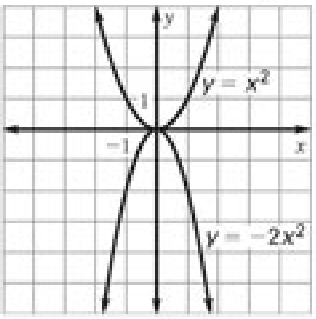
Chapter 9

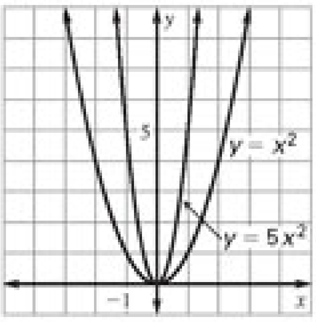
9.1 Skill Practice **1.** parabola **3.** C **5.** B

7.



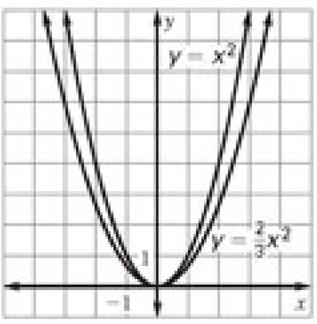
The graph is a vertical stretch (by a factor of 2) with a reflection in the x-axis of the graph of $y = x^2$.

9.



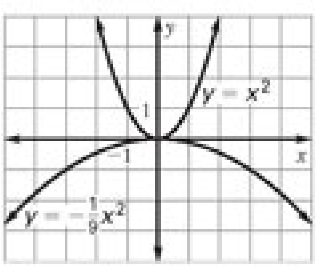
The graph is a vertical stretch (by a factor of 5) of the graph of $y = x^2$.

11.



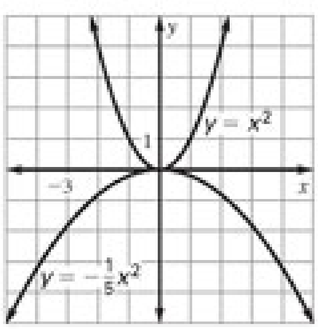
The graph is a vertical shrink $\left(\text{by a factor of } \frac{2}{3}\right)$ of the graph of $y = x^2$.

13.



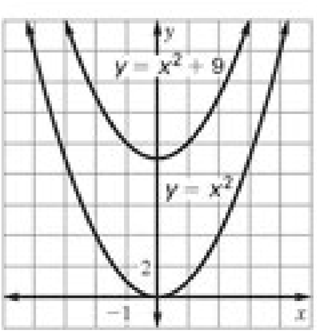
The graph is a vertical shrink $\left(\text{by a factor of } \frac{1}{9}\right)$ with a reflection in the x-axis of the graph of $y = x^2$.

15.



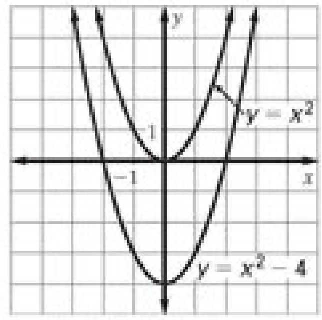
The graph is a vertical shrink $\left(\text{by a factor of } \frac{1}{5}\right)$ with a reflection in the x-axis of the graph of $y = x^2$.

17.



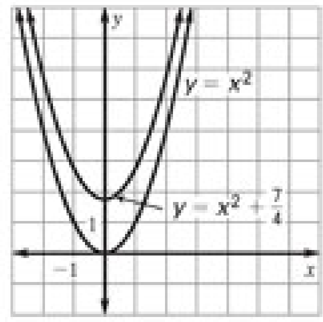
The graph is a vertical translation (of 9 units up) of the graph of $y = x^2$.

19.



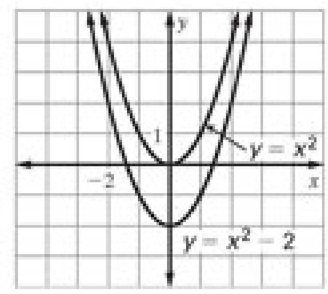
The graph is a vertical translation (of 4 units down) of the graph of $y = x^2$.

21.

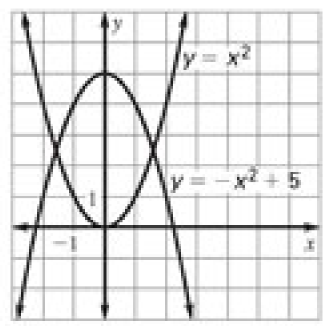


The graph is a vertical translation $\left(\text{of } \frac{7}{4} \text{ units up}\right)$ of the graph of $y = x^2$.

