1.4 Exercises

See CalcChat.com for tutorial help and worked-out solutions to odd-numbered exercises.

For instructions on how to use a graphing utility, see Appendix A.

Vocabulary and Concept Check

1. Name three types of rigid transformations.
2. Match the rigid transformation of $y = f(x)$ with the correct representation, where $c > 0$.

a. $h(x) = f(x) + c$	i. horizontal shift c units to the left
b. $h(x) = f(x) - c$	ii. vertical shift c units upward
c. $h(x) = f(x - c)$	iii. horizontal shift c units to the right
d. $h(x) = f(x + c)$	iv. vertical shift c units downward

In Exercises 3 and 4, fill in the blanks.

3. A reflection in the x-axis of $y = f(x)$ is represented by $h(x) =$ ____ , while a reflection in the y-axis of $y = f(x)$ is represented by $h(x) =$ ____ .
4. A nonrigid transformation of $y = f(x)$ represented by $cf(x)$ is a vertical stretch when ____ and a vertical shrink when ____ .

Procedures and Problem Solving

Sketching Transformations In Exercises 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18, sketch the graphs of the three functions by hand on the same rectangular coordinate system. Verify your results with a graphing utility.

5. $f(x) = x$

   $g(x) = x - 4$

   $h(x) = 3x$

6. $f(x) = \frac{1}{2}x$

   $g(x) = \frac{1}{2}x + 2$

   $h(x) = 4(x - 2)$

7. $f(x) = x^2$

   $g(x) = x^2 + 2$

   $h(x) = (x - 2)^2$

8. $f(x) = x^2$

   $g(x) = 3x^2$

   $h(x) = (x + 2)^2 + 1$

9. $f(x) = -x^2$

   $g(x) = -x^2 + 1$

   $h(x) = -(x + 3)^2$

10. $f(x) = (x - 2)^2$

    $g(x) = (x + 2)^2 + 2$

    $h(x) = -(x - 2)^2 - 1$

11. $f(x) = x^2$

    $g(x) = \frac{1}{2}x^2$

    $h(x) = (2x)^2$

12. $f(x) = x^2$

    $g(x) = \frac{1}{4}x^2 + 2$

    $h(x) = -\frac{1}{4}x^2$

13. $f(x) = |x|$

    $g(x) = |x| - 1$

    $h(x) = 3|x - 3|$

14. $f(x) = |x|$

    $g(x) = |2x|$

    $h(x) = -2|x + 2| - 1$

15. $f(x) = -\sqrt{x}$

$g(x) = \sqrt{x+1}$

$h(x) = \sqrt{x-2}+1$

16. $f(x) = \sqrt{x}$

$g(x) = \frac{1}{2}\sqrt{x}$

$h(x) = -\sqrt{x-4}$

17. $f(x) = \frac{1}{x}$

$g(x) = \frac{1}{x} - 2$

$h(x) = \frac{1}{x-1} + 2$

18. $f(x) = \frac{1}{x}$

$g(x) = \frac{1}{x} - 4$

$h(x) = \frac{1}{x+3} - 1$

Sketching Transformations In Exercises 19 and 20, use the graph of f to sketch each graph. To print an enlarged copy of the graph, go to MathGraphs.com.

19.

a. $y = f(x) + 2$

b. $y = -f(x)$

c. $y = f(x-2)$

d. $y = f(x+3)$

e. $y = 2f(x)$

f. $y = f(-x)$

g. $y = f\left(\frac{1}{2}x\right)$

20. 

a. $y = f(x) - 1$

b. $y = f(x+2)$

c. $y = f(x - 1)$

d. $y = -f(x - 2)$

e. $y = f(-x)$

f. $y = \frac{1}{2}f(x)$

g. $y = f(2x)$

Error Analysis In Exercises 21 and 22, describe the error in graphing the function.

21. $f(x) = (x + 1)^2$

22. $f(x) = (x - 1)^2$

Library of Parent Functions In Exercises 23, 24, 25, 26, 27, and 28, compare the graph of the function with the graph of its parent function.

