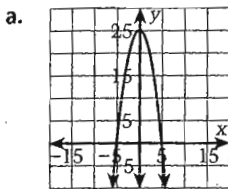
1.  $\sqrt{25}$  5
2.  $-\sqrt{0.06}$  -0.24
3.  $\sqrt{47}$  6.86
4.  $\sqrt{-(-0.25)}$  0.5
5.  $\sqrt{32}$  5.66
6.  $\sqrt{30^2 - 4(6)(3)}$  28.77
7.  $\sqrt{\frac{4}{36}}$   $\frac{1}{3}$
8.  $-\sqrt{\frac{4}{13}}$  -0.55

In Exercises 9–12, solve the equation using square roots. (9.2)

9.  $w^2 - 144 = 0$   $\pm 12$
10.  $8y^2 = 968$   $\pm 11$
11.  $16t^2 - 81 = 0$   $\pm \frac{9}{4}$
12.  $4x^2 - 19 = 6$   $\pm \frac{5}{2}$

In Exercises 13–16, match the equation with its graph. (9.3)

13.  $y = x^2 - 9$  d
14.  $y = -x^2 + 25$  a
15.  $y = -x^2 + 3x - 2$  c
16.  $y = x^2 - x - 20$  b



In Exercises 17–20, sketch the graph of the equation. Label the vertex. (9.3) See Additional Answers for graphs.

17.  $-x^2 - 3x + 2 = y$   $(-\frac{3}{2}, \frac{17}{4})$
18.  $x^2 = y$   $(0, 0)$
19.  $\frac{1}{4}x^2 + 2x - 4 = y$   $(-4, -8)$
20.  $-6x^2 + 10x + 2 = y$   $(\frac{5}{6}, \frac{37}{6})$

In Exercises 21–26, solve the equation. (9.4)

21.  $x^2 - \frac{1}{4}x + \frac{1}{64} = 0$   $\frac{1}{8}$
22.  $3x^2 - 4x + 1 = 0$   $1, \frac{1}{3}$
23.  $-\frac{1}{4}x^2 + 3x - 9 = 0$  6
24.  $-x^2 + x - \frac{1}{8} = 0$
25.  $-2x^2 + x + 6 = 0$   $-\frac{3}{2}, 2$
26.  $-\frac{1}{4}x^2 + \frac{1}{4}x + \frac{1}{2} = 0$  -1, 2
24.  $\frac{-1 + \sqrt{0.5}}{-2} \approx 0.15,$
- $\frac{-1 - \sqrt{0.5}}{-2} \approx 0.85$

In Exercises 27–30, sketch the graph of the inequality. (9.6) See margin.

27.  $x^2 - 3 \geq y$
28.  $\frac{1}{2}x^2 + 3x - 4 < y$
29.  $-x^2 - 2x + 3 \leq y$
30.  $-4x^2 + 2x + 5 > y$

In Exercises 31–34, construct a scatter plot of the data. Then decide which type of model best fits the data. (9.7) See margin.

31.  $(-3, 4), (-2, 1), (-1, 0), (0, 1), (1, 4), (2, 9), (3, 16)$  Quadratic
32.  $(-3, -7), (-2, -4), (-1, -1), (0, 2), (1, 5), (2, 8), (3, 11)$  Linear
33.  $(-3, \frac{1}{8}), (-2, \frac{1}{4}), (-1, \frac{1}{2}), (0, 1), (1, 2), (2, 4), (3, 8)$  Exponential
34.  $(-3, 0), (-2, -2), (-1, -4), (0, -2), (1, 0), (2, 2), (3, 4)$  Absolute value

## Chapter TEST

In Exercises 1–6, evaluate the expression. Give the exact value if possible. Otherwise give an approximation to two decimal places. (9.1)

1.  $-\sqrt{4} - 2$

2.  $\sqrt{0.0081} \cdot 0.09$

3.  $\sqrt{\frac{4}{25} \cdot \frac{2}{5}}$

4.  $\sqrt{-9}$  No solution

5.  $\sqrt{4^2 - 4(3)(-2)} \cdot 6.32$

6.  $\sqrt{8^2 - 4(2)(8)} \cdot 0$

In Exercises 7–12, solve the equation. (9.2, 9.4) 10., 11. See margin.

7.  $\frac{1}{2}x^2 - 8 = 0 \pm 4$

8.  $-3x^2 + 243 = 0 \pm 9$

9.  $x^2 - 8x + 7 = 0$  7, 1

10.  $-2x^2 + 5x + 9 = 0$

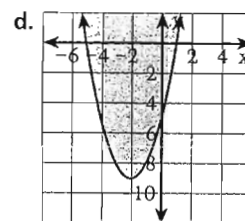
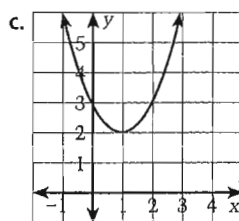
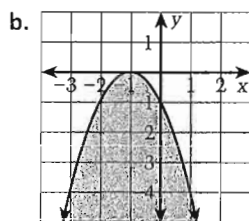
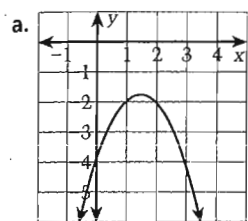
11.  $x^2 + 9x - 3 = 0$

12.  $x^2 + 3x + 3 = 0$

No solution

In Exercises 13–16, match the equation or inequality with its graph. (9.4)

13.  $y = x^2 - 2x + 3$  14.  $y = -x^2 + 3x - 4$  15.  $y \geq x^2 + 4x - 5$  16.  $y \leq -x^2 - 2x - 1$



c

a

d

b

In Exercises 17–20, sketch the graph of the equation or inequality. (9.6) See margin.

17.  $y = \frac{1}{3}x^2 + 2x - 3$

18.  $y = -x^2 + 5x - 6$

19.  $y \leq -\frac{1}{2}x^2 + 2x + \frac{5}{2}$

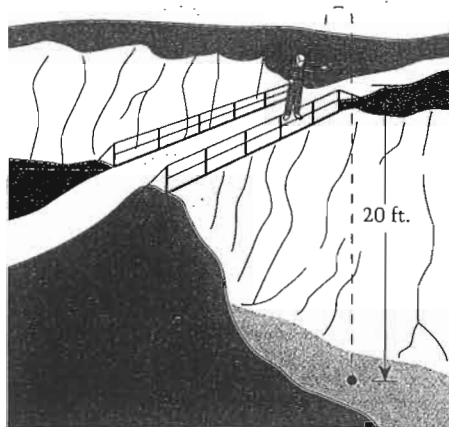
20.  $y \leq x^2 + 7x + 6$

21. **Trying to Fit a Square Peg into a Round Hole** A round hole has a diameter of 2 inches. You have a square peg with sides of  $1\frac{1}{2}$  inches. Will the square peg fit into the round hole? Explain. (9.2) See margin.