23. The graph of $y = x^2 - 2$ should be shifted 2 units down, not 2 units up. The vertex should be at $(0, -2)$.

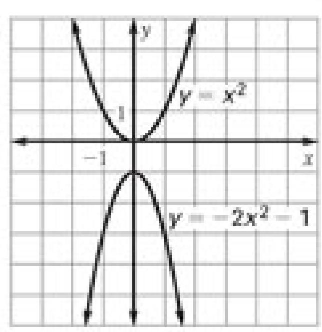


25.



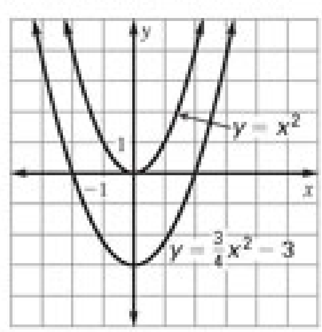
The graph is a reflection in the x-axis with a vertical translation (of 5 units up) of the graph of $y = x^2$.

27.

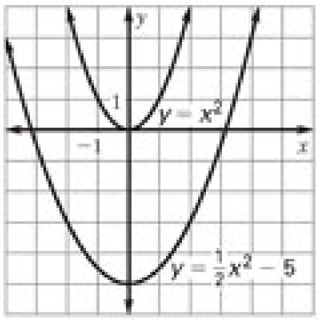


The graph is a vertical stretch (by a factor of 2) with a vertical translation (of 1 unit down) and a reflection in the x-axis of the graph of $y = x^2$.

29.



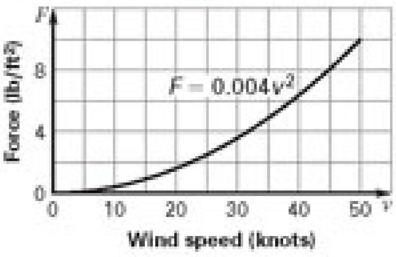
The graph is a vertical shrink $\left(\text{by a factor of } \frac{3}{4}\right)$ with a vertical translation (of 3 units down) of the graph of $y = x^2$.

31. 

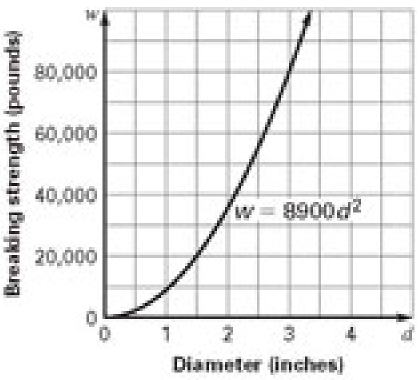
The graph is a vertical shrink (by a factor of $\frac{1}{2}$) with a vertical translation (of 5 units down) of the graph of $y = x^2$.

35. Translate the graph of f 5 units down.

9.1 Problem Solving

41. a. 

b. about 16 knots **c.** about 35 knots

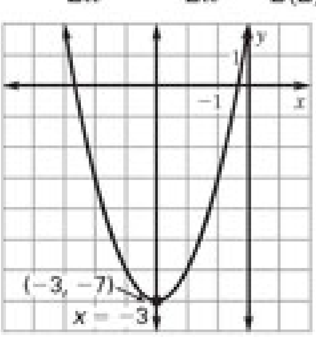
43. a. 

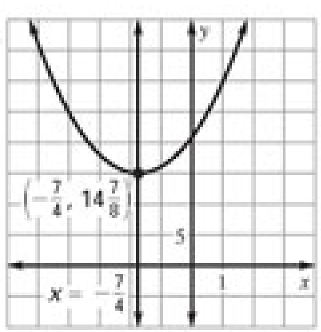
b. No. *Sample answer:* Let D be the diameter of a rope with 4 times the breaking strength of a rope with diameter d. Then $8900D^2 = 4(8900d^2)$; $D^2 = 4d^2$; $D = \sqrt{4d^2}$; $D = 2d$. Thus, the diameter of the rope with 4 times the breaking strength is only two times the diameter of the other rope.

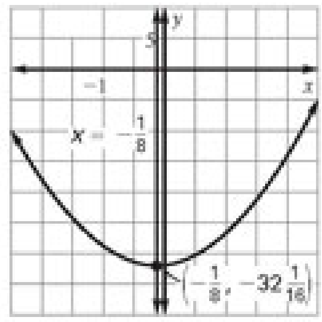
9.2 Skill Practice

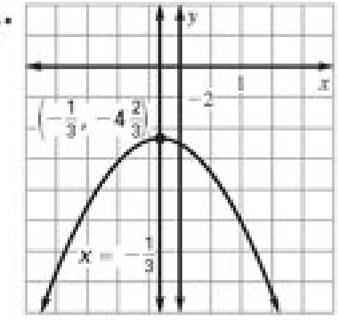
1. When the function is in standard form, $y = ax^2 + bx + c$, it will have a minimum value if $a > 0$ and a maximum value if $a < 0$. **3.** $x = 2$, $(2, -2)$ **5.** $x = 4$, $(4, 26)$ **7.** $x = -\frac{1}{2}$, $\left(-\frac{1}{2}, -\frac{3}{2}\right)$ **9.** $x = 0$, $(0, -1)$ **11.** $x = 6$, $(6, 7)$