23. $y = \sqrt{x} + 2$

24. $y = \frac{1}{x} - 5$

25. $y = (x - 4)^3$

26. $y = |x + 5|$

27. $y = x^2 - 2$

28. $y = \sqrt{x - 2}$

Library of Parent Functions In Exercises 29, 30, 31, 32, 33, and 34, identify the parent function and describe the transformation shown in the graph. Write an equation for the graphed function.

29. 

30. 

31. 

32. 

33. 

34. 

Rigid and Nonrigid Transformations In Exercises 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, and 46, compare the graph of the function with the graph of its parent function.

35. $y = -x$

36. $y = |-x|$

37. $y = (-x)^2$

38. $y = -x^3$

39. $y = \dfrac{1}{-x}$

40. $y = -\dfrac{1}{x}$

41. $h(x) = 4|x|$

42. $p(x) = \dfrac{1}{2}x^2$

43. $g(x) = \dfrac{1}{4}x^3$

44. $y = 2\sqrt{x}$

45. $f(x) = \sqrt{4x}$

46. $y = \left|\dfrac{1}{2}x\right|$

Rigid and Nonrigid Transformations In Exercises 47, 48, 49, and 50, use a graphing utility to graph the three functions in the same viewing window. Describe the graphs

of g and h relative to the graph of f.

47. $f(x) = x^3 - 3x^2$

$g(x) = f(x + 2)$

$h(x) = \frac{1}{2}f(x)$

48. $f(x) = x^3 - 3x^2 + 2$

$g(x) = f(x - 1)$

$h(x) = f(3x)$

49. $f(x) = x^3 - 3x^2$

$g(x) = -\frac{1}{3}f(x)$

$h(x) = f(-x)$

50. $f(x) = x^3 - 3x^2 + 2$

$g(x) = -f(x)$

$h(x) = f(2x)$

Describing Transformations In Exercises 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, and 64, g is related to one of the six parent functions in 1.4 Shifting, Reflecting, and Stretching Graphs.

a. Identify the parent function f.

b. Describe the sequence of transformations from f to g.

c. Sketch the graph of g by hand.

d. Use function notation to write g in terms of the parent function f.

51. $g(x) = 2 - (x + 5)^2$

52. $g(x) = (x - 10)^2 + 5$

53. $g(x) = 3 + 2(x - 4)^2$

54. $g(x) = -\frac{1}{4}(x + 2)^2 - 2$

55. $g(x) = \frac{1}{3}(x - 2)^3$

56. $g(x) = \frac{1}{2}(x + 1)^3$

57. $g(x) = (x - 1)^3 + 2$

58. $g(x) = -(x+3)^3 - 10$

59. $g(x) = \dfrac{1}{x+8} - 9$

60. $g(x) = \dfrac{1}{x-7} + 4$

61. $g(x) = -2|x-1| - 4$

62. $g(x) = \dfrac{1}{2}|x-2| - 3$

63. $g(x) = -\dfrac{1}{2}\sqrt{x+3} - 1$

64. $g(x) = -3\sqrt{x+1} - 6$

65. Modeling Data The numbers N (in millions) of households in the United States from 2000 through 2013 are given by the ordered pairs of the form $(t, N(t))$, where $t = 0$ represents 2000. A model for the data is

$$N(t) = -0.03(t - 26.17)^2 + 126.5.$$

(Source: U.S. Census Bureau)

$(0, 104.7)$

$(1, 108.2)$

$(2, 109.3)$

$(3, 111.3)$

$(4, 112.0)$

$(5, 113.3)$

$(6, 114.4)$

$(7, 116.0)$

$(8, 116.8)$

$(9, 117.2)$

$(10, 117.5)$

$(11, 119.9)$

$(12, 121.1)$

$(13, 122.5)$

a. Describe the transformation of the parent function $f(t) = t^2$.

b. Use a graphing utility to graph the model and the data in the same viewing window.

c. Rewrite the function so that $t = 0$ represents 2009. Explain how you got your answer.

66. Why You Should Learn It? *(*1.4 Shifting, Reflecting, and Stretching Graphs*)* The depreciation D (in millions of dollars) of the WD-40 Company assets from 2009 through 2013 can be approximated by the function

$$D(t) = 1.9\sqrt{t + 3.7}$$

where $t = 0$ represents 2009. (Source: WD-40 Company)

a. Describe the transformation of the parent function $f(t) = \sqrt{t}$.

b. Use a graphing utility to graph the model over the interval $0 \leq t \leq 4$.

c. According to the model, in what year will the depreciation of WD-40 assets be approximately 6 million dollars?

d. Rewrite the function so that $t = 0$ represents 2011. Explain how you got your answer.