22. Henry is standing on a bridge over a creek. He releases a stone 20 feet from the water. How long will it take the stone to hit the water? (9.2)  $\approx 1.12$  seconds

23. Henry takes another stone and tosses it straight up with a velocity of 30 feet per second. How long will it take this stone to hit the water? (9.4)  $\approx 2.40$  seconds

24. If Henry could throw a stone straight up into the air with a velocity of 50 feet per second, could the stone reach a height of 60 feet above the creek? (9.4) No



## Mid-Chapter SELF-TEST

Take this test as you would take a test in class. The answers to the exercises are given in the back of the book.

In Exercises 1 and 2, perform the indicated operation. Use a horizontal format. (10.1)

1.  $(x^2 + 2x - 1) + (3x - 4x^2 + 2)$   
 $-3x^2 + 5x + 1$
2.  $(-2x^2 + 4x - 5) - (3 - 7x + x^2)$   
 $-3x^2 + 11x - 8$

In Exercises 3 and 4, perform the indicated operation. Use a vertical format. (10.1)

3.  $(3x^2 - x + 2) + (x^2 - 3x + 2)$   
 $4x^2 - 4x + 4$
4.  $(7x^2 - 5x + 10) - (3x^2 + 2x + 5)$   
 $4x^2 - 7x + 5$

In Exercises 5–8, multiply. (10.2)

5.  $(3x + 2)(3x + 5)$   $9x^2 + 21x + 10$
6.  $(4x - 5)(2x + 10)$   $8x^2 + 30x - 50$
7.  $(x + 1)(2x^2 - 3x + 2)$   $2x^3 - x^2 - x + 2$
8.  $(2x + 1)(5x^2 + 7x - 3)$   $10x^3 + 19x^2 + x - 3$

In Exercises 9–12, multiply using the FOIL pattern. (10.2)

9.  $(x + 2)(x - 3)$   
 $x^2 - x - 6$
10.  $(x - 3)(x - 6)$   
 $x^2 - 9x + 18$
11.  $(2x + 3)(4 - x)$   
 $-2x^2 + 5x + 12$
12.  $(3 + x)(4 + x)$   
 $x^2 + 7x + 12$

In Exercises 13–16, use the special-product patterns to multiply. (10.3)

13.  $(2x + 3)^2$   
 $4x^2 + 12x + 9$
14.  $(4x - 5)^2$   
 $16x^2 - 40x + 25$
15.  $(2x - 6)(2x + 6)$   
 $4x^2 - 36$
16.  $(x - 7)(x + 7)$   
 $x^2 - 49$

In Exercises 17–22, factor the polynomial. (10.4)

17.  $4x^2 - 49$   $(2x + 7)(2x - 7)$
18.  $3x^2 - 108$   $3(x + 6)(x - 6)$
19.  $x^2 - 2x + 1$   $(x - 1)^2$
20.  $7x^2 + 42x + 63$   $7(x + 3)^2$
21.  $9x^2 + 12x + 4$   $(3x + 2)^2$
22.  $x^2 - 169$   $(x + 13)(x - 13)$

23. From 1970 to 1990, the number of pieces,  $F$ , of first-class U.S. mail can be modeled by

$$F = 50,262 + 99.2t^2 \text{ (in millions)}$$

where  $t = 0$  represents 1970. The number of pieces,  $K$ , of all other types of U.S. mail can be modeled by

$$K = 33,045 + 140.7t^2 \text{ (in millions)}$$

Find a model for the number of pieces,  $M$ , of all types of U.S. mail.

(Source: Statistical Abstract, 1990) (10.1)  $M = 83,307 + 239.9t^2$

24. Three storage cubes have sides of  $(x + 1)$ ,  $(x + 3)$ , and  $(x + 5)$ . Write an expression for the total volume of the three cubes. (10.2)

25. You are making a tick-tack-toe board for your cousin's birthday. Each square will have a side of  $x$  inches, and the board will have a 1-inch-wide border. Write a polynomial for the area of the board. (10.3)

$$(3x + 2)^2$$

26. You want to frame a 16-inch by 20-inch watercolor for your parents' anniversary. The frame is  $x$  inches wide on all four sides. Write a polynomial for the area of the framed picture. (10.2)

$$(2x + 16)(2x + 20)$$

## EXERCISES

### Guided Practice

#### CRITICAL THINKING about the Lesson

- Factor  $x^2 - 4x + 3$ . When testing possible factorizations, why is it unnecessary to test  $(x - 1)(x + 3)$  and  $(x + 1)(x - 3)$ ?
- Factor  $x^2 + 2x - 3$ . When testing possible factorizations, why is it unnecessary to test  $(x - 1)(x - 3)$  and  $(x + 1)(x + 3)$ ?
- What is the discriminant of  $ax^2 + bx + c$ ?  
 $b^2 - 4ac$
- If the discriminant of  $ax^2 + bx + c$  is 35, can the trinomial be factored with integer coefficients? Explain.  
No. The discriminant must be the square of an integer.

### Independent Practice

In Exercises 5–10, choose the correct factorization. (If neither is correct, find the correct factorization.)

- |                            |                       |                            |
|----------------------------|-----------------------|----------------------------|
| 5. $x^2 + x - 20$ a        | 6. $x^2 + 8x + 16$ b  | 7. $x^2 - 10x + 24$ a      |
| a. $(x - 4)(x + 5)$        | a. $(x + 2)(x + 8)$   | a. $(x - 6)(x - 4)$        |
| b. $(x + 4)(x - 5)$        | b. $(x + 4)(x + 4)$   | b. $(x - 12)(x + 2)$       |
| 8. $3x^2 - 7x - 6$ a       | 9. $6x^2 - 7x - 5$ b  | 10. $2x^2 - 7x - 9$        |
| a. <del>3</del> $(3x + 2)$ | a. $(6x + 1)(x - 5)$  | a. $(x - 1)(2x + 9)$       |
| b. $(x + 3)(3x - 2)$       | b. $(2x + 1)(3x - 5)$ | b. $(2x - 1)(x + 9)$       |
|                            |                       | Neither, $(x + 1)(2x - 9)$ |

In Exercises 11–28, factor the trinomial.