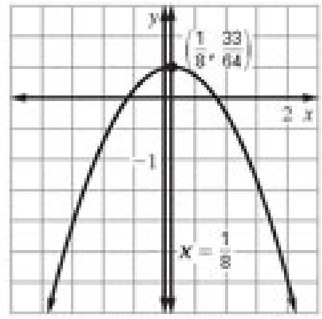
13. The equation of the axis of symmetry is $x = \frac{-b}{2a}$, not $x = \frac{b}{2a}$; $x = \frac{-b}{2a} = \frac{-16}{2(2)}$, $x = -4$.

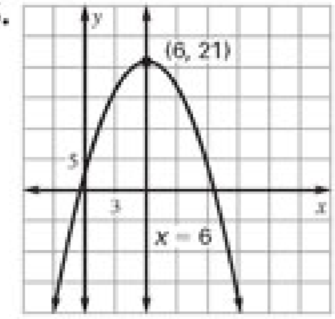
15. 

17. 

19. 

21. 

23. 

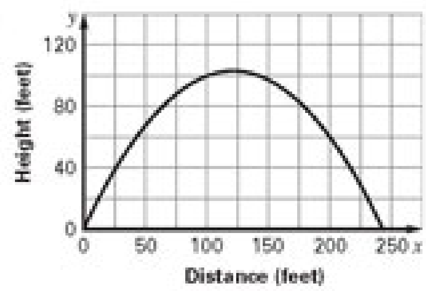
25. 

29. maximum value; 7 **31.** maximum value; −8 **33.** maximum value; $\frac{81}{8}$ **35.** maximum value; 54

37. The graph of $y = x^2 + 4x + 1$ is a horizontal translation (of 4 units left) of the graph of $y = x^2 - 4x + 1$.

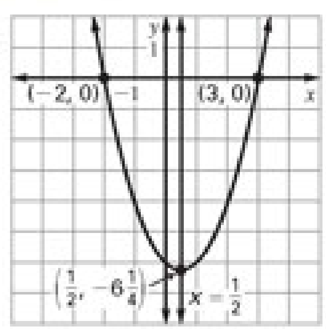
9.2 Problem Solving

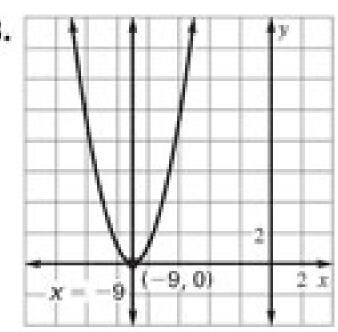
41. about 66 ft

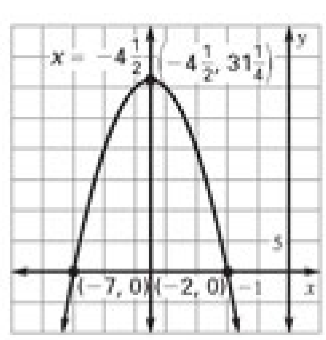
43. 

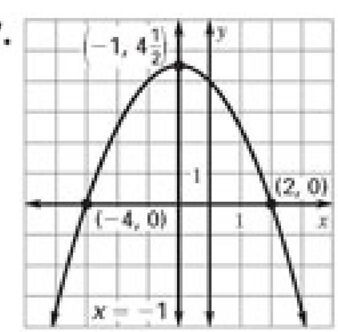
about 243 ft

Extension

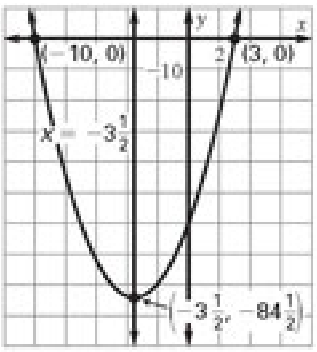
1. 

3. 

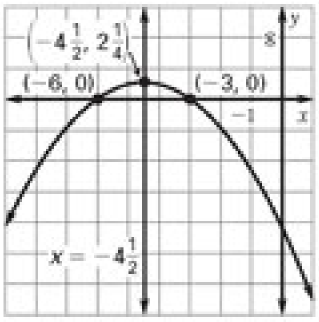
5. 

7. 

9.



11.