Conclusions

True or False? In Exercises 67 and 68, determine whether the statement is true or false. Justify your answer.

67. The graph of $y = f(-x)$ is a reflection of the graph of $y = f(x)$ in the x-axis.

True False

68. The graphs of $f(x) = |x| + 6$ and $f(x) = |-x| + 6$ are identical.

Exploration In Exercises 69, 70, 71, and 72, use the fact that the graph of $y = f(x)$ has x-intercepts at $x = 2$ and $x = -3$ to find the x-intercepts of the given graph. If not possible, state the reason.

69. $y = f(-x)$

70. $y = 2f(x)$

71. $y = f(x) + 2$

72. $y = f(x - 3)$

Library of Parent Functions In Exercises 73, 74, 75, and 76, determine which equation(s) may be represented by the graph shown. (There may be more than one correct answer.)

73. 

a. $f(x) = |x + 2| + 1$

b. $f(x) = |x - 1| + 2$

c. $f(x) = |x - 2| + 1$

d. $f(x) = 2 + |x - 2|$

e. $f(x) = |(x - 2) + 1|$

f. $f(x) = 1 - |x - 2|$

74. 

a. $f(x) = -\sqrt{x} - 4$

b. $f(x) = -4 - \sqrt{x}$

c. $f(x) = -4 - \sqrt{-x}$

d. $f(x) = \sqrt{-x} - 4$

e. $f(x) = \sqrt{-x} + 4$

f. $f(x) = \sqrt{x} - 4$

75. 

a. $f(x) = (x - 2)^2 - 2$

b. $f(x) = (x + 4)^2 - 4$

c. $f(x) = (x - 2)^2 - 4$

d. $f(x) = (x + 2)^2 - 4$

e. $f(x) = 4 - (x - 2)^2$

f. $f(x) = 4 - (x + 2)^2$

76. 

a. $f(x) = -(x - 4)^3 + 2$

b. $f(x) = -(x + 4)^3 + 2$

c. $f(x) = -(x - 2)^3 + 4$

d. $f(x) = (-x - 4)^3 + 2$

e. $f(x) = (x + 4)^3 + 2$

f. $f(x) = (-x + 4)^3 + 2$

77. Think about It You can use either of two methods to graph a function: plotting points, or translating a parent function as shown in this section. Which method do you prefer to use for each function? Explain.

a. $f(x) = 3x^2 - 4x + 1$

b. $f(x) = 2(x - 1)^2 - 6$

78. Think about It The graph of $y = f(x)$ passes through the points $(0, 1)$, $(1, 2)$, and $(2, 3)$. Find the corresponding points on the graph of $y = f(x + 2) - 1$.

79. Think about It Compare the graph of $g(x) = ax^2$ with the graph of $f(x) = x^2$ when

a. $0 < a < 1$ and

b. $a > 1$.

80. How Do You See It? Use the graph of $y = f(x)$ to find the intervals on which each of the graphs in (a)–(c) is increasing and decreasing. If not possible, then state the reason.

a. $y = -f(x)$

b. $y = f(x) - 3$

c. $y = f(x - 1)$

Cumulative Mixed Review

Parallel and Perpendicular Lines In Exercises 81 and 82, determine whether the lines L_1 and L_2 passing through the pairs of points are parallel, perpendicular, or neither.

81. L_1: $(-2, -2)$, $(2, 10)$

    L_2: $(-1, 3)$, $(3, 9)$

82. L_1: $(-1, -7)$, $(4, 3)$

    L_2: $(1, 5)$, $(-2, -7)$

Finding the Domain of a Function In Exercises 83, 84, 85, and 86, find the domain of the function.

83. $f(x) = \dfrac{4}{9 - x}$

84. $f(x) = \dfrac{\sqrt{x - 5}}{x - 7}$

85. $f(x) = \sqrt{100 - x^2}$

86. $f(x) = \sqrt[3]{16 - x^2}$

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