- |  |  |                       |
|--|--|-----------------------|
| 11. $x^2 + 3x - 4$ $(x + 4)(x - 1)$    | 12. $x^2 - 5x + 6$ $(x - 2)(x - 3)$      | 13. $x^2 + 3x - 18$   |
| 14. $y^2 - 16y - 36$ $(y - 18)(y + 2)$ | 15. $x^2 - 10x + 24$ $(x - 6)(x - 4)$    | 16. $x^2 + 13x + 22$  |
| 17. $x^2 + 15x + 50$ $(x + 10)(x + 5)$ | 18. $y^2 + 30y + 216$ $(y + 12)(y + 18)$ | 19. $y^2 - 35y + 300$ |
| 20. $t^2 - 4t - 21$ $(t - 7)(t + 3)$   | 21. $3x^2 + 8x + 5$ $(3x + 5)(x + 1)$    | 22. $6x^2 + 5x - 4$   |
| 23. $2x^2 - x - 21$ $(2x - 7)(x + 3)$  | 24. $3x^2 + 11x + 10$ $(3x + 5)(x + 2)$  | 25. $48 - 16y + y^2$  |
| 26. $32 + 12x + x^2$ $(x + 4)(x + 8)$  | 27. $2x^2 - x - 6$ $(2x + 3)(x - 2)$     | 28. $5 + 34x - 7x^2$  |

In Exercises 29–34, use the discriminant to decide whether the polynomial can be factored with integer coefficients. If it can be factored, then find the factors:

- |                              |   |  |
|------------------------------|---|--|
| 29. $12x^2 - 11x + 3$ Cannot | 30. $2x^2 - 5x - 12$ $(2x + 3)(x - 4)$    | 31. $2(3x - 2)(x - 1)$<br>$6x^2 - 10x + 4$ |
| 32. $10x^2 - 9x + 6$ Cannot  | 33. $14x^2 - 19x - 40$ $(7x + 8)(2x - 5)$ | 34. $24x^2 + 3x - 11$<br>Cannot            |
35. **Geometry** The area of a rectangle is given by  $A = x^2 + 4x - 5$ . Find expressions for possible lengths and widths of the rectangle.  $x + 5$ ,  $x - 1$
36. **Geometry** The area of a circle is given by  $A = \pi(4x^2 + 12x + 9)$ . Find an expression for the radius of the circle.  $2x + 3$

# EXERCISES

1.  $a = 0$  or  $b = 0$

## Guided Practice

### CRITICAL THINKING about the Lesson

- Use the Zero-Product Property to complete the statement. If  $ab = 0$ , then  $\boxed{?}$ .
- Solve the equation:  $3x^2 + 4x = 0$ .  $0, -\frac{4}{3}$
- True or False?** If  $(5x - 1)(x + 3) = 1$ , then  $5x - 1 = 1$  or  $x + 3 = 1$ . Explain.  
False. The product of any number and its reciprocal is 1; so neither factor has to equal 1.
- Solve the equation:  $(x - 2)(x + 1) = 0$ .  $2, -1$
- Which two numbers satisfy the statement, "The sum of a number and its square is zero."?  $0, -1$
- True or False?** If  $(x + 3)(x - 3) = 0$ , then  $x + 3 = 0$  or  $x - 3 = 0$ . Explain.  
True. A product cannot equal 0, unless one of the factors is 0.

## Independent Practice

In Exercises 7–10, solve the equation.

- $(x + 1)(x + 2) = 0$   $-1, -2$
- $(x + 3)(x + 4) = 0$   $-3, -4$
- $(x - 3)(x + 7) = 0$   $3, -7$
- $(x + 6)(x - 5) = 0$   $-6, 5$

In Exercises 11–16, solve the equation by factoring.

- $x^2 + 5x - 6 = 0$   $-6, 1$
- $2x^2 + 5x + 3 = 0$   $-\frac{3}{2}, -1$
- $3x^2 + 7x + 2 = 0$   $-\frac{1}{3}, -2$
- $3x^2 + 11x - 4 = 0$   $\frac{1}{3}, -4$
- $6x^2 + 13x + 5 = 0$   $-\frac{1}{2}, -\frac{5}{3}$
- $12x^2 - 5x - 3 = 0$   $\frac{3}{4}, -\frac{1}{3}$

In Exercises 17–24, match the equation with its solutions.

- |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|
| 17. $x^2 - 5x + 6 = 0$ f | 18. $x^2 + 5x + 6 = 0$ b | 19. $x^2 - 7x + 6 = 0$ g | 20. $x^2 + 7x + 6 = 0$ a |
| 21. $x^2 - 5x - 6 = 0$ d | 22. $x^2 + 5x - 6 = 0$ c | 23. $x^2 + x - 6 = 0$ e  | 24. $x^2 - x - 6 = 0$ h  |
| a. $-1, -6$              | b. $-2, -3$              | c. $1, -6$               | d. $-1, 6$               |
| e. $2, -3$               | f. $2, 3$                | g. $1, 6$                | h. $-2, 3$               |

In Exercises 25–33, solve the equation by finding square roots, by the quadratic formula, or by factoring.

- $x(x - 9) = 0$   $0, 9$
- $x^2 - 12 = -3 \pm 3$
- $4x^2 + 2x = 0$   $0, -\frac{1}{2}$
- $2y(y + 6) = 0$   $0, -6$
- $x^2 - 8x = -16$   $4$
- $4y^2 - 18y = 0$   $0, \frac{9}{2}$
- $y^2 - 7y + 6 = -6$   $3, 4$
- $x^2 + 4x + 7 = 3$   $-2$
- $x^2 - 12x + 40 = 4$   $6$

In Exercises 34 and 35, multiply both sides of the equation by an appropriate power of ten to obtain integer coefficients. Then solve by factoring.

- $0.8x^2 + 3.2x + 2.4 = 0$   $-1, -3$
- $0.23x^2 - 0.54x + 0.16 = 0$   $\frac{8}{23}, 2$



## Integrated Review

In Exercises 40–45, multiply and simplify.