9.3 Skill Practice **1.** $2x^2 - 9x + 11 = 0$ **3.** 4, 1 **5.** −4, −2 **7.** 8, −2 **9.** 3 **11.** −5 **13.** −7 **15.** no solution **17.** no solution **19.** −6, 2 **21.** Any solution of a quadratic equation is an x-intercept of the graph of the related quadratic function. The x-intercept of the function shown in the graph is 2, not 4; the only solution of the equation is 2. **23.** −3, 4 **25.** −5, 2 **27.** −5, 4 **29.** 1, 11 **31.** $-1\frac{1}{2}$, 1 **33.** $\frac{1}{2}$ **35.** no solution **37.** −3.4, −0.6 **39.** −1.4, 3.4 **41.** 0.8, 6.2 **43.** −1.3, 0.8 **45.** −4.7, −1.3

9.3 Problem Solving **51.** 24.1 ft **53.** 16 ft; the distance from the nozzle to the circle is the distance between the x-intercepts of $y = -0.75x^2 + 6x$. Substitute 0 for y and solve for x: $0 = -0.75x^2 + 6x$ has solutions 0 and 8. The radius of the display circle is 8 feet, so the diameter is 16 feet.

9.3 Graphing Calculator Activity

1. $1\frac{2}{3}$ **3.** −3.75 **5.** about −3.5 **7.** −1.11, 3.61 **9.** −1.61, 5.61 **11.** 0.90, 2.18 **13.** −7.03, 2.15 **15.** 0; the maximum or minimum value of a quadratic function occurs at the vertex of the parabola that is the graph of the function. When a quadratic function has only one zero, its graph has only one x-intercept, which must also be the x-coordinate of the vertex of the parabola. Then the y-coordinate of the vertex is 0, so the maximum or minimum value of the function is 0.

9.4 Skill Practice **1.** square root **3.** ±1 **5.** ±10 **7.** 0 **9.** $\pm\frac{1}{2}$ **11.** $\pm\frac{7}{3}$ **13.** 0 **17.** ±2.65 **19.** no solution **21.** 0 **23.** ±2.24 **25.** ±3.78 **27.** ±1.32 **31.** Negative numbers do not have real number square roots, so $\pm\sqrt{-\frac{11}{7}}$ are not real numbers; there is no solution. **33.** 0.76, 5.24 **35.** −8.16, −1.84 **37.** −16.65, −11.35 **39.** −5.69, 3.69 **41.** ±4 **43.** ±1.41 **45.** 0.37, 13.63 **47.** 12 in. **49.** 11.66 ft **51.** $\pm\frac{6}{5}$, or ±1.2. *Sample answer:* Rewrite the decimal as a fraction and then take square roots of each side of the equation: $x^2 = \frac{144}{100}$, so $x = \pm\sqrt{\frac{144}{100}} = \pm\frac{12}{10} = \pm\frac{6}{5}$ or ±1.2.

9.4 Problem Solving **59. a.** 6.8 mm **b.** 5.9 mm **c.** 5.6 mm **61. a.** $D = 4 \pm \sqrt{\frac{16V}{L}}$ **b.** 11.1 in., 10.7 in., 10.3 in., 10.0 in.

9.4 Problem Solving Workshop **1.** about 1.5 sec **3. a.** $V = 25x^2$ **b.** length: about 9 in., width: 5 in., height: about 1.8 in.

c.

Height, x (inches)	1.7	1.8	1.9
Width (inches)	5	5	5
Length, $5x$ (inches)	8.5	9	9.5
Volume, V (cubic inches)	72.25	81	90.25

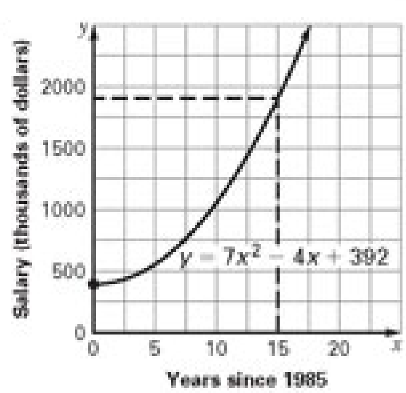
The volume in the table closest to 83 cubic inches is 81 cubic inches. To the nearest tenth of an inch, the height of the box is about 1.8 inches. The length of the box is $5x \approx 9$ inches, and the width is 5 inches. **5.** To rewrite the equation $6 = -16t^2 + 54$ so that one side is 0, you must subtract 6 from each side; $0 = -16t^2 + 48$, replace 48 with the closest perfect square, 49. $0 = -16t^2 + 49 = -(16t^2 - 49) = -(4t + 7)(4t - 7)$, so the approximate solutions of this equation are $\pm\frac{7}{4}$. Disregard the negative solution because time cannot be negative; so, it takes about $\frac{7}{4}$, or 1.75, seconds for the shoe to hit the net.