40.  $(2x + 6)(\frac{1}{2}x - 3)$   $x^2 - 3x - 18$

41.  $(x + 9)(4x - 3)$   $4x^2 + 33x - 27$

42.  $36 - (x + 2)(x - 3)$

43.  $3(x - \frac{1}{3})(3x + 7)$   
 $9x^2 + 18x - 7$

44.  $4(x + 3)(3x - 1) + 1$   
 $12x^2 + 32x - 11$

45.  $5 + (2x - \frac{1}{2})(\frac{1}{2}x + 1)$   
 $x^2 + \frac{7}{4}x + \frac{9}{2}$

In Exercises 46–51, decide whether the number is a solution of the equation.

46.  $x^2 - 3x + 4 = 0$ ; 2 Is not

47.  $x^2 + 5x + 4 = 0$ ; -1 Is

48.  $\frac{1}{3}x^2 + 2x - 36 = 0$ ; 6 Is not

49.  $2x^2 - 3x - 4 = 0$ ; 2 Is not

50.  $4x^2 + 3x - 27 = 0$ ; -3 Is

51.  $\frac{1}{2}x^2 - x + 8 = 0$ ; 4 Is not

In Exercises 52–57, use the quadratic formula to solve the equation. 53., 55.–57. See margin.

52.  $x^2 + 4x + 3 = 0$  -1, -3

53.  $x^2 - 7x + 9 = 0$

54.  $2x^2 - 5x + 3 = 0$   $\frac{3}{2}, 1$

55.  $3x^2 - 11x - 24 = 0$

56.  $5x^2 - 16x - 12 = 0$

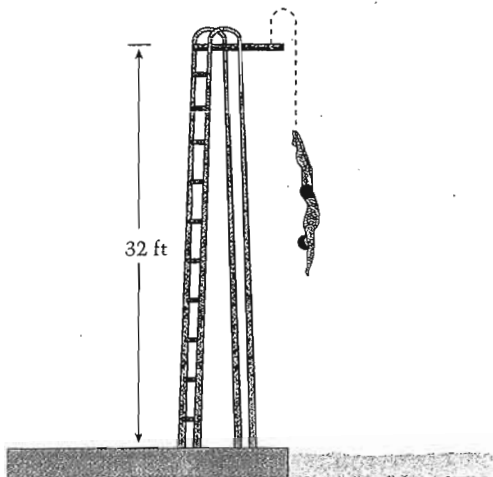
57.  $9x^2 - 17x + 6 = 0$

**58. Height of a Diver** A diver jumps from a diving board that is 32 feet above the water. The height of the diver is given by

$$\text{Height} = -16(t - 2)(t + 1)$$

where the height is measured in feet, and the time,  $t$ , is measured in seconds. When will the diver hit the water? Can you see a quick way to find the answer? Explain.

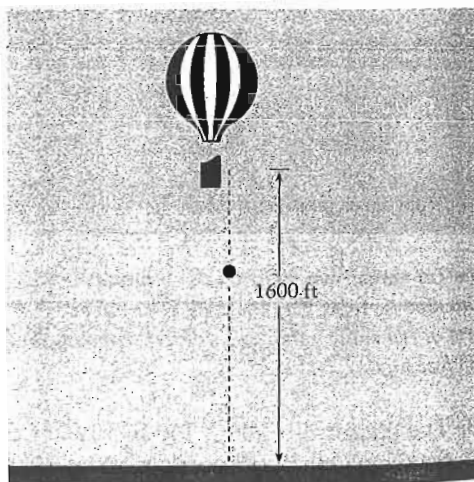
58., 59. See margin.



**59. Balloon Drop** An object is dropped from a hot-air balloon 1600 feet above the ground. The height of the object is given by

$$\text{Height} = -16(t - 10)(t + 10)$$

where the height is measured in feet, and the time,  $t$ , is measured in seconds. When will the object hit the ground? Can you see a quick way to find the answer? Explain.



**60. Graphing Calculator** Sketch  $y = x^2 + 5x - 6$  and  $y = (x + 6)(x - 1)$  on the same screen. What do you notice? They are the same graph.

**61. Graphing Calculator** Sketch  $y = x^2 - 7x - 8$  and  $y = (x - 8)(x + 1)$  on the same screen. What do you notice? They are the same graph.

See margin for graphs.

## Exploration and Extension

62.  $x^2 - x - 12 = 0$

64.  $x^2 + 7x + 10 = 0$

**Tutoring a Friend** In Exercises 62–65, you are tutoring a friend and want to create some quadratic equations that can be solved by factoring. Find a quadratic equation that has the given solutions and explain the procedure you used to obtain the equation.

62. 4 and  $-3$

63. 5 and 5.  $x^2 - 10x + 25 = 0$

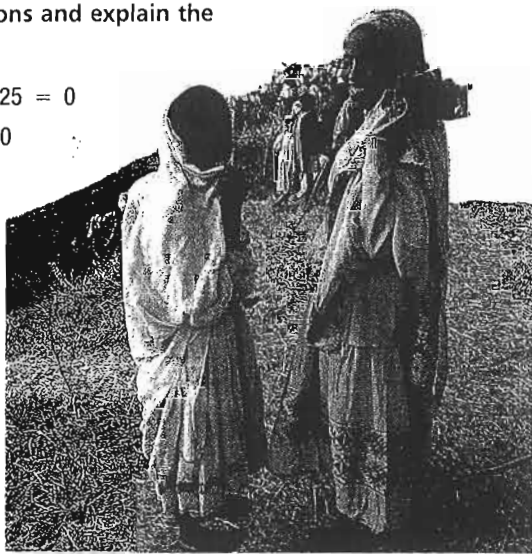
64.  $-2$  and  $-5$

65. 0 and  $-1$ .  $x^2 + x = 0$

66. Let  $a$  and  $b$  be real numbers such that  $a \neq 0$ . Find the solutions of  $ax^2 + bx = 0$ . 0,  $-\frac{b}{a}$

67. Let  $a$  be a nonzero real number. Find the solutions of  $ax^2 - ax = 0$ . 0, 1

68. **Ethiopian Weavers** In every square inch of the cotton fabric used for a shammash, the warp (lengthwise threads) intersects the weft (crosswise threads) 5000 times. The density (number of threads per inch) of the weft threads is twice that of the warp threads. How many weft threads are in each inch? How many warp threads are in each inch? 100, 50



These Ethiopian women are wearing a fine cotton fabric known as a shammash, a national costume that is often edged with bright trimming.