9.5 Skill Practice **1.** completing the square **3.** 9; $(x + 3)^2$ **5.** 4; $(x - 2)^2$ **7.** $\frac{9}{4}$; $\left(x - \frac{3}{2}\right)^2$ **9.** 1.44; $(x + 1.2)^2$ **11.** $\frac{4}{9}$; $\left(x - \frac{2}{3}\right)^2$ **13.** −12, 2 **15.** −6, 12 **17.** −7, 3 **19.** −10.5, −0.5 **21.** −0.80, 8.80 **23.** −2.5, −0.5 **27.** The perfect square trinomial $x^2 - 2x + 1$ factors as $(x - 1)^2$ not $(x + 1)^2$, $(x - 1)^2 = 5$, $x - 1 = \pm\sqrt{5}$, $x = 1 \pm \sqrt{5}$. **29.** −11.57, −0.43 **31.** −1.91, 0.91 **33.** −0.96, 6.96 **35.** 0.79, 2.21 **37.** −3.68, −0.32 **39.** −0.25, 0.75 **41.** 4.87

9.5 Problem Solving

45. 3 ft **47. a.** $1904 = 7x^2 - 4x + 392$, 2000

b.

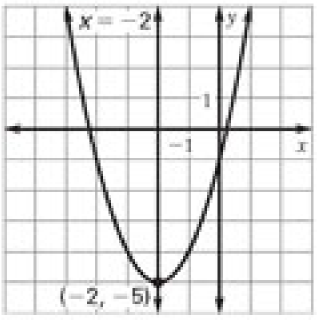


When $y \approx 1904$, the value of x is about 15. So the year 2000 (1985 + 15) found in part (a) is correct.

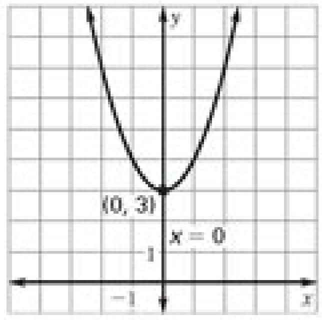
49. Yes; to find the number of days x after which the stock price was \$23.50 per share, substitute 23.5 for y and solve for x by completing the square to find that the solutions are 10 and 30. You could have sold the stock for \$23.50 per share 10 days after you purchased it.

Extension

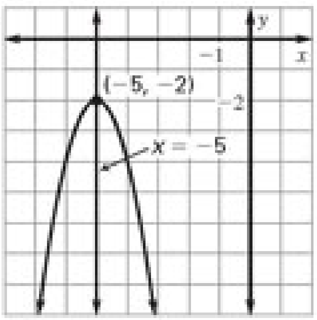
1.



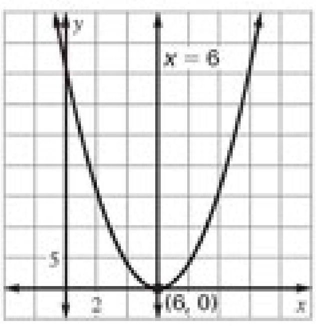
3.



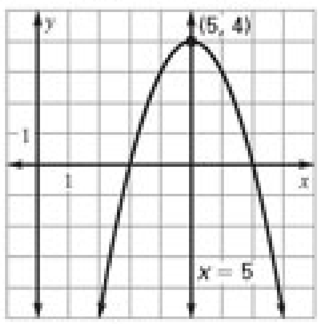
5.



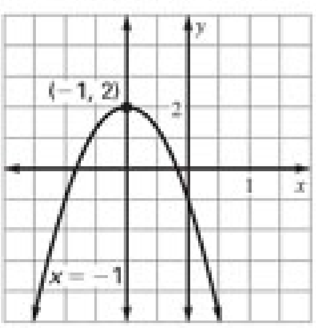
7. $y = (x - 6)^2$



9. $y = -(x - 5)^2 + 4$



11. $y = -3(x + 1)^2 + 2$



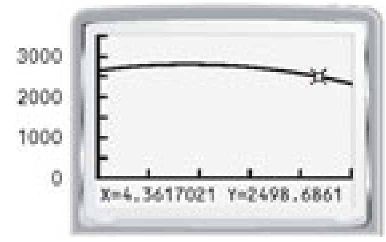
13. $y = \frac{1}{4}(x + 6)^2 + 1$

9.6 Skill Practice **1.** quadratic formula **3.** −13, 8 **5.** −2, 2.33 **7.** −3.27, 4.27 **9.** −2.5 **11.** −0.63, 2.13 **13.** −2, 7 **15.** −1, 1.29 **17.** 3.27, 6.73 **19.** −0.54, 2.29 **21.** −0.66, 1.09 **23.** −1.77, −0.57 **27.** Before identifying the values of a, b, and c, the equation must be written in standard form $ax^2 + bx + c = 0$; $-2x^2 + 3x - 1 = 0$, so $c = -1$, not 1; $x = \frac{-3 \pm \sqrt{3^2 - 4(-2)(-1)}}{2(-2)}$, $x = \frac{-3 \pm \sqrt{1}}{-4}$, $x = \frac{1}{2}$ and $x = 1$. **29–33.** Sample answers are given.