## Mixed REVIEW

5.  $m = \frac{-2n + 3}{4}$

13. 8,  $-8$

14.  $x$ ,  $-x$

$\frac{25}{p}$

1. Simplify  $x^2y^{-1} \div 3x \cdot y^2$ . (8.3)  $\frac{xy}{3}$

3. Find the quotient of  $3x^2$  and  $9x$ . (8.3)  $\frac{x}{3}$

5. Solve  $4m + 2n = 3$  for  $m$ . (3.6)

7. Write  $2 \cdot x \cdot x \cdot x \cdot x$  in exponential form. (1.3)  $2x^4$

9. Evaluate  $(2 \times 10^{-3}) \cdot (4 \times 10^4)$ . (8.4) 80

11. Solve  $|x + 3| \leq 4$ . (4.8)  $-7 \leq x \leq 1$

13. What are the square roots of 64? (9.1)

15. Sketch the graph of  $2x + y = 6$ . (4.4)

17. Is  $-6$  a solution of  $2^{-x} < -7x$ ? (8.2) No

19. Solve the system.  $\begin{cases} x - 7y = -17 \\ 3x + y = -7 \end{cases}$  (7.2, 7.3)  $(-3, 2)$

2. Simplify  $(p^2q^4 \div 2p) \cdot (4p^{-2} \div q^{-2})$ . (8.2)

4. Find the sum of  $2p$  and  $-4p$ . (2.6)  $-2p$

6. Solve  $ab + a = 5$  for  $a$ . (3.6)  $a = \frac{5}{b+1}$

8. Write 0.00012 in scientific notation. (8.4)  $1.2 \times 10^{-4}$

10. Evaluate  $(3.2 \times 10^6) \div (1.6 \times 10^{-1})$ . (8.4)  $2 \times 10^7$

12. Solve  $2|3 - x| > 1$ . (4.8)  $x > \frac{7}{2}$  or  $x < \frac{5}{2}$

14. What are the square roots of  $x^2$ ? (9.1)

16. Sketch the graph of  $2|x + 2| + 3 = 0$ . (4.7)

18. Is  $(-1, -2)$  a solution of  $y = -|2x|$ ? (2.1) Yes

20. Solve the system.  $\begin{cases} 4x + 3y = -1 \\ 5x - 6y = 28 \end{cases}$  (7.2, 7.3)  $(2, -3)$

## EXERCISES

### Guided Practice

#### CRITICAL THINKING about the Lesson

1. Which is a perfect square trinomial?
  - a.  $x^2 - 8x + 8$
  - b.  $x^2 - 8x + 16$
  - c.  $x^2 - 8x + 64$

3. What term must be added to  $x^2 + 6x$  to create a perfect square trinomial? 9

$$2 + \sqrt{12}, 2 - \sqrt{12}; \text{ no difference}$$

2. Solve  $x^2 - 4x = 8$  by completing the square. Solve the same equation by the quadratic formula. Explain the difference in the results.

4. Name the five methods for solving a quadratic equation. See chart on page 550.

### Independent Practice

In Exercises 5–10, find the term that must be added to the expression to create a perfect square trinomial.

5.  $x^2 - 18x$  81

8.  $x^2 - 10x$  25

6.  $x^2 + 6x$  9

9.  $x^2 - 7x$   $\frac{49}{4}$

7.  $x^2 + 12x$  36

10.  $x^2 - 5x$   $\frac{25}{4}$

In Exercises 11–28, solve the equation by completing the square. 16.  $-\frac{1}{2}, -\frac{17}{2}$  25.  $-\frac{1}{3}, -1$  21, 3

11.  $x^2 + 10x - 11 = 0$  1, -11

12.  $x^2 + 14x - 15 = 0$  1, -15

13.  $y^2 - 24y + 63 = 0$

14.  $y^2 - 8y + 12 = 0$  6, 2

15.  $t^2 + 3t - \frac{7}{4} = 0$   $\frac{1}{2}, -\frac{7}{2}$

16.  $y^2 + 9y + \frac{17}{4} = 0$

17.  $x^2 - \frac{2}{3}x - 3 = 0$

18.  $x^2 + \frac{4}{5}x - 1 = 0$

19.  $x^2 + x - 1 = 0$

20.  $1 + x - x^2 = 0$

21.  $4y^2 + 4y - 9 = 0$

22.  $3x^2 - 24x - 5 = 0$

23.  $2x^2 - 6x - 15 = 5$  5, -2

24.  $5x^2 - 20x - 20 = 5$  5, -1

25.  $3x^2 + 4x + 4 = 3$

26.  $4x^2 + 6x - 6 = 2$

27.  $x^2 + 2x = 2$

28.  $x^2 - 2x = 2$

17–22., 26., 27. See margin.

In Exercises 29–43, use the most convenient method to solve the equation. Explain why you made your choice. 29., 34., 36., 37. See margin.

29.  $x^2 - 3x - 1 = 0$

30.  $4x^2 - 12 = 0$   $\sqrt{3}, -\sqrt{3}$

$-3 + \frac{\sqrt{132}}{2}, -3 - \frac{\sqrt{132}}{2}$

32.  $4x^2 - 25 = 0$   $\frac{5}{2}, -\frac{5}{2}$

33.  $x^2 + 7x + 10 = 0$  -5, -2

31.  $y^2 + 6y - 24 = 0$

35.  $3x^2 - 5x = 0$  0,  $\frac{5}{3}$

36.  $y^2 + 2y - 26 = 0$

34.  $u^2 + 5u + 2 = 0$

38.  $4x^2 + 4x + 1 = 0$   $-\frac{1}{2}, -\frac{1}{2}$

39.  $7x^2 - 14x = 0$  0, 2

37.  $9z^2 + 10z - 4 = 0$

41.  $8x^2 - 10x + 3 = 0$   $\frac{3}{4}, \frac{1}{2}$

42.  $7x^2 - 14 = 0$   $\sqrt{2}, -\sqrt{2}$

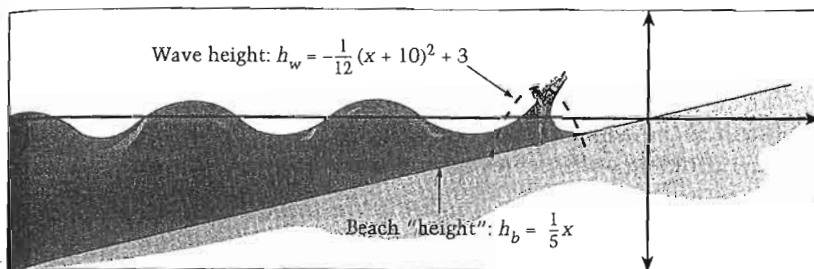
40.  $4x^2 - 13x + 3 = 0$

44. **Money in the Bank** At your seventh grade graduation, you and your twin sister each received \$200. You each deposited the money in savings accounts that compound interest annually. Two years later your sister's deposit has grown by \$28.98. Your account is in a different bank that pays an interest rate that is 1% more than your sister receives. What is your balance after two years? \$233.28