29. Using square roots, the equation can be written in the form $x^2 = d$. **31.** Factoring, the expression $m^2 + 5m + 6$ factors easily. **33.** Quadratic formula, the equation does not factor easily. **35.** 4 **37.** 6 **39.** −1.94, 2.19 **41.** −0.41, 2.41 **43.** 5; 13 m by 7 m

9.6 Problem Solving

47. 1993 **49. a.** 2001 **b.**



Extension **1.** $-2 - \sqrt{2}, -2 + \sqrt{2}$ **3.** $-4 - 2\sqrt{2}, -4 + 2\sqrt{2}$ **5.** $-1 - \frac{2\sqrt{3}}{3}, -1 + \frac{2\sqrt{3}}{3}$ **7.** $\frac{1}{5} - \frac{\sqrt{11}}{5}, \frac{1}{5} + \frac{\sqrt{11}}{5}$ **9.** $\frac{1}{2} - \frac{\sqrt{13}}{2}, \frac{1}{2} + \frac{\sqrt{13}}{2}$ **11.** $\frac{7}{2} - \frac{\sqrt{61}}{2}, \frac{7}{2} + \frac{\sqrt{61}}{2}$ **13.** $2 - \sqrt{2}, 2 + \sqrt{2}$ **15.** $-\frac{\sqrt{6}}{3}, \frac{\sqrt{6}}{3}$ **17.** $-\frac{1}{6} - \frac{\sqrt{73}}{6}, -\frac{1}{6} + \frac{\sqrt{73}}{6}$ **21.** Sum: $-\frac{b}{a}$, product: $\frac{c}{a}$. *Sample answer:* $y = 2x^2 - 4x + 1$

9.7 Skill Practice **1.** First solve one of the equations for a variable. Then substitute that expression for the variable in the other equation. Solve the resulting equation in one variable. Use that solution to substitute into one of the original equations to find the value of the other variable. **3.** (−1, 4) and (3, 8) **5.** (−2, 6) and $\left(\frac{1}{2}, -\frac{1}{4}\right)$ **7.** (−2, 6) and (1, −3) **9.** The student substituted incorrectly. Substitute 4 for y and then the solutions are (0, 4) and (2, 4). **11.** C **13.** (–1, 10) and (3, 14) **15.** (2, 0) and (6, 4) **17.** (–3, 14) and (1, 2) **19.** –1 **21.** 1 and –2 **23.** (0, –1) **25.** no solution **27.** (–1, 2.5), (0, 1) **29.** 1 and 2 **31.** 3 **33.** (1, –1)

9.7 Problem Solving **35.** No; *Sample answer:* The graphs of the equations that model the paths do not intersect, so the dogs' paths will not cross. **37.** The graphs intersect when the two girls have the same amount of money saved. Miranda has more money saved for the first 20 months, and then again after 104 months, because the graphs intersect near $x = 20$ and $x = 104$. **39. a.** (1, 4) and (2.5, 8.5) **b.** (1, 4) **c.** (0, 6) and (1, 4) **d.** yes; (1, 4)

9.8 Skill Practice **1.** exponential function **3.** B **5.** A **7.** linear function **9.** exponential function **11.** quadratic function **13.** quadratic function; $y = -x^2$ **15.** linear function; $y = 3x + 1$

17. exponential function; $y = 4\left(\frac{1}{4}\right)^x$ **19.** The x- and y-values were reversed when substituting the coordinates of the ordered pair (2, 10) into the equation $y = ax^2$. Substituting 2 for x and 10 for y gives $10 = a(2)^2$, $a = 2.5$; so, the equation is $y = 2.5x^2$. **21.** $A = \left(\frac{\sqrt{3}}{4}\right)s^2$; $25\sqrt{3}$ cm^2

9.8 Problem Solving **23.** linear function; $y = 0.34x + 24.6$ **25. a.** Troy: Population doubled every decade; data can be modeled by an exponential function. Union: Population increased by a fixed amount every decade; data can be modeled by a linear function.

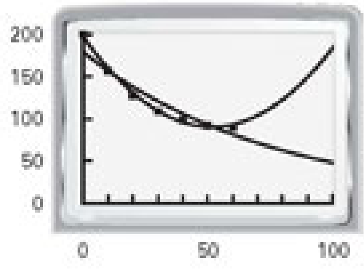
b.