43.  $y^2 + \frac{20y}{\sqrt{360}} + 10 = 0$   
 $-10 + \frac{\sqrt{360}}{2}, -10 - \frac{\sqrt{360}}{2}$

40. 3,  $\frac{1}{4}$

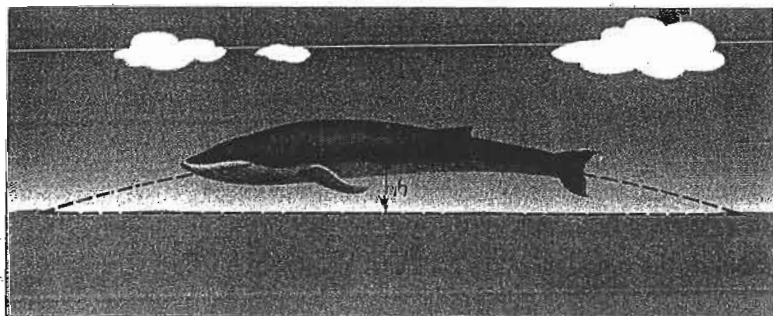
45. **Splash!** You and Jared are playing in the surf at the beach. Jared is 5 feet 4 inches tall and is standing at the point where the wave crests, as shown below. Did the wave go over his head? Explain. No. See margin.



46. **Whale Watching** At the beach you see an 80-foot whale jump above water. The path followed by the whale is given by the model

$$h = -\frac{1}{400}x^2 + \frac{4}{5}x - 52$$

where  $h$  is the height (in feet) above the sea and  $x$  is the horizontal distance (in feet) traveled by the whale. Sketch a graph of this equation. For how many horizontal feet did the whale travel over the water before reaching its maximum height? 69.28 ft See margin.



*To attain a maximum thrust, a whale beats its tail down when a wave moves water upward (the front face of the wave) and beats its tail up when the wave moves water downward (the back face of the wave).*

47. **Waterfall** The Vettisfoss waterfall falls over a vertical cliff. The path followed by the water as it flows over the Vettisfoss Falls can be modeled by

$$h = -\frac{1}{30}(x - 10)^2 + 900$$

where  $h$  is the height (in feet) above the lower river level, and  $x$  measures the horizontal distance (in feet) from the base of the cliff. How far from the base of the cliff does the water hit the river?  $\approx 174$  ft

48. How long does it take the water to hit the lower river? (Use a vertical motion model. See page 474.) 7.5 seconds



*Vettisfoss Falls, in Norway, is one of the most famous waterfalls in the world. The distance between the lower river and the top of the falls is 900 feet.*

## Integrated Review

In Exercises 49–54, solve the equation.

49.  $x^2 = 16 \pm 4$

50.  $x^2 + 3 = 7 \pm 2$

51.  $x^2 + 4 = 29 \pm 5$

52.  $\frac{1}{7}x^2 + 8 = 15 \pm 7$

53.  $2x^2 - 7 = 11 \pm 3$

54.  $3x^2 - 8 = 100 \pm 6$

In Exercises 55–60, sketch the graph of the equation and find any  $x$ -intercepts. Explain how factoring could be used to find the  $x$ -intercepts. See Additional Answers for graphs.

55.  $y = x^2 - 6x + 8$  (2, 0), (4, 0)

56.  $y = -2x^2 - 8x - 6$

57.  $y = -x^2 - 2x - 1$  (-1, 0)

58.  $y = x^2 + 8x + 16$  (-4, 0)

59.  $y = 2x^2 - x - 10$  ( $\frac{5}{2}$ , 0), (-2, 0)

60.  $y = x^2 + 5x - 6$  (-6, 0), (1, 0)

In Exercises 61–66, factor the expression. See below.

61.  $3x^2 - 15x - 18$

62.  $12x^2 + 46x - 8$

63.  $140y^2 + 340y + 120$

64.  $-18y^2 + 156y + 54$

65.  $12a^2 + 36a + 24$

66.  $10x^2 + 15x + 5$

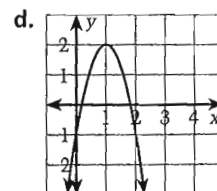
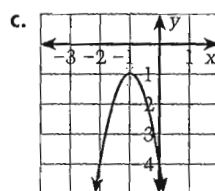
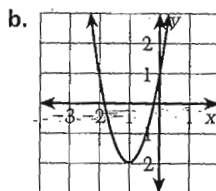
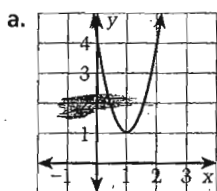
In Exercises 67–70, match the equation with its graph.

67.  $y = -3x^2 + 6x - 1$  d

68.  $y = 3x^2 - 6x + 4$  a

69.  $y = 3x^2 + 6x + 1$  b

70.  $y = -3x^2 - 6x - 4$  c



In Exercises 71–74, sketch the graph of the inequality. See Additional Answers.

71.  $y \geq \frac{1}{2}x^2 - 4x + 6$

72.  $y < \frac{1}{3}x^2 + 2x + 1$

73.  $y > -x^2 + 8x - 16$

74.  $y \leq -x^2 - 4x - 5$

## Exploration and Extension

- ★ 75. **Revenue** The revenue,  $R$ , for selling  $x$  units of a product is given by

$$R = x(50 - \frac{1}{2}x).$$

How many units must be sold to produce a revenue of \$1218? 58 or 42

- ★ 76. **Revenue** The revenue,  $R$ , for selling  $x$  units of a product is given by

$$R = x(100 - \frac{1}{10}x).$$

How many units must be sold to produce a revenue of \$990? 990 or 10

- ★ 77. **College Entrance Exam Sample** If  $x$  and  $y$  are positive integers,  $x^2 + y^2 = 25$ , and  $x^2 - y^2 = 7$ , then  $y = \boxed{?}$ .

a. 3    b. 4    c. 5    d. 9    e. 16

61.  $3(x - 6)(x + 1)$     62.  $2(6x - 1)(x + 4)$     63.  $20(7y + 3)(y + 2)$     64.  $-6(3y + 1)(y - 9)$   
 65.  $12(a + 1)(a + 2)$     66.  $5(2x + 1)(x + 1)$

## Chapter REVIEW

In Exercises 1–8, classify the polynomial by degree and by terms. (10.1)

- |   |   |
|---|---|
| 1. $x^2 - 1$ Quadratic, binomial            | 2. $3x^2 + 2x - 2$ Quadratic, trinomial     |
| 3. 121 Constant, monomial                   | 4. $4x$ Linear, monomial                    |
| 5. $x^4 - x^2 + 2x + 3$ Quartic, polynomial | 6. $49x - 2$ Linear, binomial               |
| 7. $8x^3 - 27$ Cubic, binomial              | 8. $2x^3 + 4x^2 - 5x + 6$ Cubic, polynomial |
| 11. $3x^2 + x + 5$                          | 12. $-x^3 - x^2 + 2x + 6$                   |
|   | 13. $-3x^2 + 8x - 7$                        |

In Exercises 9–20, perform the indicated operation. Use a horizontal format. (10.1, 10.2) See margin.

- |  |  |
|--|--|
| 9. $(x + 2 - x^2) + (3x^2 + 4x + 5)$ $2x^2 + 5x + 7$ | 10. $(4x^3 + x^2 - 1) + (2 - x - x^2)$ $4x^3 - x + 1$      |
| 11. $(15 + 3x - x^2) + (4x^2 - 2x - 10)$             | 12. $(3x + 2 - x^2) + (4 - x - x^3)$                       |
| 13. $(x^2 + 3x - 1) - (4x^2 - 5x + 6)$               | 14. $(x^2 + 9x + 2) - (5 + 8x - 3x^2)$                     |
| 15. $(3x^2 - 2x + 4) - (-x^3 + 2x - 6)$ See margin.  | 16. $(x^3 + 5x^2 - 4x) - (3x^2 - 6x + 2)$                  |
| 17. $(x - 5)(x - 10)$ $x^2 - 15x + 50$               | 18. $(2x + 2)(x + 4)$ $2x^2 + 10x + 8$                     |
| 19. $(6 + x)(x^2 - 2x + 3)$ $x^3 + 4x^2 - 9x + 18$   | 20. $(7 - x)(3x^2 + 2x - 6)$<br>$-3x^3 + 19x^2 + 20x - 42$ |

In Exercises 21–32, perform the indicated operation. Use a vertical format. (10.1, 10.2) See margin.

- |   |  |
|---|--|
| 21. $(6x^2 + 2x - 1) + (x^2 - 2)$ $7x^2 + 2x - 3$       | 22. $(x - 2) + (4x^2 - 7x + 5)$ $4x^2 - 6x + 3$            |
| 23. $(x^2 - x + 2) + (x^2 + 2x - 4)$ $x^2 - x - 2$      | 24. $(x^2 + 3x + 5) + (3x^2 - 4x + 6)$ $4x^2 - x + 11$     |
| 25. $(x^2 - 3) - (4x^2 - 3x + 2)$ $-3x^2 + 3x - 5$      | 26. $(x^2 + 3x - 7) - (-2x^2 + x + 14)$                    |
| 27. $(x^2 - 4x + 2) - (6x^2 + 4x - 3)$                  | 28. $(10x^2 + 3x - 4) - (5x^2 + 2x - 6)$ $5x^2 + x + 2$    |
| 29. $(x - 2)(3x^2 + 4x - 1)$ $3x^3 - 2x^2 - 9x + 2$     | 30. $(10 - x)(x^2 + x + 1)$ $-x^3 + 9x^2 + 9x + 10$        |
| 31. $(2x + 2)(4x^2 - 6x + 2)$<br>$8x^3 - 4x^2 - 8x + 4$ | 32. $(4 + 3x)(1 - 4x + 6x^2)$<br>$18x^3 + 12x^2 - 13x + 4$ |

In Exercises 33–36, multiply. (10.3)

- |                                    |                                     |
|------------------------------------|-------------------------------------|
| 33. $(x + 15)(x - 15)$ $x^2 - 225$ | 34. $(3x + 2)(3x - 2)$ $9x^2 - 4$   |
| 35. $(x + 2)^2$ $x^2 + 4x + 4$     | 36. $(5x - 6)^2$ $25x^2 - 60x + 36$ |

In Exercises 37–46, use the discriminant to determine whether the polynomial can be factored. If possible, factor the polynomial. (10.4, 10.5)

- |   |   |
|---|---|
| 37. $x^2 - 2x - 15$ $(x - 5)(x + 3)$    | 38. $x^2 + 3x - 70$ $(x + 10)(x - 7)$   |
| 39. $x^2 - 64$ $(x - 8)(x + 8)$         | 40. $4x^2 + 25$ No factors              |
| 41. $x^2 - 8x + 8$ No factors           | 42. $9x^2 + 12x + 4$ $(3x + 2)^2$       |
| 43. $x^2 + 10x + 25$ $(x + 5)^2$        | 44. $x^2 - 8x + 16$ $(x - 4)^2$         |
| 45. $4x^2 - 32x + 60$ $4(x - 5)(x - 3)$ | 46. $3x^2 + 21x + 30$ $3(x + 2)(x + 5)$ |

In Exercises 47–54, solve the equation. (10.6)

50. 5, -2

10, 20

47.  $x^2 - 21x + 108 = 0$  9, 12

48.  $x^2 - 8x - 240 = 0$  20, -12

49.  $-x^2 + 30x - 200 = 0$

50.  $-15x^2 + 45x + 150 = 0$

51.  $36x^2 - 49 = 0$   $\pm \frac{7}{6}$

52.  $x^2 + 26x + 169 = 0$  -13

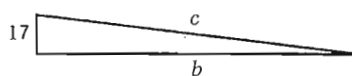
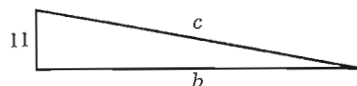
53.  $x^2 - 14x + 36 = 0$   
 $7 + \frac{\sqrt{52}}{2}, 7 - \frac{\sqrt{52}}{2}$