Decades since 1970	Troy's pop.
0	3000
1	6000
2	12,000
3	24,000
4	48,000

Decades since 1970	Union's pop.
0	3000
1	6000
2	9000
3	12,000
4	15,000

Troy: Ratios of successive y-values are equal. Union: First differences are constant. **c.** Let P = population and n = number of decades since 1970. Troy: $P = 3000 \cdot 2^n$, 192,000; Union: $P = 3000n + 3000$, 21,000 **27. a.** quadratic function; $\ell = 0.82t^2$ **b.** 0.205 ft **c.** The period decreases by about 71%. For example, consider $t = 4$ for $\ell = 13.12$. To find t for 50% of ℓ, solve $0.5(13.12) = 0.82t^2$; $t \approx 2.83$, and $\frac{2.83}{4} = 0.708$, so the period decreased by about 71%. Consider $t = 2$ for $\ell = 3.28$. To find t for 50% of ℓ, solve $0.5(3.28) = 0.82t^2$; $t \approx 1.41$, and $\frac{1.41}{2} = 0.705$, so the period decreased by about 71%. Consider $t = 1$ for $\ell = 0.82$. To find t for 50% of ℓ, solve $0.5(0.82) = 0.82t^2$; $t \approx 0.707$, and $\frac{0.707}{1} = 0.707$, so the period decreased by about 71%.

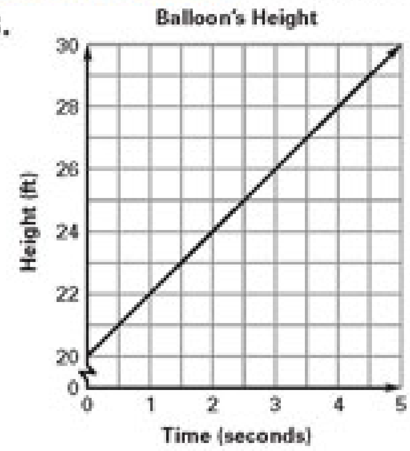
9.8 Graphing Calculator Activity
1. $y = 15{,}600(0.866)^x$; about \$5698
3. $y = 179(0.987)^x$, $y = 0.040x^2 - 4.13x + 197$



The exponential model; although the quadratic model appears to fit the given data points more closely than the exponential model does, the graph shows that after the last data point, (60, 90), the quadratic model implies increasing temperatures as time goes on, while the exponential model shows gradually decreasing temperatures as time goes on; the exponential model is a more accurate model of what will happen as the hot chocolate continues to cool.

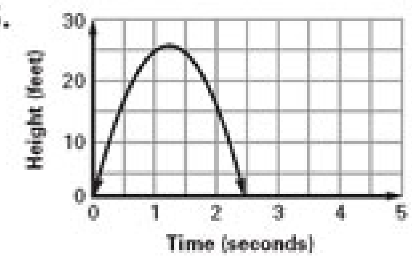
9.9 Skill Practice **1.** verbal model

3.



The function is increasing throughout its domain, $x \geq 0$. As the time since it resumed its ascent increases, the altitude of the balloon increases.

5.



The function is increasing from $x = 0$ to about $x = 1.25$. This is the time during which the ball is traveling upward until it reaches its maximum height at about 1.25 seconds. The graph is decreasing from about $x = 1.25$ to $x = 2.5$. This is the time during which the ball is traveling downward until the juggler catches it at 2.5 seconds. **7.** A function that increases by a constant percent should be modeled by an exponential growth function. **9.** The slope of Linear Function 1 is –1 while the slope of Linear Function 2 is –2. So Linear Function 2 is decreasing more rapidly. **11.** C

9.9 Problem Solving **13.** Connie's playlist is growing faster. **15.** The number of spores in the Petri dish represents growth; the growth rate is 50%. There are no intercepts. If there were an x-intercept, there would be no area. If there were a y-intercept, the fountain would have no measurable length or width. **17.** The rowing crew's distances are decaying by a constant percent rate per unit interval of time. The decay rate is 20%. **19a.** the exponential function $y = 2^x$ **b.** the exponential function $y = 3^x + 1$ **c.** the exponential growth function

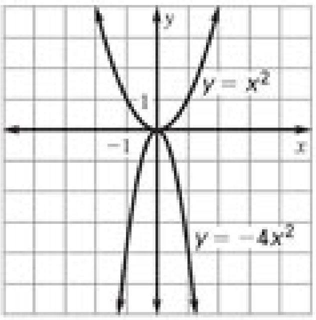
9.9 Graphing Calculator Activity
1. Depending on the interval, the average rate of change can be very large or very small, but it is always positive. **3.** For $y = 2x - 3$, the average rate of change is the constant 2. **5.** $y = x + 1$: 1, 1; $y = x^2 + 1$: 1100, 11,000; $y = 2^x$: very large, very large, extremely large; as x increases, the average rate of change of the

exponential function increases much more rapidly than the average rate of change of the quadratic function. The linear function maintains a constant rate of change.

Chapter Review

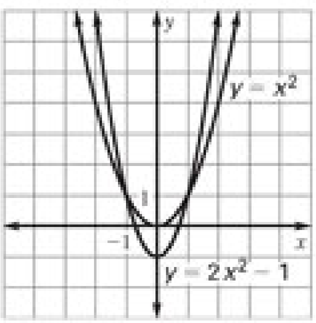
1. axis of symmetry **3.** maximum

5.



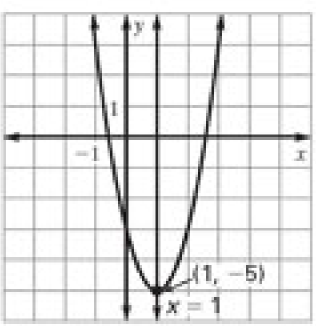
The graph is a vertical stretch (by a factor of 4) with a reflection in the x-axis of the graph of $y = x^2$.

7.



The graph is a vertical stretch (by a factor of 2) with a vertical translation (of 1 unit down) of the graph of $y = x^2$.

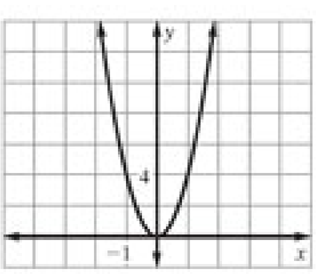
9.



11. no solution **13.** −8, 1 **15.** no solution **17.** ±0.76 **19.** 2.71, 5.29 **21.** 0.32, −6.32 **23.** −0.62, 1.62 **25.** −3.89, 0.39 **27.** 0.16, 1.24 **29.** −1.22, 1 **31.** (−1, 1), (2, −2) **33.** (−0.5, 1), (1.5, 5) **35.** linear function **37.** exponential

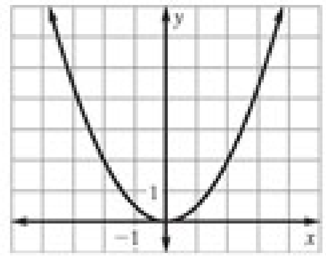
Chapter 9 Extra Practice

1.



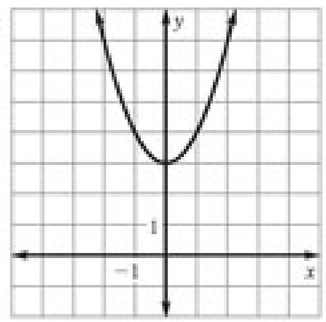
The graph is a vertical stretch by a factor of 4 of the graph of $y = x^2$.

3.



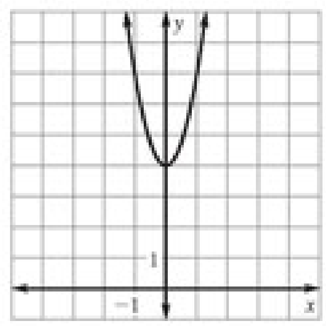
The graph is a vertical shrink by a factor of $\frac{1}{2}$ of the graph of $y = x^2$.

5.



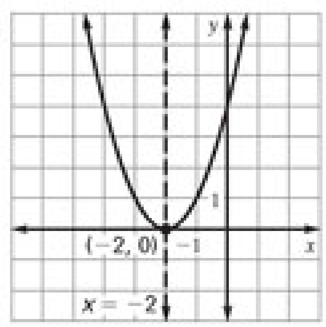
The graph is a vertical translation 3 units up of the graph of $y = x^2$.

7.

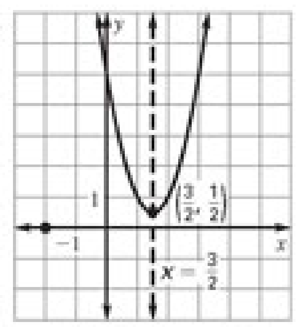


The graph is a vertical stretch by a factor of 3 with a vertical translation 4 units up of the graph of $y = x^2$.

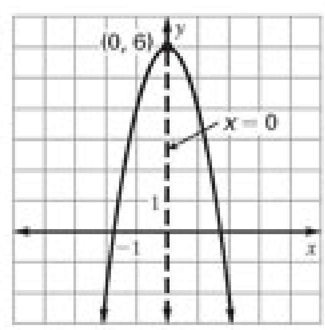
9.



11.



13.



15. −5, 2 **17.** −3, 6 **19.** $-2, \frac{3}{2}$ **21.** ±7 **23.** ±0.75 **25.** ±1.73 **27.** −7, 3 **29.** −2.66, 0.66 **31.** 0.33, 2 **33.** 0.21, 4.79 **35.** −0.35, 1.15 **37.** (0, −1) and (3, −4)

39. quadratic function; $y = 3x^2$ **41.** exponential function; $y = 0.5 \cdot 2^x$ **43.** The slope of Linear Function 1 is $\frac{5}{2}$, while the slope of Linear Function 2 is $\frac{5}{3}$. So Linear Function 1 is increasing more rapidly.