54.  $x^2 + 10x - 3 = 0$   $-5 + \frac{\sqrt{112}}{2}, -5 - \frac{\sqrt{112}}{2}$

**Right-Triangle Triple** In Exercises 55 and 56, find the right-triangle triple. (10.4)

55.  $11^2 + b^2 = c^2$  11, 60, 61

56.  $17^2 + b^2 = c^2$  17, 144, 145



57. **Tossing a Ball** A ball is tossed into the air from a height of 10 feet with an initial velocity of 12 feet per second. Find the time,  $t$  (in seconds), for the object to reach the ground by solving the equation

$$-16t^2 + 12t + 10 = 0. \text{ 1.25 seconds}$$

58. **Summer Business** Your friend's weekly revenue,  $R$  (in dollars), from her tie-dye T-shirt business can be modeled by

$$R = -2t^2 + 37t + 60$$

where  $t$  represents the week of sales, with  $t = 0$  for the first week.

In the first week, 3 T-shirts were sold. After that, the sales increased by 2 T-shirts per week. Did the price of T-shirts remain constant during the 8-week summer season? Explain. No. See margin.

**Huffing and Puffing** In Exercises 59 and 60, use the following information.

Porcupine fish, members of the puffer fish family, range between 10 and 20 inches in length. When in danger, the body of the fish puffs up by taking in water or air. (The tail, which is about 3 inches long, does not puff up.)

$$\frac{\pi}{6}x^3 - \frac{3\pi}{2}x^2 + \frac{9\pi}{2}x - \frac{9\pi}{2}$$

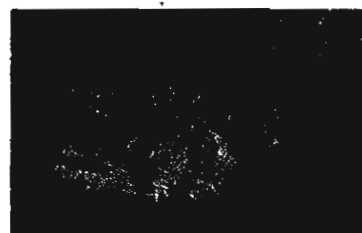
59. The volume of a "puffed-up" porcupine fish can be modeled by

$$V = \left(\frac{1}{6}\right)\pi(x - 3)^3$$

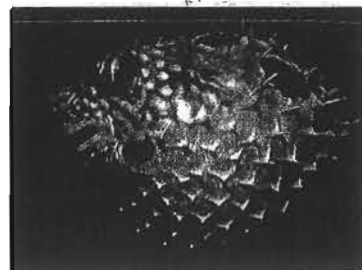
where  $x$  is the total length of the fish in inches. Write the right side of this equation in standard polynomial form.

60. Approximate the volume of an 11-inch porcupine fish. 268 in.<sup>3</sup>

**Porcupine Fish:**  
Deflated



Inflated



# Chapter TEST

In Exercises 1–12, perform the indicated operations. (10.1, 10.2, 10.3) 4.  $x^3 - 2x^2 + 7x - 4$

1.  $(x^2 + 3x - 1) + (4x^2 + 2)$   $5x^2 + 3x + 1$
2.  $(x^4 + 3x^2 + 2) + (2x^4 - 3x^2 + 6)$   $3x^4 + 8$
3.  $(5x^2 - 2x + 1) - (7x + 10)$   $5x^2 - 9x - 9$
4.  $(5x^3 + 2x - 4) - (4x^3 + 2x^2 - 5x)$
5.  $(9x + 2)(9x - 2)$   $81x^2 - 4$
6.  $(5x - 4)(5x + 4)$   $25x^2 - 16$
7.  $(x - 14)^2$   $x^2 - 28x + 196$
8.  $(3x + 5)^2$   $9x^2 + 30x + 25$
9.  $(x + 2)(3x + 5)$   $3x^2 + 11x + 10$
10.  $(2x - 1)(13x + 5)$   $26x^2 - 3x - 5$
11.  $(x - 6)(4x^2 + 3x - 5)$   $4x^3 - 21x^2 - 23x + 30$
12.  $(4x^3 - 6x + 7)(x + 1)$   $4x^4 + 4x^3 - 6x^2 + x + 7$

In Exercises 13–20, factor the expression. (10.4, 10.5) See margin.

13.  $x^2 - 144$
14.  $36x^2 - 25$
15.  $x^2 - 12x + 36$
16.  $x^2 + 10x + 25$
17.  $3x^2 + 2x - 1$
18.  $5x^2 - 3x - 2$
19.  $x^3 + 2x^2 + x$
20.  $2x^2 - 28x + 96$

In Exercises 21–26, solve the equation. (10.6)

21.  $x^2 + 4x + 4 = 0$   $-2$
22.  $x^2 - 7x + 6 = 0$   $1, 6$
23.  $x^2 - 5x - 150 = 0$   $15, -10$
24.  $x^2 + 6x - 91 = 0$   $7, -13$
25.  $12x^2 + 15x + 3 = 0$   $-\frac{1}{4}, -1$
26.  $4x^2 - 10x - 36 = 0$   $\frac{9}{2}, -2$

In Exercises 27–30, solve the equation by completing the square. (10.7)

27.  $x^2 - 4x + 1 = 0$   $2 + \sqrt{3}, 2 - \sqrt{3}$
28.  $x^2 + 6x - 9 = 0$   $-3 + \sqrt{18}, -3 - \sqrt{18}$
29.  $x^2 + 20x + 3 = 0$   $-10 + \sqrt{97}, -10 - \sqrt{97}$
30.  $x^2 - 2x - 5 = 0$   $1 + \sqrt{6}, 1 - \sqrt{6}$

31. Find a right-triangle triple such that  $5^2 + b^2 = c^2$ . (10.4)  $5, 12, 13$
32. The length of a bedroom is 3 feet less than twice its width. The area of the bedroom is 135 square feet. What are the dimensions of the room? (10.5)  $9 \text{ ft by } 15 \text{ ft}$
33. A deposit of \$5000 was put into a savings account paying an annual interest of  $r\%$ , compounded yearly. After 2 years, the balance in the account was \$5,644.53. What was the rate of interest? (10.4)  $\approx 6.25\%$
34. The bed of a pond can be modeled by  $25y = 2x^2 - 20x + 1$ , where  $x$  and  $y$  are measured in meters and the  $x$ -axis matches the water level of the pond. What is the width of the pond? (10.5)  $\approx 9.9 \text{ m}$

